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Labour market transitions and skills investment needs of the green transition – a new approach

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Estimating labour market transitions and skills investment needs of the green transition – a new approach

Abstract

The green transition is affecting the entire economy and is leading to significant transformations in some specific sectors, including sectors such as the *energy* industries, *mining and quarrying*, *construction*, *manufacturing*, or *waste management*. The ongoing transformations have impacts on the demand for overall labour market, skills, occupations, wages and working conditions. The paper aims at providing evidence on labour market transitions in the context of the shift towards climate neutrality. Based on data from the EU Labour Force Survey we find that in recent years there was a net inflow of workers into all of the ‘transforming sectors’ except for *mining and extraction* in the EU. In addition, and contrary to expectations, we find that workers in ‘energy-intensive industries’ overall make less transitions towards non-employment (inactivity or unemployment) than those working in other sectors. This may be due to the higher incidence of trade union density in these sectors and also to the fact that these industries are significantly male-dominated hence less affected by transitions into inactivity due to caring responsibilities. While crucial in fostering the transition towards climate neutrality, we find that training and education in some sectors that are key in this context is lagging behind. Our paper also provides novel estimations on the additional amount of workforce needed and the associated training costs from deployment of renewable energy at Member State level in 2030. Our findings show that the additional installations of wind turbines and solar panels to deliver on the EU Green Deal targets would require about 130 000 to 145 000 additional skilled workers in the EU, with associated investment in skills reaching 1.1 to 1.4 billion EUR by 2030. Job creation nonetheless differs across Member States, and those with relatively higher shares of renewable capacity already installed may present lower re-training costs per worker in 2030.

Keywords: labour market transitions, net-zero economy, green transition, social investment, skills needs

JEL code: J21, J24, J62, Q42, Q47

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Fair Transitions Working Papers

Analytical publications related to fair green and digital transitions and research are published on an ad-hoc basis. These Working Papers present analytical findings providing new evidence or insights and policy-relevant conclusions of in-depth in-house analytical work and, where relevant, joint projects, notably with other services of the European Commission and other stakeholders. Their main aim is to disseminate the outcomes of policy analysis and research, thereby informing the Commission's policy-making activities and contributing to academic and policy debates.

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1. Introduction

Reaching climate neutrality in the EU by 2050, as enshrined in the European Climate Law adopted in July 2021, requires a fast and effective decarbonisation of the European Union (EU) economy. This includes an accelerated roll-out of renewable sources of energy, improvements in energy efficiency, low emission mobility, and a shift to leaner, more circular and less resource-intensive modes of production and consumption. Key initiatives have been introduced by the European Commission in recent years in the area of climate and energy to advance the EU's ability to achieve climate neutrality, such as the 'Fit for 55' package (1), the Green Deal Industrial Plan (2) with its Net Zero Industry Act (3), the Critical Raw Material Act (4), and, most recently, the Communication on a 2040 Climate Target Plan (5) which proposes an intermediate target of reducing net greenhouse gas emissions by 90% by 2040 in the EU. To reach the goals of the European Green Deal, additional investments are paramount, and are estimated to be around EUR 520bn (billion) per year from 2021-2030, in particular in the energy and transport sectors, and help to deliver on environmental objectives. (6) To boost the EU's capacity to manufacture net-zero technologies, additional investments amount to around EUR 92bn from 2023 until 2030 as estimated in the investment needs assessment accompanying the Net Zero Industry Act. (7)

These transformations affect labour markets and employment structures, and increasing attention is being paid to the need for policy measures to ensure that the necessary social investments are made to deliver the transition to a net-zero economy by 2050 in a fair manner. However, while recognised already in the 2020 Green Deal Investment Plan (8), social investments linked to the green transition have been overlooked to some extent in policymaking and analysis. Various studies provide evidence that the Green Deal, with the right accompanying policies in place, can foster new job growth in the EU, with a limited but net positive impact on total employment overall across all skill levels, though with diverse impacts on regions, sectors, and occupations. Sectors such as renewable energy, manufacture of clean technologies and other electrical products, and construction as well as the circular economy will experience a net expansion of their labour force. (9) Energy- and emission-intensive industries, on the other hand, need to transform their production processes and supply chains. Yet, changes that decarbonisation and greening of the economy bring on the labour market spread wider than that. While some sectors grow in demand, others may shrink. A significant share of existing jobs even outside of the sectors directly impacted will undergo changes due to an uptake of new environmentally-conscious production methods or technologies (e.g. for example in the education or healthcare sectors).

