UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

CLG Europe

Working towards a climate neutral Europe:

Jobs and skills in a changing world

Technical Report

funded by

WE MEAN BUSINESS

The University of Cambridge Institute for Sustainability Leadership

The University of Cambridge Institute for Sustainability Leadership (CISL) is a globally influential Institute developing leadership and solutions for a sustainable economy. We believe the economy can be 'rewired', through focused collaboration between business, government and finance institutions, to deliver positive outcomes for people and environment. For over three decades we have built the leadership capacity and capabilities of individuals and organisations, and created industry-leading collaborations, to catalyse change and accelerate the path to a sustainable economy. Our interdisciplinary research engagement builds the evidence base for practical action.

This report was funded by the We Mean Business Coalition and the European Climate Foundation.

Authors

Cambridge Econometrics

Luca Barbieri, Economist
Mike May-Gillings, Principal Consultant
Cornelia Suta, Project Manager
Pim Vercoulen, Economic Modeller

University of Cambridge Institute for Sustainability Leadership

Sanna Markkanen, Research Associate
Romain Pardo, Programme Manager
Martin Porter, Executive Chair, CISL Brussels
Annabelle Roblin, Project Manager
Eliot Whittington, Director, CLG Europe
Ursula Woodburn, Programme Director, Head of EU Relations

Citing this report

Please cite this report as: University of Cambridge Institute for Sustainability Leadership (CISL). (2020). Working towards a climate neutral Europe: Jobs and skills in a changing world. Technical Report. Cambridge, UK: CLG Europe.

Acknowledgements

We would like to thank the following people and companies for their time and contributions:

ACCIONA

- Raúl Iván Alfaro Pelico
- Noelia Souto Concepción

EDGE

- Fabienne Cézanne

HYBRIT

- Jesper Kansbod

Iberdrola/Scottish Power

- Gonzalo Saenz De Miera
- Miguel Muñoz Rodriguez
- Manuel Quijano Ruiz
- Samuel Gardner

Signify

- Harry Verhaar

We would also like to thank CISL colleagues as well as Sara Baiocco, Researcher, Jobs and Skills Unit, Centre for European Policy Studies, Martin Kaul, Head of Office, Foundation 2° - German CEOs for Climate Protection, Julian Popov, Fellow, European Climate Foundation, Rannveig van Iterson, Senior Associate, Industry and Innovation, European Climate Foundation, and Dimitri Zenghelis, Senior Visiting Fellow, Grantham Research Institute, LSE for their helpful and constructive comments.

Foreword

Work is at the heart of our economy. Who has which jobs, what skills are required, whether we have the right mix of workers to business needs – all of these are critical questions that help determine the shape and scale of our economy, its competitiveness with the rest of the world and its ability to provide inclusive prosperity to society. With this report we have set out an analysis of the long-term factors affecting jobs and skills in Europe, and examined how a proactive policy response to the climate crisis can affect that future. The bulk of the work was completed in early March 2020 – before the impact of recent events became apparent.

At the time of writing, the immediate public concern is quite rightly focused on public health provision, loss of employment and incomes, and the full implications of social distancing. The spread of COVID-19 into a global pandemic has led to a healthcare crisis with tragic implications for thousands of people; forcing countries across the world to declare 'lockdown' measures, and close down schools, shops and factories. This has resulted in a sharp decline in economic activity and a steep increase in new unemployment claims. The full extent of the economic and social impacts will take months and years to play out, but forecasts by the International Monetary Fund (IMF) suggest the worst recession since the Great Depression, vastly exceeding the scale of the 2008 global financial crisis (IMF, 2020).

In its April 2020 World Economic Outlook, the IMF is projecting the global economy to contract by three per cent in 2020 - a downgrade of 6.3 percentage points from January 2020 forecast (IMF, 2020). The most recent preliminary estimates by the International Labour Organisation (ILO) suggest severe negative impacts and "catastrophic losses" for businesses around the world. The operations and solvency of smaller enterprises in particular are under threat, putting millions of workers at risk of income loss and layoff. According to the ILO, working hours are expected to decline by 6.7 per cent in the second quarter of 2020, equivalent to 195 million full-time workers globally and some 15 million full-time jobs in Europe (ILO, 2020).

But as terrible as the short-term impacts are, the longer-term implications of the pandemic remain unclear. All of the current estimates are just that - estimates at a time of high uncertainty. They are subject to change depending on the duration of the lockdown, the speed of the economic recovery in the second half of 2020 and the effectiveness of responding policy measures. Assuming that the pandemic fades in the second half of 2020 and that policy actions are effective in preventing widespread bankruptcies and system-wide financial strains, the IMF suggests that the global economy could rebound as soon as 2021 (IMF,2020). Should the lockdown continue into the third quarter of 2020, economic recovery in 2021 is likely to be considerably slower. Moreover, a resurgence of COVID-19 in 2021 could leave the global economy struggling for several years (Wink, 2020).

In this context, the pressure is mounting on policymakers to implement socially and environmentally responsible recovery packages that avoid repeating the mistakes made in the aftermath of the 2008 financial crisis. Pressure that many politicians and policy makers understand and support (Simon, 2020; Piccard and Timmermans, 2020).

In Europe, governments are increasingly recognising the need to ensure that decisions taken now should focus both on the economic recovery and achieving a prosperous and climate neutral economy by 2050.

The ability of the EU policymakers to rise to the challenge in supporting the economic recovery following the COVID-19 crisis will also have implications on the findings and recommendations made in this report. Whilst it has not been possible to fully integrate the expected impacts of COVID-19 in much of the content, many of its recommendations now seem even more urgent and significant. The need to develop firm foundations for future employment, and to develop a skilled and competitive workforce, has grown, not diminished, and must be a core topic for future policy action.

Contents

Introduction ... 6
Megatrends ... 9
Introduction ... 9
Automation/accelerating technological change ... 9
Globalisation ... 14
Demography ... 22
Resource scarcity ... 28
Modelling the economic and environmental impact of the megatrends ... 33
Case studies ... 39
Introduction ... 39
Case study 1: UK offshore wind power generation ... 40
Case study 2: German automotive industry ... 46
Case study 3: European coal regions (Romania) ... 54
Case study 4: Steel in Sweden ... 63
Case study 5: Agriculture in Southern Europe (Spain) ... 75
Policy recommendations ... 85
References ... 91

Introduction

In December 2019, European Commission President Ursula von der Leyen announced the European Green Deal, the new growth strategy for the EU which sets a pathway for at least EUR 1 trillion of investment over the next ten years and a just transition to a climate neutral economy by 2050. It is due to put in place new strategies and measures across policy areas and sectors including energy, sustainable finance, industry, buildings, transport and agriculture, with additional plans to preserve biodiversity and to eliminate pollution.

[The European Green Deal] is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy… where economic growth is decoupled from resource use.
(European Commission, 2019b, p 2)

Delivering the Green Deal will require an unprecedented degree of cooperation and collaborative effort involving industry, research and government. Reducing greenhouse gas (GHG) emissions by 50–55 per cent by 2030 and to net zero by 2050 will require substantial changes across the economy. Companies across the economy will need to alter their production processes and potentially change their business models, towards the green and circular transition. These changes will have implications for skills demand and regional and sectoral distribution of jobs. For example, the required level of energy efficiency improvements in the buildings sector will increase the demand for trained workers with skills and qualifications that are currently not widely available.

Since the announcement of the Green Deal, however, the EU is now responding to the COVID-19 emergency and beginning to lay plans for the post-COVID-19 recovery package. Experience from the 2009 global financial crisis, and in the context of the European focus on achieving climate goals, means that this could include major stimulus packages and potentially the immediate ramping up of green investments – in renewables, efficiency retrofits of homes, public transport and connected demand response mechanisms.

Beyond the enormous impact of current events, this report addresses the fact that the policy-driven transition to a climate neutral Europe will need to take place within a context that is influenced by additional socio-economic–environmental dynamics taking place worldwide, known as megatrends. Specifically, the report assesses technological change (artificial intelligence (AI), big data, digitalisation), demographic change, globalisation and resource scarcity. These forces will impact the global economy, business and society, and can be complementary or inconsistent with the ambitious social, environmental and climate objectives of the Green Deal. Subsequently, the extent to which various megatrends will impact European societies can aid or impede progress towards a fair and prosperous, climate neutral economy.

Understanding the nature of the interactions between the most influential megatrends, and how these impact on the effectiveness of climate and wider economic policies, is key to harnessing the benefits from possible synergies while mitigating contradictory outcomes – even if the scale of the impacts and interactions cannot yet be reliably assessed.

For example, early action to achieve an ambitious climate target can accelerate innovation and change, enabling European businesses to become world leaders in clean products, technologies and sustainable business models that are research efficient and are compatible with the circular economy and resource efficiency. However, to achieve these benefits and to future-proof their operations, European businesses must understand and prepare for the potential impacts of the megatrends and climate policy on their operations and the viability of their business models. This includes collaborating with policymakers at European, national and local levels to prepare and build resilience in the face of impending changes. Policymakers, on the other hand, will need to support businesses and society by developing and implementing a progressive and comprehensive policy framework to ensure that the transformation of the European economy will be just and inclusive.

A key area in which major transformations are expected to take place in the next 30 years is the labour market, which is vital to the scale, competitiveness and stability of the European economy. Employment is also an essential component of well-being, social participation and a source of household income: in 2018, 73.1 per cent of EU residents aged 20–64 (some 220 million) were in employment (Eurostat, 2019a). The ability of the Green Deal to deliver a just and inclusive transition will most likely be measured primarily through the economic and labour market impacts of the specific policy measures. Most attempts to comprehensively estimate and forecast the labour market impacts of climate policy have so far focused on a specific dimension of the topic, such as the transition of the energy sector (European Commission, 2013; IRENA, 2020), circular economy (Morgan and Mitchell, 2015; European Commission, 2018a), energy efficiency of buildings (Energy Bill Revolution, 2014; European Commission, 2015, 2017a) or the transport sector (European Climate Foundation, 2013; Cambridge Econometrics, 2018). Even more general studies on the overall labour market impacts of a broader set of climate policies (eg OECD, 2012, 2017a; ILO, 2018a, 2019a; Vivid Economics, 2019) tend to explore these impacts in isolation of other relevant policies or external forces.[1] However, these focused accounts – even when drawing on extensive amounts of high-quality research and data – are largely unable to provide a sufficiently nuanced picture of the complex reality where labour markets are volatile even without climate policy interventions, and vulnerable to the impacts of financial and economic crisis, industrial and political transitions, and technological change.

The purpose of this report is to reframe the implications of the transition to a climate neutral Europe in the context of broader megatrends to inform policy and business actions in response, articulating how climate action can facilitate a positive jobs and skills agenda and how climate policies are providing direction on the future shape of the economy. The four megatrends covered in this report include technological change (AI, big data, digitalisation), demographic change, globalisation and resource scarcity – all of which are likely to shape the

[1] While some recent studies acknowledge that the actual labour market impacts will be subject to interaction effects associated with external forces, such as more widespread deployment of AI (ILO, 2019b), the quantitative results are still presented in reference to climate policies alone.

demand and supply for labour in Europe in the next 30 years. The scope and direction of these megatrends and the effects they will have on employment and skills demand will depend on policies and actions at local, regional, national and EU levels – including climate policies. While simultaneous and overlapping transitions will create new paths to prosperity, they will also disrupt existing work arrangements.

Future businesses will need to be equipped to adjust to the context of these megatrends. This will involve developing strategies for how to respond to the changing realities at sectoral and at business level, including forecasting future skills and labour demand, adjusting business models and preparing workers for the inevitable changes. Adequate levels of support from governments and national policymakers will be essential to enable businesses to transition their operations to be compatible with the target of climate neutrality by 2050. The ability of the EU to achieve a healthier, more prosperous, and more egalitarian climate neutral economy by 2050 largely depends on the implementation of complementary policies to retain employers in Europe, to ensure an adequate supply of appropriately skilled workers, and to provide a safety net for workers whose skills and capabilities will no longer be in demand. Large-scale investment in Europe's assets – whether human, knowledge or physical – will enable countries to improve their resilience and to thrive as the continent transitions to a resource-efficient low carbon future.

This report is divided into two main sections. The first section describes the four megatrends and their implications for jobs and skills in Europe. In the second part of the report, these megatrends are contextualised with a set of case studies that focus on specific sectors of the economy that need to transition for Europe to achieve climate neutrality by 2050. Each sectoral case study is located in a specific country to allow us to explore the impact of national/regional policy on the jobs and skills in relation to this sector. It also includes several business case studies highlighting how businesses are dealing with different megatrends. Subsequently, a concluding section offers some high-level policy insights based on the main content of the report.

During the final stages of the drafting of this report, the global COVID-19 pandemic has presented an immediate and far-reaching disruption to European and global economies and labour markets. As the EU responds to the emergency and begins to lay plans for recovery, discussions have already begun on major stimulus packages and how they can be best aligned with Europe's long term climate goals. The COVID-19 crisis may also highlight the need to develop mechanisms to respond and mitigate the negative impacts of the megatrends.

Megatrends

Introduction

Technological innovation, global economic integration, demographic and generational shifts, and climate change and sustainability challenges are radically altering global business models regardless of size, sector or location. These changes will affect the nature and sectoral distribution of employment, and have already led to concerns about a global shortage of skilled labour (ILO, 2019a), with the skills gap being considered a major issue by 78 per cent of executives (ILO, 2019a). Finding workers who possess the relevant skills has become problematic even for entry-level positions, and many business executives feel that new graduates are not adequately prepared for current or future work.

There are many uncertainties surrounding the overall impact of the megatrends, and it is important to understand the various ways in which impacts may be felt. In this section we highlight how the main megatrends are likely to impact on the number and nature of jobs, and what implications these changes will have for future skills demand. For each megatrend, the analysis also looks at the interaction with other megatrends and the challenge of transitioning to a climate neutral economy by 2050.

Automation/accelerating technological change

Megatrend explanation

Rapid advances in technology, particularly in automation and artificial intelligence (AI), will most likely have a substantial impact on the labour market. Exponential advancements in computer science (better algorithms), computer power (more powerful processors) and availability of data (big data) have dramatically improved the capabilities of technology to perform an increasing number of tasks more efficiently than humans (McKinsey Global Institute, 2017). At the same time, these developments create a need for workers with a new set of skills.

Although the world of work has, for centuries, been constantly reshaped by technological progress (World Bank, 2019), the current wave of technological development has the *potential* to impact on a much wider range of tasks than before, across all sectors, and faster than before. If labour markets are not able to keep up with the speed of this change, the new technological advances could lead to increasing unemployment and inequality. On the other hand, society might be able to harness the potential of automation and AI in such a way that the benefits are shared across prosperous new societies that become characterised by high productivity and an abundance of free time. The final outcome is uncertain and depends on a number of factors, which are discussed below.

Current situation

In recent years there has been a rapid increase in the number and scope of tasks that robots and AI can perform:

- **AI** has improved exponentially thanks to big data and machine learning algorithms, and is now being used in healthcare, transport, finance, retail and many other sectors (Deloitte, 2017a). Some applications include: medical diagnostics; insurance risk pricing; screening legal data; improving energy use in data centres; identifying the best locations to drill for oil; and powering search engine responses (International Federation of Robotics, 2018a).
- **Advances in AI** combined with **hardware improvements** (eg grippers and sensors) are allowing robots to perform tasks such as: identifying, picking, and passing objects; inspecting objects to detect faults; and moving in unpredictable environments (International Federation of Robotics, 2018b).
- **Process optimisation** allows the continuous improvement of tasks performed by robots, while **predictive maintenance** allows problems with machines to be fixed before they occur (International Federation of Robotics, 2018a, 2018b).
- **Manufacturers** are becoming capable of switching production lines to quickly accommodate customer demand, while **services** such as healthcare deploy automated solutions to develop and test drugs and to deliver patient treatment (International Federation of Robotics, 2018a).

Upcoming trends/things to look out for

Technological development led by robotics and automation are linked with other developments, such as:

- An increase in the level of education among all age groups. The share of highly educated individuals has expanded rapidly in the last decade and is forecast to grow further in the next, raising concerns over the availability of high-skill jobs (Suta et al, 2018).
- Increased policymaking activity at the EU level. European institutions are aware of the challenge and opportunities posed by digitalisation and automation, as testified by recent legislation such as the General Data Protection Regulation (European Parliament, C. of the E.U., 2016) and the priority attached to the topic by the European Commission (European Commission, 2019a).
- International competition to become leaders in the field of AI. The biggest contenders vying for the leadership position are implementing different strategies: the US is exploiting its corporate might, China is leader in the number of patents filed by research institutions, while the EU has a more balanced profile between public and private effort (Joint Research Centre, 2019a).

Impacts

The automation of processes and tasks enabled by the technologies described above will have profound consequences for labour markets, productivity and income distribution.

In the past, machines were used mainly to execute particular physical tasks that were previously assigned to humans (eg lifting, assembling components). However, recent advances in technology, and particularly in AI, are now allowing machines to replace an increasing number of tasks that require *skills* that were previously only embodied in humans. Continuous advances in machine learning mean that **more and more workers, who undertake tasks that are now more easily replaceable by machines,**[2] **can be displaced, while a decreasing share of workers have skills that are complementary to machines**. However, workers skilled in **non-linear reasoning**[3] **and interaction with people**, and who are capable of performing non-standardised tasks, will be **less likely to be replaced** by machines.

Automation impacts on the labour market in the literature

Frey and Osborne compute the risk of displacement for US workers based on the scope for automation of their skills and find that 47 per cent of workers are at risk of automation, and argue that even high-skill occupations could be at risk (Frey and Osborne, 2013). On the other hand, Nedelkoska and Quintini perform a similar analysis on a panel of Organisation for Economic Co-operation and Development (OECD) countries and find automation risk to be 14 per cent of jobs on average (Nedelkoska and Quintini, 2018). In terms of realised job losses, some studies find that automation has small positive or neutral effects on employment (Bughin et al, 2018; Hawksworth and Fertig, 2018; PwC, 2018b), while others find a detrimental impact (Acemoglu and Restrepo, 2017). Eurofound estimates the effects of an accelerated rate of automation on employment, and finds that between 10 per cent and 16 per cent of jobs are lost compared to a scenario with no additional investment in automation (Eurofound, 2019a). As can be seen, estimates vary, but it is agreed that **automation is likely to have a deep impact on labour markets**.

Automation could bring huge productivity gains. For example, more capital-intensive sectors are generally estimated to see the greatest productivity gains from AI uptake, since the productivity of the capital-driven processes can be enhanced considerably through the use of AI (PwC, 2018b). This is much needed in a context of low productivity growth and ageing population in both developed and developing economies (McKinsey Global Institute, 2017). Besides allowing the production of more output at a lower unit cost, automation could provide a balancing mechanism to the displacement effect:

- **Higher productivity in the production chain increases the value of workers** performing the non-automated tasks (Autor, 2015), thus increasing the demand for skills that are complementary to automation.

[2] eg literacy, information gathering and logic-based tasks.
[3] eg critical thinking, decision making and creativity.

- **Higher productivity will command higher wages for the non-displaced workers**, who in turn will spend more, thus increasing demand and mitigating the loss of employment due to substitution (Joint Research Centre, 2019a).

Automation (particularly AI) could also increase the pace of innovation and thus further accelerate productivity growth (Joint Research Centre, 2019a). Moreover, automation can accelerate the development of new products and services and changes in business models (ILO, 2019a; McKinsey Global Institute, 2017).

At an organisational level, technology innovation enables new ways of working (eg virtual interaction and remote working) and expands digital networks of suppliers and business partners.

Automation poses the risk of an increase in inequality. Higher inequality could be the outcome of labour market dynamics, factor endowments and institutional factors:

- Literature has detected the emergence of a **job polarisation pattern** happening in many countries: employment grows in high-skill occupations and in low-skill occupations, while decreasing in the middle (Autor, 2015). It is therefore possible that technological improvement will **create a segregation within the labour market between "low-skill/low-pay" and "high-skill/high-pay" workers** (Schwab, 2018). However, one recent study has found evidence of occupational upgrading, ie most of the jobs are in high-quality occupations,[4] rather than a polarisation (Oesch and Piccitto, 2019).
- **Monopolies arise because of the increased digitalisation of the economy**, which allows a small set of 'superstar' firms to charge higher prices and extract monopoly rents[5] (Korinek, 2019), for example through the exploitation of network effects. Such firms tend to have a low share of labour in their value added, which in turn lowers the share of labour in national income (Goos et al, 2019).
- **Public policies might be unable to compensate** the losers from the adoption of automation (Korinek, 2019). In particular, individuals with low levels of digital skills[6] and so-called 'learning skills', who might find it difficult to adapt, especially if the educational system and lifelong learning training providers do not keep up with the pace of technological change (Brynjolfsson and McAfee, 2016; World Bank, 2019).

Uncertainties

The outcome of the automation process is still **uncertain**:

- To what extent will automation replace workers? Will it replace them completely or will it only reallocate tasks?

---

[4] With quality of occupation measured by earnings, education, prestige and job satisfaction.
[5] Digital platforms such as Facebook, Google or Amazon become natural monopolies and the number of users of these platforms attracts even more users.
[6] The term 'digital skills' is used to refer to a range of abilities to use digital devices, communication applications and networks to access and manage information.

- Will governments and businesses be able to equip workers with the skills needed to coexist alongside machines? Will there be enough jobs for skilled workers, or will machines also replace them?
- Will governments implement policies to mitigate the negative consequences of automation such as increased inequality (eg through taxation)?
- What will be the pace of technological diffusion (McKinsey Global Institute, 2017)? This will be dependent on:
    - how technically feasible it is to implement automated solutions in the workplace
    - how costly it is to develop and deploy automated processes
    - the benefits received by firms beside labour cost savings
    - labour market dynamics and prevailing wage levels
    - acceptance by society, workers and regulators.

Link to climate transition

New technologies are fundamental in the transition towards a climate neutral economy, but the right policy framework will be needed to ensure net benefits.

New technologies and AI could help curb emissions in a variety of ways, for example, to:

- enhance weather predictions to maximise the efficiency of wind turbines and solar panels (Victor, 2019)
- improve traffic and route management (Rolnick et al, 2019)
- improve forecast of supply and demand, allowing a better scheduling of energy supply (Rolnick et al, 2019)
- improve the energy efficiency of buildings (Rolnick et al, 2019)
- reduce waste and increase the productivity of solid waste pickup, screening and pricing (McKinsey Global Institute, 2019).

Microsoft and PwC estimate that **applying AI to environmental problems could curb emissions by 1.5–4 per cent by 2030**, compared to a business-as-usual scenario (Microsoft and PwC, 2019), while also improving well-being, (McKinsey Global Institute, 2019).

However, it is possible that better energy efficiency simply leads to increased consumption. This so-called rebound effect may offset all or some of the potential gains in terms of emissions, unless policies are utilised to effectively control it. AI is also likely to reduce costs for more polluting energy sources competing with renewables such as oil and gas, and the IT infrastructure needed to run AI solutions is highly electricity intensive (see Andrae and Edler, 2015).

In terms of jobs, Eurofound (2019a) estimates that the investment in new technologies needed to achieve a low carbon economy will **expand employment for the EU-28 by 0.5 per cent in 2030**, compared to a baseline without such investment.

CASE STUDY

Buildings for people and the planet: harnessing digitalisation to improve the working environment

In 2018 EDGE changed their business model from a traditional real estate development company to a purpose-driven organisation with a strong focus on sustainability and the well-being of people.

In order for Europe to achieve climate neutrality by 2050, approximately 97 per cent of buildings within the EU need to be renovated/redeveloped/upgraded. Such improvements can also help increase productivity and well-being, in addition to reducing emissions.

EDGE is working to address this challenge by reusing and upcycling existing materials and utilising smart technology. Digitalisation enables EDGE to track, control and optimise all the different variables within the building, leading to significant increases in energy efficiency and space optimisation. These measures enable better performance and improved well-being among the users of the buildings, while also improving energy efficiency and reducing emissions from light, heating and cooling.

Some of EDGE's flagship projects include the world's first energy-neutral building 'Las Palmas' in Rotterdam (2007), the world's most sustainable building 'The Edge' in Amsterdam (2015) and the world's healthiest headquarters at 'EDGE Olympic Amsterdam' in 2019. The company's future plans include creating EDGE buildings in each of the world's mega hubs to set an example and create a benchmark for other developers.

Globalisation

Megatrend explanation

The term globalisation refers to the growing interdependence of national economies, cultures and populations caused by cross-border flows of goods, services, technology, investment, people and information (PIIE, 2019). Globalisation is an overarching phenomenon, with complex, politically charged effects and with unequal impacts between and within societies.

The most evident feature of globalisation is the vast increase in international trade during the last 80 years: from a 10 per cent share in 1945, cross-border trade now accounts for more than 50 per cent of global gross domestic product (GDP) (Our World in Data, 2020). During this period tariffs were reduced and other restrictions to international trade were removed (PIIE, 2019).

Current situation

The wave of globalisation that started in the late 20th century has created a situation characterised by:

- The integration of production processes in **global value chains (GVC)**. Final products are the outcome of production activities executed in multiple countries. The trade in intermediate goods[7] as a share of global GDP is almost twice as large as the trade in final goods (PIIE, 2019).
- The **rise of China** as a global trade and manufacturing powerhouse during the globalisation wave driven by information and communication technologies (ICT). China became the world's largest exporter of goods in 2009, with its share of global goods trade[8] rising from 1.9 per cent in 2000 to 11.4 per cent in 2017 (McKinsey, 2019a). In 2018, China accounted for 16.4 per cent of global exports and 13.8 per cent of global imports, compared to the EU's share of 15.2 per cent of exports and 15.1 per cent of imports (European Parliament, 2019).
- **Massive international flows of data.** The ICT revolution linked to the internet allowed ideas to move easily across borders and made the exploitation of GVC possible (Baldwin, 2019). Individuals and organisations around the world are increasingly connected, with cross-border used-bandwidth increasing 45 times from 2005 to 2014 (McKinsey, 2016).
- **Increased global interlinkages** have made individual countries more vulnerable to negative events happening abroad, as testified by the COVID-19 outbreak.

Upcoming trends/things to look out for

Several developments have the potential to reshape international economic relations:

- International trade is **changing shape**, with **cross-border services** growing 60 per cent faster than trade in goods, and GVC becoming more **knowledge intensive** and reliant on high-skill labour (McKinsey, 2019b). So far, the service sector in advanced economies has been shielded from foreign competition because most services require face-to-face contact. However, digital technology is increasingly enabling the unbundling of service workers and service work with remote access that facilitates virtual presence. This dynamic might allow suitably skilled workers in poorer countries to directly compete with workers in advanced economies, without physically migrating from one country to another (Baldwin, 2019).

[7] Goods that are used as inputs to the production of other goods.
[8] ie the sum of imports and exports of goods.

- Recent years have been characterised by an **increase in protectionism**, exemplified by the US–China trade war that started in 2018.[9] The increased protectionism between China, the US and the EU could lower EU GDP by 1 per cent and employment by 0.3 per cent by 2030 (Eurofound, 2019b). Although a deal was signed in January 2020 to ease tensions between the two superpowers (BBC, 2020), and so far the effects on the EU of the tariff battle between China and the US have been limited (Viani, 2019), uncertainties remain over the unfolding of the crisis and the outcome of EU–UK negotiations post-Brexit.
- **The ICT revolution** of the late 1990s allowed firms in developed countries to move certain stages of the production process to developing countries to exploit lower wages. In the near future, **technological advancements in AI and robotics** might incentivise firms to re-shore those activities and substitute human workers with machines (Petersen, 2019). However, evidence for the re-shoring phenomenon is not conclusive (Backer et al, 2016; Banker, 2018).
- **Global demand is shifting**, with developing economies increasing their share of global consumption and a relative decrease in trade intensity, as a growing share of goods produced in these countries is consumed domestically rather than exported. This pattern is exemplified by China, where, notwithstanding increases in absolute values, the shares of exports in gross output in goods declined from 17 per cent in 2007 to 9 per cent in 2017 (McKinsey, 2019b).

Impacts

Improvements in global economic growth and reduced poverty have been linked to growth in global trade. International trade can boost growth through mechanisms such as increased and more intense competition, economies of scale and innovation. Cross-country evidence confirms the relation between higher growth, productivity and trade (Ortiz-Ospina et al, 2018). Between 1990 and 2011, trade supported growth in developing economies and allowed one billion people worldwide to exit extreme poverty (World Bank and WTO, 2015).

International trade has also facilitated job creation in developed economies. In the EU, 36 million jobs (one in seven) were supported by exports to countries outside the EU in 2017. Two-thirds of these jobs are in services and are, on average, better paid. The impact on consumers is also noteworthy, **including access to a wider variety of products at lower cost**. An average European consumer saves approximately EUR 600 a year thanks to the lower prices enabled by global trade (European Parliament, 2019).

[9] In 2013, the EU and China had a dispute over solar panels. To protect European manufacturers of solar panels, the EU levied tariffs on imports of panels from China, which responded with taxes on the imports of European wine and threatened to do the same for luxury cars (Chen, 2015). In the same year, the dispute was settled by limiting the import volumes from China and by setting a minimum import price. These measures were abandoned in 2018 (Reuters, 2018).

Global value chains allow the exploitation of comparative advantages, but gains seem to be distributed unequally. For developed economies, GVCs provide access to more competitively priced inputs, higher variety and economies of scale. In developing economies, GVCs are seen as a way to industrialise and develop. Ignatenko et al (2019) studied the macroeconomic impact of participation in GVC and its welfare implications, and found that, on average, participating in GVC has a positive impact on income per capita, investment and productivity. However, the positive effect of GVC participation tends to be concentrated in upper-middle and high-income[10] countries, while the positive effect on low and lower-middle-income countries does not appear significant. This might be due to the fact that GVCs are skill biased – ie they tend to increase demand (and earnings) for high-skill individuals, who are more plentiful in high-income countries.

The interplay between globalisation and new technological advancement might make developing countries more vulnerable, since their labour force lacks technological and/or digital skills and their source of comparative advantage lies in labour-intensive activities. Indeed, skill-biased technological change increases demand for high-skill labour capable of working alongside machines and reduces demand for low-skill labour, which is the abundant resource in less developed countries. In the recent past, developing economies could import production technology from abroad and choose a mix of factors of production. In other words, they could choose to employ, to a certain extent, a high amount of low-skill labour substituting for physical capital or high-skill labour. Nowadays, production processes are characterised by higher standards of quality and precision that cannot be met by simply increasing the amount of low-skill labour, with negative implications on emerging economies (Rodrik, 2018).

Globalisation induces specialisation and labour market adjustments across countries, which benefit different kinds of workers. Trade allocates resources to the most productive activity in each country, forcing labour markets to adjust. The ease of adjustment depends on a variety of factors, such as the sectoral structure of a country and labour mobility. In developed economies, adjustments due to globalisation have resulted in increased demand for high-skill workers in non-routine occupations, specialising in innovation activities while routine tasks are offshored to other countries. The increase in demand for high-skill workers in developed economies increases their share in employment and commands a higher skill return[11] relative to low-skill workers. On the other hand, low-wage workers in developed economies are left to face large obstacles to labour mobility and may bear the greater share of the adjustment costs (WTO, 2017).

Globalisation also affects workers through international competition, which can decrease employment and wages in sectors more exposed to import competition. For example, in Portugal employment declined among firms competing with China for market shares in other European countries (Branstetter et al, 2019).

[10] Low, low-middle, upper-middle and high-income countries as defined by the World Bank.

[11] The return on having an extra skill.

Globalisation has reduced income inequality between countries while increasing inequality between individuals within countries. The wave of globalisation that lasted from the 19th century to the decades following WWII favoured growth in developed countries, whereas late 20th century globalisation favoured developing nations: the G7 countries' share of world GDP decreased from 67 per cent to 50 per cent over 1988–2010, while their world trade share went from 52 per cent to 32 per cent over 1991–2011, in a process called the 'great convergence'. Global income inequality was consequently affected by these developments. Positive effects of globalisation on a country's income can be observed for countries at an early stage of global trade integration, while such effects become null for countries that are already fully integrated in global trade (Lang and Mendes Tavares, 2018). At the same time, income inequality increases within countries as a consequence of globalisation, with most of the gains accruing to individuals at the top of the income distribution. It has been suggested that there is a trade-off between higher inequality in advanced economies and lower global inequality. However, **income inequality might be affected by factors (eg technological change) other than globalisation, and national policies (eg progressive taxation and social transfer) might mitigate adverse distributional effects** (Dabrowski, 2018).

Globalisation has been accompanied by an increase in capital flows and financial linkages between countries, with consequences on the real economy. Cross-border financial flows steadily increased from 1990 to the 2007 peak, plummeted after the last financial crisis and then partially recovered (McKinsey, 2017a). The benefits of interconnected financial markets have been disputed, especially in the aftermath of the global financial crisis in 2008–13, which led to the loss of some 6.5 million jobs in the EU-28 (Eurostat, 2020a). International Monetary Fund (IMF) analysis (Furceri et al, 2018) suggests that liberalising international financial transactions is associated with a higher probability of financial crisis and increased inequality.

Summary of impacts

Global trade has been linked with economic growth and reduced poverty worldwide. Developing countries have been able to integrate into global value chains thanks to their comparative advantage in low-skill labour, while developed economies have specialised in more high-skill labour. This process has resulted in lower income inequality between countries but higher income inequality within countries. Looking ahead, shifting consumption demand (with increased consumption in developing economies), technological change and the rise of cross-border services might change international trade and specialisation patterns.

Uncertainties

- What will be the consequences of increased consumption demand caused by a growing middle class in emerging economies? How will trade patterns be impacted?
- How will the increase in trade in services, especially in conjunction with digitalisation, impact on labour markets?
- Are the recent examples of protectionism an isolated case or do they represent the beginning of a new trend?
- Will globalisation continue expanding? If yes, in which form? Or will there be a retreat from globalisation?

Link to climate transition

Globalisation allows the reduction of emissions through technology transfer. International trade and foreign direct investments (FDI) lead to transfer of knowledge and more carbon-efficient technologies from developed economies (where the technology is developed) to developing countries. Indeed, the developing economies most connected to the global economy (eg China, Brazil) have witnessed a large inflow of low carbon technologies in order to satisfy domestic demand for green technologies or to meet the demand induced by climate policies in developed countries. However, the poorest countries that are less connected to the global economy have not experienced the same inflows of green technology (Glachant and Dechezleprêtre, 2017). While FDI and foreign acquisitions in developing countries might increase the amount of energy used because of the increased output, they may also reduce energy intensity per output, meaning that each unit of output is produced with lower energy and lower CO_2 emissions (Brucal et al, 2019).

The rise of GVCs has also resulted in an outsourcing of emissions by developed countries to developing ones. With parts of the supply chain outsourced, **developed countries have been able to reduce emissions domestically at the expense of increased emissions in developing countries.** However, there is evidence that emissions transfers between developed and developing countries have been on a declining trend since 2006, and that the rate of decarbonisation of global trade now exceeds the rate of growth in trade value. This result can be attributed to both a slowdown in global trade since 2008 and to reduced energy intensity of trade. However, this downward trend in the emission intensity of trade could be reversed in the case of a strong increase in global trade levels, and if efforts to decarbonise fail, especially in areas such as India and Africa (Wood et al, 2019). This is an area that the EU is beginning to address just now, with a view of linking trade agreements to the Paris Agreement. Some of the recent considerations include a proposal for a carbon border tax adjustment mechanism, should third countries not reduce the carbon intensity of products.

The convergence of incomes and consumption patterns caused by globalisation could also have an effect on global emissions. Researchers have advanced the hypothesis of an inverted U-shaped relation between economic development and CO_2 emissions (the so-called ‘Environmental Kuznets Curve’, EKC): emissions rise with income up to a certain level of economic development and fall thereafter. The idea is that at low income levels the increased production has negative effects on the environment, as pollution increases and natural resources are exploited. Once a certain level of income is achieved, then the use of more efficient technologies, the switch towards more knowledge-intensive production and environmental policies allow economic growth to have positive effects on the environment. This reasoning implies that economic growth is the main path towards sustainability. A great number of studies have tested the EKC hypothesis, but results vary greatly depending on the countries considered, the time period, the explanatory variables used and other methodological choices (Shahbaz Muhammad and Sinha Avik, 2019).

In China, for example, unprecedented expansion of the economy by a factor of 30 in real terms between 1978 and 2018 lifted hundreds of millions of Chinese people out of poverty.

However, this transformation came at a high environmental cost, with China now ranking as the world's largest emitter of CO_2 emissions, while air and water pollution and soil degradation have reached alarming levels (Linster and Yang, 2018).

Overall, **globalisation could help or hinder the transition to a climate neutral economy at the global scale, depending on which aspect of it will dominate**. If globalisation and digitalisation increase trade intensity, then emissions could grow faster than would otherwise be the case. On the other hand, if reshoring and low carbon innovations can spread faster, then the world as a whole might become more energy efficient.

CASE STUDY

Brainport Eindhoven: innovation and training as an engine for economic growth

Brainport Eindhoven[12] was developed through a collaborative effort involving industry, research and government in response to the economic crisis in the 1990s, during which a third of all jobs in the Eindhoven region disappeared. The driving forces behind the Brainport were the establishment of Philips High Tech Campus in 1998 and the 1996–2002 regional economic development strategy plan known as 'Stimulus', which facilitated the emergence of a knowledge economy across the Eindhoven region. The EUR 180 million funding under the Stimulus plan accelerated mutual trust and cooperation between companies and resulted in 60 cluster projects and 400 other types of projects, the refurbishment and development of new industrial areas on a large scale, and the creation of 33,500 course places and 4,000 jobs. The success of the plan was largely attributed to the close cooperation between Philips, the local Mayor, the Chairman of Tilbury University and the Chairman of the Chamber of Commerce.

In 2003, Philips opened the High Tech Campus to other technological companies, who now benefit from a range of opportunities for cooperation, collaboration and facilities to share and multiply knowledge in an open innovation environment to achieve faster, better and more customer-oriented innovation in the application fields Health, Energy and Smart Environments. Although no longer under Philips ownership, the Campus continues to bring together high-tech private research with a strong manufacturing industry and a world-famous design sector, and has now committed to an ambitious goal to become the most sustainable campus in Europe by 2025.[13]

Brainport Eindhoven, which now encompasses multiple clusters around the region, has benefitted from the efforts of the Dutch government to maintain an internationally competitive business environment, including tax incentives and financing for innovation & entrepreneurship and reduced administrative burden. The success of the Brainport highlights the importance of innovation as an engine for economic growth and regional development during an economic transition, and the role of government in innovation and as an agent that can help facilitate private sector collaboration. Producing 44 per cent of all patent applications filed in the Netherlands and contributing EUR 2.5 billion in private research and development (R&D) spending, Eindhoven is now widely acknowledged as the high-tech capital of the Netherlands.

[12] Cf. Brainport Eindhoven website: https://brainporteindhoven.com/en/discover/what-is-brainport-eindhoven
[13] Cf. High Tech Campus website: https://www.hightechcampus.com/who-we-are

Demography

Megatrend explanation

The ageing of the population is a worldwide phenomenon, although the speed and scale of this process vary widely across countries. Despite regional differences, the trend is clear: the number of people aged 65 or more is going to increase both in absolute value and as a share of total population in all regions of the world (United Nations, 2019a). This trend is the consequence of a combination of increasing life expectancy and decreasing fertility rates. As a consequence, old-age dependency ratios[14] are projected to increase all over the world (albeit at different rates depending on the region) (United Nations, 2019b), potentially shrinking the labour force and putting pressure on government finances. Moreover, consumption patterns will change as a result of a changing age structure of the population. Within this context, migration from developing to developed economies has increased in recent years.

Current situation

- **Global population has grown and the median age has increased.** Global population amounts to 7.8 billion people in 2020 from 3.7 billion in 1970, of which 60 per cent live in Asia (median age 32 years), 17 per cent in Africa (median age 20 years), 10 per cent in Europe (median age 42 years), 5 per cent in North America (median age 39 years), 8 per cent in Latin America (median age 31 years) and 1 per cent in Oceania (median age 33 years). The median age of the global population has steadily increased from 22 in 1970 to 31 in 2020 (United Nations, 2019a).
- **Population in the EU-28 has reached 500 million and is ageing.** The median age in the EU-28 increased from 40 years in 2008 to 43 years in 2018. The proportion of people aged 65 or more in the total population increased from 17 per cent in 2008 to 20 per cent in 2018, while the old-age dependency ratio increased from 28 per cent to 33 per cent in the same period (Eurostat, 2019b, 2020b).
- **Four million people migrated to one of the EU Member States in 2017, out of which two million were not EU citizens**. The immigrants were, on average, much younger than the resident population in the country of destination, with a median age of 28 years compared to 43 years of the EU-28. In 2018, there were 22 million non-EU citizens living in the EU-28, representing 5 per cent of the EU-28 population (Eurostat, 2019c).
- **Young people are better educated than old people in the EU-28.** In 2018, 40 per cent of individuals aged 25–34 held a tertiary degree, compared to 23 per cent of individuals aged 55–64 (Eurostat, 2020c).

[14] Old-age dependency ratio defined as the number of persons aged 65+ over the number of persons aged 20–64 years.

Upcoming trends/things to look out for

- **Global population is expected to increase**, albeit at a slower pace than before, reaching 9.7 billion by 2050. The share of working-age population (aged 15–64) is expected to decrease from 65 per cent in 2019 to 63 per cent in 2050, while the share of population aged 65+ is expected to increase from 9 per cent in 2019 to 16 per cent in 2050. Africa is the only region in the world that will experience an increase in the share of working-age population during this period (United Nations, 2019a).
- **EU-27 (following Brexit) population is expected to increase slightly until the 2040s and then to decline to around 400 million in 2100.** The share of population aged 20–64 in the EU is expected to decrease from 59 per cent in 2018 to 52 per cent in 2050, while the share of people aged 65+ is expected to increase from 20 per cent in 2018 to 28 per cent in 2050. The ratio of people aged 65+ to those aged 20–64 is therefore expected to increase from 33 per cent in 2018 to 55 per cent in 2050 (Eurostat, 2020d).
- **Ageing of the EU population is expected to continue in the 21st century, coupled with slower population growth.** Because the UK's population trajectory diverts from the EU norm, some of these developments will be more pronounced for the EU-27 after the UK leaves the European Union at the end of 2020.

Impacts

Ageing has profound consequences for labour markets, by altering the size and age profile of the available labour force. Ageing has negative effects on GDP growth through two channels: first, as the number of retirees increases (in the absence of appropriate increases in the pension age), the number of workers relative to the population falls; second, workers beyond a certain age tend to work fewer hours and to be less productive (Kydland and Pretnar, 2019).

Within the European labour force, older cohorts are expected to increase in size while younger ones are expected to decline. In the EU-27 (following Brexit), according to the Cedefop Skills Forecast, the size of the labour force aged 25–49 is expected to decline by 0.6 per cent per annum from 2018 to 2030, while the labour force aged 50–64 and 65+ is expected to increase by 0.5 per cent and 4.1 per cent per annum respectively over the same period (Cedefop, 2019). A higher share of older workers may change the overall profile of the labour force in terms of skills, behaviours and productivity. Older workers have different characteristics compared to younger ones:

- They are less likely to be unemployed, but it takes more time for them to re-enter employment if they do become unemployed, increasing the likelihood of long-term economic inactivity. In the EU-28+ countries,[15] the age groups most in need of upskilling are the unemployed and people out of the labour force (inactive) aged 55–64, and inactive people aged 35–54 (Cedefop, 2020).

[15] The 28 Member States, plus Iceland and Norway.

- Participation of older workers in formal education and on-the-job training is lower than that of younger workers.
- Older workers are less mobile, ie less likely to change occupation, sector of activity and region.
- The skills of older workers may become outdated in the face of continuing innovation, thus harming productivity.

For the above reasons, the increasing age of the labour force might slow the speed of labour market adjustments following economic shocks (ILO, 2018b). As older workers begin to represent a higher share of the labour force, improving their productivity through lifelong learning will be fundamental to effectively manage the labour market impacts of the different megatrends.

Digital competences are scarce among older adults. Among employed older adults, almost half are at risk of low-level digital skills, a share which increases to 70 per cent among the unemployed and 60 per cent among the economically inactive (Cedefop, 2020). Adult education is associated with improved individual performance (DG EMPL, 2019) and many European universities are already offering courses targeted at older people (European Commission, 2018b). One promising area of intervention could be the proposition of digital technology courses for older people, which could increase their employability and support the retention of cognitive skills – although training will be unlikely to fully eradicate the disadvantage of the older generations in relation to younger people who grow up with these technologies. However, in addition to positive employability impacts, adult learning benefits mental health and provides opportunities for socialising, improving welfare and reducing loneliness and social isolation (European Commission, 2018b).

The future labour force in the EU-28 will be smaller but better educated than today, and therefore more productive. The Cedefop Skills Forecast projects a trend of upskilling of the labour force in the EU-28 between 2016 and 2030, with the share of workers with a high level of education increasing at the expense of the lower educated ones (Suta et al, 2018).

Younger cohorts in the EU-28 have higher digital skills than the older ones, resulting in an overall increase in digital skills among the workers as more young people enter the labour force (Eurostat, 2020e). This will increase productivity, which may at least partially counteract the negative effects of a smaller labour force and higher dependency ratio (Lutz et al, 2019).

Immigration might provide a way to avoid the reduction in labour force caused by ageing. However, the positive impact might be short-lived, in part because the labour market participation rate of immigrants is generally lower than that of the resident population, and in the long run migrants will also age and retire. To maximise the impact of immigration on lowering dependency ratios, effective integration policies are fundamental (Lutz et al, 2019).

Pension systems might be strained by the increase in numbers of retirees. Old-age dependency ratios in the EU-28 have increased from 28 per cent in 2008 to 33 per cent in 2018 and are projected to reach 55 per cent by 2050 (Eurostat, 2020b, 2020d).

These developments, if not counteracted by an increasing number of employed workers and/or productivity, will slow growth and reduce standards of living. These considerations have triggered pension reforms that increased the retirement age by 1.5 years by 2050 on average in OECD countries. However, simulations have shown that, given the forecast demographic trends, retirement age should increase by 8.4 years by 2050 to keep the old-age dependency ratio stable, much more than the increases foreseen in the current pension reforms. Moreover, increasing employment (especially at older age) and productivity will be fundamental to avoid a decrease in pension levels: at a given level of employment, productivity and pension contribution, a higher number of retirees inevitably means a lower level of pension payments (Boulhol and Geppert, 2018). In the EU, spending on pensions as a share of GDP is already high in many Member States (eg 16 per cent of GDP in Italy, 17 per cent in Greece and 15 per cent in France), and the increase in the number of retirees will put even more pressure on already strained public finances. It is forecast that by 2040, pension expenditure as a share of GDP will increase by 1 percentage point (pp) compared to 2016 levels. However, these results hide important country heterogeneity, whereby Member States such as Italy and Slovenia will increase spending on pensions by 3.1 and 3.2 pp respectively, while others such as Greece and Croatia will decrease spending by 4.4 and 2.2 pp respectively (DG ECFIN, 2018). Automation might help to counteract the impact of decreases in labour force (MIT, 2019) by boosting productivity and allowing a lower number of workers to produce more, and therefore paying increased contributions to fund public pensions. However, the negative effects of automation on labour demand (as presented in the Automation megatrend chapter) bring a lot of uncertainty into this discussion.

Health expenditure is projected to increase in the coming decades, but the increase is likely to be small. In the EU-28, public spending on health has increased over time, reaching 8 per cent of GDP in 2015 (DG ECFIN, 2018). The size, age structure and health status of the population are among the main determinants of public spending in healthcare. Since demand for healthcare increases with age, ageing of the population might pose a threat for the sustainability of public finances by increasing the number of recipients of healthcare services and at the same time lowering the number of contributors through a decrease in the labour force (DG ECFIN, 2018).

However, this effect is likely to be small, as shown by studies and by forecasts from the European Commission, which project a 1 pp increase in EU-28 healthcare spending as a share of GDP in the period 2016 to 2070 (DG ECFIN, 2018; European Observatory on Health Systems and Policies, 2019). The increase in demand for healthcare services will also stimulate job creation in the health sector, whose employment in the EU-28 is expected to increase by 6.6 per cent up to 2030 (Cedefop, 2019).

In extraordinary cases, an older age structure of the population might severely test the resilience of health systems, as shown by the coronavirus pandemic (NBC News, 2020; Wired, 2020).

The ageing of the population interacts with the increase in inequality seen in the last decades, creating the risk of unequal ageing. The population is ageing as a result of higher life expectancy and lower fertility rates, but people experience ageing differently based on their socio-economic characteristics. For example, highly educated individuals tend to live longer and in better health compared to lower educated ones – a trend that is closely interlinked with education-related wealth inequalities. Inequalities in dimensions such as education, health, employment and earnings reinforce each other over the course of life (OECD, 2017b), with early-life factors being powerful predictors of financial well-being among older cohorts (McGovern, 2019). In most OECD countries, inequality has been rising from one generation to the next and is highest among individuals in younger cohorts. Moreover, income of the cohorts aged 60–64 has increased on average by 13 per cent more than the income of the cohort aged 30–34 between the mid-1980s and mid-2010s. Relative poverty rates have increased the most in cohorts aged 18–25, reaching an average of 14 per cent in 2014 in OECD countries. These considerations imply that in the future the elderly will have experienced widely different outcomes in terms of employment, earnings and exposure to poverty during the course of their life, and that as a result inequality will persist also during old age (OECD, 2017b). For example, it is estimated that two-thirds of earnings inequality carries on into pension inequality (McGovern, 2019).

Summary of impacts

The continued ageing of the population has a number of consequences for the size and skill profile of the European labour force. Older workers are harder to retrain in the labour market in view of the changes that automation and digitalisation bring, and are less mobile across sectors and occupations than younger ones. At the same time, the European labour force is projected to shrink, implying that a lower number of workers will have to provide for a higher number of older people, with consequences on the sustainability of public finances (in terms of pension and health spending). To counteract these trends, an increase in productivity and employment is needed. Possible solutions are the adoption of automation, an increase in labour participation of older people and a more extensive implementation of adult learning. Moreover, the future labour force will be better educated, more digitally skilled and therefore more productive.

Uncertainties

- Will employment and productivity increase enough to offset the increase in old-age dependency ratios? What role will automation play?
- Will migration help to mitigate the effects of an ageing workforce?
- How are governments going to meet requirements for increased pension spending?

Link to climate transition

Demographic changes affect consumption patterns and energy use. On the one hand, slower population growth should reduce the growth in energy demand but, on the other hand, ageing and higher incomes might increase it.

Different age groups have different levels of economic activity and energy consumption, and are associated with different household size (with younger and older/retired households typically living in smaller households) (Liddle, 2014). The elderly in advanced economies have higher energy use than the younger population (Estiri and Zagheni, 2019; York, 2007; Zagheni, 2011; Bardazzi and Pazienza, 2019) and, consequently, induce higher emissions. Higher energy use by the elderly is especially associated with residential energy demand because of a higher sensitivity of old people to extreme weather compared to the average population. Moreover, the elderly are often late in adopting the latest, most energy-efficient, technologies (Charness and Boot, 2009; Meyer, 2011).

However, some studies suggest that current younger cohorts have higher energy consumption[16] than previous generations and are expected to continue to demand more electricity at every stage of their lives. The combination of ageing population and consumption behaviour from the younger cohorts may therefore offset the effects of a shrinking population, resulting in growing energy demand (Bardazzi and Pazienza, 2019).

In the case of the EU-28 as a whole, an increase in the population (+5 per cent) was seen alongside a decrease in residential emissions (-6.5 per cent) between 2000 and 2016, notwithstanding an increase in the number of (smaller) households. However, buildings still accounted for 40 per cent of energy consumed in 2017. The issue of domestic energy consumption is addressed in the European Green Deal, which aims to launch a “renovation wave” of public and private buildings to increase energy efficiency and affordability (European Commission, 2019b). Beyond buildings, the Green Deal will also aim to tackle the broader implications of energy consumption by decarbonising electricity and key sectors such as transport.

[16] eg through the use of electronic devices.

Resource scarcity

Megatrend explanation

Global demand for goods and services is projected to increase worldwide, fuelled by a growing population and improved living standards. In order to meet the increasing consumption needs of the population, more and more resources are being used: global demand for materials and other resources, such as water, energy and land, has increased more than ten-fold from 1900 (EEA, 2015). However, resources are not infinite and are often geographically concentrated. Moreover, their extraction and exploitation has impacts in terms of GHG emissions and degradation of the environment. Addressing these issues will also have impacts on economic outcomes and job creation.

Current situation

The current situation is characterised by:

- **Intense exploitation of global resources.** Global extraction of materials[17] more than tripled between 1970 and 2017, reaching 92 billion tonnes. During the same period, material demand per capita increased by 65 per cent. Each year, humanity has consumed more ecological resources than the Earth is capable of regenerating. The 'Earth Overshoot Day"[18] arrives sooner each year: it was 29 July in 2019, while it was 29 December in 1970 (Global Footprint Network, 2019).
- **Concentration in key markets. China is the main global supplier of the majority of critical raw materials (CRM)** such as bismuth, magnesium and phosphorus, followed by countries such as the US for helium and Russia for tungsten (European Commission, 2017b).
- **Demand differs by geography and income, with the EU-28 decreasing its domestic consumption of material per capita.** In the EU-28, domestic material consumption per capita increased between 2000 and 2008 and then decreased until 2018, reaching 14 tonnes per capita. Non-metallic mineral ores accounted for the largest share of domestic consumption demand in the EU-28 in 2018 (47 per cent), followed by biomass (26 per cent), fossil energy materials (22 per cent) and metal ores (5 per cent). Domestic material consumption per capita has been decreasing in North America since the mid-2000s, it is stable in Africa and it is on an increasing path in the other regions of the world (IRP, 2019).

Upcoming trends/things to look out for

Several developments have the potential to reshape how fast we consume the Earth's resources:

[17] Materials include biomass, fossil fuels, metals and non-metallic minerals (IRP, 2019).
[18] The date each year when humanity has consumed the available stock of regenerative resources for that year.

- **Current business-as-usual scenarios show that global GHG emissions are expected to increase by 82 per cent from 2011 to 2060.** Combustion of fossil fuels or energy supply, agriculture, production of manufacturing goods and construction are expected to account for two-thirds of emissions by 2060. The environmental impacts of extraction and processing of key metals is expected to double between 2017 and 2060. Under these projections, the target set by the Paris Climate Agreement will not be met (OECD, 2019a).
- **The EU is transitioning towards a more circular economy supported by a range of policy actions.** The European Commission launched its first EU Action Plan for the Circular Economy in 2015 to develop a carbon-neutral, resource-efficient and competitive economy (European Commission, 2015a). This action plan implemented measures across entire value chains, from circular design to recycling targets. Building on these actions, the European Commission presented a new Circular Economy Action Plan in early 2020. This new action plan sets out a pathway for decoupling economic growth from natural resource use through initiatives along the entire life cycle of products (European Commission, 2020a). The Plan includes a New Sustainable Product Policy Framework to improve the durability, reusability, upgradability and reparability of products, and increase their energy and resource efficiency. It focuses on sectors that use the greatest amount of resources and have a high potential for circularity, including electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, and food. The Plan recognises the role of the circular economy in strengthening Europe's industrial base and achieving climate neutrality and the potential of digitalisation for increased circularity.
- **Technological change in agriculture has the potential to increase production more than through land expansion.** The new technologies can also help to reduce GHG emissions and to better preserve the land, water and biodiversity. The new technologies used in agriculture will be a combination of Internet of Things, big data, AI and robotisation. However, small and medium-sized enterprise (SME) farmers are resisting the change to a digital economy, and the ageing farming population is the main reason behind the slow uptake of the new technologies. Equipping SME farmers with the necessary skills to exploit these technologies should increase the update of digital and automatable methods (Ferreira et al, 2019).

Impact

The overuse of natural resources has deep environmental consequences. Biomass, metals, non-metallic minerals and fossil resources extraction and processing account for approximately 50 per cent of global GHG emissions (IRP, 2019). A wide range of environmental consequences are linked to material use: acidification of soil and water, contribution to climate change, increasing land use, intoxication of terrestrial and aquatic ecosystems, intoxication of humans through ingestion of the food chain (OECD, 2019a). The impact on biodiversity is substantial: it is estimated that 11 per cent of species were lost by 2010 due to global land use (IRP, 2019).

Global demand for land is projected to continue increasing, given that more food will be required globally by 2050[19] and that demand for biofuel is also expected to increase. For this reason, competition for arable land has increased globally since 2000, with large transnational land acquisition, primarily in Africa, which substitutes local access to land and water with large-scale monocultures (EEA, 2019). In Europe, **urban areas increased** by 7.1 per cent between 2000 and 2018, mainly at the expense of agricultural land. At the same time, soil degradation is a concern in many parts of Europe. Recently, urban farming has surfaced in Europe as a way of reducing land use pressure. Urban farming can be defined as the production of food and non-food plants, as well as husbandry, in urban and peri-urban areas (European Parliament, 2017). Several case studies have shown that urban farming has the potential to provide for a high share of the vegetable consumption in cities. (European Parliament, 2017).

Demand for water is also expected to rise by 55 per cent by 2050, with the number of people living in water-scarce regions increasing from the current 1.9 billion to 5.7 billion, with Southern Europe possibly being affected.

Agricultural production, processing and logistics for the food sectors have sizeable environmental impacts, which are magnified by waste of resources through the food value chain. It is estimated that 88 million tonnes of food are wasted each year in the EU, for a loss of value of EUR 143 billion (EEA, 2019) and a further burden for the environment.

As demand for natural resources increases, the outlook for supply is more uncertain. Resource use tends to rise as countries develop their economies, remaining stable after reaching high-enough levels of GDP per capita. With emerging economies on the path of catching up in terms of economic growth, the demand for resources is bound to increase. It is estimated that if the global population were to increase to the average EU energy use level, this would imply a 75 per cent increase in energy consumption, while an increase to the US level would imply a 270 per cent surge (EEA, 2015).

While global demand is projected to increase, it is uncertain if the same will apply to supply. Indeed, reserves of key materials (e.g. lithium, cobalt) are concentrated in a limited number of, often politically unstable, countries.

Countries can tackle uncertainty in resource supply by identifying new sources for traditional resources or by identifying substitutes. The former will not put a stop to pollution and environmental degradation associated with mining and transport of minerals and materials, and the latter requires efforts to foster innovation. New innovations can also be used to increase access to non-renewable resources, eg by exploiting previously inaccessible oil reserves, which might further pollute the environment. Moreover, negative environmental impacts could be magnified if countries start to exploit sources previously deemed uneconomic, such as tar sands.

[19] Between 25 per cent and 100 per cent more food is expected to be required by 2050, depending on assumptions (EEA, 2019).

Uncertainty over resource supply may increase volatility in commodity prices and represent a risk for economies heavily dependent on imported resources, such as Europe (EEA, 2015). On the other hand, incentives could be put in place to increase private and public investment in innovation to exploit abundant and non-depletable resources such as wind and solar energy, to increase water and land efficiency and to reduce waste (eg through the circular economy).

Tackling resource scarcity through the circular economy might have sizeable economic benefits. The circular economy is seen as one of the main tools to reduce the environmental impact of economic activity, and it can be found at the top of European policymakers' agendas (European Commission, 2019b). The circular economy is an economic system that aims to maintain the value of products and materials for as long as possible, and minimise resource use and waste by increasing the repair, recovery, reuse and recycling of materials and products (Hedberg, A., Šipka, S., 2020). As such, the circular economy is regenerative by design, with the purpose of gradually decoupling growth from the consumption of finite resources (Ellen MacArthur Foundation, 2020).

The transition to a more circular economy is expected to have a positive impact on the overall economy and on labour markets. It is estimated that under a transition to a circular economy, EU-28 GDP will be 0.5 per cent higher in 2030 compared to a baseline without such a transition. The net increase in jobs (which takes into account both job creation and job shedding due to the circular economy) amounts to 700,000 new jobs, compared to the baseline of business-as-usual. The positive effect on economic activity is due to additional labour demand in recycling plants and repair services, and to the additional consumer demand generated by higher savings allowed by a more efficient use of resources. The sectoral composition of employment will change, with sectors producing and processing raw materials declining, and the recycling and repairing sectors growing. Services and electricity sectors will also benefit from the transition, while electronics, machinery, automotive, accommodation and construction sectors will experience a decrease in employment. On the other hand, the circular economy is expected to require the same skills already required by other trends such as technological change, and therefore may magnify areas of future skills demand already shaped by global drivers with a shift to high-skill jobs. Moreover, the net employment figure might be lower if a higher degree of automation in the waste sector than the one assumed in the model were to materialise (Cambridge Econometrics et al, 2018).

Transitioning to a climate neutral economy will need sizeable reskilling efforts. Most studies agree that the transition towards a more climate neutral economy will create more jobs than it destroys (eg more jobs will be created in the renewable energy sector than jobs are destroyed in the mining one). The International Labour Organization (ILO) estimates that the net job creation figure due to the transition to a more climate neutral economy could range between eight million and 18 million at the global level (ILO, 2019b). However, many jobs will be lost in the process, and while some workers will find a job in an equivalent occupation in another sector, others will require reskilling to transition into other occupations (ILO, 2019b). Appropriate reskilling policies must therefore be in place.