Investing in people is crucial to ensure that everyone can equally benefit from the opportunities arising from the green transition. These investments take the form of re-skilling and up-skilling the workforce in sectors that are key to the green transition, supporting job-to-job transitions and changing task profiles, and promoting quality employment and the

(1) Completion of key 'Fit for 55' legislation (europa.eu)

(2) COM(2023) 62 final

(3) COM(2023) 161

(4) COM(2023) 160 final

(5) COM(2024) 63 final and SWD(2024)63.

(6) COM/2022/83/final

(7) SWD(2023) 68 final

(8) COM(2020) 21 final

(9) For details see e.g., Aiskainen et al. (2021), Cedefop (2021), European Commission (2020 and 2023a).

integration of under-represented groups (such as women, low-skilled, young people, people with migrant background, people with disabilities) in key sectors to the transition. This is in line with the Council Recommendation on ensuring a fair transition towards climate neutrality. (10) Relevant support to address employment, social and training needs in the context of the green transition is also mainstreamed across broader EU policy in multiple ways. At EU level, the Just Transition Mechanism supports people living in the regions most affected by the transition towards climate neutrality (11), including for example re-skilling, up-skilling and job assistance. Provisions to address employment aspects of the transition can be found also under climate policies, such as the creation of Net-Zero Industry Academies that are set to develop training programs to help meet the manufacturing targets set out under the Net Zero Industry Act. Furthermore, the Recovery and Resilience Plans funded by the Recovery and Resilience Facility in place until 2030 (12) include reforms related to green skills and green jobs amounting to EUR 2.4 billion, while the European Social Fund provides investments of nearly EUR 10 billion in skills and jobs for the green transition.

In light of these efforts, and against the backdrop of rising labour and skills shortages in some of the key sectors and occupations linked to the green transition, estimating the scope of the need for workers that are key for implementation of clean energy targets is a prerequisite to any successful action in this area. This paper presents novel evidence on sectoral labour market transitions in industries that are key to the green transition (i.e. sectors under considerable transformation – so-called 'transforming sectors' which include 'energy-intensive industries'). It also presents a corresponding estimation of how many additional skilled workers will be needed for the deployment of key net-zero technologies (e.g. wind and solar energy), and of the associated investments needs in Member States, as a result of the Net Zero Industry Act. (13)

The paper is organised as follows. Section 2 explores sectoral transitions in the EU in the EU ambitious pathway towards climate neutrality. It starts with a literature review and an in-depth framing of the sectors analysed (Section 2.1). It then focuses on 'transforming sectors', and after characterising them and presenting their demographical composition it digs into sectoral transitions in and out of 'transforming sectors' (Section 2.2). Section 3 discusses the role of re-skilling and/or up-skilling in the 'transforming sectors' and explores whether workers are already engaging in lifelong learning and how this relates to workers' sector-to-sector mobility. Section 4 provides estimations of skills investment needs of the green transition arising from additional job creation and re-training requisites due to enhanced production of solar PV and wind energy. By presenting the background and detailed methodology on the estimations regarding additional workforce and skills investments needed for deployment of wind and solar energy, this paper supports the

(10) On 16 June 2022 Member States unanimously adopted the Council Recommendation on ensuring a fair transition towards climate neutrality (2022/C 243/04). The Recommendation invites Member States to adopt measures which address the employment and social aspects of climate, energy and environmental policies. The Commission proposal was accompanied by a Staff Working Document (https://ec.europa.eu/social/BlobServlet?docId=25029&langId=en) that provides an overview and discussion of the available analytical evidence underpinning the recommended policy interventions, building on the analyses presented in relevant impact assessment reports accompanying the 2030 Climate Target Plan and the various initiatives of the 'Fit for 55' package.

(11) Under the Just Transition Fund, EUR 40 billion is earmarked to assist Member States with providing training and education support to persons in regions most affected by the transition, including up-skilling and re-skilling programs to promote employment out of emission-intensive and into greener employment.