To address these issues, in January 2020 the European Commission launched the Just Transition Mechanism,[20] which comprises a set of instruments to finance interventions in support of the regions and workers most affected by the transition, for example in the form of reskilling initiatives (European Commission, 2020a).[21]

Summary of impacts

Global resource consumption is projected to increase in the coming decades, amidst heightened competition for scarce resources, pressure on agricultural systems and environmental risks. The adoption of the circular economy is one of the main solutions embraced by European policymakers to tackle these issues. By promoting recycling and reuse of products, the circular economy is expected to increase aggregate employment in the EU-28. However, transitioning towards a sustainable economy is not without costs and many jobs will be lost in the process. Reskilling policies will be needed in order to allow a smoother transition from declining sectors (eg fossil fuels) towards growing sectors (eg renewable energy).

Uncertainties

- What geo-political consequences will the concentration of resources in a limited number of countries have?
- Will there be a widespread use of policies to mitigate the negative impact of resource extraction?
- What kinds of policies will be implemented to address the challenges caused by resource scarcity in the EU and at global level?

Link to climate neutral transition

Lowering emissions stemming from the (over)exploitation of resources is a fundamental step towards the achievement of climate neutrality.

A significant reduction in GHG emissions would be achieved by implementing the practices of the circular economy.[22] Such practices involve the reuse and recirculation of materials, the reduction of material flows through better resource efficiency and increased product lifetime, the improvement of asset utilisation and the substitution of goods with services (eg through sharing services). In this way, the use of energy-intensive goods/materials such as iron and steel, aluminium, glass, paper, cement and plastic could be reduced.

---

[20] See https://ec.europa.eu/commission/presscorner/detail/en/ip_20_17.
[21] See, for example, the discussion of the Just Transition Fund in the 'Implication for jobs and skills' section in Case study 3: European coal regions (Romania).
[22] The EU Action Plan for the Circular Economy envisages a reduction in GHG of 500 million tonnes between 2015 and 2035 (European Commission, 2015b).

Nevertheless, cost-saving effects and a reduction in prices[23] caused by the circular economy might lead to increased consumption, which would partially offset the environmental benefits (ie rebound effect).

Recent estimates point to a 56 per cent reduction in emissions from heavy industry compared to baseline levels by 2050, thanks to a stronger implementation of the circular economy. However, demand-side measures to avoid the rebound effect are needed to achieve this result (Material Economics, 2018) – for example carbon pricing, which would discourage expenditure on carbon-intensive goods (Baranzini et al, 2017). The importance of the circular economy in reducing emissions is enshrined in European policymaking through the European Commission's long-term strategy to become climate neutral by 2050 (European Commission, 2018c, 2018d). The analysis shows that the circular economy is fundamental to the transition towards a climate neutral economy while minimising requirements in terms of investments, thus indicating a high cost-effectiveness.

The transition towards a climate neutral economy will require the use of renewable energy technologies that are highly reliant on rare earth elements and other critical raw materials. Europe is vulnerable regarding the supply of rare earth elements and raw materials required by technologies such as wind turbines, photovoltaic panels and electric vehicles (Blagoeva et al, 2016). To avoid environmental impacts from the materials used in the production of renewable energy and low carbon technologies, advancements in recycling and material substitution are needed, while the development of dedicated mines in Europe could alleviate the issue of supply. The cost of mitigation for the EU and the global economy strongly depends on the ability to ensure resilient, socially fair and environmentally sustainable supply chains for low carbon technologies.

Modelling the economic and environmental impact of the megatrends

The employment impacts of the transition to a climate neutral economy have been widely studied using various modelling techniques. However, these modelling exercises tend either to compare the effects of the low carbon transition to a 'business-as-usual' baseline case, in which current trends in the economy persist over the period to 2050, or one of the broad Shared Socioeconomic Pathway (SSP) scenarios (eg Riahi et al, 2017; O'Neill et al, 2017). While both approaches can be useful for identifying the potential impacts of the transition to a climate neutral economy, they assume that economic structures, beyond those affected by climate policy, remain largely unchanged. In reality, this will not be the case.

---

[23] Cambridge Econometrics et al (2018) project a 0.1 per cent decrease in consumer prices by 2030, compared to baseline.

Recent modelling commissioned by the European Commission (DG Energy) from a consortium led by Cambridge Econometrics considers some of the transitions, so-called megatrends, that may take place simultaneously and interact with the transition to a climate neutral economy (European Commission, 2020h).[24]

The four megatrends included in the analysis are:

1. The Technology change scenarios, which capture different futures depending on the level of digital technology take-up, productivity changes, automation of jobs and government policies accompanying these changes. These scenarios focus on how AI and similar technologies could transform production and the demand for labour.
2. The Globalisation scenarios, which focus on trade and global value chains, considering the impact of digital innovations (internet and communication infrastructure, 3D printing) and the effects of trade policies.
3. The Demographic change scenarios, which explore the impacts of different demographic trends on the economy and labour markets (based on the demographic assumptions of the SSP scenarios). These scenarios also capture how changing levels of educational attainment increase productivity, output and welfare.
4. The Resource use scenarios, which concentrate on the material efficiency of production, material prices and potential supply bottlenecks.

The modelling involved designing a set of scenarios based on a range of possible outcomes for the four megatrends. For each megatrend, a 'middle-of-the-road' baseline case was constructed, followed by four alternative scenarios based on the uncertainty dimensions specific to each megatrend. In some alternative scenarios, accompanying government policies were included to mitigate the negative effects and to maximise the positive outcomes.

In addition to the set of scenarios for each of the four megatrends, a low carbon pathway was also modelled to explore the economic outcomes in a scenario that includes a set of policies to achieve a CO_2 emission reduction pathway that is consistent with a 1.5°C climate target.[25]

Below, we provide a brief summary of some of the preliminary results for economic growth (GDP), employment and CO_2 emissions from the E3ME model.

---

[24] European Commission, 2020 (forthcoming) *Macroeconomics of the Energy Union: Policy Report for Modelling Megatrends.* This report presents work commissioned by the European Commission (EC) from Cambridge Econometrics and E3 Modelling. The information and views set out in the study are those of the author(s) and do not necessarily reflect the official opinion of the Commission.
In the original work commissioned by EC, the term 'low-carbon transition' was used to refer to scenarios leading to CO_2 reductions that are compatible with limiting global warming to 1.5°C by 2100.
In the original work commissioned by EC, all scenarios were assessed using two macroeconomic models, E3ME (Cambridge Econometrics) and GEM-E3-FIT (E3-Modelling). For the sake of clarity and simplicity, this report presented only the results from E3ME modelling. Full results for both modelling approaches are available in the original report published by EC.
[25] This low carbon pathway is slightly less ambitious than the EU's climate neutrality target by 2050, achieving net zero carbon emissions by 2060 (both in the EU and globally).

As shown in Table 1, **the potential scale of impacts from the different megatrends by 2050 varies widely. The employment and economic impacts associated with technological change, primarily developments in AI/automation, could lead to substantial net employment losses, reduced household income, and decreased consumption and output, leading to losses in GDP** as well.

However, these losses depend on the potential for automation for each sector, and are thus distributed unevenly. While the overall impact is negative for business and consumer services in all scenarios, the construction sector benefits from the infrastructural needs of the transition under some scenarios. Indirect effects such as reallocation of labour resources towards the growing sector can therefore be used to counterbalance some of the initial employment shocks. The impacts associated with globalisation are minor in comparison, and partially linked to technological developments that are already ongoing. Digitalisation of trade could slightly boost economies through lower trade costs, while restrictive tariffs could slow down growth. The employment impacts in all globalisation scenarios are low, as are the employment and economic impacts in the resource use scenarios.

The modelling results for demographic change show high variation in the least favourable and most favourable outcomes. These results illustrate the crucial role that government policies play in determining educational and health outcomes. Increased spending on education and health has positive economic effects, while increased spending on educational attainment boosts the productivity of the economy and competitiveness.

The results for economic growth and employment follow a similar pattern, with more favourable outcomes in one generally coupled with a more favourable outcome in the other. CO_2 emissions, on the other hand, move in the opposite direction, with greater decline in emissions being associated with worse employment and economic outcomes.

When modelled without assuming any specific megatrend effects, the low carbon transition scenario shows slight positive outcomes for GDP and employment.[26] These results indicate that decoupling emissions from economic growth and employment is possible in a well-designed policy framework. However, these results also show that, when assessed in isolation, technological change and demographic change could have more intense effects on the European economy and employment than the transition to climate neutrality.

[26] The results for the low carbon scenario are expressed as percentage difference from a baseline scenario, in which only existing policies are implemented. It is important to note that an existing policy framework (business-as-usual baseline scenario used for the low carbon scenrio) already sets the EU on a path of increasing GDP and employment, and declining CO_2 emissions. These results therefore indicate a slight *further* increase in GDP and employment, and a substantial *further* decline in emissions.

Table 1: Highest and lowest economic impacts of each megatrend in (EU-27+UK) by 2050 (E3ME analysis), percentage difference compared to baseline scenario

per cent, 2050	GDP		EMPLOYMENT		CO_2 EMISSIONS	
	Low	High	Low	High	Low	High
Technological change	-8.0	-0.1	-23.2	-9.9	-5.9	-2.9
Globalisation	-0.1	2.2	0.0	0.7	-0.1	1.3
Demographic change	-10.0	10.6	-5.8	6.2	-4.2	4.0
Resource use	-0.3	0.6	0.1	0.1	-0.2	2.9
Low carbon transition		1.06		1.01		-74.1

Source: E3ME, Cambridge Econometrics; compiled by authors from preliminary results that are to be published in the *Macroeconomics of the Energy Union: Policy Report for Modelling Megatrends* (European Commission, 2020h (forthcoming))

Note: The 'low' and 'high' values in Table 1 refer to the most favourable outcome (high) and the least favourable outcome (low) across the four scenarios for each megatrend. For the low carbon scenario, only one set of results is available.

Interactions across the megatrends

Interactions across the megatrends arise through the impacts of each megatrend on the wider economy. To see the range of potential future trajectories, the best and worst scenarios for each megatrend were combined to develop scenarios that show the least favourable and most favourable combinations of scenarios in terms of GDP and employment for the EU. These scenarios map out two possible futures for the EU: one which exploits the possible synergies for highest potential benefits, and another that combines the most pessimistic trajectories. The results for these two scenarios are presented in Table 2.

The best combination of scenarios is one in which smart regulation works with markets and technological change to create a dynamic economy that can adapt to the key challenges faced by society. Compared to the reference case, **the ideal outlook shows positive impacts on EU GDP, with an increase of 7.8 per cent by 2030 and 12.5 per cent by 2050**. However, this is paired with a rather high effect on the workforce: while employment is relatively unaffected by 2030, reduction of employment reaches 3.4 per cent by 2050. This can be attributed to automation effects coming from the assumptions of the technological change megatrend. Due to the increased levels of economic activity, there is a small increase in emissions, reaching an addition of 0.1 per cent compared to the reference case by 2050. Even in this ideal scenario, there remains a challenge for policymakers to address the negative effects of displaced workers.

The worst combination of scenarios shows a case in which technological change and other fast-moving developments create social problems that governments are not able to cope with, resulting in significant negative impacts compared to the reference case.

Impact on the EU-27+UK GDP reaches -3.9 per cent by 2030 and -17.1 per cent by 2050 (compared to the reference case). Employment follows a similar pattern: decreasing by 9.5 per cent by 2030 and by 27.5 per cent by 2050. The decline in employment is most likely driven by combined effects of the demography and the technological change megatrends – employment drops because of more automation and declines further because an ageing and inefficient working age population reduces aggregate demand. These developments lead to a substantial drop in emissions, reaching a decrease of -10.6 per cent (-9.1 per cent by 2050 compared to the reference case), however this decline can be attributed entirely to declining rates of economic activity.

Table 2: Combined megatrend impacts in EU-27+UK-28, summary indicators in 2030 and 2050

Combined megatrends (MT)	2030		2050	
	Least favourable market conditions	Ideal outlook	Least favourable market conditions	Ideal outlook
	per cent from reference case		per cent from reference case	
GDP	-3.9	7.8	-17.1	12.5
Employment	-9.5	0.1	-27.5	-3.4
CO2 emissions	-2.6	2.4	-10.6	0.1

Source: E3ME, Cambridge Econometrics

When the low carbon transition is added on to these best and worst-case scenarios (Table 3), the results reveal the impact that **the low carbon policies add to the positive and negative synergies**. These direct interaction effects between the low carbon transition and other megatrends are relatively small, meaning that the impacts of the low carbon transition are relatively independent of developments in the other megatrends in the E3ME modelling framework. **The results suggest a small positive impact on GDP and employment from the low carbon policies of around 1 per cent in 2050 in both scenarios (compared to the version without the low carbon policies). These positive results arise from low carbon policies (due to restructuring the economy on a sectoral level) replacing some of the jobs lost to automation in the non-low carbon scenarios.** In both scenarios, emissions decline substantially. These results are presented as percentage point (pp) difference from the results for combined megatrends (Table 3).

Table 3: Combined megatrend impacts + low carbon policies in EU-27+UK, summary indicators in 2030 and 2050[27]

Combined megatrends (MT) + low carbon policies	2030		2050	
	Least favourable market conditions	Ideal outlook	Least favourable market conditions	Ideal outlook
	pp from combined MT scenarios		pp from combined MT scenarios	
GDP	1.0	1.1	0.9	1.4
Employment	0.6	0.6	1.2	1.4
CO_2 emissions	-28.8	-30.2	-66.3	-70.7

Source: E3ME, Cambridge Econometrics

Conclusions

The low carbon transition is often thought of as a major contributing factor to economic restructuring. However, the modelling results from E3ME show that, **at aggregate level, the effects of the low carbon transition on GDP and employment might be a lot smaller than the impacts of some of the other megatrends** (eg demographic changes, automation, digitalisation of trade) that are going to occur regardless of policy development. However, **the comparatively minor aggregate impacts of the low carbon transition also hide substantial sectoral differences**, and **careful policymaking is required to ensure that the negative impacts of the low carbon transition will not exacerbate the negative impacts of the other megatrends**.

The multi-layered modelling that combines the various megatrends with the low carbon scenario shows that **low carbon policies are relatively independent of what happens in the other megatrends, and decoupling of emissions and economic growth, achieving higher growth with lower production, is possible for the EU**. This is partially the result of a modelling approach that involved the inclusion of the same set of low carbon policies in the low carbon variant of each megatrend.

Policy framework that supports the development of a flexible economy that is able to adapt to change is a crucial determinant for success as the multiple transitions take place. Best economic and employment outcomes are achieved in scenarios where smart regulation works with markets and technological change to create a dynamic economy. In some cases, **the low carbon transition may complement other changes and can contribute to offsetting certain other negative impacts.**

[27] In the complete set of results published by the European Commission (2020, forthcoming), low carbon scenarios have also been assessed separately for each megatrend. These results show the additional impact that the low carbon transition adds to the megatrend effects, compared to reference scenario outcomes. The results from these scenario variants also give an indication of how the impacts of the low carbon transition might vary under different baseline conditions. These results indicate that the relative impacts of the low carbon scenarios for each megatrend are very similar to the low carbon scenario reference case.

Case studies

Introduction

This section features five case studies that zoom into the impact of selected megatrends on sectors that will play a key role in achieving climate neutrality by 2050. The purpose of these case studies is to broadcast how specific sectors that are relevant for delivering climate neutrality are impacted by the megatrends, how they expect to be impacted in the future, and how the changes are managed. In particular, the case studies are designed to draw out implications of the megatrends for jobs and skills in specific sectors, using examples from relevant countries.

Even though each sector-focused case study is placed in a national policy context, much of the content on the impacts of megatrends on the sector and the associated changes in skills demand are applicable also in other countries. However, situating the case studies in a national policy context enables a more in-depth analysis of the impacts that policy can have, again providing information that will be relevant for governments in other EU countries. The selected case studies are summarised in Table 4.

Table 4: Summary of the case studies

Country context	Sector	Relevant megatrends	Coverage
UK	Offshore wind	Globalisation; automation	UK Offshore Wind Sector Deal setting high level of ambition; Growing number of jobs; potential for redeployment of offshore oil and gas workers; export potential; regional distribution of new employment opportunities; skills profile changing due to automation.
Germany	Automotive manufacturing	Globalisation; automation; demographic changes; resource scarcity	Transition from ICEs to EVs; demographic changes; impacts on supply chains; job losses due to automation and changing production methods; future of the German automotive industry in the face of growing competition from China.
Romania	Coal mining	Resource scarcity; demographic changes	Phasing out of coal essential for achieving climate neutrality by 2050; impacts on employment; social and cultural impacts (breakdown of communities); impact of policy on economic diversification and revival of local economies; reskilling projects by business and government; shift to renewable energy generation.

Country context	Sector	Relevant megatrends	Coverage
Sweden	Steel	Resource scarcity; globalisation; technological changes; demographic changes	Decarbonisation of heavy industry, a major challenge for climate neutrality; impacts of policy on facilitating the development of innovative technologies; shift to circular economy; progressive business practices (cross-sectoral collaboration); competitiveness.
Spain	Agriculture	Digitalisation, demographic changes, (possibly globalisation)	Reducing agricultural emissions presents a challenge for reaching climate neutrality by 2050; better utilisation of smart technologies (including digitalisation, AI, robotics); future demand and for labour; ageing of the agricultural workforce; skills demand implications; resistance to take-up of new technologies.

Case study 1: UK offshore wind power generation

Introduction

Increased electricity generation from renewable sources will be crucial for Europe to achieve climate neutrality by 2050. In the UK, strong government support for the offshore wind industry has enabled the sector to grow substantially over the past decade. Although the offshore wind industry does not yet qualify for the status of a ‘major employer’, the future potential for growth is substantial. The offshore wind industry may also provide alternative employment for offshore oil and gas workers as this sector of the economy contracts. The skilled jobs provided by the offshore wind industry will also enable regions that may otherwise suffer from the shift away from offshore oil and gas to retain economic activity in the area.

An expected large increase in the global offshore wind sector will provide the UK with both opportunities (new markets) and challenges (competition). Automation and new technologies could help increase efficiency and reduce costs.

Offshore wind power in the UK

The UK is the global leader in the offshore wind power generation sector, with the highest power generation capacity, a mature supply chain and world-class engineering expertise. Offshore wind farms are located mostly in the south-east and north-west of England (The Crown Estate, 2019), with key clusters of manufacturing activities being located in the North East (e.g. Newcastle, Blyth and Sunderland), the Humber basin (Grimsby and Hull), North Wales (Mostyn) and East Anglia (Great Yarmouth and Lowestoft).

In Scotland, three offshore wind farms are being commissioned in the next few years and regional clusters are developing in Moray Firth, Forth and Tay (HM Government, 2019). Installed capacity reached 8.5 GW in 2019, and 8 per cent of national electricity is generated through offshore wind (from 0.8 per cent in 2010) (Noonan, 2019). The sector employed an estimated 7,200 full-time equivalent (FTE) and generated £3.7 billion of turnover in 2018. Out of the 7,200 FTEs, 70 per cent are located in England, 23 per cent in Scotland, 4 per cent in Wales and 1 per cent in Northern Ireland (figures are rounded) (Office for National Statistics, 2020). Workers in offshore wind are mostly highly skilled, with technical professionals (corresponding to Office for National Statistics Standard Occupational Classification (ONS SOC) code 2 and 3) and managers (ONS SOC code 1) representing the bulk of the sectoral labour force (Cambridge Econometrics, 2017; Cambridge Econometrics et al, 2013). The sector experienced the sharpest increase in investment among low carbon technologies in 2015–18, accounting for 50 per cent of the £8 billion total investment in renewable energy in 2018. UK exports from the sector amounted to £0.5 billion, contributing positively to the UK current account balance by £0.25 billion (Office for National Statistics, 2020).

Offshore Wind Sector Deal

The development of offshore wind directly follows the UK's effort to become a climate neutral economy. The UK climate policy framework was established in the 2008 Climate Change Act, which set a target of an 80 per cent reduction in GHG emissions compared to 1990 levels by 2050 (BEIS, 2018). This target has recently been revised upwards to 100 per cent (Committee on Climate Change, 2020), and the UK has become the first major economy in the world to establish by law the target of net zero emissions by 2050. Following the climate policy guidelines in the 2017 Clean Growth Strategy (HM Government, 2017), the UK government detailed its ambition for the offshore wind sector in the Offshore Wind Sector Deal of 2019 (HM Government, 2019). Several key commitments, ambitions and targets are put forward in this deal:

- A target of 30 GW of total installed capacity by 2030, thereby providing one-third of national electricity generation.
- A target of 60 per cent UK content within offshore wind projects, up from the 2017 value of 48 per cent (RenewableUK, 2017), increasing especially the UK content in capital expenditure.
- An ambition to employ 27,000 highly skilled workers in the sector by 2030. This will be accomplished by developing new curricula and accreditation, and by facilitating job mobility between energy sectors (eg from oil and gas).
- A commitment of £557 million for support during the next Contract for Difference (CfD)[28] rounds, to be held regularly in the 2020s.

[28] The UK's Contracts for Difference (CfD) system issues 15-year contracts at a given strike price, which is the price contracted with an auction mechanism between the electricity provider and the government. If the wholesale power price drops below that rate, the government tops up their revenue to match it. If the wholesale price is above the strike price, the project owner pays the difference back to the government (Parnell, 2019).

- An ambition of increasing offshore wind exports from £500 million in 2018 to £2.6 billion in 2030.
- A commitment by industry players to invest £250 million to strengthen the UK offshore wind supply chain.

The Offshore Wind Sector Deal represents an important support for offshore wind players, since it guarantees the availability of a long pipeline of projects throughout the 2020s. Indeed, the current pipeline of consented and planned projects should allow the sector to meet and possibly exceed the 30 GW target from the sector deal (Noonan, 2019). However, challenges remain, such as:

- Pressure to reduce costs might limit the ability of firms to invest in better infrastructure and innovation (Noonan, 2019).
- The lack of large British-owned suppliers, in particular in turbine manufacturing, casts a shadow on the feasibility of reaching the 60 per cent local content target.

Offshore wind power and automation

Automation could make operating wind farms more efficient and safer, but will need highly skilled individuals capable of deploying automated systems and analysing data.

The round of CfD auctions held in 2019 resulted in a strike price of around £40 per MWh (Parnell, 2019), a sharp decrease compared to £120 in the 2015 round (Noonan, 2019). This massive cost reduction was made possible by the ever-increasing size of the blades (Vox, 2019). Offshore wind farms utilising the world's largest blades are being constructed in Dogger Bank, near the north-east coast of England (CNBC, 2020). However, the decrease in the strike price is squeezing profit margins from energy production. At the same time, expenditure in the Operation and Maintenance stage is expected to increase from the current £600 million to £2 billion per year by 2030, following the construction of new wind farms (Watson, 2019). Hence, in order for the offshore wind business to be profitable, operators will have to increase efficiency along the supply chain and especially in the Operation and Maintenance stage.

Advancements in digital technologies, big data and machine learning techniques might decrease the costs of operating and maintaining an offshore wind farm by allowing continuous monitoring of performance, to predict and avoid failures and to optimise processes (van Heck, 2019). Robotics and autonomous systems might make operation and maintenance of an offshore wind farm easier and safer. Currently, robots are mostly used in remotely operated tasks, such as blade and cable inspections, but have various shortcomings such as limited autonomy and the need for manual retrieval. Autonomous systems capable of operating beyond the line of sight of a human operator are being developed and could perform tasks such as transporting equipment/parts, carrying out site and subsea surveys and maintenance (Fong, 2019). Moreover, the use of such systems might result in upskilling of the current workforce and job creation rather than replacement, since they will need highly skilled humans who could program, maintain and supervise them.

For example, technicians currently working offshore could be reskilled/upskilled to deploy robots from land and to analyse the wealth of data gathered from autonomous systems (Watson, 2019).

Offshore wind power and globalisation

The expansion of the global offshore wind market represents a sizeable opportunity for UK firms and could support job creation through increasing exports.

Offshore wind is an example of a truly globalised sector, where ownership, components and expertise travel across borders. The UK is the global sector leader for installed capacity and engineering expertise, but few wind farm owners and big suppliers are of British origin (Whitmarsh et al, 2019): Orsted (Danish), Vattenfall (Swedish) and E.ON (German) accounted for 64 per cent of UK market share in 2018 (ORE Catapult, 2018a). Many smaller and successful businesses are also foreign owned (eg the Polish JDR Cables, leader in the cable segment). The UK, as a result of the legacy of sectors such as automotive and oil and gas, has developed a world-renowned expertise in the offshore energy domain, and is currently exporting its products and services around the world. In 2016, 29 per cent of UK offshore wind exports were manufacturing services, while the rest included services such as monitoring, surveying, commissioning and testing, forecasting and support services (RenewableUK, 2016). In 2018–19, UK-based companies signed 317 offshore wind contracts in 15 countries, for a maximum contract value of £8.8 million and a total combined value per company up to £53 million, offering services such as blade transport and installation, cable protection systems, equipment and engineering expertise (RenewableUK, 2019).[29]

The deployment of offshore wind technology has expanded dramatically in the last few years: total installed capacity jumped from 1 GW in 2008 to 23 GW in 2018 worldwide (GWEC, 2019), and is expected to increase to well above 100 GW by 2030 (GWEC, 2018; U.S. Department of Energy, 2019). This expansion could, in principle, create the opportunity to supply countries that have strong ambitions in offshore wind but that still have underdeveloped capabilities, such as South Korea, Taiwan and the US. It is estimated that 21,000 jobs could be supported by offshore wind exports by 2050, of which 7,000 would be in turbine manufacturing and 5,600 in operation and maintenance (O&M) (Vivid Economics et al, 2019). However, national policies such as Local Content Requirement and local standards (OECD, 2015) might hinder UK exports. For example, intellectual property regulation in China, which is the fastest growing offshore wind market and accounts for 20 per cent of global total installed capacity, severely penalises foreign firms in government procurement (OECD, 2015). Moreover, competition will inevitably rise once local markets acquire enough experience to become independent.

[29] These figures refer to a sample of firms, meaning that the number of contracts won and destinations could be higher (RenewableUK, 2019).

Implications for jobs and skills

A 2017 study by Cambridge Econometrics estimates that by 2032 the offshore wind sector might provide 21,000 FTE jobs (more than doubling from current levels) while indirect and induced employment could result in an additional 37,000 FTE positions, resulting in a total of 58,000 FTE jobs. Within the offshore wind sector, technical professionals is the prevalent occupation and most jobs are expected to be created in the North East of England and in the Humber region (Cambridge Econometrics, 2017). The UK has traditionally been capable of producing a world-class offshore workforce employed mainly in the oil and gas sector, whose skills could be easily transferred to offshore wind (ORE Catapult, 2018b). Skills that will be crucial in the development of the offshore wind sector include: engineering and technical skills (mechanical, electrical and control & instrumentation, blade and turbine technicians, with an increased role of IT skills), scientists (with degrees in disciplines such as marine biology, geophysics, hydrography, oceanography) and offshore-specific skills (working in confined spaces, working at heights, team working, team living). However, supplying the skilled workforce needed to meet the expansion of the sector might be challenging. It is estimated that the UK is already short of 20,000 engineering graduates per year for all sectoral demand. Moreover, attracting talent could be more challenging for SMEs (which represent the bulk of the UK offshore wind sector) than it is for large companies (Energy and Utility Skills, 2018).

In March 2020, on the first anniversary of the Offshore Wind Sector Deal, the Offshore Wind Industry Council announced plans to address the skills shortage through apprenticeship training, with a target to employ 3,000 apprentices by 2030. This plan involves recruiting future workers from minority ethnic backgrounds to improve the representation of minority ethnic populations in the energy sector, as well as former military personnel who have transferable skills. The apprentices will work in a wide variety of jobs, from turbine technicians and maintenance engineers to roles in management and finance (Norris, 2020).

CASE STUDY

How Iberdrola leads on offshore wind: a commitment to talent and skills development

For two decades, the Iberdrola Group has been supporting the clean energy transition. Since 2015, it has been actively taking steps to align its operations with the goals of the Paris Agreement and the EU and UK commitments to a net zero carbon economy by 2050. As part of this transformation, the company is:

- investing EUR 100 billion in renewable energies, smart grids and energy storage
- contributing to a fair transition by transforming local industries, such as shipyards, into leaders in renewable energies – a process which is also generating some 420,000 highly skilled jobs globally
- rapidly closing down operations generating electricity from coal or fuel oil (down from 7.5 GW in 2001 to less than 875 MW by February 2020).

In addition to other renewable energy projects, Iberdrola has built a global leadership in offshore wind industry projects with a total capacity of more than 10 GW under development in the UK, Germany, France and the US. In the framework of the UK's Industrial Strategy for the Offshore Wind Sector Deal, Iberdrola's UK-based subsidiary company ScottishPower plays a key role within the Iberdrola Group in the provision of offshore wind-related training and talent-fostering at a global level.

In recent years, ScottishPower has worked actively to improve diversity in the workforce and to increase mobility between offshore renewables and extractive industries. For example, ScottishPower Renewables (SPR) is involved in the creation and development of training courses at the East of England Offshore Wind Skills Centre. As a part of their £55,000 donation, SPR sponsored ten places on an 'Offshore Wind Transition Course', which is aimed at individuals with previous experience in engineering, and focuses on key elements such as working at height and Global Wind Organisation basic technical training. SPR also collaborates with the centre to ensure that the training meets the needs of the sector and can be adapted as the industry evolves. SPR staff members from the local O&M facility regularly attend the college to provide career talks and interview training. One of the early success stories includes the recruitment of a local Lowestoft resident as a trainee balance of plant technician, following on from their successful completion of the funded transition into offshore wind training.

Case study 2: German automotive industry

Introduction

The German automotive industry is an important sector both domestically and in Europe, both in terms of its economic impact and as a source of employment. The industry's supply chains stretch across many European and non-European countries, contributing to employment and economic development especially in Central and Eastern Europe.

However, the German automotive industry is under pressure to transform from a number of directions, including both technological trends and the pressure to reduce GHG emissions. Although some electric vehicles are already manufactured in Germany, a large-scale transformation of the sector will be required, with severe implications for the industry's supply chains, demand for workers and skills requirements. Fierce competition from China and availability of raw materials required for electric vehicle production present additional challenges to the German car industry.

Strong and supportive policy responses will be required to assist the regions, in both Germany and other EU countries, where the local economy relies heavily on employment in automotive manufacturing or production of components for the industry. Policies, subsidies and support will be needed for workers who lose their jobs and who need upskilling or reskilling to re-enter the labour market, as well as businesses that need to change their product supply or business model.

Automotive industry in Germany

The automotive industry is the largest industrial sector in Germany. In 2017, it generated almost EUR 500 billion of turnover (representing 27 per cent of national manufacturing turnover) and employed 866,000 people (representing 12 per cent of national manufacturing employment) (Eurostat, 2020f). Germany is also the largest car manufacturer in Europe: in 2018, it produced 5.6 million vehicles, representing 30 per cent of all vehicles produced in the EU (ACEA, 2019).

However, in 2019, car production in Germany reached a 22-year low of 4.7 million cars. Developments such as lower export demand for German cars (due to competition from elsewhere), technological change and tight emission restrictions imposed by European regulations are challenging the resilience of the sector (The Local, 2020). These developments, combined with the disruption of traditional business models associated with the shift towards the production of electric vehicles, have led German car manufacturers to announce that tens of thousands of jobs are at risk.

Heightened domestic competition in markets such as China and North America as a result of the trade war, the emergence of new competitors with products such as autonomous cars, and the consequences of Brexit[30] are further weakening the outlook for the sector. The coronavirus outbreak is adding further uncertainty in the European automotive sector, with many carmakers (eg Volkswagen, Daimler, Fiat Chrysler Automobiles, Renault) shutting down factories as part of the measures to fight the virus (Fortune, 2020).

German automotive and electric cars

The automotive sector worldwide is preparing to phase out vehicles with internal combustion engines (ICE) and to gradually switch automotive manufacturing to the production of electric vehicles. Many countries and cities, in Europe and elsewhere, have already adopted specific time schedules for the ban of ICE vehicles, and the topic is being discussed at the European level (Burch and Gilchrist, 2018; Euractiv, 2019). The UK is likely to make the phase-out one of their key priorities during the upcoming United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties.

Sales of electric vehicles are expected to surpass sales of ICE vehicles by 2040 (Bloomberg NEF, 2019), with hundreds of millions of electric vehicles entering the global market in the coming decades (Bloomberg NEF, 2019; IEA, 2019a). Fuel cells powered by hydrogen could also play a role in the phase-out of ICEs (McKinsey, 2017b).

In recent years, European regulations on emissions from vehicles have been tightened, with a view of encouraging German and other European carmakers to increase efforts into research, development and production of electric vehicles and hybrids, so they are better positioned to maintain market share.

In April 2019, the European Parliament and European Council adopted regulation, entering into force from 1 January 2020, that sets lower CO_2 emission standards for new passenger cars and light commercial vehicles, including the introduction of more severe penalties for not meeting these standards. The regulation's expected benefits include: contributing towards the achievement of EU commitments in terms of emission reduction under the Paris Agreement; lower levels of pollution; reduced fuel consumption and costs for consumers; and improved competitiveness of the EU automotive industry (European Commission, 2020b; European Parliament and European Council, 2019).[31] These targets are due to be reviewed under the European Green Deal in the framework of a Sustainable Mobility Strategy and to ensure the standards fit with achieving higher climate ambition in 2030 and climate neutrality in 2050.

---

[30] A study from Deloitte estimated that a Hard Brexit could have put at risk 18,000 jobs (Deloitte, 2017b). A Hard Brexit is now unlikely to occur, so that figure can be considered as an upper bound of the impact of Brexit on employment in the German automotive sector. However, future relations are still uncertain, and every additional obstacle to trade would negatively impact the German and European automotive sector (VDA, 2019).

[31] The regulation sets a fleet-wide target for the average emissions of new passenger cars of 95 g CO_2/km, and a penalty of EUR 95 for each g CO_2/km multiplied by the number of newly registered vehicles (European Parliament and European Council, 2019).

EU, national and local government policies aimed at reducing vehicle emissions,[32] together with foreign competition and changing consumer preferences, are pushing German producers to increase their production targets for electric vehicles. Some examples of positive action and future plans announced by German car manufacturers include:

- Volkswagen's plans to produce one million electric cars by 2023 and to have electric vehicles represent 40 per cent of VW cars sold globally by 2030
- BMW projections that electric vehicles will account for 15–25 per cent of its sales by 2025[33]
- Daimler's aim to introduce more than ten electric models by 2022 (Business Insider, 2020).

Overall Germany's automotive industry is expected to invest EUR 60 billion over the next three years on developing electric cars and automated driving (Automotive News Europe, 2019).

On the consumer side, a low driving range, a higher price and a lack of charging infrastructure have been shown to deter potential buyers so far (Deloitte, 2019), and the level of **uptake of electric vehicles**, measured as a percentage of total passenger car registrations, remains low to date, although the demand for electric vehicles increased substantially between 2013 and 2017. They still account for less than 5 per cent in large markets such as Germany, France, the US and China (Bruegel, 2018), but dramatic increases in Norway show one example of how the market might develop. In 2018, there were 5.1 million electric vehicles registered worldwide, of which 2.3 million were in China, 1.2 million in Europe and 1.1 million in the US (IEA, 2019a). Data for the last quarter of 2019 point to an increase in electric vehicle penetration in Western Europe, reaching 3 per cent of the total market (Schmidt, 2020).

However, many of these constraints to electric vehicle demand should be at least partially solved in the coming years as the reduction in battery prices is expected to make electric vehicles cost-competitive with ICE vehicles by the mid-2020s (Bloomberg NEF, 2019) and the next generation of electric vehicles will have a longer driving range (Deloitte, 2019). Increasing the market share of electric vehicles in Europe from the current 2.6 per cent of all new car registrations to 30–50 per cent by 2030 will be required to achieve the EU targets on transport sector emissions reductions (Deutsche Bank Research, 2020).

To ease the transition, the German government has recently announced a plan to stimulate demand for electric vehicles by extending financial incentives up to EUR 6,000 per vehicle through to 2025 and by committing to installing 50,000 recharging stations within two years (Bloomberg, 2019).

[32] eg future national bans on ICEs, EU regulations on fleet-wide emissions targets and local clean air zones.
[33] The category electrified vehicles might include different kinds of vehicles other than pure Battery Electric Vehicles.

Additional policy measures to boost the demand for electric vehicles include a tax exemption for the charging of electric vehicles and an exemption from the motor vehicles tax (BMWi, 2020). Many similar measures are also already in place in other EU countries and the UK.

Economic impact of transition towards electric vehicles

The transition towards the production of electric vehicles might impact the economy through various channels.[34] First, the production of electric vehicles directly generates value within the German economy through domestic sales, exports and investment in charging infrastructure. In Germany, the cumulative investment required is estimated at EUR 8 billion by 2030 (Cambridge Econometrics et al, 2017), although the need to import battery cells for electric vehicles may partially reduce the economic gains by generating value abroad. However, the shift away from petroleum will allow Germany to capture a higher value added from the energy used in mobility through the domestic production of low carbon electricity. Hybrid and electric vehicles are also more efficient in their energy use, which will lower mobility costs for households and allow them to shift their spending towards areas with a higher domestic value added, such as non-essential services.

Based on specific assumptions about the location of battery production and on future oil prices, German GDP would be 0.5 per cent higher in 2030 because of investment in electric vehicles, with a potential net employment creation of approximately 145,000 jobs, primarily in construction, electricity, hydrogen, services and manufacturing (Cambridge Econometrics et al, 2017). However, regions where the automotive sector, including the production of components, constitutes a significant share of total employment might be negatively affected.

German automotive and automation

Automotive manufacturing is one of the sectors with the highest concentrations of industrial robots. In Germany, robots have increased productivity, reduced the number of new entrants in manufacturing industries (including automotive) and increased gains for capital owners.

Germany is the fifth-largest market for robots in the world, with almost 27,000 industrial robots installed in 2018, most of them in the automotive industry (International Federation of Robotics, 2019). However, the increased use of robots is estimated to have had a more significant impact on the sectoral composition of the workforce rather than on total employment (Dauth et al, 2017). As analysis by Dauth et al (2017) shows, employment in manufacturing, and especially automotive manufacturing, was negatively affected by the additional use of robots between 1994 and 2014, ie one additional robot led to the loss of two manufacturing jobs. However, this impact was almost entirely due to a reduction in job creation rather than robots replacing existing jobs.

Although robots do not seem to have directly displaced existing workers in Germany, they do appear to have led to increased income inequality by increasing the earnings of high-skill

[34] See ETUI (2019) for a comprehensive discussion.

workers and decreasing the earnings of low and medium-skill workers, particularly in machine-operating occupations. Moreover, robots increased aggregate productivity without a corresponding increase in the average wage, implying that the additional gains from higher productivity were captured mostly by capital owners (Dauth et al, 2017). Consistent with these findings, employment in the German automotive sector is forecast to increase by only 0.1 per cent over 2018–30, mostly in high-skill occupations (eg science and engineering professionals), despite an expected decline of 0.4 per cent in the labour force during the same period (Cedefop, 2019).

German automotive and globalisation

Germany is the biggest car exporter in the world, accounting for 20 per cent of global car exports, followed by Japan, the US and the UK (United Nations, 2020). In 2018, Germany exported **motor vehicles** to a value of EUR 162 billion, accounting for 12 per cent of Germany's total exports, equally divided among exports to the EU-28 and outside the EU-28. However, the German automotive manufacturing sector is highly vulnerable to the new production processes associated with the transition to electric vehicle production as well as growing competition from countries such as China. In particular, China is positioning itself as the global leader in the production of electric vehicles.

In terms of electric vehicle value chains, China has also established itself as the leader in electric vehicle battery manufacturing, together with South Korea and Japan (Bruegel, 2018). In 2018, less than 3 per cent of electric vehicle battery supply was provided by companies outside these countries (McKinsey, 2019c). Within the EU-28, Germany is leading the way in terms of R&D in low carbon vehicles (which include electric, hybrid and hydrogen vehicles) with companies such as Volkswagen, Bosch and BMW accounting for a substantial share of patent activity between 2012 and 2014 (Bruegel, 2018).

The switch of the automotive sector towards electric vehicle production will disrupt the traditional supply chains based on internal combustion engines. Electric vehicles have fewer components and are easier to manufacture compared to traditional vehicles, and their production requires a lower number of workers. This might entail employment losses not only in car manufacturing but also in the repair and maintenance sector (which in 2017 employed 69,000 workers in Germany (Eurostat, 2020f).

Moreover, it has been estimated that 60 per cent of the content of an electric vehicle originates from outside the traditional supply chain (Bruegel, 2018). There is already evidence of supply chain restructuring in Europe, with German manufacturers of components such as Bosch, Mahle and Schaeffler making redundancies because of lower employment needs connected to electric vehicle manufacturing. Certain regions in Germany, the Czech Republic, Italy, Hungary, Romania, Slovakia, Sweden and the UK have been identified as more vulnerable to potential losses in employment due to the switch to electric vehicles (FTI Intelligence, 2018), as demand for the components that are produced in these locations declines.

Despite these challenges, setting up the supply chains to produce electric vehicles will be fundamental to avoid further job losses stemming from a loss of international competitiveness. There will be significant impacts on manufacturing and employment in Germany should third countries (eg China) take a lead in electric vehicle manufacturing.

Moreover, a certain number of jobs will also be created as a result of increased electric vehicle production: new facilities for the production of electric vehicle parts are being created in Europe by a few European companies, and Asian companies are opening battery plants in Europe (especially in Hungary) (Eurofound, 2020). According to recent announcements, the construction of 11 battery manufacturing facilities (four located in Germany) is planned to deliver 131 GWh in capacity by 2023 and 274 GWh by 2028, potentially creating 120,000 jobs by 2023 and 250,000 jobs by 2028 in the EU (taking into account both direct and indirect job creation) (Transport & Environment, 2019).

German automotive and resource scarcity

The batteries in electric vehicles will require a large amount of raw materials such as cobalt, lithium and nickel, the supply of which is concentrated in a limited number of countries (eg cobalt comes mostly from the Democratic Republic of Congo and China (Alves Dias, Blagoeva et al, 2018). Securing a reliable and sustainable supply of these raw materials will be fundamental in order to develop a competitive electric vehicle industry in Germany and Europe, and create jobs. At the same time, access to domestic supply of rare minerals and metals such as cobalt improves China's competitive advantage.

German automotive producers are aware of these constraints (Reuters, 2017), with manufacturers such as Volkswagen and BMW exploring new methods of procurement – eg buying directly from suppliers without relying on intermediaries, or using blockchains to trace the origin of raw materials (Electrive, 2019; MoDo, 2019). Implementing effective practices to reuse and recycle batteries will also be an important step towards reducing the need for raw materials and limiting the risk of shortages (IEA, 2019a).

In order to address the challenges described above, the European Commission launched in 2017 the European Battery Alliance (EBA), which gathers together institutional and industrial stakeholders, and whose aim is to create a competitive manufacturing value chain of sustainable battery cells in Europe (European Commission, 2020c). The EBA promotes measures to:

- secure access to raw materials and support a European battery value chain, while promoting socially responsible mining in third countries
- support the sustainability of the European battery cell manufacturing industry and ensure consistency with the broader EU regulatory framework
- develop and strengthen a highly skilled workforce along the value chain.

In terms of developing specialised battery-related skills in the workforce, the European Commission is implementing the following actions (European Commission, 2020c):

- including batteries as a key topic for funding as part of the Blueprint for Sectoral Cooperation on Skills under Erasmus+
- developing robust master-level energy-transition-related curricula and degrees, together with executive training for companies' staff
- encouraging research centres to offer access to their battery laboratories, as the Joint Research Centre (JRC) has already done.

The new Industrial Strategy of the European Commission (European Commission, 2020e) also continues to include a focus on batteries.

Implications for jobs and skills

Estimates of the employment impacts of the transition to electric vehicle production are influenced by assumptions regarding the speed of the transition, the degree of automation, the impact of globalisation on manufacturing in Europe, the proportion of electric vehicle components that will be produced domestically, and the scope and perspective of the analysis. As such, all of these estimates are subject to a high degree of uncertainty.

What seems to be agreed is that the switch to electric vehicles will entail some job losses. Electric vehicles contain fewer parts than traditional ICEs and are faster to manufacture, resulting in lower demand for component parts (as many will become obsolete) and less work for assembly workers (Cambridge Econometrics et al, 2017; Wissenbach, 2018; Woolsey, 2018).

So far, substantial job losses in the automotive industry have not materialised: in 2017–18, the number of jobs in the German automotive industry increased rather than declined (Statista, 2019). However, predictions regarding future employment impacts range from the loss of 400,000[35] jobs by 2030 to more moderate losses of approximately 75,000 to 100,000 jobs, primarily in engine and gearbox manufacturing (ETUI, 2019; Financial Times, 2020; Wissenbach, 2018). However, it is important to note that these figures rely heavily on a number of assumptions, some of which are more plausible than others, and so they should be viewed with caution.

At the same time, some studies estimate net gains from new jobs in vehicle electronics and batteries (Wissenbach, 2018). At the European level, some sources also estimate a net increase in the number of jobs across the economy as a result of electromobility, largely arising from fuel-switching from petroleum from imported oil to domestically generated renewable energy (Transport & Environment, 2017). It has also been argued that some job losses in automotive sector value chains, both in Germany and elsewhere in Europe, could be avoided by repurposing car parts factories and training workers to build components for electric vehicles (Campbell, 2018).

[35] A study by the National Platform Future of Mobility, an advisory council for the German government, predicts a strong negative impact on employment because of higher imported inputs and a higher degree of automation (Nationale Plattform Zukunft der Mobilität, 2020).

The skills profile needed in the manufacturing of electric vehicles will be a combination of traditional and new skills. On one hand, managerial design and marketing capabilities already utilised in traditional automotive production are transferable to electric vehicles. On the other hand, the production of batteries, the need for lighter materials and changing production processes (which will likely be more automated, not least for safety reasons), require new occupational profiles and different skill sets from the current workforce. Occupations that are likely to increase in numbers include chemists, material scientists, engineers (eg chemical, electrical, industrial and mechanical engineers) and computer analysts. All these occupations require at least a tertiary-level education, with postgraduate degrees needed for occupations involving research and development.

New skills required will include the ability to set up, operate and maintain automated systems, in particular for assembling electrical motors, computers, electronic control devices and sensing equipment. Machine tool operators (eg mechanics) will need to complete a formal vocational training programme focused on working with electrical and electronic systems (Cambridge Econometrics et al, 2017). There is also the need for more transversal skills such as social and intellectual skills (required to evaluate and organise information and data), with a focus on adaptability (Eurofound, 2020). The production of electric vehicles might become more dangerous as workers are exposed to higher voltages, temperatures or toxic materials (Eurofound, 2020), increasing the demand for specialised health and safety training.

In 2017, the European Commission launched a framework for addressing skills needs in key sectors, called the Blueprint for Sectoral Cooperation on Skills, which includes a focus on automotive (European Commission, 2017c). Within this framework, several pan-European projects[36] aim at understanding the future skills needs of the automotive sector and develop appropriate training for upskilling and reskilling with the involvement of the industry (European Commission, 2020d). The DRIVES, project, for example, involves 24 partners from 11 countries, and will reach 270,450 companies of all sizes, representing over seven million workers (DRIVES, 2020).

[36] The DRIVES project and COSME-funded project.

Case study 3: European coal regions (Romania)

For Europe to reach climate neutrality by 2050, it will be necessary for the consumption of coal for energy generation to be phased out across the region. As the vast majority of coal is used for energy generation, most coal mining activity will need to cease altogether. The coal sector has been in decline since the early 1990s, partly as a result of the coal industry having become uneconomical during industrial restructuring in the 1990s, and partly as a result of the closure of mines due to fall in energy demand, gas price protection and environmental pressures (Baicu, 2017; Visenescu and Bartelet, 2017). Subsequently, many former coal-mining regions were left with weak economies and negative demographic trends characterised by high out-migration and an ageing population.

Under the EU commitment to Just Transition as part of the European Green Deal, disadvantaged regions that depend on coal mining for employment and economic activity are to receive support to help diversify their economies and to reskill workers. Reskilling and redeployment of former coal industry employees in the renewable energy sector could provide at least a partial solution, with employment opportunities that are aligned with the EU's 2050 climate neutrality target. This approach is particularly appealing, especially in countries such as Romania and Bulgaria that have a high potential for wind and solar energy generation. In Romania, the renewable energy sector has been successful, and has significant cost-competitive potential, placing the country in a strong position for a future increase in this sector as power generation needs to shift away from the use of coal (Bankwatch, 2020b). However, currently the government has not demonstrated ambition for future renewables targets and the sector faces a number of barriers (Bankwatch, 2020a).

Coal industry in Romania

Employing 16,000 people (2018), the Romanian coal sector is the third largest coal sector in terms of employment in the EU-28, after Poland and Germany (Euracol, 2020). Besides mining jobs, it provides 10,000 additional jobs (2015) through indirect employment[37] (Alves Dias, Kennellopoulos et al, 2018). Around 80 per cent of the coal sector workforce is represented by production and auxiliary staff, which include roles such as equipment operators, electricians and mechanics (Alves Dias, Kennellopoulos et al, 2018).

Although the coal industry employs only a very small proportion of the 8.6 million (2018) workers in Romania (Eurostat, 2020a), coal and coal products are important to the country's electricity mix, accounting for 24 per cent of Romanian electricity generation (Eurostat, 2020g). In 2020, according to the official figures, there are eight functioning coal power plants in Romania, with an installed gross capacity of 5,315 MW (Bankwatch, 2020b).

The coal industry is geographically concentrated in Sud-Vest Oltenia and Vest, where reserves of hard coal are found in the Jiu Valley basin (within Hunedoara County) and lignite in Oltenia (within Gorj County) (Euracol, 2020), and is therefore of high economic importance to these

[37] Indirect employment refers to activities such as power generation, equipment supply, services and R&D.

regions. Employment in mining and quarrying[38] in Hunedoara and Gorj counties accounted for around 20 per cent of total employment in each in 1992, while in 2018 it accounted for 2 per cent and 7 per cent of total employment respectively (NSI Romania, 2020a, 2020b).

Romania has a long-standing tradition of coal extraction, but the sector has been shrinking rapidly over the past 30 years. In the 1990s, employment in the hard coal sector amounted to 171,000 workers (Ecoaction et al, 2019). Since then, a deep restructuring process has caused closures of mines and a large number of layoffs. In 1997, 20,000 workers were laid off and employment has subsequently declined at a pace of several thousands of layoffs per year (Ecoaction et al, 2019). The restructuring of the sector was unavoidable given the inefficiencies of the coal mines and their dependence on state aid. After its accession to the EU in 2007 and following a Council decision of 2010, Romania is no longer allowed to offer state aid in any sector (Bankwatch, 2019), although some exemptions were granted to subsidise production costs in the hard coal sector, first until 2011 and then until 2018 (Ecoaction et al, 2019).

Although negative effects of the restructuring process were partially mitigated by international loans from the World Bank (Bankwatch, 2019), the decline of coal has had a major impact on the economy of the coal regions. Oltenia had a level of GDP per capita of around 75 per cent of the national figure and almost double the national unemployment rate in 2016 (6 per cent at the national level versus 10 per cent in Oltenia) (Alves Dias, Kennellopoulos et al, 2018).

The coal mines that remain operational in the Vest region show some of the lowest outputs per employee in Europe. Coal mines and power plants in the Vest region and Oltenia are also among the most polluting in Europe, accounting for 50 per cent of emissions of sulphur dioxide and nitrogen oxides in the region (Alves Dias, Kennellopoulos et al, 2018). The environmental unsustainability of the Romanian coal sector is exemplified by the performance of the two biggest mining companies, which are also major regional employers. In Vest region, Complexul Energetic Oltenia (CEO) is responsible for 99 per cent of national lignite production and directly employing 13,000 workers, while reporting EUR 230 million of losses. According to Euracol (2020), these losses were exacerbated by the CEO taking out loans to purchase CO_2 allowances, which account for half of its total operating costs. In Sud-Vest region, Complexul Energetic Hunedoara (CEH), employing 3,022 workers, filed for insolvency in 2019 (Euracol, 2020).

Despite the decline of the sector, increasing EU-ETS (Emission Trading System) prices and the expiration of the technical life of 2,400 MW of capacity (out of a total coal-based capacity of 3,700 MW in 2020), the Romanian government has not set a date for completing the phase-out of coal. Until recently, the government had declared the intention of maintaining and

[38] Mining and quarrying includes resources other than coal, but a breakdown of employment by type of resource is not available. However, based on employees data (for which such breakdown is available), it is possible to observe that coal accounts for a substantial share of mining and quarrying in those regions.

increasing current capacity, enshrining the role of coal in ensuring energy security to 2030 and beyond (Ecoaction et al, 2019). However, this might be changing given that the 600 MW lignite unit in Rovinari is no longer mentioned in the latest version of Romania's list of investment plans (Bankwatch, 2020b). According to a recent restructuring proposal, additional lignite capacity is planned to close as follows:

- The two units (150 MW each) at Craiova II will be closed in 2025. They will be replaced in 2024 with a 200 MW gas unit.
- Ișalnița unit 8 will be closed in 2025, and unit 7 in 2026. Both will be replaced one year prior to their closing with a 400 MW unit working on gas.
- Unit 3 at Turceni (330 MW) will be closed in 2025. It will be replaced in the year prior with a 400 MW gas unit (Bankwatch, 2020b).

Renewable energy in Romania

The structural changes implemented since 1990 have led to a substantial drop in emissions, making Romania the fourth-fastest EU-28 member state in terms of reducing its emissions against 1990 levels (Sandbag, 2020). Romania's energy mix has two contrasting features: on the one hand, its share of electricity produced by renewables, at 41 per cent in 2018, is higher than the EU-28 average of 33 per cent; on the other hand, 24 per cent of electricity is produced using coal, exceeding the EU-28 average of 19 per cent (Eurostat, 2020g). The share of renewables in final energy consumption stood at 23.9 per cent in 2018, only just below the target of 24 per cent for 2020, having declined by 1 pp since 2014 (EurObserv'ER, 2020).

In 2019, Romania had a renewable energy capacity of nearly 11.25 GW generated by wind (3,030 MW), solar photovoltaics (PV) (1,377 MW), hydropower (6,692 MW), and biomass and biogas (141 MW) (IRENA, 2019). In 2018, the renewable energy sector employed 55,000 FTEs,[39] making it the seventh largest, in absolute terms, within the EU-28. Eighty-five per cent of employment in renewables (46,800 FTEs[40]) was in biomass and biofuels, followed by 6 per cent (3,300 FTEs) in hydro, 4 per cent (2,200 FTEs) in wind, and 2 per cent (1,100 FTEs) in both solar PV and geothermal, with the rest distributed among residual sources (EurObserv'ER, 2020). At the national level, it is estimated that future increases in renewable electricity generation capacity could provide employment for a total of 12,000 FTEs in wind and more than 3,000 FTEs in solar by 2050 (Kapetaki et al, 2020).

Romania's draft Integrated National Energy and Climate Change Plan (INECCP) 2021–30 sets out a target for 2030 of 27.9 per cent for the total share of renewable energy in final gross energy consumption (Energy Policy Group, 2018). This target is below the EU target of 32 per cent in 2030. However, the Romanian Wind Energy Association (RWEA) estimates that a share of 35 per cent by 2030 could be achieved with a smaller investment and a similar consumer price to the one in INECCP (Nicuţ, 2019a), suggesting that the 2030 target should be higher.

---

[39] These figures consider both direct and indirect employment but not induced employment.
[40] These high employment figures are due to the size of the agricultural sector in Romania.

Subsequent versions of the INECCP have allocated higher targets of 30.7 per cent in gross energy consumption so this may still evolve (Bankwatch, 2020a).

Despite the importance of wind energy in total consumption (10 per cent), there were no new investments in the sector in 2018, and from the draft INECCP it appears that capacity might not be increased until 2025 when the country will be divided into at least ten regions of development for wind and solar energy (Nicuţ, 2019b).

Romania coal sector and demography

Demographic trends in Romania are characterised by a declining and ageing population and a net negative migration. Between 2000 and 2018, total population in Romania decreased by 13 per cent, mainly because of negative net migration, with an average of 0.5 per cent of the population leaving the country each year. The coal regions present a more extreme variation of the national picture. Gorj County in the Sud-Vest Oltenia region experienced a decrease at 19 per cent and an average net negative migration of 0.4 per cent per year, while Hunedoara County in the Vest region saw a decrease of 26 per cent and an average net negative migration of 0.7 per cent per year (Eurostat, 2020h). In terms of age structure, the median age in Romania is increasing constantly: it was 41 years in 2014 and 42.5 in 2019. During the same period, the median age in Gorj increased from 41 to 44 years and in Hunedoara from 44 to 46 (Eurostat, 2020i, p. 3). As mentioned in the demography megatrend, older workers tend to participate less in educational activities or training, therefore ageing could pose a problem in terms of updating the skills of older workers in view of transitioning to employment in the renewable energy sector. In addition, Romania faces a major challenge when it comes to research and development, with one of the lowest levels of investment in the EU (Eurostat, 2019d).

Throughout most of the 20th century, the growing coal mining industry in the coal regions attracted workers from other regions across Romania, resulting in growing populations and local economies dependent on one sector. Since the restructuring of the mining sector and the wave of layoffs during the 1990s, a combination of decreasing birth rate, increasing death rate and emigration have resulted in a steep population decline (Bankwatch, 2019). These effects were most noticeable in small towns whose economies were dependent on coal mining and that were strongly hit by the process of economic restructuring (Burlacu et al, 2019). For example, in Hunedoara County (which includes the Jiu Valley), unemployment rates went from 4.5 per cent in 1991 to 21 per cent in 1999 and oscillated around 10 per cent until 2010. However, the level of unemployment has since gradually decreased to 3.4 per cent in 2018 (NSI Romania, 2020c). According to some sources, the rise in unemployment during the 1990s was exacerbated by the educational system, where the curricula at vocational, technical and university level were largely based around training requirements for the mining sector (Ecoaction et al, 2019). The high level of unemployment and subsequent emigration have influenced the age structure of the local population, with ageing populations being a constant trend since the early 1990s (Burlacu et al, 2019).

Romania coal sector and climate policy

The phase-out of coal in Romania could be compensated by greater investment in renewable energy technologies. It is estimated that coal regions in Romania have a technical potential of 10–25 GW for wind and 20–80 GW for solar (ground-mounted) PV. Offshore wind could also contribute with an additional capacity of 8 GW (Kapetaki et al, 2020; Bódis et al, 2019). The coal regions of Sud-Vest Oltenia and Vest have a high solar capacity factor[41] compared to the European average, and Oltenia has a high wind capacity factor, compared to the European average (Alves Dias, Kennellopoulos et al, 2018).

The exploitation of renewable energy resources could in principle transform the economic model of the coal regions away from mining into a more diversified and sustainable one. The economy based on coal mines had deep environmental consequences such as land deterioration, excessive land use and water pollution (Ecoaction et al, 2019). The closure and conversion of coal mines into wind and solar PV farms could have several advantages, including the restoration of the environment; the recovery of extensive areas of land which could host the new renewable farms; the possibility to reconvert some of the existing infrastructure to be used in renewable energy generation; lower land transaction costs because of fewer owners; a positive impact on the local economy through new employment and re-employment opportunities especially in the construction phase; and a higher social acceptance of renewable energy farms, which could be placed in closed mining sites instead of valuable land (Alves Dias, Kennellopoulos et al, 2018). It is estimated that, in Oltenia, the optimal mix of energy generated from reclaimed mines should be 30 per cent wind and 70 per cent solar (Kapetaki et al, 2020). However, to maximise long-term employment benefits, a long-term renewables development plan which leads to a building in capacity across the renewables sectors would be required.

Implications for jobs and skills

To meet the Paris Agreement emissions reduction targets, global coal use will need to decline by approximately 60 per cent by 2040 (IEA, 2019b). The European Green Deal announced by the European Commission in December 2019 clearly expresses the aim to phase out coal in Europe completely and build an energy sector based entirely on renewable and other low carbon sources (European Commission, 2019b). The transition towards a less carbon-intensive energy sector will have an impact on workers and regions that have already experienced some negative impacts from the previous decline of the coal industry, but where the local economies did not manage to find alternative sources of development. One such example is the Jiu Valley, within Hunedoara County, which contains cities specialised in coal mining-related activities. During the period of restructuring in the 1990s, the unemployment rate reached 27 per cent in the Jiu Valley and mine closures also reduced activity in the machinery equipment and power generation sectors (Burlacu et al, 2019).

---

[41] Capacity factor is defined as the ratio of energy produced from a certain source and total installed capacity (that is, the maximum energy that it is possible to generate).

Since then, entrepreneurial activities have been limited, and 40 per cent of the workforce is concentrated in the mining sector (Burlacu et al, 2019). In Romania, job losses in the coal sector are likely to continue with further decommissioning of power plants and the closure of remaining mines. More than 10,000 jobs are estimated to be at risk by 2030, mostly in the Sud-Vest region (Alves Dias, Kennellopoulos et al, 2018). The Cedefop Skills Forecast expects a 7 per cent per annum decline in employment in the coal sector in Romania during the period 2018–30 (Cedefop, 2019).

In 2017, the European Commission launched the Platform for Coal Regions in Transition to bring together relevant stakeholders to share best practices and experiences (European Commission, 2020f). In December 2018, more than 50 countries signed the Just Transition Silesia Declaration to pledge their commitment to ensuring that the social aspects of the low carbon transition are not overlooked (COP24, 2018). In January 2020, the European Commission published its proposal for a Just Transition Mechanism, intended to provide support to territories facing serious socio-economic challenges related to the transition towards climate neutrality. The Mechanism comprises three pillars (Cameron et al, 2020):

- a Just Transition Fund worth EUR 7.5 billion in the period 2021–27
- mobilisation of a portion of InvestEU financing to mobilise EUR 45 billion of investment in 'Just Transition projects' in the period 2021–27
- creation of a public sector loan facility at the European Investment Bank to mobilise a further EUR 25–30 billion of additional public investment in the period 2021–27.

The government is now expected to draw up the regional plans for transition to a climate neutral economy, focusing mainly on local economy diversification, reskilling of workers and ecological transformation of the areas previously used for coal and oil extraction (Nițulescu, 2020). This could also present at least a partial solution for energy poverty in Romania as it would force local and central government to invest in energy efficiency through retrofitting and all new construction being "nearly Zero Energy Buildings" (Popov, 2019).

The phase-out of coal means that workers will have to adjust to the new economic conditions. For example, they will have to decide whether to search for an occupation in the same sector (eg mining[42] of gold, silver, salt or copper, in which Romania is rich (Thomson Reuters, 2019)), whether to update their skills/retrain to work in another sector, or whether to move to other regions. For example, a coal industry worker could stay in the energy sector, with the same skills and in the same region, as a power plant operator working in a biomass power plant after the plant conversion. At the other extreme, an industrial electrician could retrain to become a technician on a wind farm in another region. The wind and solar PV industries demand highly skilled engineers and technicians, and have been identified as suitable redeployment options for coal workers through reskilling/upskilling (Alves Dias, Kennellopoulos et al, 2018).

[42] Gold and silver can be found in Centru and Vest regions. There are seven operating salt mines; some can be found in Sud-Vest and Nord-Est.

However, some regions such as Oltenia are considering replacing the coal-generation capacity with gas units (Spasić, 2020) which tend to be less labour intensive to maintain and would therefore mean fewer employment opportunities than the development of renewables (IRENA, 2011; Behrens et al, 2014).

Several programmes, funded mainly by the World Bank, were carried out between 2000 and 2012 to counteract the negative socio-economic consequences of restructuring the mining sector. Implemented measures included micro-credit, enterprise support, community capacity building and employment and training incentives. The latter consisted of covering on-the-job training costs incurred by employers willing to hire laid-off workers from the mining sector. Performance indicators in 2005 pointed to 6,763 jobs created because of this measure (Bankwatch, 2019).

Funded by the Platform for Coal Regions in Transition, one major programme to reskill miners from the Jiu Valley was launched in 2019 by the RWEA in collaboration with Monsson–RESS, CEZ Romania, the Romanian Ministry for Energy, and Petroșani University. In the next ten years, the reskilling programme is expected to support approximately 5,000 individuals to acquire new professional qualifications to access skilled jobs in wind energy, while 3,000 participants will be trained to take skilled jobs in the energy distribution sector – although the ability of these workers to then access gainful employment locally would depend on Romania substantially increasing their wind capacity. The reskilling programmes will take place at a Renewable Energy School of Skills to be created in the Jiu Valley. A similar centre already exists in Constanta and has trained 4,500 workers who now work in maintaining the 3,000 MW wind energy capacity in Romania. Of these professionals, 95 per cent also spend time working abroad as part of their duties (energynomics.ro, 2019). While most miners in the Jiu Valley are mindful of a lack of future prospects for their current job, some are reluctant to retrain as wind technicians, as this would involve being away from family while working abroad (Gurzu, 2019).

Developing a local renewable energy sector could boost the local economy and provide considerable environmental and health benefits. Transitioning from a coal-based economy to one based on renewables will not be easy or quick. Although employment increases in wind and solar energy in the coal regions are not expected to be sufficient to substitute all coal-related jobs,[43] long-term development plans that also take into account infrastructure could lead to more significant opportunities. In addition, energy efficiency interventions could be capable of absorbing a significant proportion of the remaining workers (Kapetaki et al, 2020).

[43] This estimation in based on the EUCO3232.5 scenario, consistent with a 32 per cent share of renewable energy in gross final energy consumption and 32.5 per cent energy efficiency target in the EU. These forecasts are based on estimates of the future installed capacity in the region, which in turn depend on indicators such as regional GDP, the current level of technological adoption, percentage of national surface covered, level of technology-related employment, labour market data, competitiveness indicators, technical capacity and others.

While the coal regions might have the technical potential to transform into renewable-energy regions,[44] the legacy of their mono-industrial past may weigh negatively on their future (particularly in terms of employment, but also in terms of stranded assets[45]).

Therefore, comprehensive and timely efforts to improve the local economic environment must be put in place. Unless the transition is swiftly managed, there is a risk of the current diversified engineering and educated workforce leaving the region. Possible measures include: implementing qualification/re-qualification and vocational training programmes, developing entrepreneurship and supporting business creation, strengthening administrative capacity, strengthening the role of universities, increasing the connectivity of the area, and developing and promoting a regional brand (Burlacu et al, 2019).

[44] Technical potential is the highest amount of energy that could be generated taking into account geographical constraints and system performances, but not economic or market constraints.
[45] See discussion of potential use of land previously used for coal mining in the section on 'Romania coal and climate policy', above.

CASE STUDY

Transforming Bulgaria's Maritsa East into the 'Energy Technology Valley of Southeast Europe'

The future plans for the Maritsa East (ME) region could see 240 km^2 open cast lignite mines transformed into an economic zone that would combine clean energy-generation technologies with industrial and R&D enterprises associated with the regional and global energy transition. This transition, driven by industry, local government and potential investors, and supported by the Bulgarian government, could enable the area, which is naturally unsuitable for agriculture, to be productively repurposed to preserve employment and facilitate economic development.

ME is close to key industry centres and at a crossroad of three major EU transport corridors. As a focal point of the Bulgarian national and trans-border electricity grid, ME is connected to three high-voltage lines that are listed as EU Projects of Common Interest. The redevelopment plan would involve complementing the favourable geographic position with improvements to existing infrastructure, a favourable tax regime and low-cost, high-skill labour to attract investors. The three key principles of the redevelopment proposal for ME include: (a) preserving the 3.3 GW power-generation capacity of the region, using a combination of technologies including various renewable-energy technologies, to protect Bulgaria's energy security; (b) preserving and increasing the number, quality and pay grade of employment in the region; and (c) retaining and increasing the economic output of the region. The redevelopment would also increase the number of high-skill jobs in the region and thus help reverse brain and youth drain, which are currently depleting the population.

Funding for the redevelopment is being sought from the EU coal regions in transition platform, EU cohesion funds, the European Regional Development Fund (ERDF) and the EU's multiannual financial framework (MFF) funds designated for climate-related activities and R&D, among other sources. In the longer term, the region would be expected to also attract private investment. The most ambitious development scenario would require several billion EUR in investment, but would see ME emerge as one of the main EU new energy and energy-related R&D and industrial centres driving EU competitiveness forward on the basis of competition and cooperation with key players in China, the US and Japan.

Case study 4: Steel in Sweden

Introduction

Steel is used widely in almost all industries, with a growing trend around the globe. At the same time, iron and steel production are responsible for nearly a quarter of global industrial CO_2 emissions. Following the adoption of the EU's 2050 climate neutrality target, the steel industry is under intense pressure to improve energy efficiency, recycle more and switch to low carbon production processes. However, in a capital-intensive industry characterised by path dependency and technological lock-ins, sustainability transitions are not straightforward. The steel industry is generally known as one of the sectors of heavy industry that are classified as 'difficult to decarbonise'. Although recycling-based production mechanisms, which can reduce emissions from steel production to very low levels, are already widely used, the limited availability of high-quality scrap steel means that some new production will be required to meet the growing demand in the coming decades. The technologies to decarbonise so-called virgin steel production are subject to extensive research and investment – both within and outside the EU.

This case study is set in the Swedish context, where the government and industry are already working together to achieve two major climate targets: 100 per cent renewable electricity generation by 2040 and a net zero carbon economy by 2045.

These ambitious goals, together with the Fossil Free Sweden initiative, which predated the COP21 Climate Change Conference in 2015, put a lot of pressure on all Swedish industries to decarbonise.

Fossil Free Sweden is an institutional innovation which was designed to function as an intermediary between the various government ministries and the industry, and to facilitate new forms of collaboration between business and nation state. Under this initiative, Swedish industries have developed roadmaps for fossil-free competitiveness for 13 industry sectors, including steel. The purpose of these roadmaps is to detail what actions each sector must take and what policies are needed to enable them to make meaningful progress. By designing their own roadmaps, each sector is presenting themselves as progressive players in the transition to a net zero carbon economy by 2045. By taking ownership of the process, industries are also seeking to foster a sense of pride, build a positive public opinion and attract new talent.

The commitment to develop fossil-free steel production is supported by both the Swedish government and the industry, with decarbonisation being embedded in the long-term plans of both of the country's large incumbent iron and steel producers: LKAB (a state-owned mining company) and SSAB, which operates the country's two remaining plants that use blast furnaces (Nuur et al, 2018). These two companies are leading entrepreneurial activity and experimentation with new technologies to decarbonise virgin steel production, with the help of substantial financial support from the Swedish Energy Agency.

For these companies, investing in innovation makes economic sense. At present, SSAB relies on imported coal to operate its blast furnaces, instead of using readily available, domestically generated, fossil-free electricity. Second, by taking the lead in the development and implementation of new technology, SSAB aims to enhance its competitiveness in the long term (Nuur et al, 2018).

The lack of resistance against the pressures to decarbonise the steel industry from the part of the incumbents is likely to facilitate a faster and smoother decision-making process (Nuur et al, 2018). A high degree of collaboration across the industry is further assisted by the Jernkontoret,[46] which focuses primarily on supporting cooperation in research, education, standardisation, sustainability and communication-related topics. The support of the Jernkontoret is essential in the context of the ageing workforce in the steel sector, and lack of suitably qualified new entrants. These challenges are likely to increase in magnitude in the future as the skills demand in the steel industry changes due to new technological advances, including the transition to decarbonised steel production.

Steel industry in Europe and the world

Steel is an alloy of iron and carbon, used for a variety of purposes in many industries such as construction, machinery manufacturing, domestic metal products and domestic appliances, automotive, energy, and shipbuilding and other transportation (Posco Research Institute, 2017). Steel is produced mainly through two methods, differing in the type of fuel used: the blast furnace, which uses iron ores and recycled steel as inputs and burns coal as the main energy input, and the electric arc furnace, which uses mainly recycled steel as inputs and uses electricity (produced using fossil fuels or renewable sources) as the main energy input (World Steel Association, 2020). In 2018, 71 per cent of steel was produced in blast furnaces globally (World Steel Association, 2019a), which is a method that contributes significantly to global emissions by using highly polluting coal for iron ore reduction.

Steel production is of high importance to the EU and global economies. In 2018, world production of steel amounted to 1.8 billion tonnes, 9 per cent of which was produced in the EU and 70 per cent in Asia (mainly China). In the same year, the European steel sector generated 320,000 direct jobs spread among 23 member states, 1.6 million indirect jobs and 701,000 induced jobs, for a total of 2.6 million jobs (Eurofer, 2019). When measured by value of production, the iron and steel industry ranks as the fourth largest industrial sector in the EU (Oxford Economics, 2019). In 2017, the EU steel industry produced EUR 147.8 billion worth of output and EUR 10 billion in direct tax impact (ie taxes paid by steel companies and their employees), with the total tax impact (which also includes taxes on activity in the supply chain and staff spending) estimated to be around EUR 60 billion (Oxford Economics, 2019).

[46] Jernkontoret is the Swedish steel producers' association that was set up in 1747 to safeguard the iron and steel industry's interests and to strengthen its networks.

In the last decade, the European steel sector has faced increasing international competition: between 2008 and 2018 the share of EU output in global steel production decreased by 5 percentage points (pp), while China's share increased by 13 pp. These competitive pressures have been exacerbated by less stringent energy standards outside of the EU, by discriminatory trade practices, and by global overproduction that has lowered the price of steel (European Commission, 2019e).

Apart from a dip in the aftermath of the financial crisis, demand for steel in the EU has followed an increasing trend, rising by 20 per cent between 2009 and 2018. Over 2000–16, the trade balance (in value terms) of iron and steel products was positive. However, from 2017 the trade balance in iron and steel turned negative (Eurostat, 2020m). If these trends were to continue, increased EU demand for steel might be serviced from elsewhere, rather than domestically, with consequences for employment and availability of a key material. In response, the European Commission has put in place a series of measures to sustain the sector and foster innovation (for example under H2020 projects, or through the Research Fund for Coal and Steel) (European Commission, 2016a).

Worldwide, the steel sector accounted for one-quarter of industrial CO_2 emissions in 2017 (IEA, 2019c). Despite a reduction in both CO_2 and energy intensity, expanding production has increased total energy demand and CO_2 emissions. To attain the goals set by the Sustainable Development Scenario (SDS),[47] CO_2 and energy intensities should decline at a rate of 1.9 per cent and 1 per cent a year respectively in the period 2017–30. To achieve these targets, changing modes of production away from blast furnaces using coals into more sustainable methods (IEA, 2019c), such as the one based on hydrogen being experimented in Sweden, will be essential. The European Green Deal recognises the importance of the steel sector for the European supply chain and for environmental sustainability, and explicitly supports initiatives towards the development of zero carbon steelmaking technologies (European Commission, 2019b).

Steel sector in Sweden

Sweden's steel production accounts for 3 per cent of total European steel production (Eurofer, 2019) and for 2 per cent of Sweden's GDP[48] (Eurostat, 2020n). It also plays a key role in the industrial competitiveness in Sweden (Nuur et al, 2018). In 2018, the steel sector in Sweden employed 15,700 workers directly and 26,500 indirectly, and accounted for 4 per cent of Sweden's total exports of goods (Jernkontoret, 2020). Although jobs in the manufacture of basic metals sector in Sweden have been declining over the last ten years (a 16 per cent reduction in employment between 2008 and 2018), employment in manufacture

[47] The Sustainable Development Scenario is designed by the International Energy Agency (IEA) and identifies pathways to reach climate mitigation targets, cleaner air and universal access to energy (IEA, 2019d).
[48] The GDP figure refers to NACE sector 24 Manufacture of basic metals, which includes metals other than steel. A more detailed breakdown of GDP from the national accounts is not available.

of basic steel has remained broadly constant over the same period. However, employment in manufacture of steel products has declined (-36 per cent) (Eurostat, 2020f).[49]

The Cedefop Skills Forecast projects a decline of 1 per cent a year over 2018–30 in the manufacture of basic metals sector in Sweden (Cedefop, 2019).

In response to foreign competitive pressures, Sweden has developed expertise in high-strength steel grades[50] and niche-oriented products made of environmentally friendly steel. The country has two integrated ore-based iron and steel plants, ten scrap-based plants and 15 finishing plants (Jernkontoret, 2020). In 2018, high-quality alloy steel accounted for 60 per cent of total Swedish steel production, compared to 10–15 per cent in the rest of the EU, the US and Japan. Residual products created as a result of iron and steel production processes are mostly reused or recycled: 50 per cent is sold externally (eg sold as products), 30 per cent is reused in the production process and 20 per cent is waste that is disposed of in landfill, although the share of this is steadily declining (Jernkontoret, 2018, 2020).

Because standard steel grades are no longer produced in Sweden, the internal consumption of steel is mainly supplied by imports, while much of the high-grade steel manufactured in Sweden is exported, mostly to the EU (70 per cent of all exports), China, the US and many other countries in the world. In terms of value, Sweden exports more steel than it imports, but in terms of weight, the amounts of steel imports and steel exports are similar, implying that Sweden exports high value-added steel while it imports steel with a lower value-added. More than 90 per cent of imported steel comes from other EU member states and the UK (Jernkontoret, 2020).

Green steel in Sweden

In 2017, the iron and steel industry produced about 6 per cent of global CO_2 emissions (IEA, 2019e) and accounted for about 10 per cent of Swedish CO_2 emissions (SCB, 2020). Traditional steel production involves using coke in a blast furnace for iron ore reduction, which is highly polluting.

Decarbonisation of virgin steel production is an essential to avoid a steep decline in the number of jobs that the European steel industry supports, as the EU seeks to achieve climate neutrality by 2050. To this end, new production processes are being explored, which uses hydrogen instead of coke for iron ore reduction and produces water vapour as a by-product instead of CO_2. If the energy to produce hydrogen is derived from renewable sources, the production process of steel can become emission free (FCHEA, 2019). In Sweden, the steel industry incumbents are actively involved in the exploration of decarbonisation technologies, with a view of contributing to Sweden's goal of net zero emissions by 2045 and improving their own competitiveness in the global markets.

---

[49] Manufacture of basic steel refers to NACE 24.1, while manufacture of steel products refers to NACE 24.2 and 24.3.

[50] eg stainless steel, tool steel, high-speed steel, bearing steel, commercial steel, iron alloy for electrical resistance heating, iron powder (Jernkontoret, 2020).

To give one example of ongoing efforts in Sweden, a steel manufacturer (SSAB), a mining company (LKAB) and an energy provider (Vattenfall) have formed a joint venture company, called HYBRIT Development AB (HYBRIT, 2020a), which is exploring the use of hydrogen in steel production processes. The hydrogen will be generated using fossil-free electricity.

With this new method of producing steel, CO_2 emissions generated from the steel industry could be eliminated (HYBRIT, 2020b), while retaining the steel industry in Sweden. Developing this technology would also help improve the competitiveness of the Swedish steel industry in the decarbonising world (Nuur et al, 2018). Construction of a pilot plant began in 2018, with EUR 52 million of assistance from the Swedish Energy Agency. The pilot phase should last until 2024, with a subsequent demonstration phase from 2025 to 2035 (FCHEA, 2019).[51]

However, implementing this production process is not without its challenges. Although no major technical obstacle has been identified, the transition will require a restructuring of supply chains, which is expected to increase production costs. Operating costs will be 20–30 per cent higher than traditional production based on coal. Hydrogen-based production will require a lot of electricity, and therefore its profitability will depend to a significant extent on electricity prices. In the future, ETS prices will make using coal more expensive and renewable energies will be cheaper and abundant, which will reduce the cost difference between the two production methods. Nevertheless, the buyer of fossil-free steel will need to be willing to pay a premium for it. Both the pilot and demonstration phases will be extremely expensive, and public funding from the government or the EU will be needed (Euractiv, 2018).

Sweden is well placed for the production of fossil-free steel. First, Sweden has an abundant and fossil-free electricity production mix and is expected to have electricity surpluses in the future. Second, there is no resistance from the industry or from society to the adoption of the new technology (which is being pioneered by a large incumbent in the steel sector). Cooperation in the industry is very strong, with frequent knowledge exchange, and competition coming mainly from foreign markets. However, SSAB's blast furnaces are already considered to be among the most efficient in the world and devising an equally efficient and stable system based on hydrogen will be challenging (Karakaya et al, 2018).

Hydrogen is not the only solution being investigated to produce green steel, with European-funded projects playing a key role. Technologies for CO_2 mitigation in the steel industry can be grouped into three categories: Carbon Direct Avoidance (CDA), Process Integration (PI) and Carbon Capture, Storage (CCS) and Usage (CCU). CDA technologies aim at reducing CO_2 emissions directly, using alternative methods for the production of steel, by using, for example, hydrogen, biomass and electrolysis to reduce iron ore and other elements involved in the process. HYBRIT is included among these technologies, together with EU-funded projects such as ULCOS, IERO and SALCOS.

[51] During the pilot phase, a pilot plant is built and used to perform tests, experiments and determine the optimal settings for a limited period of time (up to two months). During the demonstration phase, a demonstration plant will run as an industrial facility operating 24/7 for many months (Euractiv, 2018).

PI technologies aim at reducing the use of carbon in steel production, for example by using organic sludge in steelmaking (OSMet S2) or by a better use of steel plant gases (CO2RED, RenewableSteelGases). CCU technologies concern different methods of carbon capture based on chemical biological processes of CO_2 conversion and capturing. For example, projects are trying to convert industrial CO_2 into fuel, other chemical products and materials such as plastics (BIOCON-CO2, CarbonNext, Carbon4PUR) (ESSA, 2019).

In terms of future employment prospects, much depends on which technologies are the first to achieve commercial viability. At the moment, all of the above-mentioned projects that focus on developing new technologies to decarbonise virgin steel production are exploratory in nature, and the employment opportunities associated with each are difficult to estimate. However, considering that the new production processes are highly likely to utilise the latest technological advances, we can assume that the majority of the future jobs in the steel industry will require skilled workers, especially workers with a high level of digital skill. In Sweden, the heavy involvement of the largest incumbents in the development of hydrogen-based technologies would suggest that many of the future jobs may be located through the hydrogen value chain.

Steel sector and automation

Technological innovation will be essential for the competitiveness of the steel sector. According to the European Commission, the steel sector cannot compete on the basis of low wages or reducing the costs associated with working conditions and social standards. Instead, the European steel industry should base its competitiveness on innovation, technology, quality and highly skilled people (ESSA, 2019). The main challenges around the adoption of Industry 4.0 in the steel industry concern legacy equipment, uncertainty over the impact on jobs and issues of data protection/safety (ESSA, 2019) among others.

The applications of new technologies in the steel sector are many. For example, real-time data helps with the monitoring of processes and products. Every product can be checked by sensors along the production chain, and errors can easily be traced back and amended. Thanks to data availability and machine learning, maintenance work can be anticipated and thus faults can be avoided. Checks can be performed either autonomously by the equipment itself, or remotely. Thanks to AI, production systems can work autonomously and organise themselves, thus reducing errors, increasing speed and cutting costs. Greater connectivity and data sharing can help with, among other things, stock management, automatically re-ordering materials when stocks are running low. Digital technologies will allow closer interactions between steel producers and customers, and will be utilised to deliver products tailored to customers' needs (ESSA, 2019). Although it is currently difficult to put a value on the productivity gains and cost savings that can be achieved through improved data availability, automation, mobile technology and computational power, the impacts of these new technologies in the metal industry overall are expected to be significant (McKinsey, 2018). Other examples of technologies adopted in the steel industry include: Internet of Things Systems; big data analytics and cloud computing; robot-assisted production; production line simulation; self-organising production; Cyber Physical Systems; smart supply network; vertical/horizontal integration; predictive maintenance; augmented reality; self-driving logistics vehicles; digitalisation of knowledge management; and additive manufacturing (ESSA, 2019).

Automated technologies will be implemented also within the HYBRIT project for the production of fossil-free steel. Given the reliance of this method on electricity, a high energy efficiency will be fundamental to reducing operating costs.

Therefore, the HYBRIT pilot plant will be equipped with intelligent switchgears and frequency converters, together with a software simulation solution that will allow operators to learn and test processes in a safe environment, thus enabling quick commissioning and reducing the risk of unplanned shutdowns (ABB, 2020).

Swedish steel and resource scarcity

Steel is the widest-used metal because of its good mechanical properties and affordability (IRP, 2019), as well as high recycling rate. Iron is one of the most abundant metallic elements, with iron ores (from which steel is made) making up 5 per cent of the Earth's crust and being mined in 50 countries (with Australia and Brazil accounting for two-thirds of exports) (World Steel Association, 2019b). However, iron causes the highest climate impact among metals, due to the large volumes of steel produced yearly and the energy-intensive processing of the ore into iron and steel, with the sector accounting for about one-quarter of global industrial energy demand. Therefore, recycling steel will be fundamental to reducing its environmental impact, given that recycling steel allows savings in terms of CO_2 emissions in the range of 62 per cent to 90 per cent compared to primary production using currently available most efficient technology (IRP, 2019).

Recycling-based steel production, which uses electric arc furnaces that can be powered using low carbon and renewable electricity, will be fundamental to reducing the CO_2 emissions from the steel industry (even the most efficient blast furnaces required for virgin steel production still use coke). Recycling-based production also uses less energy, approximately 10–15 per cent of what is needed for virgin steel production (Material Economics, 2019). To reach the SDS target by 2030, electric furnaces based on scrap will need to account for more than 40 per cent of production by 2030 globally, up from 28 per cent in 2017. Increasing the availability of scrap through higher recycling will therefore be fundamental (IEA, 2019c).

In Sweden, AI methods are being applied in metal recycling: software can analyse sensor data in real time and allow robots to sort objects, thus being able to distinguish between different types of metal (eg copper, steel, aluminium etc) and specific objects (eg electric motors, wires etc) (Recycling Magazine, 2019). However, recycling-based production capacity depends on the availability of suitable scrap steel, which is not sufficient to meet the growing demand for steel (IRP, 2019). It is likely that in the future steel production from virgin steel material will still be needed in order to meet the global demand for steel, although the estimates regarding the share of virgin steel production or the total steel production vary considerably. According to Material Economics (2019), improvements to scrap handling and reduced contamination would enable 70 per cent of EU steel production to be met from scrap, reducing the need for virgin production to 30 per cent of the total. Other estimates, however, are slightly less optimistic, pointing to at least 50 per cent of global steel production still coming from virgin material by 2050 (Morfeldt et al, 2015). At global level, OECD estimates that between 57 per cent and 61 per cent of steel production (expected to roughly double in a baseline scenario) will be serviced by virgin materials by 2060 (OECD, 2019a). Therefore, adopting new and less polluting production processes, such as the ones based on hydrogen, will be fundamental.

Steel is a material which is particularly suited for use within a circular economy. First of all, research has managed in the past decades to keep lowering the quantity of steel used in products while maintaining the same characteristics (eg strength and functionality), thus ensuring a more efficient use of materials. Second, steel is a material with a high durability which can be reused or repurposed in many ways. Rates of reuse will increase once eco-design becomes more commonplace. Third, many steel products can be remanufactured, ie they can be restored to like-new conditions. Fourth, steel is 100 per cent recyclable and can be recycled multiple times without losing its properties, and is the most recycled material in the world (World Steel Association, 2015).

Implications for jobs and skills

The steel sector is often perceived by younger generations as involving low-skill, low-pay, and less safe occupations (European Commission, 2019e). However, the reality of the modern steel industry is different, with salaries comparable to other industrial jobs and highly automated, high-tech workplaces. Occupations in the sector increasingly require engineering and scientific knowledge, proficiency with technology and understanding of processes. Subsequently, there is a high demand for science, technology, engineering and maths (STEM) graduates in the sector.

Low student enrolment in STEM curricula has been identified as one of the main factors behind recruitment difficulties in the steel industry. In addition to low enrolment, only a small a proportion of students who choose to pursue STEM degrees specialise in metallurgy and material science. Moreover, those graduating in STEM subjects tend to choose to work in sectors considered more attractive (eg ICT services, banking, finance and insurance, professional services), highlighting a lack of awareness of the career opportunities offered by the steel sector (European Commission, 2019e).

Similar issues are experienced in Sweden, which reports a falling interest in technical specialist subjects among students. Moreover, younger generations are inclined to change job more often, therefore limiting the accumulation of specialist knowledge of the metal industry (Jernkontoret et al, 2013). In Sweden, the percentage of tertiary-level students graduating every year in STEM fields was 27.5 per cent in 2017, slightly above the EU-28 average of 25.8 per cent (Eurostat, 2020n).[52]

[52] The fields of study chosen in the Eurostat dataset are: natural sciences; mathematics and statistics; information and communication technologies; engineering, manufacturing and construction.

However, looking at graduates in STEM fields per 1,000 inhabitants aged 20–29, Sweden had a value of 15pp. in 2016, compared to an EU-28 average of 18.7 (Eurostat, 2020o). Instead, looking at doctoral-level graduates per 1,000 inhabitants aged 25–34, Sweden has a value of 1.3, higher than the EU-28 average of 0.8.[53] Therefore, although STEM graduates represent a significant portion of tertiary graduates and doctoral STEM graduates are more available than in other member states, the absolute number of STEM graduates is lower than the European average and could give rise to shortages of the appropriate qualifications. The field of study mismatch[54] for all fields of study in Sweden is 34 per cent, meaning that 34 per cent of workers are employed in occupations not requiring their field of specialisation. However, looking at the science, mathematics and computing field, the mismatch surpasses 50 per cent, implying that many graduates in sciences choose to work in other fields, potentially increasing recruitment difficulties for the Swedish steel industry. The mismatch for the engineering, manufacturing and construction field of study is lower, at around 30 per cent (OECD, 2016).

In terms of occupations, the European and Swedish steel sectors alike have a strong demand for skilled professionals in different levels of the supply chain, with a predominant focus on engineers and skilled production workers. Demand is high for metallurgical engineers, specialised metallurgists and automation engineers and technicians such as computer scientists, application managers and ICT managers (European Commission, 2019e). Engineers in the steel sector might expect to work in areas such as material development, operation research, production techniques, environmental technology, process controls and application engineering. Production area operators are also in high demand, for example machinists, welder mechanics, furnace operators, electricians, engineering and production technicians and design engineers. Non-engineering profiles that are required are human resources (HR) specialists, professional communicators and economists (European Commission, 2019e; Jernkontoret, 2020).

Besides technical knowledge, employers in the steel industry increasingly look for a diversified skill profile.[55] The synergy between different competencies is crucial, with employers in the steel industry demanding workers with an area of specialism complemented by a series of transferable skills such as general technical skills, digital skills and soft skills. It will be important for workers to be able to move across tasks and areas of the supply chain. Soft skills required for managers include entrepreneurial skills (eg a solid understanding of the steel market and customer needs), while technicians and metal workers are no longer required to simply perform a task, but need to understand how that task fits within the overall functioning of the plant, and therefore need to continuously improve and update their skills. Technical skills include knowledge of material science, mathematics, physics and chemistry, with digital skills being in growing demand. Indeed, the use of computers is no

[53] Value calculated manually as a simple average of the EU-28 member states.
[54] Field of study mismatch arises when workers are employed in a different field from that which they have specialised in. Results for this indicator are based on the Survey of Adult Skills (PIACC) of 2012 (OECD, 2016).
[55] As highlighted by surveys and interviews with experts (European Commission, 2019e).

longer linked to specific departments or tasks but has become a general requirement (European Commission, 2019e).

In addition to shortages of workers with adequate profiles such as STEM graduates, other factors are presenting further difficulties for employers in the steel industry to obtain suitable workers. While production processes will become more automated and digitalised, integrating new technologies and processes among site workers, especially the older ones, is challenging. Moreover, the large age gap between current and prospective employees limits the transfer of fundamental domain knowledge.

Reskilling/upskilling needs are felt by employers, but so far a lack of investment in training and education from steel companies or lack of a long-term skill strategy has prevented meaningful progress (European Commission, 2019e).

The problem of the ageing of the workforce is particularly felt in the steel industry. The average age of workers in the steel industry is relatively high, with consequences on the abilities of employers to adapt their workforce to new skills, such as digital skills which are more common in younger adults. Older workers seem to be more resistant to change and to adopting more flexible approaches to tasks and responsibilities. This attitude changes based on the roles covered, with specialised technicians or engineers being more adaptive to changes than crane operators or forklift workers (European Commission, 2019e). In the steel industry, knowledge acquisition relies heavily on on-the-job informal education, with knowledge being transferred between the older and the younger generations. However, the low number of young entrants and the increasing age of steel workers creates a gap in knowledge transfers, with expert older workers retiring without being able to pass on their knowledge (European Commission, 2019e).

In-company training programmes do not seem to adequately address the skills needed, since they are targeted at very specific roles and tasks and do not build the flexible skills profile required (European Commission, 2019e). In Sweden, the problem of the availability of skills is partially addressed by a high level of cooperation between industry and educational institutions, with students of degree programmes having to prepare a project in collaboration with companies. Companies often offer placements, summer jobs or traineeships, where trainees are enabled to work on different tasks within the company (Jernkontoret, 2020).

Going forwards, in the steel sector the demand for low-skill labour performing routine tasks will decrease, while the demand for high-skill labour will increase. The jobs linked with administrative functions will be the ones at greatest risk of automation. Production workers will still make up the majority of hiring in the steel sector but will perform different tasks and will require a varied and flexible skillset. Specialised technical skills and advanced technology skills will remain in demand in the near future. The knowledge of steelmaking processes and materials will remain fundamental, but the importance of digital skills will rise substantially, implying that workers will still need in-depth knowledge of tasks but will not be performing them. Green skills[56] are projected to become increasingly important, which is in line with the efforts of the industry to meet the EU 2050 targets. An increasing number of R&D profiles will be needed to lead research in sustainable steel and new production processes, while floor workers will need competences in resource efficiency, material reutilisation and recycling (European Commission, 2019e).

[56] Competences in circular economy, environmental issues, resource reutilisation/recycling, sustainability.

CASE STUDY

Modelling technological changes in the steel industry

Under the HYBRIT joint venture, the Swedish firms SSAB, Vattenfall and LKAB are collaborating to develop a fossil-free hydrogen-based steelmaking process as an alternative to coal-based steelmaking by 2035. While the main objective is to reduce the environmental impact of steelmaking, the economic impacts are also important. This short case study looks at how Cambridge Econometrics' technology diffusion model Future Technology Transformations (FTT): Steel, together with the Energy-Economy-Environment Macro-econometric (E3ME) model, can be used to estimate the potential impacts of green steel production.

After a fossil-free hydrogen-based steelmaking technology is successfully developed, the broader adoption of the new technology depends largely on the policies enacted by the Swedish government. We can model the likely impacts using two different scenarios: a baseline scenario where the Swedish government does not enact additional policies beyond the current policies already in place, and a scenario in which policies to support and encourage further carbon reductions (such as higher carbon tax, subsidies for clean technologies in steel and power sectors, and support for clean hydrogen production) are enacted. The prevalence of three different types of steel production technologies (carbon-based, hydrogen-based and recycling) are presented in Figure 1.

As Figure 1 shows, in the baseline scenario the adoption of the hydrogen-based production technology remains low, while the share of production using recycling grows steadily. This is because existing policies already encourage a shift towards recycling-based production. However, if all countries globally shift to recycling-based production to the same extent, the availability of scrap steel may start to constrain production capacity. In the 'mitigation' scenario, where supporting policies for hydrogen-based production are introduced, this production mode increases more rapidly, reducing both carbon-based production and recycling-based production. In this scenario, the need for scrap steel is lower than in the baseline scenario, meaning that similar or even higher levels of output can be maintained even if global competition for scrap steel intensifies.

In Figure 2, we can see the emissions and employment impacts of the two scenarios. Emissions are presented as percentage difference from the 'baseline' scenario, and show a substantial decrease in the emissions from steel production in the 'mitigation' scenario. This is primarily because of reduced virgin production using carbon-based technologies (the emission intensity of recycling and hydrogen-based production are currently similar). However, hydrogen-based production is slightly less labour intensive than carbon-based production, so the employment grows less in the mitigation scenario than the baseline scenario (a small increase in output is assumed here, which explains the slight increase in employment in both scenarios). The difference between the 'mitigation' and 'baseline' scenarios is moderated by the fact that recycling-based production is less labour intensive than hydrogen-based production.

For steel production to continue in a decarbonised economy, then developing and deploying innovative zero carbon primary production methods like hydrogen will ensure minimal negative impacts on employment.

Figure 1: Production by technology

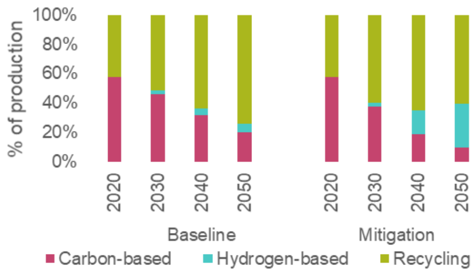
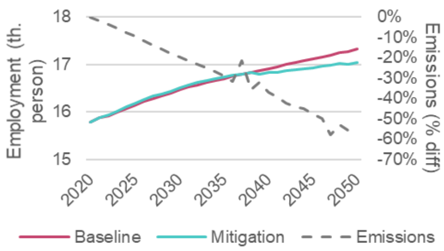


Figure 2: Employment and emissions



Source: Cambridge Econometrics' own calculations.

Case study 5: Agriculture in Southern Europe (Spain)

Introduction

According to the IPCC report on climate change and land (Ferreira et al, 2019), agriculture and food production lead to changes in the land that in turn drive climate change. Land damaged by soil erosion and desertification has less capacity to absorb carbon and can actually become a net source of carbon emissions.

So far, the impact of climate change on agriculture in Europe has mainly been felt by countries in the south of Europe and among small-scale livestock farmers. The increase in droughts and floods decreases yields, while water scarcity makes small farms less viable. Implementation of soil management can be used to mitigate desertification while the newest technology and agricultural practices can help farms to adapt to climate change.

This case study focuses on the impact of changing climate on agriculture in Spain, and how new technologies could help the farmers adapt to climate change. Although this case study is set in the Spanish context, many of the conclusions are applicable across various EU countries where the characteristics of the agricultural sector are similar to those in Spain, namely a large share of farms being run as small family businesses, an ageing workforce, population decline in rural areas, and lack of educational opportunities resulting in a lower level of digital skills among rural populations. In Spain, as well as many other parts of Europe, small-scale farmers are heavily reliant on EU subsidies and vulnerable to growing competition from non-EU countries. The small size of farms, together with limited digital skills and access to further training, present financial and skills-related barriers to the adoption of new technologies that could improve resilience and productivity in unfavourable climatic and demographic conditions. In such contexts, strong support will be needed to enable farmers to embrace new technologies and alternative farming methods that will improve their ability to adapt to climate change and growing market pressures.

The agriculture sector in Spain

Agriculture is one of the most important sectors of the Spanish economy. In 2017, agriculture accounted for 2.7 per cent of GDP (down from 3.9 per cent in 2000). As such, the share of agriculture in total GDP is higher than in other big member states, such as Italy, France and Germany, and higher than the EU-28 average. Between 2000 and 2017, agricultural production in Spain grew by approximately 1.6 per cent per annum. During the same period (2000–17), employment in the sector declined slightly, from 882,000 workers employed (5.3 per cent share of employment) in 2000 to 750,000 workers (4 per cent of total employment) in 2017. The economic importance of the agro-industrial sector as a whole (including all activities linked with agriculture such as food processing, distribution etc.) is even greater, accounting for 11 per cent of GDP and 14 per cent of total employment in Spain in 2016 (PwC, 2019).

In 2017, Spanish agricultural land covered one-third of its national surface and accounted for 13 per cent of EU agricultural land. While Spain accounted for 8 per cent of EU GDP, its share of EU agriculture production was 13 per cent.

Agriculture in Spain is characterised by the highest diversification of products among EU member states. On the one hand, a higher variety of products reduces risks associated with a specific crop (eg oscillation in international prices) and production can continue through the whole year. On the other hand, each type of crop will be vulnerable to different diseases and will require different kinds of treatment (PwC, 2019).

Although traditional cultivation methods are still important in Spain, the surface dedicated to them has decreased by 24 per cent since 2007 (PwC, 2019). At the same time, conservation agriculture and, most of all, organic farming, have seen strong growth. Indeed, Spain is now the European country with the highest amount of surface dedicated to organic farming, and the fourth largest at the global level. Organic farming is usually more labour intensive than conventional farming (ie it uses more labour per hectare), but in Spain an agricultural worker needs to tend more hectares in organic farms than those working on conventional farms, simply because of a lower productivity of land (ie a single worker will have to work on a larger area of land in order to be profitable) (European Commission, 2013). However, organic farming employed 92,000 workers in 2018, with a 9 per cent increase from 2017 (Gobierno de España, 2019). Precision agriculture[57] has also developed in recent years, and is focused mainly in Andalusia (PwC, 2019).

[57] Precision agriculture is a modern farming management concept using digital techniques to monitor and optimise agricultural production processes.

The average size of farms in Spain is relatively small, at 25 hectares (compared to 90 hectares in the UK or 62 hectares in France), and the vast majority of them (93 per cent) are owned by a single person. Moreover, 91 per cent of cultivations employ primarily members of the owner's family as workers (PwC, 2019), especially in northern Spain (Schuh et al, 2019) – however, this pattern is not unique to Spain and reflects the situation in many other European countries, including France. The small size of farms limits productivity, because smaller enterprises are less capable of incorporating more physical and human capital or to innovate (PwC, 2019). The small size of the farms also impacts on employment in the sector: many agricultural workers do not work in the sector full time. In Spain, the share of foreign workers in agriculture increased from 20 per cent to 25 per cent between 2011 and 2017 (Schuh et al, 2019). The COVID-19 pandemic has highlighted the reliance of European agriculture on seasonal workers, with both France and the UK reportedly struggling to attract sufficient manpower to ensure seasonal fruit and vegetable harvests (Evans et al, 2020).

Profit margins for farmers are low in Spain because of high levels of intermediate consumption, which includes: phytosanitary[58] concerns, fertilisers, energy and lubricants, seeds, animal feeds, vet bills, equipment, building maintenance and others (Euractiv, 2016). Subsequently, Spanish agriculture is highly dependent on the Common Agricultural Policy (CAP). In 2017, Spain received EUR 6.8 billion from CAP, the second highest amount in the EU. An 83 per cent share went as direct subsidy to farmers, while 17 per cent was used for rural development (PwC, 2019). Estimates of the effectiveness of CAP interventions in the EU vary, but some studies point to positive effects of Pillar 2 Rural Development policies on rural jobs (Schuh et al, 2019) and on knowledge, skills and innovation (European Commission, 2019c).

Agriculture in Spain and globalisation

Spain has a competitive advantage in agriculture compared to other countries because of its climate, which allows year-long production. Agriculture accounted for 6 per cent of Spanish exports in 2017 and is the sixth largest exporting sector in the economy.

Spain accounts for 2.4 per cent of global agricultural exports, with the main exported products being olive oil (Spain accounts for 44 per cent of the global production of olive oil) and wine. In terms of countries of destination, 87 per cent of agricultural exports are sent to other EU countries, especially France and Germany, and the UK.[59] The main other export destinations outside the EU are Switzerland, the US and the United Arab Emirates. Agricultural exports contributed positively to the current account by EUR 6.6 million. The surplus coming from agricultural exports helps to reduce the trade deficit that Spain has incurred in recent years (PwC, 2019). Because of its export orientation, the agricultural sector is more resilient to a downturn in the Spanish economy than other sectors (PwC, 2019).

[58] Plant health.

[59] The UK left the EU on 31 January 2020.

Some categories of product, like cereals, have to be imported since national production is not enough to satisfy demand. Fifty-four per cent of agricultural imports to Spain come from outside the EU, from countries such as the US and Brazil (PwC, 2019). Recently, however, imports of other products have also increased, including products that are grown in Spain in sufficient quantities to meet the demand of the domestic market. Imports of such goods from countries that do not meet EU production requirements have led to lower market prices in the EU, which do not allow small-scale farmers in Spain to cover production costs. The farmers have subsequently accused large supermarket chains of slashing the prices of fruit and vegetables, forcing small producers to lower their own prices or go out of business[60] (Euronews, 2020).

The likely loss of exports caused by Brexit and a proposed 14 per cent cut in EU subsidies risks putting even more pressure on small farming in Spain (Euronews, 2020).

Agriculture in Spain and technological change

Technology is increasingly used in agriculture to enhance productivity while reducing the environmental impact and resource use stemming from agricultural activities. Technology can support farmers in facing challenges such as extreme weather, volatile prices, changes in consumer behaviour, natural disasters and diseases (Pesce et al, 2019). Some technologies can thus help farmers to cope better with climate-change-induced uncertainties that will affect their operations.

Several trends are driving the adoption of new technologies in agriculture. Demand for food is putting pressure on agricultural systems: global population and the middle classes are expected to increase and to consume more food. At the same time, climate change and more frequent extreme weather conditions are putting crops at risk.

Technology could have the potential to increase productivity and meet higher demand, while supporting adaptation to climate change. Changing consumer tastes and higher awareness are also driving the adoption of new technologies. Consumers in Europe are increasingly aware of environmental problems, care more about fair trade, and want healthy, high-quality food. Although the demand for organic food is booming, production is not yet sufficient to satisfy consumers' needs, because of a lack of dedicated organic farmland, higher costs and lower productivity rates. New technologies such as autonomous systems and advanced data analysis could increase the yield of organic products. Moreover, new technologies promise to allow a better cooperation through agri-food value chains (eg cooperative farming), to change farming practices (eg precision farming) (Pesce et al, 2019) and to use resources more efficiently, thus reducing harmful environmental impacts of agriculture (for example, by utilising less water or reducing GHG emissions).

[60] Given the low prices that small producers are facing, any increase in labour costs, such as recent increases in agricultural minimum wages, is going to impact profitability (El Confidencial, 2020).

However, various challenges prevent further adoption of new technologies in the Spanish agricultural sector, where the uptake of such technologies lags behind countries such as the US.

These challenges include an unevenly distributed broadband coverage, especially in small rural areas; resistance to change among farmers; lack of investment capabilities for small farmers; and a risk of asymmetric information, which enables certain players in the food value chains who have broader access to valuable data to use this to strengthen their market position (Pesce et al, 2019).

The list of technologies being developed for agricultural use is long, but some of the most relevant examples are listed below (for a more comprehensive list, see Pesce et al 2019 and OECD, 2019b).

- The Internet of Things (IoT)[61] could combine different kinds of data produced in various places and make it available for relevant players, allowing greater monitoring capacity, efficiency and higher quality of products.
- Robots are currently being used to collect data about chemical and water use, and to select plants with better traits (eg a higher resistance to adverse conditions). Research is being undertaken to develop robotic weeding and harvesting systems, but it is still in its infancy.
- AI has been applied in a variety of ways in agriculture, for example yield prediction, disease detection, weed detection, water management and soil management. Research is progressing also in the field of biotechnologies, such as molecular biology and genetic engineering. Although these techniques have huge potential benefits such as lowering the volatility of yields, increasing production and reducing the use of pesticides, their application is still controversial (Pesce et al, 2019).
- The technology listed above produces and makes use of big data. Data is extracted from various stages of the agricultural chain (eg production, storage, transport, sales and consumption) and combined into usable information. The use of big data can improve farm production practices and enhance the efficiency of the supply chain. Some of the technologies used to collect big data are: satellite imaging, drones, wireless sensor networks, radio frequency identification and many others (Pesce et al, 2019).

In the last decade, agriculture in Spain has become increasingly mechanised and technological advancements are being incorporated. Many farmers have already adopted solutions such as geographic information systems (GIS). In 2015, R&D investments in agriculture amounted to EUR 60 million, increasing to EUR 241 million across the whole agro-industrial sector.

[61] The IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.

However, while R&D investment in Europe increased by 37 per cent between 2006 and 2015, Spain experienced a decrease in such investment of 17 per cent in the same period (PwC, 2019). Digitalisation of agriculture can help Spanish farmers to alleviate the negative effects of some major problems, such as water scarcity. Indeed, modern irrigation techniques are already widespread and make use of sensors, data processing and information analysis.

Examples of irrigation systems that are increasingly employed in the Spanish agricultural sector include micro-irrigation systems, hydroponic crops, management of irrigation through mobile phones, changing shifts and adjusting the system when it rains (Smart Water Magazine, 2019). IoT methods have been implemented in vineyards through sensors that register, send to the cloud and combine in a readable format data on variables such as temperature, humidity, rainfall, wind speed and solar radiation (Libelium, 2018, 2019). Businesses in Spain have also used big data to predict crop diseases and yields, and to give recommendations (La Huerta Digital, 2016). Several initiatives to develop technological solutions for the agricultural sector are being undertaken under European projects: an irrigation management system based on the IoT is being implemented under SmartAgriHubs (SmartAgriHubs, 2020); many projects on water systems, organic farming and supply chains were presented at the EIP-AGRI events (EIP-AGRI, 2019).

The technologies described so far will be fundamental in meeting the objectives set by the CAP in terms of viable food production, sustainable management of resources, and climate action and balanced territorial development. The new CAP being discussed envisages the development of a system based on year-round remote observation of agricultural activities through the data provided by the Copernicus Sentinel satellites. This system will allow a more efficient policy monitoring process, will decrease administrative burdens, and will provide a wealth of data such as crop monitoring and yield forecasting (Pesce et al, 2019).

Agriculture in Spain and demography

Spain is facing a problem of shrinking population in rural areas. Between 2000 and 2018, rural population decreased by 10 per cent, while total population increased by 15 per cent. Only 16 per cent of the population is registered in rural municipalities, which cover 84 per cent of the national territory (EFE AGRO, 2019). Half of the municipalities in Spain have fewer than 1,000 inhabitants. The causes of depopulation include ageing, a low generational replacement, a low birth rate and lack of employment (El Pais, 2017). As mentioned in the demography megatrend, older workers tend to participate less in educational activities or training, therefore ageing could pose a problem in terms of updating the skills of older workers in view of the deployment of digital technologies in agriculture.

On average, women are more likely to leave rural areas and move into cities, with a negative impact on birth rates in rural areas, resulting in a rapidly ageing population. **The ageing of rural areas in Spain is reflected in the average age of the agricultural labour force: only 4 per cent of farm owners were less than 35 years of age in 2016**, 14 per cent were 36–44, 51 per cent 45–64 **and 31 per cent were over 65**. In Europe, only Italy has a higher percentage of farm owners older than 65 years of age (41 per cent) (PwC, 2019).

The decrease in rural population automatically reduces the labour force in rural areas, with a consequent reduction in economic activity, which in turn causes people to emigrate and feeds a vicious cycle. The depopulation of rural areas also affects the quality of public infrastructure (which becomes more expensive to service) and causes the abandonment of cultivable land, which becomes more prone to bushfires (PwC, 2019).

Agriculture in Spain and resource scarcity

Climate change will have a deep impact on agriculture. First of all, rising temperatures and the increased likelihood of extreme weather events will affect crop yields. Spain already faces high risks of desertification for the characteristic of its soil. Rising temperatures, lower volumes of precipitation and more frequent droughts and bushfires could put three million hectares of land at risk of desertification in the next 50 years, implying that, at the end of this century, 80 per cent of Spain's territory could be at risk of desertification. The consequent reduction in land availability will force farmers to use more intensive production methods and preserve the soil at the same time. Less productive methods such as organic farming could consequently suffer (PwC, 2019).

Precipitation is expected to decline in volume but to be concentrated in torrential episodes, further aggravating the problem of water scarcity faced by Spain. It is estimated that precipitation could decrease by 20 per cent and river basins decrease by 40 per cent in some cases. As a consequence, it is estimated that the share of land area that is suitable for agricultural cultivation[62] could decrease from covering 39 per cent of Spain's land surface in 2000 to 22 per cent by the end of the century (PwC, 2019).

Agricultural activity is partially responsible for these developments, insofar as it generates GHG emissions and causes soil erosion through excessive vegetation felling and water exploitation. Indeed, agriculture in Spain consumes 70 per cent of fresh water, and national water resources are under stress (PwC, 2019), with a withdrawal ratio[63] of 28 per cent in 2016 (Eurostat, 2020j). Moreover, almost half of the subterranean reserves of water are contaminated by fertilizers used in agricultural activities (Euronews, 2019). At the same time, agriculture could help fight climate change by implementing new methods of production. In the next 25 years, the agriculture sector could capture 10 per cent of carbon emissions, increase soil quality, contain soil erosion and desertification, and support biodiversity. To this end, technological solutions capable of reducing emissions, optimising the use of fertilisers, reducing the quantity of land, energy and water exploited will be fundamental (PwC, 2019).

The European Green Deal identifies a sustainable and healthy food system as one of its priorities and proposes that at least 40 per cent of the CAP budget for the period 2021–27 should contribute to climate action.

[62] ie lands which show a value of the aridity index above 0.65 (Joint Research Centre, 2019b).
[63] The annual total fresh water abstraction in a country as a percentage of the country's long-term annual average available water from renewable freshwater resources.

Moreover, it stipulates that national strategic plans for agriculture should lead to the use of sustainable practices such as precision agriculture and organic farming. It foresees rewards for the environmental efforts of famers, such as storing carbon in the soil, improved nutrient management, improved water quality and reducing emissions. An ambition to reduce the use of chemical fertilisers, pesticides and antibiotics is also put forward (European Commission, 2019b).

Implications for jobs and skills

In order to successfully exploit the solutions offered by technologies in agriculture, the workforce must be equipped with advanced technical skills and be capable of implementing and managing innovative systems. Therefore, in the future, farmers will need a multidisciplinary skillset, being able to control machinery and at the same time having knowledge of informatics, robotics, meteorology, chemistry and biology (PwC, 2019).

Interventions to improve the digital skills of the agricultural labour force encompass various dimensions. First of all, education in high-tech skills needs to be boosted, and a great level of lifelong learning must be implemented to allow workers to keep up with the speed of technological change. Moreover, changing the professional profile of farmers to a more digital one could help attract younger workers. New forms of learning are also needed, such as virtual and blended learning (a mix of face-to-face and virtual learning), Massive Open Online Courses (MOOC) offered by universities and peer-to-peer learning. Forms of long-distance learning (eg based on smartphone apps) could be particularly useful for agricultural workers and small-scale farmers who may be unable to participate in costly and time-intensive traditional training formats (EPRS, 2016).

Farming is, by definition, concentrated in rural areas, where the educational performance is lower and the propensity to leave formal education at a younger age is higher. In 2018, 52 per cent of the rural population aged 15–64 in Spain had only primary education, while 25 per cent had tertiary education. This trend was reversed in cities, where 35 per cent of this age group were educated only to primary level, and 40 per cent had received tertiary education. However, when restricting the analysis to the younger age groups (aged 18–24) alone, the trends are similar for both urban and rural areas, with a decreasing share of people with only primary education, a large increase in people with secondary education, and a gradual increase in people with tertiary education (Eurostat, 2020k). Increasing levels of education among the youth in rural areas could favour a stronger uptake of digital technologies in agriculture. Recent data show higher levels of digital skills in the Spanish population compared to the EU-28, even among workers in agriculture, forestry and fishery (Eurostat, 2020e).

Rural areas require special attention in terms of education, since they show relatively high drop-out rates and relatively low tertiary education rates. Rural workers who wish to upskill or reskill face a double challenge: bridging the educational gap with the urban population while learning new skills which might not be readily available in the local educational system (EPRS, 2016). These tendencies are accentuated in Spain, which had an 18 per cent rate of early leavers from education and training in the group aged 18–24 in 2018, the highest among the

EU-28. While in the EU-28 the percentage of early leavers from training is broadly similar in cities and rural areas, in Spain a 4 percentage point gap exists between cities (15.5 per cent) and rural areas (19.7 per cent). However, it should be recognised that huge decreases in the percentage of early leavers has occurred since the early 2000s (Eurostat, 2020l).

Workers in the Spanish agricultural sector tend to have lower educational attainment than the national average. However, an increase of 16 per cent in the number of farm owners with tertiary education was registered over 2005–13, mostly driven by the attainment of the younger generation (PwC, 2019). The CAP acknowledges the challenges faced by younger farmers and suggests, going forward, a set of policies to support generational renewal such as: income support and investment support for young farmers; promoting cooperation exchanges of assets and knowledge from older to younger workers, and promoting training and educational exchange in the field of agriculture and credit support (European Commission, 2019d).

The benefits of higher levels of education and increased take-up of new technologies will potentially change the nature of jobs in agriculture, without necessarily increasing the total number of jobs. The Cedefop Skills Forecast projects a decrease of 2.4 per cent per annum in agriculture employment between 2018 and 2030, concentrated mainly among low-skill workers (Cedefop, 2019). This outcome is the result of a general declining trend in agricultural employment in the past 20 years. Supply dynamics related to the depopulation and ageing of rural areas explain the declining employment in the sector. Indeed, while population in rural areas declines, the share of foreign labour employed in agriculture increased from 20 per cent in 2011 to 25 per cent in 2017. Aragona is a regional example of the various trends described, with a declining population and a high importance of the agricultural sector in regional value added. Temporary employment is prevalent in the region and is mostly covered by foreign workers (Schuh et al, 2019).

CASE STUDY

Adapting to climate risks: how digital and AI skills can strengthen the resilience of wine-making in Spain

Grupo Bodegas Palacio 1894 is one of ACCIONA's business lines with more than 100 years producing and ageing quality wines in Spain, in world-known regions such as Rioja or Ribera del Duero. The company has responded efficiently to a very dynamic market over the century, and understands that vineyards are vulnerable to the growing challenges of an ever-changing climate. Its research and development unit is therefore collaborating with the winery business line to test and adopt adaptation and mitigation technologies to address climate risks.

Through the 'Aggregate Farming in the Cloud' (AFarCloud) project, the company is studying the application of cloud-based, sensor and drone technologies to monitor soil texture, moisture and water stress in its vineyards, and help promote precision viticulture management. The study is funded by the European Union, and coordinated by Universidad Politécnica de Madrid.

Amid changing hydro-meteorological patterns, AFarCloud is looking into the possibility of detecting, by a drone and an infrared camera, areas where irrigation is needed, helping agronomists save time and water, at the same time as increasing crop productivity and quality. Besides addressing climate impacts, the use of drones can mitigate health risks on farmers, families and inhabitants of surrounding vineyards by reducing agrochemical product use. The project aims to make farming robots accessible to more users, by enabling farming vehicles to work in a cooperative network, opening up new applications and ensuring re-usability. The use of this ICT-based farming solution will require the development of technical skills linked to the implementation of AI and digitalisation processes in the value chain. This will apply to all key actors, for the development, demonstration and commercialisation of precision farming technologies in Spain. Younger segments of the population are likely to provide most of these highly specialised skills.

The AFarCloud project is a key example of a company responding to climate risks and the related resource scarcity. Ultimately, the project should increase efficiency and reduce farm labour costs and risks in an already tough context, as Spain and other countries across the EU are facing challenges linked to productivity and cost-effectiveness due to labour shortages and depopulation of rural areas. In turn, the development of such projects will provide new and more specialised job profiles.

Policy recommendations

In order to maintain and develop a competitive economy, the EU will need to manage the effects of several megatrends (automation, demography, resource scarcity and globalisation) on the labour market. This will happen in the aftermath of the COVID-19 crisis, which will also have profound implications on the jobs and skills agenda. At the same time, if it wants to achieve climate neutrality it will need to introduce policies with significant social and employment impacts. These objectives can and should be combined. Policies should be designed to harness the climate benefits of these megatrends and overcome some of the challenges they bring in a way that delivers a competitive, prosperous and socially just climate neutral economy with a thriving and resilient labour market. At the same time as governments face up to the economic fallout of the pandemic, and develop longer term plans for recovery, they should ensure that they are building back better supporting economic activity with genuine long-term sustainability, aligned with the industries of the future and effective in addressing to other concerns like the climate challenge.

Policymakers have started to grasp the range and depth of actions they need to take to achieve this objective, and the EU already has experience and initiatives it can build on. However, some instruments will need to be adapted and strengthened, approaches joined up to exploit synergies and avoid fragmentation, and new policies will need to be developed through a strong social dialogue.

At this moment, there is both opportunity and necessity for climate and environmental breakdown, economic damage, social inequalities and resilience to all be addressed together, if we are to build a stronger and more resilient European economy.

Commit to the European Green Deal and a clear and managed transition to a climate neutral economy

The European Green Deal, with climate neutrality at its core, provides an opportunity for the EU to develop policies across a wide range of areas to help promote a reinvigorated and modernised labour market in the context of the megatrends and the task of addressing climate change. **Action to mitigate climate change is not optional**, and sensible, **well-managed approaches can have a positive impact on the environment, economy and employment**.

Developing jobs in the circular economy

The development of the circular economy is essential to efficiently and affordably engage with the challenges of resource scarcity through increased material recirculation, reuse and recycling. The European Commission has recognised the role of the circular economy in strengthening Europe's industrial base and lowering emissions. **The number of jobs linked to circular economy activity has grown rapidly over the past decade, and this trend is likely to continue.** According to a report from Circle Economy on *Jobs and Skills in the Circular Economy*, circular jobs can be classified in three main categories: core circular jobs which ensure that raw material cycles are closed (eg jobs in renewable energy, repair and resource and waste management), enabling circular jobs that will accelerate and upscale core circular economy activities (eg engineering and digital experts) and indirect circular economy jobs which provide services to the primary circular activities (eg jobs in logistics, education and the public sector) (Dufourmont et al, 2020).

Looking at heavy industry sectors such as steel, while significant innovation will be required to achieve net zero carbon production, greater use of circularity can reduce the overall costs of that transition and support greater employment benefits. Steel is a material particularly well suited with the circular economy. As indicated in section 4.5 in reference to Sweden, already one-third of steel production in the country is recycling based.

The European Commission's Circular Economy Action Plan sets out a pathway for decoupling economic growth from natural resource use by reducing the consumption of resources and making products more sustainable (European Commission, 2020g). The Plan also aims to ensure that the EU instruments supporting skills and job creation also contribute to the acceleration to a circular economy. In order to achieve this objective, more must be done to identify the type of skills that will be needed to fill jobs related to the circular economy and address skills gaps accordingly. For example, initiatives targeting digital skills must also consider the application of these skills in the circular economy in order to ensure that the digital sector can contribute to increased resource efficiency throughout the economy, and that circular economy professionals can use digital tools to achieve this objective. Furthermore, circularity should be integrated into education and training programmes to provide skilling and reskilling opportunities for workers (Dufourmont et al, 2020).

Developing a comprehensive vision to scale up digital skills and adaptability

The European workforce will cope better if they are supported to be as adaptable as possible to a changing work environment. Consistently throughout this report, **automation and digitalisation have been identified as the megatrend likely to most significantly impact jobs and skills**. This trend is expected to transform a large number of occupations over the coming decades. Digital skills will also be important because of their potential to enable the development and diffusion of innovative technologies that can lower emissions and support the transition towards a circular economy.

The importance of digitalisation for the economy is widely acknowledged, including by policymakers. Several initiatives are already in place and various instruments are currently being developed on digital skills. The Digital Europe Programme proposes to allocate EUR 700 million for advanced digital skills to support short and long-term training for students and entrepreneurs, and EUR 1.3 billion of funding to ensure the use of digital technologies across the economy, including by industry, under the next multiannual financial framework (MFF) (European Commission, 2019f). The Digital Skills and Jobs Coalition, launched in December 2016 under the Skills Agenda, brings together member states and education, employment and industry stakeholders to develop digital skills in education and the workforce (European Commission, 2020i).

The Skills Agenda will be updated to place a greater emphasis on digital skills (European Commission, 2016b). The Digital Education Plan, which aims to support technology use and the development of digital competences in education at all stages of life, will also be updated to boost the digital skills of young people and adults (European Commission, 2018e).

Scaling efforts on digital skills is a necessity to enable workers to harness the benefits of these technologies and adapt to the changes brought about by the digital revolution. The case studies in this report have identified some under-recognised priorities and challenges for supporting digital skills in the workforce. Digital skills are in growing demand in sectors such as agriculture, where an ageing workforce and limited access to educational opportunities currently restrict their uptake. Generally older workers, who will comprise a growing part of the workforce, might need additional support in acquiring digital skills. Similarly, smaller businesses will often need additional investment and support.

Finally, the **COVID-19** crisis has led to a massive requirement for digital infrastructure and skills, with children pursuing schooling online and teleworking, virtual meetings and webinars taking over. It is likely that teleworking and digital services will continue at much higher levels than before (Liebreich, 2020).

Given that these skills are key for adaptability, **it is important that initiatives in this field do not leave significant parts of the workforce behind**. The EU also needs to avoid fragmentation of its initiatives and bring them together behind **a comprehensive vision** that addresses what digital skills need to be developed across various sectors to increase economic competitiveness, resilience and innovation in support of its climate neutrality goal. In this regard, the new Industrial Strategy, which recognises the need to upskill and reskill workers to deal with the twin transitions towards climate neutrality and digital leadership, is an initiative which could help to build this comprehensive approach (European Commission, 2020e). It will therefore be essential that this is indeed done in the follow-up work to implement the strategy in practice. The development of digital skills must also go hand in hand with the development of cognitive and non-cognitive skills, as successful businesses will be the ones able to integrate digital technologies in their operations and business models, and for workers to be able to develop, maintain and upgrade these technologies (Dhéret et al, 2019).

Establish an inclusive economy through a just transition

Although the circular economy and digitalisation both have a great potential in terms of job creation, they will also disrupt the economy in a way that leads to job losses. Some skills and jobs will become obsolete as certain sectors of the economy shrink. **Policymakers have an essential role to play in providing support for businesses and workers that are negatively impacted by the megatrends and the transition to a climate neutral economy.** A number of the case studies in this report indicate sectors that are contracting (energy generation from fossil fuels, car manufacturing based around the internal combustion engine), shedding jobs through productivity improvements (agriculture), or transforming in a way that will shift the required skill set (steel). In each case existing jobs will be lost through the process of economic change and workers will need to be supported to find new careers.

The Just Transition Mechanism (JTM) is a European Commission initiative to direct help to regions, industries and workers that will be the most affected by the transition towards the climate neutral economy. The initiative aims to provide EUR 100 billion worth of financial support including through a Just Transition Fund (EUR 7.5 billion) and InvestEU 'Just Transition' Scheme (EUR 45 billion of investments) (European Commission, 2020j). The JTM also aims to provide technical assistance via a Just Transition Platform. The Mechanism references various sectors including steel and chemicals, but mainly focuses on coal and the transition to clean energy.

The geographic concentration of employment from an affected industry is a key concern. **Regions with a high dependence on a single declining sector should be a priority for support.** While coal regions will be amongst the most impacted and thus require greatest support, **more must be done to anticipate future disruptions in other sectors including the heavy industry and automotive sectors.**

Transition plans, designed to help regions steer investments, will need to be consistent with the objective to achieve climate neutrality by 2050 and elaborated through close cooperation between regional governments, industry, investors and trade unions. These plans should include public support and investments in both reskilling and upskilling initiatives to enable low-skill workers to have access to higher skilled and better paid jobs. External support from outside the affected region is likely to be essential to bring in new investment and capacities. Reskilling and upskilling initiatives should also be combined with the collection, harmonisation and dissemination of regional labour data with pension-bridging grants and mobility grants also considered as eligible activities for social support (Cameron et al, 2020). While initiatives should be implemented at regional level, funds should be allocated on a project basis rather than a geographical basis (Cameron et al, 2020).

Case studies in this report drawn from Romania (Maritsa East) and the Netherlands (Brainport Eindhoven) show the challenges of this process of regional reinvention and that it can be possible to succeed.

The Commission also proposed a European Social Fund+ (ESF+) worth EUR 101.2 billion, under the next MFF (European Commission, 2018f). This fund, which is a continuation of the current European Social Fund 2014–20, will provide the main EU financial instrument to improve workers' mobility and employment opportunities, strengthen social cohesion and improve social fairness with investments in education, employment and social inclusion. As such, ESF+ will play an important role in helping workers to acquire the necessary skills to transfer from declining to growing sectors (Dhéret et al, 2019).

Defining a shared European agenda for the future of work

As illustrated throughout this report, a number of sectors are undergoing transformative change, driven by trends of innovation and competition, but also by the need to decarbonise the economy. **To deliver sustainable economic development, policymakers will need to work with businesses to identify sectors that will thrive in the future.** As businesses transform their operations to take advantage of new economic opportunities and adapt to changing markets, they are developing an understanding of their workforce needs in a rapidly evolving economic context. In this context they can help to identify skills gaps and shortages that policies could seek to address. Enhanced cooperation between businesses, governments, and education and training systems, can help to ensure that students acquire skills that improve their employability before entering the labour market and that workers have access to reskilling and upskilling opportunities that will enable them to adapt to economic transformations. Moreover, the support of social partners is a crucial factor of success of EU initiatives in this area (Dhéret et al, 2019).

This should not be limited to large-scale incumbent industries – in many sectors new businesses are emerging, such as those centred around renewable energy generation. As demonstrated in the offshore wind and coal case studies, such new businesses are often able to repurpose some of the skillset of outgoing workers from declining sectors, or where automation is improving productivity and leading to declining labour demand.

Social partners such as labour unions will also be important. Social dialogue should be considered as an enabler for the transition towards a competitive, prosperous and socially just climate neutral economy. As such, social partners and policymakers need to work together to elaborate a regulatory framework for the future of work in a way that delivers a thriving and resilient labour market. The need for collective action has been recognised by the Commission. The European Pact for Skills will launch large multi-stakeholder partnerships, bringing together businesses, public authorities and trade unions to identify job opportunities in areas like the circular economy, contribute to upskilling and reskilling of workers, and unlock private and public investments. The Pact will focus on sectors with a high growth potential for Europe or those undergoing the most significant change (European Commission, 2020e). This represents an opportunity to develop ideas and initiatives for an agenda for the future of work that is consistent with climate neutrality.

Implement green and equitable recovery plans, while urgently addressing which skills will be needed for the future

The COVID-19 pandemic and its response will inevitably lead to significant economic damage and loss of employment. Recovery plans will need to address both public spending and investment, and also put in place policies and funding instruments (for example from the European Investment Bank and the European Bank for Reconstruction and Development), that incentivise private investment to rebuild economic capacity in an environmentally sustainable way. Public spending can invest in **critical infrastructure** such as energy, transport and digital communications, support **innovation** and clean technologies and fund areas such as **health and social care**, **sustainable land management** and **energy efficiency programmes for buildings**. Sustainable finance principles including the EU Low Carbon Taxonomy should be used to encourage **long-term investment alignment with sustainability goals.** Other key policy options include **public procurement** to provide markets for innovative goods and services such as electric vehicles. All of these are key areas for business investment, and essential areas to innovate to develop a competitive, climate neutral economy. Policy incentives, such as mandates, fiscal incentives and regulation should all be aligned to ensure private sector activity helps public finance go further. The right expenditure can deliver more jobs quickly. For example, energy efficiency developments are labour intensive and can result in significant job creation, although they will need to be accompanied by **targeted training**. As can be seen in the Romania case study, renovation of the building stock can also offer major opportunities in some of the most disadvantaged regions of Europe. On the other hand, where appropriate **companies receiving public support** should be required to align their investments with common goals such as climate action and resilience.

Increasing action at national and international levels

The future of the European labour market will depend on the EU's ability to remain competitive at a global level. Throughout this report we have documented the competitive pressures that EU sectors are facing. As the EU is losing ground to international competitors when it comes to the development of some innovative technologies, increasing the EU's know-how and entrepreneurial capacity in low carbon technologies and the circular economy will contribute to **position Europe as a leader in growing international markets for clean products**. Increased competitiveness from its leadership in innovation and climate neutral and circular lead-market creation, and in particular an improved ability to convert early-stage research into scalable solutions and commercial success, will need to be combined with the EU's ability to use trade as an instrument to achieve social, environmental and climate objectives.

Of course, **European action depends on aligned implementation from its member states**. While policies related to jobs and skills are mostly national competences, the EU provides guidance to member states through the European Semester. The 2020 country recommendations aim to help make the bloc carbon neutral by 2050. For the first time, these reports analyse socio-economic challenges and opportunities from the climate and energy transition and urge countries to deliver on the implementation of the European Pillar of Social Rights to ensure that climate and digital transitions are socially just (European Commission, 2020j). While this constitutes a positive development, national governments will need to incorporate these recommendations into their climate and social policies.

References

ABB, 2020. ABB helps maximize energy efficiency at future fossil-free steel pilot [WWW Document]. ABB. URL https://new.abb.com/news/detail/56610/abb-helps-maximize-energy-efficiency-at-future-fossil-free-steel-pilot

ACEA, 2019. The Automobile Industry Pocket Guide 2019–2020. ACES.

Acemoglu, D., Restrepo, P., 2017. Robots and jobs: evidence from US labour markets. Work. Pap. 23285, NBER Working Paper Series.

Alves Dias, P., Blagoeva, D., Pavel, C., Arvanitidis, N., 2018. Cobalt: demand-supply balances in the transition to electric mobility (JRC science for policy report). Luxembourg.

Alves Dias, P., Kennellopoulos, K., Medarac, H., Kapetaki, Z., Miranda Barbosa, E., Shortall, R., Czako, V., Telsnig, T., Vazquez Hernandez, C., Lacal Arantegui, R., Nijs, W., Gonzalez Aparicio, I., Trombetti, M., Mandras, G., Peteves, E., Tzimas, E., 2018. EU coal regions: opportunities and challenges ahead (JRC science for policy report). Luxembourg.

Andrae, A.S.G., Edler, T., 2015. On Global Electricity Usage of Communication Technology: Trends to 2030. Challenges 6, 117–157. https://doi.org/10.3390/challe6010117

Automotive News Europe, 2019. German industry to invest $68 billion in electric cars and automation [WWW Document]. Automot. News Eur. URL https://europe.autonews.com/automakers/german-industry-invest-68-billion-electric-cars-and-automation (accessed 2.11.20).

Autor, D., 2015. Why are there still so many jobs? The history and future of workplace automation. J. Econ. Perspect. 29, 3–30.

Backer, K.D., Menon, C., Desnoyers-James, I., Moussiegt, L., 2016. Reshoring: Myth or Reality? https://doi.org/10.1787/5jm56frbm38s-en

Baicu, G., 2017. After 25 Years of Restructuring, the Romanian Power Sector Is at a Crossroad. [WWW Document]. Emerging Europe. URL https://emerging-europe.com/voices/after-25-years-of-restructuring-the-romanian-power-sector-is-at-a-crossroad/

Baldwin, R., 2019. Globalisation 1.0 and 2.0 helped the G7. Globalisation 3.0 helped India and China instead. What will Globalisation 4.0 do? [WWW Document]. voxeu.org. URL https://voxeu.org/content/globalisation-10-and-20-helped-g7-globalisation-30-helped-india-and-china-instead-what-will-globalisation-40-do (accessed 2.3.20).

Banker, S., 2018. U.S. Manufacturers Are Not Reshoring [WWW Document]. Forbes. URL https://www.forbes.com/sites/stevebanker/2018/07/11/u-s-manufacturers-are-not-reshoring/#69914989460c (accessed 2.3.20).

Bankwatch, 2019. Retrained and forgotten – Measures for mitigating the impact of layoffs from the mines in the Jiu Valley.

Bankwatch, 2020a. Coal phase-out by 2030: An unreachable goal? An analysis of Romania's National Energy and Climate Plan.

Bankwatch, 2020b. The energy sector in Romania [WWW Document]. URL https://bankwatch.org/beyond-coal/the-energy-sector-in-romania

Baranzini, A., van den Bergh, J.C.J.M., Carattini, S., Howarth, R.B., Padilla, E., Roca, J., 2017. Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations. WIREs Clim. Change 8, e462. https://doi.org/10.1002/wcc.462

Bardazzi, R., Pazienza, M.G., 2019. When I was your age...Population Dynamics and Household Energy Consumption (Working Papers – Economics No. wp2019_20.rdf). Università degli Studi di Firenze, Dipartimento di Scienze per l'Economia e l'Impresa.

Behrens, A., Coulie, C., Genoese, F., Alessi, M., Wieczorkiewicz, J. and Egenhofer, C., Impact of the Decarbonisation of the Energy System on Employment in Europe (February 7, 2014). CEPS Special Report No. 82. Available at SSRN: https://ssrn.com/abstract=2395116

BBC, 2020. US and China sign deal to ease trade war [WWW Document]. BBC. URL https://www.bbc.com/news/business-51114425 (accessed 2.4.20).

BEIS, 2018. Clean Growth Strategy: executive summary [WWW Document]. GOV.UK. URL https://www.gov.uk/government/publications/clean-growth-strategy/clean-growth-strategy-executive-summary (accessed 1.31.20).

Blagoeva, D., Alves Dias, P., Marmier, A., Pavel, C., 2016. Assessment of Potential Bottlenecks along the Materials Supply Chain for the Future Deployment of Low-Carbon Energy and Transport Technologies in the EU: Wind Power, Photovoltaic and Electric Vehicles Technologies, Time Frame: 2015–2030 (JRC science for policy report). JRC.

Bloomberg, 2019. Germany Boosts Electric-Car Incentives to Stimulate Demand [WWW Document]. URL https://www.bloomberg.com/news/articles/2019-11-05/germany-to-boost-electric-car-incentives-in-push-to-lift-demand (accessed 2.17.20).

Bloomberg NEF, 2019. Electric Vehicle Outlook 2019 [WWW Document]. Bloom. NEF. URL https://about.bnef.com/electric-vehicle-outlook/ (accessed 2.25.20).

BMWi, 2020. Regulatory environment and incentives for using electric vehicles and developing a charging infrastructure [WWW Document]. BMWi. URL https://www.bmwi.de/Redaktion/EN/Artikel/Industry/regulatory-environment-and-incentives-for-using-electric-vehicles.html

Bódis K, Kougias I, Taylor N, Jäger-Waldau A. Solar Photovoltaic Electricity Generation: A Lifeline for the European Coal Regions in Transition. *Sustainability*. 2019; 11(13):3703.

Boulhol, H., Geppert, C., 2018. Population ageing: Pension policies alone will not prevent the decline in the relative size of the labour force [WWW Document]. voxeu.org. URL https://voxeu.org/article/effect-population-ageing-pensions (accessed 2.5.20).

Brainport Eindhoven (no date). What is Brainport Eindhoven? [WWW Document] URL https://brainporteindhoven.com/en/discover/what-is-brainport-eindhoven

Branstetter, L.G., Kovak, B.K., Mauro, J., Venancio, A., 2019. The China Shock and Employment in Portuguese Firms. NBER Working Paper No. 26252.

Brucal, A., Javorcik, B., Love, I., 2019. Good for the environment, good for business: Foreign acquisitions and energy intensity. J. Int. Econ. 121, 103247. https://doi.org/10.1016/j.jinteco.2019.07.002

Bruegel, 2018. Is the European automotive industry ready for the global electric vehicle revolution? (Policy Contribution No. 26).

Brynjolfsson, E., McAfee, A., 2016. The Second Machine Age: Work, Progress, and Prosperity in the Time of Brilliant Technologies. W. W. Norton, New York.

Bughin, J., Seong, J., Manyika, J., Chui, M., Joshi, R., 2018. Notes from the AI frontier – Modeling the impact of AI on the world economy. McKinsey Global Institute.

Burch, I., Gilchrist, J., 2018. Survey of Global Activity to Phase Out Internal Combustion Engine Vehicles. The Climate Center.

Burlacu, R., Suditu, B., Gaftea, V., 2019. Just transition in Hunedoara – Economic diversification in a fair and sustainable manner. Cerope, Greenpeace Romania, Bankwatch Romania.

Business Insider, 2020. All the things carmakers say they'll accomplish with their future electric vehicles between now and 2030 [WWW Document]. Bus. Insid. URL https://www.businessinsider.com/promises-carmakers-have-made-about-their-future-electric-vehicles-2020-1?r=US&IR=T (accessed 2.25.20).

Cambridge Econometrics, 2018. Reviewing the impact of the low-carbon mobility transition on jobs. A report for the European Climate Foundation.

Cambridge Econometrics, 2017. Future UK Employment in the Offshore Wind Industry. Aura.

Cambridge Econometrics, Element Energy, Ricardo – AEA, 2017. Low-Carbon Cars in Germany Technical report.

Cambridge Econometrics, IER, IFF Research, 2013. Working for a Green Britain & Northern Ireland 2013–23. RenewableUK.

Cambridge Econometrics, Trinomics, ICF, 2018. Cambridge Econometrics, Trinomics, and ICF May – 2018 Impacts of circular economy policies on the labour market. European Commission.

Cameron, A., Claeys, G., Midões, C., Tagliapietra, S., 2020. How good is the European Commission's Just Transition Fund proposal? Bruegel.

Campbell, P., 2018, March 14. 'Union warns of jobs risk in shift to electric cars'. Financial Times. URL https://www.ft.com/content/0a0fab3a-26b4-11e8-b27e-cc62a39d57a0

Cedefop, 2020. Empowering adults through upskilling and reskilling pathways. Volume 1, Cedefop reference series 112. Publications Office of the European Union, Luxembourg.

Cedefop, 2019. Skills Forecast [WWW Document]. Cedefop. URL https://www.cedefop.europa.eu/en/publications-and-resources/data-visualisations/skills-forecast (accessed 2.17.20).

Charness, N., Boot, W.R., 2009. Aging and Information Technology Use: Potential and Barriers. Curr. Dir. Psychol. Sci. 18, 253–258. https://doi.org/10.1111/j.1467-8721.2009.01647.x

Chen, Y., 2015. EU–China Solar Panels Trade Dispute: Settlement and challenges to the EU. European Institute for Asian Studies.

CNBC, 2020. Work starts on world's 'largest offshore wind farm' that could power 4.5 million homes [WWW Document]. URL https://www.cnbc.com/2020/01/17/work-starts-on-huge-wind-farm-that-could-power-4point5-million-homes.html

Committee on Climate Change, 2020. UK regulations: the Climate Change Act [WWW Document]. Comm. Clim. Change. URL https://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/the-climate-change-act/ (accessed 2.13.20).

COP24, 2018. Just Transition Declaration [WWW Document]. COP24 Katow. 2018. URL https://cop24.gov.pl/presidency/initiatives/just-transition-declaration/

Dabrowski, M., 2018. Examining interrelation between global and national income inequalities. Russ. J. Econ. 4, 266–284.

Dauth, W., Findeisen, S., Südekum, J., Wößner, N., 2017. German Robots – The Impact of Industrial Robots on Workers. IAB Discuss. Pap.

Deloitte, 2019. New Market. New entrants. New challenges. Battery Electric Vehicles.

Deloitte, 2017a. Beyond the Noise – The Megatrends of Tomorrow's world.

Deloitte, 2017b. Brake Block Brexit – How a hard Brexit would impact the German automotive industry (Deloitte Brexit Briefing No. 5).

Deutsche Bank Research, 2020. E-mobility.

DG ECFIN, 2018. The 2018 Ageing Report. European Commission, Luxembourg.

DG EMPL, 2019. Employment and Social Developments in Europe 2019. European Commission, Luxembourg.

Dhéret, C., Guagliardo, S., Palimariciuc, M., 2019. The future of work: Towards a progressive agenda for all. European Policy Centre.

DRIVES, 2020. About DRIVES. [WWW Document]. URL https://www.project-drives.eu/en/home

Dufourmont, J., Goodwin Brown, E., 2020. Jobs and Skills in the Circular Economy: State of Play and Future Pathways. Circle Economy.

Ecoaction, Alternativa, Germanwatch, 2019. Transformation Experiences of Coal Regions: Recommendations for Ukraine and other European countries.

EEA, 2019. The European environment – state and outlook 2020. European Environment Agency.

EEA, 2015. European environment – state and outlook 2015: Assessment of global megatrends. European Environment Agency.

EFE AGRO, 2019. La población rural cae un 10% desde el año 2000 [WWW Document]. EFE AGRO. URL https://www.efeagro.com/noticia/la-poblacion-rural-baja-10-desde-ano-2000/ (accessed 3.5.20).

EIP-AGRI, 2019. INNOVATIVE PROJECTS CATALOGUE UPDATE MARCH 2019.

El Confidencial, 2020. La condena del campo: los agricultores asumen el 90% de la caída de los precios [WWW Document]. URL https://www.elconfidencial.com/economia/2020-02-02/salario-minimo-agricultura-problema-formacion-precios_2436900/

El Pais, 2017. La mitad de los municipios españoles está en riesgo de extinción [WWW Document]. El Pais. URL https://elpais.com/elpais/2017/02/02/media/1486066904_389254.html (accessed 3.5.20).

Electrive, 2019. BMW is changing their resource strategy [WWW Document]. electrive.com. URL https://www.electrive.com/2019/10/21/bmw-is-changing-their-resource-strategy/ (accessed 3.27.20).

Ellen MacArthur Foundation, 2020. What is a circular economy? URL https://www.ellenmacarthurfoundation.org/circular-economy/concept

Energy and Utility Skills, 2018. Skills and Labour Requirements of the UK Offshore Wind Industry. Aura.

Energy Bill Revolution, E3G. 2014. Building the Future: The economic and fiscal impacts of making homes energy efficient.

Energy Policy Group, 2018. Proiectul Planului Național Integrat în domeniul Energiei și Schimbărilor Climatice 2021–2030.

energynomics.ro, 2019. RWEA anunță proiectul de reconversie profesională a 8.000 de mineri în 10 ani [WWW Document]. energynomics.ro. URL http://www.energynomics.ro/ro/rwea-anunta-proiectul-de-reconversie-profesionala-a-8-000-de-mineri-in-10-ani/

EPRS, 2016. Precision agriculture and the future of farming in Europe (Science and Technology Options Assessment). European Parliament.

ESSA, 2019. Digital Transformation in European Steel Industry: State of Art and Future Scenario.

Estiri, H., Zagheni, E., 2019. Age matters: Ageing and household energy demand in the United States. Energy Res. Soc. Sci. 55, 62–70. https://doi.org/10.1016/j.erss.2019.05.006

ETUI, 2019. Towards a just transition: coal, cars and the world of work. ETUI, Brussels.

Euracol, 2020. Coal Industry across Europe. Euracol.

Euractiv, 2019. Denmark calls for EU plan to phase out diesel and petrol cars [WWW Document]. URL https://www.euractiv.com/section/transport/news/denmark-calls-for-eu-plan-to-phase-out-diesel-and-petrol-cars/ (accessed 3.26.20).

Euractiv, 2018. Swedish steel boss: 'Our pilot plant will only emit water vapour' [WWW Document]. Euractiv. URL https://www.euractiv.com/section/energy/interview/hybrit-ceo-our-pilot-steel-plant-will-only-emit-water-vapour/ (accessed 3.12.20).

Euractiv, 2016. How Spanish farmers try to make a profit [WWW Document]. Euractiv. URL https://www.euractiv.com/section/agriculture-food/news/how-spanish-farmers-try-to-make-a-profit/ (accessed 3.5.20).

EurObserv'ER, 2020. The state of renewable energies in Europe Edition 2019.

Eurofer, 2019. European Steel in Figures.

Eurofound, 2020. Game-changing technologies: Transforming production and employment in Europe. Eurofound.

Eurofound, 2019a. The future of manufacturing in Europe (Research report).

Eurofound, 2019b. Trade scenario: Employment implications in Europe of a large increase in global tariffs. Luxembourg.

Euronews, 2020. Why are Spanish farmers protesting against low prices? [WWW Document]. Euronews. URL https://www.euronews.com/2020/02/18/why-are-spanish-farmers-protesting-against-low-prices (accessed 3.5.20).

Euronews, 2019. Cómo la agricultura irresponsable ha envenenado los recursos hídricos de España [WWW Document]. Euronews. URL https://es.euronews.com/2019/12/17/como-la-agricultura-irresponsable-ha-envenenado-los-recursos-hidricos-de-espana (accessed 3.5.20).

European Climate Foundation, 2013. Fuelling Europe's Future. How Auto Innovation leads to EU jobs.

European Commission, 2015. Assessing the Employment and Social Impact of Energy Efficiency.

European Commission, 2013. Employment Effects of selected scenarios from the Energy roadmap 2050 – Final report for the European Commission (DG Energy).

European Commission, 2020a. Financing the green transition: The European Green Deal Investment Plan and Just Transition Mechanism [WWW Document]. URL https://ec.europa.eu/commission/presscorner/detail/en/ip_20_17 (accessed 3.27.20).

European Commission, 2020b. CO_2 emission performance standards for cars and vans (2020 onwards) [WWW Document]. Eur. Comm. URL https://ec.europa.eu/clima/policies/transport/vehicles/regulation_en#tab-0-0

European Commission, 2020c. European Battery Alliance [WWW Document]. Eur. Comm. URL https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en (accessed 2.13.20).

European Commission, 2020d. Policy and Strategy [WWW Document]. URL https://ec.europa.eu/growth/sectors/automotive/policy-strategy_en (accessed 2.14.20).

European Commission, 2020e. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – A New Industrial Strategy for Europe [WWW Document]. URL https://ec.europa.eu/info/sites/info/files/communication-eu-industrial-strategy-march-2020_en.pdf

European Commission, 2020f. Coal regions in transition [WWW Document]. URL https://ec.europa.eu/energy/en/topics/oil-gas-and-coal/EU-coal-regions/coal-regions-transition (accessed 3.4.20).

European Commission, 2020g. Circular Economy Action Plan. [WWW Document]. URL https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf

European Commission, 2020h (forthcoming) Macroeconomics of the Energy Union: Policy Report for Modelling Megatrends.

European Commission, 2020i. The Digital Skills and Jobs Coalition. [WWW Document]. URL https://ec.europa.eu/digital-single-market/en/digital-skills-jobs-coalition

European Commission, 2020j. The Just Transition Mechanism: Making Sure No-One Is Left Behind. [WWW Document] URL https://ec.europa.eu/commission/presscorner/detail/en/fs_20_39

European Commission, 2020k. 2020 European Semester: Country Reports and Communication. [WWW Document] URL https://ec.europa.eu/info/publications/2020-european-semester-country-reports-and-communication_en

European Commission, 2019a. A Europe fit for the digital age [WWW Document]. URL https://ec.europa.eu/info/priorities/europe-fit-digital-age_en

European Commission, 2019b. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: The European Green Deal (No. COM(2019) 640 final). Brussels.

European Commission, 2019c. Evaluation of the impact of the CAP on generational renewal, local development and jobs in rural areas. DG AGRI.

European Commission, 2019d. Structural Change and Generational Renewal (Brief), Cap Specific Objectives...explained.

European Commission, 2019e. Towards an EU strategy addressing the skills needs of the steel sector: European vision on steel-related skills of today and tomorrow. European Commission, Luxembourg.

European Commission, 2019f. Digital Europe Programme: a proposed €9.2 Billion of funding for 2021-–2027. [WWW Document]. URL https://ec.europa.eu/digital-single-market/en/news/digital-europe-programme-proposed-eu92-billion-funding-2021-2027

European Commission, 2018a. Impacts of circular economy policies on the labour market – Final report.

European Commission, 2018b. The Silver Economy. European Commission.

European Commission, 2018c. A Clean Planet for all – A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy.

European Commission, 2018d. In-Depth Analysis in Support of the Commission Communication COM(2018) 773. European Commission, Brussels.

European Commission, 2018e. Digital Education Action Plan. [WWW Document] URL https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en

European Commission, 2018f. Proposal for regulation of the European Parliament and of the Council on the European Social Fund Plus (ESF+). [WWW Document]. URL https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52018PC0382

European Commission, 2017a. The macro-level and sectoral impacts of Energy Efficiency policies. Final report.

European Commission, 2017b. Study on the review of the list of Critical Raw Materials – Criticality Assessments. European Commission.

European Commission, 2017c. Blueprint for Sectoral Cooperation on Skills. European Commission, Luxembourg.

European Commission, 2016a. Steel: Preserving sustainable jobs and growth in Europe [WWW Document]. URL https://ec.europa.eu/commission/presscorner/detail/en/MEMO_16_805 (accessed 3.26.20).

European Commission, 2015a. Closing the loop – An EU action plan for the Circular Economy. European Commission.

European Commission, 2015b. Circular Economy Closing the Loop, An Ambitious EU Circular Economy Package. European Commission.

European Commission, 2013. Organic versus conventional farming, which performs better financially, Farm Economic Briefs.

European Commission, 2016b. New Skills Agenda for Europe. [WWW Document]. URL https://ec.europa.eu/social/main.jsp?catId=1223

European Observatory on Health Systems and Policies, 2019. Sustainable health financing with an ageing population – Will population ageing lead to uncontrolled health expenditure growth? World Health Organization.

European Parliament, 2019. Facts: the benefits of economic globalisation in Europe [WWW Document]. News Eur. Parliam. URL https://www.europarl.europa.eu/news/en/headlines/economy/20190603STO53520/facts-the-benefits-of-economic-globalisation-in-europe

European Parliament, 2017. Urban agriculture in Europe – Patterns, challenges and policies. European Parliament.

European Parliament, C. of the E.U., 2016. General Data Protection Regulation, 2016/679.

European Parliament, European Council, 2019. REGULATION (EU) 2019/631 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011.

Eurostat, 2020a. nama_10_a64_e. Eurostat.

Eurostat, 2020b. demo_pjan. Eurostat.

Eurostat, 2020c. edat_lfs_9903. Eurostat.

Eurostat, 2020d. proj_18np. Eurostat.

Eurostat, 2020e. isoc_sk_dskl_i. Eurostat.

Eurostat, 2020f. sbs_na_ind_r2. Eurostat.

Eurostat, 2020g. nrg_bal_peh. Eurostat.

Eurostat, 2020h. demo_r_gind3. Eurostat.

Eurostat, 2020i. demo_r_pjanind3.

Eurostat, 2020j. T2020_RD220.

Eurostat, 2020k. edat_lfs_9913. Eurostat.

Eurostat, 2020l. edat_lfse_30. Eurostat.

Eurostat, 2020m. DS-018995.

Eurostat, 2020n. nama_10_a64.

Eurostat, 2020o. educ_uoe_grad04.

Eurostat, 2019a. Europe 2020 indicators – employment ageing [WWW Document]. Eurostat Stat. Explain. URL https://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_employment#General_overview (accessed 2.6.20)

Eurostat, 2019b. Population structure and ageing [WWW Document]. Eurostat Stat. Explain. URL https://ec.europa.eu/eurostat/statistics-explained/index.php/Population_structure_and_ageing (accessed 2.6.20).

Eurostat, 2019c. Migration and migrant population statistics [WWW Document]. Eurostat Stat. Explain. URL https://ec.europa.eu/eurostat/statistics-explained/index.php/Migration_and_migrant_population_statistics (accessed 2.6.20).

Eurostat, 2019d. R&D expenditure in the EU increased slightly to 2.07% of GDP in 2017. News release.

Evans et al, 2020, March 27. 'Farmers warn over food supply with harvest workers shut out'. Financial Times. URL https://www.ft.com/content/e27a9395-db47-4e7b-b054-3ec6ba4cbba3

FCHEA, 2019. Hydrogen as a Clean Alternative in the Iron and Steel Industry [WWW Document]. Fuel Cell Hydrog. Energy Assoc. URL http://www.fchea.org/in-transition/2019/11/25/hydrogen-in-the-iron-and-steel-industry

Ferreira, I., Kirova, M., Montanari, F., Montfort, C., Moroni, J., Neirynck, R., Pesce, M., 2019. Megatrends in the agri-food sector: global overview and possible policy response from an EU perspective (Research for AGRI Committee). Policy Department for Structural Cohesion Policies, Brussels.

Financial Times, 2020. Germany's shift to electric cars puts 400,000 jobs at risk in next decade [WWW Document]. Financ. Times. URL https://www.ft.com/content/c80707b2-361d-11ea-a6d3-9a26f8c3cba4 (accessed 2.11.20).

Fong, T., 2019. Robotics and Autonomous Systems in O&M – Removing the Barriers to BVLOS Operations. ORE Catapult.

Fortune, 2020. Europe's auto factories are closing. Experts fear a lost decade is coming [WWW Document]. Fortune. URL https://fortune.com/2020/03/17/coronavirus-impact-shutdown-european-auto-sector-volkswagen/

Frey, C.B., Osborne, M., 2013. The Future of Employment: How susceptible are jobs to computerisation? Oxford Martin School, Oxford.

FTI Intelligence, 2018. Impact of Electrically Chargeable Vehicles on Jobs and Growth in the EU.

Furceri, D., Loungani, P., Ostry, J.D., 2018. The Aggregate and Distributional Effects of Financial Globalization: Evidence from Macro and Sectoral Data. IMF Working Papers.

Glachant, M., Dechezleprêtre, A., 2017. What role for climate negotiations on technology transfer? Clim. Policy 17, 962–981. https://doi.org/10.1080/14693062.2016.1222257

Global Footprint Network, 2019. Earth Overshoot Day [WWW Document]. Earth Overshoot Day. URL https://www.overshootday.org/about/ (accessed 2.6.20).

Gobierno de España, 2019. INFORME SOBRE EVALUACIÓN Y CARACTERIZACIÓN DEL POTENCIAL DE CONTRIBUCIÓN DE LA PRODUCCIÓN ECOLÓGICA A LA SOSTENIBILIDAD DEL MEDIO RURAL ESPAÑOL. Ministerio de agricultura, pesca y alimentacion, Madrid.

Goos, M., Arntz, M., Zierahn, U., Gregory, T., Carretero Gomez, S., Gonzalez Vazquez, I., Jonkers, K., 2019. The impact of Technological innovation on the Future of Work (JRC Technical Report). Joint Research Centre.

Gurzu, A., 2019. Coal miners wary of a greener future [WWW Document]. Politico. URL https://www.politico.eu/article/coal-miners-wary-of-a-greener-future/

GWEC, 2019. Global Wind Report 2018. Global Wind Energy Council.

GWEC, 2018. GLOBAL WIND REPORT – Annual Market Update 2017. Global Wind Energy Council.

Hawksworth, J., Fertig, Y., 2018. What will be the net impact of AI and related technologies on jobs in the UK?, in: UK Economic Outlook. PWC.

Hedberg, A., Šipka, S. 2020. The circular economy: going digital (EPC). URL https://wms.flexious.be/editor/plugins/imagemanager/content/2140/PDF/2020/DRCE_web.pdf

High Tech Campus Eindhoven (no date). About the Campus. [WWW Document]. URL https://www.hightechcampus.com/who-we-are

HM Government, 2019. Industrial Strategy – Offshore wind sector deal. HM Government.

HM Government, 2017. The Clean Growth Strategy – Leading the way to a low carbon future. HM Government.

HYBRIT, 2020a. HYBRIT fossil-free steel [WWW Document]. URL http://www.hybritdevelopment.com/

HYBRIT, 2020b. HYBRIT brochure.

IEA, 2019a. Global EV Outlook 2019 [WWW Document]. IEA. URL https://www.iea.org/reports/global-ev-outlook-2019 (accessed 2.25.20).

IEA, 2019b. World Energy Outlook 2019. IEA, Paris.

IEA, 2019c. Tracking Industry – Iron and steel [WWW Document]. URL https://www.iea.org/reports/tracking-industry/iron-and-steel

IEA, 2019d. Understanding the World Energy Outlook scenarios [WWW Document]. IEA. URL https://www.iea.org/commentaries/understanding-the-world-energy-outlook-scenarios (accessed 3.26.20).

IEA, 2019e. Tracking Industry [WWW Document]. URL https://www.iea.org/reports/tracking-industry (accessed 3.26.20).

Ignatenko, A., Raei, F., Mircheva, B., 2019. Global Value Chains: What are the Benefits and Why Do Countries Participate? IMF Working Papers.

ILO, 2020. ILO Monitor: COVID-19 and the world of work. Second edition. Updated estimates and analysis.

ILO, 2018a. World Employment Social Outlook 2018. Greening with jobs. ILO, Geneva.

ILO, 2019a. Skills for a greener future: a global view based on 32 country studies. ILO, Geneva.

ILO, 2019b. Changing Business and Opportunities for Employer and Business Organizations (Publication).

ILO, 2018b. World Employment and Social Outlook: Trends 2018. ILO, Geneva.

International Monetary Fund (IMF), 2020. World Economic Outlook, April 2020: Chapter 1.

International Federation of Robotics, 2019. Executive Summary World Robotics 2019 Industrial Robots. IFR.

International Federation of Robotics, 2018a. Robots and the Workplace of the Future (Positioning paper). International Federation of Robotics.

International Federation of Robotics, 2018b. Artificial Intelligence in Robotics (Media Backgrounder). International Federation of Robotics.

IRENA, 2020. Measuring the Socio-economics of Transition: Focus on Jobs.

IRENA, 2019. Renewable Energy Market Analysis Southeast Europe.

IRENA, 2011. Renewable Energy Jobs: Status, Prospects & Policies Biofuels and Grid-Connected Electricity Generation.

IRP, 2019. Global Resources Outlook 2019: natural resources for the future we want. International Resource Panel.

Jernkontoret, 2018. Steel production residues [WWW Document]. URL https://www.jernkontoret.se/en/the-steel-industry/production-utilisation-recycling/steel-production-residues/ (accessed 3.12.20).

Jernkontoret, 2020. Jernkontoret [WWW Document]. URL https://www.jernkontoret.se/en/ (accessed 3.12.20).

Jernkontoret, Swedish Aluminium, Swedish Foundry Association, 2013. National action for metallic materials.

Joint Research Centre, 2019a. Artificial intelligence: a European perspective. (Website). European Commission.

Joint Research Centre, 2019b. World Atlas of Desertification [WWW Document]. URL https://wad.jrc.ec.europa.eu/patternsaridity (accessed 3.27.20).

Kapetaki, Z., Ruiz Castello, P., Armani, R., Bodis, K., Fahl, F., Gonzalez Aparicio, I., Jaeger-Waldau, A., Lebedeva, N., Pinedo Pascua, I., Scarlat, N., Taylor, N., Telsnig, T., Uihlein, A., Vazquez Hernandez, C., Zangheri, P., 2020. Clean energy technologies in coal regions: Opportunities for jobs and growth (JRC science for policy report).

Karakaya, E., Nuur, C., Assbring, L., 2018. Potential transitions in the iron and steel industry in Sweden: Towards a hydrogen-based future? J. Clean. Prod. 195, 651–663. https://doi.org/10.1016/j.jclepro.2018.05.142

Korinek, A., 2019. Labor in the Age of Automation and Artificial Intelligence. Econ. Incl. Prosper.

Kydland, F., Pretnar, N., 2019. Who will care for all the old people?, in: Live Long and Prosper? The Economics of Ageing Populations. VoxEU, pp. 18–23.

La Huerta Digital, 2016. Agricultura Digital, la 4ª Revolución del sector [WWW Document]. Huerta Digit. URL https://lahuertadigital.es/agricultura-digital/ (accessed 3.5.20).

Lang, V.F., Mendes Tavares, M., 2018. The Distribution of Gains from Globalization. IMF Working Papers.

Libelium, 2019. New vineyard project developed with Libelium IoT platform on Agrotech, the app for crop management, powered by Efor and Ibercaja on Microsoft Azure [WWW Document]. Libelium. URL www.libelium.com/new-vineyard-project-developed-with-libelium-iot-platform-on-agrotech-the-app-for-crop-management-powered-by-efor-and-ibercaja-on-microsoft-azure/ (accessed 6.6.20).

Libelium, 2018. Smart Wine: Libelium's IoT technology allows predictive control of vineyards in the Pago Aylés winery, Spain [WWW Document]. Libelium. URL www.libelium.com/smart-wine-libeliums-iot-technology-allows-predictive-control-of-vineyards-in-the-pago-ayles-winery-spain/ (accessed 3.6.20).

Liddle, B., 2014. Impact of population, age structure, and urbanization on carbon emissions/energy consumption: evidence from macro-level, cross-country analyses. Popul. Environ. 35, 286–304. https://doi.org/10.1007/s11111-013-0198-4

Liebreich, M. 2020. March 26. Covid-19 – The Low-Carbon Crisis. [WWW Document] URL https://about.bnef.com/blog/covid-19-the-low-carbon-crisis/

Linster, M., Yang, C., 2018. China's Progress Towards Green Growth. https://doi.org/10.1787/76401a8c-en

Lutz, W., Amran, G., Bélanger, A., Conte, A., Gailey, N., Ghio, D., Grapsa, E., Jensen, K., Loichinger, M., Marois, G., Muttarak, R., Potančoková, M., Sabourin, P., Stonawski, M., 2019. Demographic Scenarios for the EU – Migration, Population and Education. European Commission, Luxembourg.

Material Economics, 2019. Industrial Transformation 2050 – Pathways to Net-Zero Emissions from EU Heavy Industry.

Material Economics, 2018. The Circular Economy – a Powerful Force for Climate Mitigation. Stockholm.

McGovern, M., 2019. Life cycle origins of pre-retirement financial status: Insights from birth cohort data, in: Live Long and Prosper? The Economics of Ageing Populations. VoxEU, pp. 74–80.

McKinsey, 2019a. China and the world: Inside the dynamics of a changing relationship. McKinsey Global Institute.

McKinsey, 2017a. The new dynamics of financial globalisation. McKinsey Global Institute.

McKinsey, 2016. Digital Globalization: The New Era of Global Flows. McKinsey Global Institute.

McKinsey, 2019b. Globalization in transition: the future of trade and value chains. McKinsey Global Institute.

McKinsey, 2019c. Recharging economies: The EV-battery manufacturing outlook for Europe [WWW Document]. McKinsey. URL https://www.mckinsey.com/industries/oil-and-gas/our-insights/recharging-economies-the-ev-battery-manufacturing-outlook-for-europe# (accessed 2.25.20).

McKinsey, 2017b. Hydrogen: The next wave for electric vehicles? [WWW Document]. URL https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/hydrogen-the-next-wave-for-electric-vehicles (accessed 3.26.20).

McKinsey, 2018. Unlocking the digital opportunity in metals.

McKinsey Global Institute, 2019. Tech for Good (Discussion Paper). McKinsey.

McKinsey Global Institute, 2017. A future that works: automation, employment and productivity.

Meyer, J., 2011. Workforce age and technology adoption in small and medium-sized service firms. Small Bus. Econ. 37, 305–324. https://doi.org/10.1007/s11187-009-9246-y

Microsoft, PwC, 2019. How AI can enable a Sustainable Future.

MIT, 2019. The work of the future: Shaping Technology and Institutions (No. Fall 2019 Report), MIT work of the future.

MoDo, 2019. Raw materials and blockchain: Volkswagen's sustainability [WWW Document]. URL https://modo.volkswagengroup.it/en/vision/raw-materials-and-blockchain-volkswagens-sustainability (accessed 3.27.20).

Morfeldt, J., Nijs, W., Silveira, S., 2015. The impact of climate targets on future steel production – an analysis based on a global energy system model. J. Clean. Prod. 103, 469–482. https://doi.org/10.1016/j.jclepro.2014.04.045

Morgan, J., Mitchell, P., 2015. Opportunities to tackle Britain's labour market challenges through growth in the circular economy.

Nationale Plattform Zukunft der Mobilität, 2020. 1. ZWISCHENBERICHT ZUR STRATEGISCHEN PERSONALPLANUNG UND -ENTWICKLUNG IM MOBILITÄTSSEKTOR. Nationale Plattform Zukunft der Mobilität.

NBC News, 2020. Italy has a world-class health system. The coronavirus has pushed it to the breaking point. [WWW Document]. URL https://www.nbcnews.com/health/health-news/italy-has-world-class-health-system-coronavirus-has-pushed-it-n1162786

Nedelkoska, L., Quintini, G., 2018. Automation, skills use and training. OECD Soc. Employ. Migr. Work. Pap. 202.

Nicuţ, M., 2019a. România poate avea în 2030 mai mulţi MW instalaţi decât în programul Guvernului, la costuri mai mici şi acelaşi preţ la consumator – studiu RWEA [WWW Document]. E-Nergiaro. URL https://e-nergia.ro/romania-poate-avea-in-2030-mai-multi-mw-instalati-decat-in-programul-guvernului-la-costuri-mai-mici-si-acelasi-pret-la-consumator-studiu-rwea/ (accessed 2.28.20).

Nicuţ, M., 2019b. Cum a mers industria eoliană în Europa în 2018. În România nu s-a montat nici măcar o turbină nouă [WWW Document]. E-Nergiaro. URL https://e-nergia.ro/cum-a-mers-industria-eoliana-in-europa-in-2018-in-romania-nu-s-a-montat-nici-macar-o-turbina-noua/ (accessed 2.28.20).

Nițulescu, G., 2020. România, între primii trei beneficiari ai finanțărilor de susținere a trecerii la economia neutră climatic. Șase județe vor profita din plin. Report. Glob.

Noonan, M., 2019. UK Offshore Wind: Realising the Sector Deal Opportunity. ORE Catapult.

Norris, R., 2020. Offshore wind industry announces targets to employ 3,000 apprentices and a more diverse workforce. Renewable UK. [WWW Document]. URL https://www.renewableuk.com/news/491745/Offshore-wind-industry-announces-targets-to-employ-3000-apprentices-and-a-more-diverse-workforce.htm

NSI Romania, 2020a. FOM103A [WWW Document]. URL http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table (accessed 3.11.20).

NSI Romania, 2020b. FOM103D [WWW Document]. URL http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table (accessed 3.11.20).

NSI Romania, 2020c. SOM103A.

Nuur, C., Karakaya, E., Gustavsson, L., 2018. Potential transitions in the iron and steel industry in Sweden: Towards a hydrogen-based future? Journal of Cleaner Production. 195. 10.1016/j.jclepro.2018.05.142

OECD, 2012. The jobs potential of a shift towards a low-carbon economy. Final Report for the European Commission, DG Employment.

OECD, 2019a. Global Material Resource Outlook to 2060: Economic Drivers and Environmental Consequences. OECD, Paris.

OECD, 2019b. Digital Opportunities for Better Agricultural Policies. OECD, Paris.

OECD, 2017a. Employment Implications of Green Growth: Linking jobs, growth, and green policies. OECD Report for the G7 Environment Ministers.

OECD, 2017b. Preventing Ageing Unequally. https://doi.org/10.1787/9789264279087-en

OECD, 2016. Getting Skills Right: Sweden. https://doi.org/10.1787/9789264265479-en

OECD, 2015. Overcoming Barriers to International Investment in Clean Energy, Green Finance and Investment. OECD, Paris.

Oesch, D., Piccitto, G., 2019. The Polarization Myth: Occupational Upgrading in Germany, Spain, Sweden, and the UK, 1992–2015. Work Occup. 46, 441–469. https://doi.org/10.1177/0730888419860880

Office for National Statistics, 2020. Low carbon and renewable energy economy, UK: 2018 [WWW Document]. Off. Natl. Stat. URL https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2018#exports-and-imports (accessed 1.30.20).

O'Neill et al, 2017. The roads ahead: narratives for Shared Socioeconomic Pathways describing world futures in the 21st century, Global Environ. Change (2016). 10.1016/j.gloenvcha.2015.01.004

ORE Catapult, 2018a. An innovator's guide to the offshore wind market. ORE Catapult.

ORE Catapult, 2018b. Offshore Wind Industry Prospectus. Offshore Wind Industry Council.

Ortiz-Ospina, E., Beltekian, D., Roser, M., 2018. Trade and Globalization [WWW Document]. Our World Data. URL https://ourworldindata.org/trade-and-globalization (accessed 2.4.20).

Our World in Data, 2020. Globalization over 5 centuries [WWW Document]. Our World Data. URL https://ourworldindata.org/grapher/globalization-over-5-centuries?time=1500..2017 (accessed 2.3.20).

Oxford Economics, 2019. The impact of the European steel industry on the EU economy.

Parnell, J., 2019. UK's Offshore Wind Auction So Successful It Might Have Made Itself Redundant [WWW Document]. Greentech Media. URL https://www.greentechmedia.com/articles/read/prices-tumble-as-u-k-awards-5-5gw-of-offshore-wind (accessed 1.30.20).

Pesce, M., Kirova, M., Bogaardt, M.-J., Poppe, K., Thurston, C., Monfort Belles, C., Wolfert, S., Beers, G., Urdu, D., 2019. Impacts of the digital economy on the food-chain and the CAP. European Parliament.

Petersen, T., 2019. What Is the Impact of Reshoring? [WWW Document]. New Perspect. Glob. Econ. Dyn. URL https://ged-project.de/allgemein-en/what-is-the-impact-of-reshoring/?cn-reloaded=1 (accessed 2.3.20).

Piccard, B. and Timmermans, F., 2020. Which world do we want after COVID-19? Euractiv. [WWW Document].URL https://www.euractiv.com/section/climate-environment/opinion/which-world-do-we-want-after-covid-19/

PIIE, 2019. What Is Globalization? And How has The Global Economy Shaped the United States? [WWW Document]. Peterson Inst. Int. Econ. URL https://www.piie.com/microsites/globalization/what-is-globalization (accessed 2.3.20).

Popov, J., 2019. România și oferta industrială a energiei curate. Report. Glob.

Posco Research Institute, 2017. Asian Steel Watch.

PwC, 2019. El futuro del sector agrícola español.

PwC, 2018a. What will be the net impact of AI and related technologies on jobs in China?

PwC, 2018b. The macroeconomic impact of artificial intelligence.

Recycling Magazine, 2019. Robots to sort scrap metal in Sweden [WWW Document]. URL https://www.recycling-magazine.com/2019/03/14/robots-to-sort-scrap-metal-in-sweden/

RenewableUK, 2019. Export Nation – UK Wind, Wave and Tidal Exports. RenewableUK.

RenewableUK, 2017. Offshore Wind Industry Investment in the UK – 2017 Report on Offshore Wind UK Content.

RenewableUK, 2016. Exporting Offshore Wind. RenewableUK.

Reuters, 2018. EU ends trade controls on Chinese solar panels [WWW Document]. Reuters. URL https://www.reuters.com/article/us-eu-china-trade/eu-ends-trade-controls-on-chinese-solar-panels-idUSKCN1LG1QM (accessed 2.27.20).

Reuters, 2017. German car makers warned of possible battery materials shortage [WWW Document]. Reuters. URL https://www.reuters.com/article/germany-materials-electromobility/german-car-makers-warned-of-possible-battery-materials-shortage-welt-am-sonntag-idUSL8N1NW0I4 (accessed 2.12.20).

Riahi et al, 2017. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview, in Global Environmental Change, Vol 42, January 2017, pp. 153–168, https://www.sciencedirect.com/science/article/pii/S0959378016300681

Rodrik, D., 2018. New Technologies, Global Value Chains, and the Developing Economies, Pathways for Prosperity Commission Background Paper Series.

Rolnick, D., Donti, P.L., Kaack, L.H., Kochanski, K., Lacoste, A., Sankaran, K., Ross, A.S., Milojevic-Dupont, N., Jaques, N., Waldman-Brown, A., Luccioni, A., Maharaj, T., Sherwin, E.D., Mukkavilli, S.K., Kording, K.P., Gomes, C., Ng, A.Y., Hassabis, D., Platt, J.C., Creutzig, F., Chayes, J., Bengio, Y., 2019. Tackling Climate Change with Machine Learning.

Sandbag, B., 2020. Financing the low carbon transition up to 2030 in Romania.

SCB, 2020. Greenhouse gas emissions and removals [WWW Document]. URL https://www.scb.se/en/finding-statistics/statistics-by-subject-area/environment/emissions/greenhouse-gas-emissions-and-removals/

Schmidt, M., 2020. Record 0.35 million pure electric cars registered in W-Europe in 2019 [WWW Document]. URL https://www.schmidtmatthias.de/post/record-0-35-million-pure-electric-cars-registered-in-w-europe-in-2019 (accessed 3.26.20).

Schuh, B., Maucorps, A., Munch, A., Brkanovic, S., 2019. The EU farming employment: current challenges and future prospects. European Parliament.

Schwab, K., 2018. Grappling With Globalization 4.0 [WWW Document]. Proj. Synd. URL https://www.project-syndicate.org/commentary/globalization-4-0-by-klaus-schwab-2018-11

Shahbaz, M., Sinha, A., 2019. Environmental Kuznets curve for CO2 emissions: a literature survey. J. Econ. Stud. 46, 106–168. https://doi.org/10.1108/JES-09-2017-0249

Simon, F., 2020. 'Green recovery alliance' launched in European Parliament. Euractiv. [WWW Document]. URL https://www.euractiv.com/section/energy-environment/news/green-recovery-alliance-launched-in-european-parliament/

Smart Water Magazine, 2019. Agriculture in Spain: water as a key player [WWW Document]. Smart Water Mag. URL https://smartwatermagazine.com/news/smart-water-magazine/agriculture-spain-water-a-key-player (accessed 3.5.20).

SmartAgriHubs, 2020. FIE22 – Iberian Irrigation Portal [WWW Document]. SmartAgriHubs. URL https://www.smartagrihubs.eu/flagship-innovation-experiment/22-FIE-online-irrigation-portal (accessed 3.5.20).

Spasić, V., 2020. UPDATE: Romania's CE Oltenia to close four units in coal power plants by 2025. [WWW Document]. Balkan Green Energy News. URL https://balkangreenenergynews.com/update-romanias-ce-oltenia-to-close-four-units-in-coal-power-plants-by-2025/

Statista, 2019. Number of employees in the automobile industry in Germany from 2005 to 2018 [WWW Document]. URL https://www.statista.com/statistics/587576/number-employees-german-car-industry/

Suta, C., Barbieri, L., May-Gillings, M., 2018. Future Employment and Automation, in: Economy, Employment and Skills: European, Regional and Global Perspectives in an Age of Uncertainty. Fondazione G. Brodolini.

The Crown Estate, 2019. Offshore wind operational report January–December 2018. The Crown Estate.

The Local, 2020. Why has German car production hit a 22-year low? [WWW Document]. The Local. URL https://www.thelocal.de/20200106/plunging-german-car-production-heralds-year-of-transformation (accessed 2.11.20).

Thomson Reuters, 2019. Mining in Romania: overview [WWW Document]. Thomson Reuters Pract. Law. URL https://uk.practicallaw.thomsonreuters.com/7-566-1143?transitionType=Default&contextData=(sc.Default) (accessed 3.10.20).

Transport & Environment, 2019. Electric Surge: Carmakers' electric car plans across Europe 2019–2025.

Transport & Environment, 2017. How will electric vehicle transition impact EU jobs?

United Nations, 2020. UN Comtrade Database [WWW Document]. URL https://comtrade.un.org/data (accessed 2.12.20).

United Nations, 2019a. World Population Prospects 2019 [WWW Document]. World Popul. Prospects 2019. URL https://population.un.org/wpp/DataQuery/ (accessed 2.6.20).

United Nations, 2019b. World population ageing 2019 – Highlights. United Nations.

U.S. Department of Energy, 2019. 2018 Offshore Wind Technologies Market Report. U.S. Department of Energy.

van Heck, P., 2019. Climbing the Digital Maturity Ladder – Data and Digitalisation in Offshore Renewables. ORE Catapult.

VDA, 2019. EU Automotive leaders unite to say "no" to 'no deal' Brexit [WWW Document]. VDA. URL https://www.vda.de/en/press/press-releases/190923-EU-Automotive-leaders-unite-to-say--no--to--no-deal--Brexit.html (accessed 2.26.20).

Viani, F., 2019. The latest protectionist trade trends and their impact on the European Union, Economic Bulletin. Banco de España.

Victor, D.G., 2019. How artificial intelligence will affect the future of energy and climate, in: A Blueprint for the Future of AI. Brookings Institution, Washington, D.C.

Visenescu, R. and Bartelet, H. 2017. How Romania can become a key player in the European gas market. [WWW Document]. Euractiv. URL: https://energypost.eu/romania-key-player-gas-eu/

Vivid Economics, 2019. Why a just transition is crucial for effective climate action.

Vivid Economics, Carbon Trust, E4tech, Imperial College London, Fraxer-Nash Consultancy, Catapult Energy Systems, 2019. Energy Innovation Needs Assessment Sub-theme report: Offshore Wind. BEIS.

Vox, 2019. These huge new wind turbines are a marvel. They're also the future. [WWW Document]. Vox. URL https://www.vox.com/energy-and-environment/2018/3/8/17084158/wind-turbine-power-energy-blades (accessed 1.29.20).

Watson, M., 2019. Robotics and Autonomous Systems: The Economic Opportunity [WWW Document]. ORE Catapult. URL https://ore.catapult.org.uk/blog/robotics-automation-offshore-wind-opportunity/

Whitmarsh, M., Canning, C., Ellson, T., Sinclair, V., Thorogood, M., 2019. The UK Offshore Wind Industry: Supply Chain Review. Offshore Wind Industry Council.

Wink, B., 2020. The IMF says its forecast for the COVID-19 recession might now be too optimistic. World Economic Forum. [WWW Document] URL https://www.weforum.org/agenda/2020/04/imf-economy-coronavirus-covid-19-recession

Wired, 2020. Why the Coronavirus Hit Italy So Hard [WWW Document]. URL https://www.wired.com/story/why-the-coronavirus-hit-italy-so-hard/ (accessed 3.20.20).

Wissenbach, I., 2018. EV push threatens 75,000 German auto industry jobs, study says [WWW Document]. Automot. News Eur. URL https://europe.autonews.com/article/20180605/ANE/180609877/ev-push-threatens-75-000-german-auto-industry-jobs-study-says

Wood, R., Grubb, M., Anger-Kraavi, A., Pollitt, H., Rizzo, B., Alexandri, E., Stadler, K., Moran, D., Hertwich, E., Tukker, A., 2019. Beyond peak emission transfers: historical impacts of globalization and future impacts of climate policies on international emission transfers. Clim. Policy 0, 1–14. https://doi.org/10.1080/14693062.2019.1619507

Woolsey, B., 2018. How electric cars will charge Germany's job market [WWW Document]. URL https://www.handelsblatt.com/today/robot-wars-how-electric-cars-will-charge-germanys-job-market/23580652.html?ticket=ST-6311113-IbQrs02vMgybOdNdFNIN-ap3

World Bank, 2019. World Development Report 2019: The Changing Nature of Work. World Bank, Washington, D.C.

World Bank, WTO, 2015. The role of trade in ending poverty. World Bank, WTO.

World Steel Association, 2020. About steel [WWW Document]. URL https://www.worldsteel.org/about-steel.html

World Steel Association, 2019a. World steel in figures 2019.

World Steel Association, 2019b. Factsheet – Steel and raw materials.

World Steel Association, 2015. Steel in the circular economy – A life cycle perspective.

WTO, 2017. World Trade Report 2017. WTO.

York, R., 2007. Demographic trends and energy consumption in European Union Nations, 1960–2025. Soc. Sci. Res. 36, 855–872. https://doi.org/10.1016/j.ssresearch.2006.06.007

Zagheni, E., 2011. The Leverage of Demographic Dynamics on Carbon Dioxide Emissions: Does Age Structure Matter? Demography 48, 371–399. https://doi.org/10.1007/s13524-010-0004-1