(12) Recovery and Resilience Scoreboard (europa.eu)

(13) The analysis presented in this paper has been developed under two joint projects between Directorate-General Employment, Social Affairs and Inclusion (DG EMPL) and the Joint Research Centre (JRC) of the European Commission. The two projects are: "Assessing and monitoring employment and distributional impacts of the Green Deal (GD-AMEDI)" running from 2020 to 2023; and "Assessing distributional impacts of geopolitical developments and their direct and indirect socio-economic implications, and socio-economic stress tests for future energy price scenarios (AMEDI+)" running from 2023 until 2026. The two projects combine macro-economic modelling work and micro-economic modelling approaches, with the ultimate goal of enhancing the Commission's modelling and analysis capacities for assessing and monitoring employment, social and distributional impacts of climate and energy policies as well as of energy market effects and price developments caused by Russia's war of aggression against Ukraine. For more information see https://ec.europa.eu/social/main.jsp?langId=en&catId=1588

evidence on this matter presented in the 2024 European Semester Country Reports, notably Annex 8 ("Fair Transition to Climate Neutrality"). (14) Section 5 draws conclusions.

2. Exploring labour market transitions towards the net-zero economy

2.1. Literature review and definitions

To understand the impact of the green transition on the labour market, it is important to study the flows of workers between the different sectors that will see the largest transformations. This is because the green transition will lead to the expansion of some sectors (e.g. workers in renewable energy industries), decline of other sectors (e.g. mining), and in depth transformation related to low-carbon requirements in some industries (e.g. construction, transportation, etc). The green transition will require more workers to transition into expanding sectors to avoid further exacerbating already high labour shortages in some of the most affected sectors (e.g. construction, transportation, etc.). Understanding the dynamics of flows out of shrinking sectors is key in order to design effective policies to support workers transitioning to other industries. Relatively high degrees of labour transitions in the sectors most affected by the green transition should be seen as positive, as it would facilitate a smoother labour market adjustment to the expected sectoral changes. (15) Section 0 presents an analysis of the EU Labour Force Survey (LFS) (16) with a focus on sectors that are relevant in the context of the transition towards climate neutrality and complement and contextualise the findings along with a review of previous studies.

We focus primarily on sectors that are experiencing significant changes due to the green transition, which we refer to as the 'transforming sectors' for the remainder of this paper. *Box 1* provides a description of these sectors (including their NACE Rev. 2 section codes). The selection of key sectors analysed in this paper covers economic activities that are based on energy-intensive, often greenhouse gas (GHG)-intensive, processes and outputs (e.g. mining) but also includes activities that are key to the implementation of the transition towards net-zero (manufacturing of electrical equipment, transportation), and are likely to expand in demand (waste management due to enhanced circular activity).

All of the 'transforming sectors' will experience significant changes in their workforce because of the transition towards climate neutrality. However, the exact impact varies across the different sectors. For instance, some sectors, like mining and quarrying, may experience a decrease in the demand for workers. Other sectors may not see a decline, but the required skills and tasks of some occupations may change significantly. For example, by 2030, the construction sector is expected to have a higher demand for workers to install heat pumps or solar photovoltaic (PVs) (17), while the need for gas fitters to install gas stoves or boilers may decrease. Besides the construction of new buildings and clean energy infrastructure, retrofitting and energy efficiency improvements are to play a key role for projected demand in growth in the sector. The automotive industry, on the other hand, will

(14) 2024 European Semester: Country Reports - European Commission (europa.eu)

(15) See also EBRD (2023), OECD (2024).

(16) The LFS, collected by national authorities and harmonised by Eurostat, is a large household sample survey that provides information on labour market participation and on people outside the labour force.

(17) See Section 3 of this working paper.

require different skills when production shifts from cars powered by internal combustion engines to electric vehicles. ([18])

CEDEFOP also finds that by 2050, the European Green Deal may lead to large relative increases in employment in sectors such as water supply and waste management, construction, and wholesale and retail trade and to decreases in sectors such as coke and refined petroleum, gas, steam and air conditioning, and mining. ([19]) The European Commission's impact assessments for the 2030, 2040 and 2050 European climate targets find similar reductions in employment in fossil fuel sectors and increases in sectors such as electricity supply or construction. ([20]) Similarly, according to Eurofound ([21]), the 'Fit for 55' package is likely to expand demand for sectors such as manufacturing of renewable energy source equipment, energy-efficient appliances, and construction, adding to net marginal employment creation, provided the right policies are in place. However, this job creation will be counterbalanced by lower economic activity in carbon-intensive sectors. Hence, some workers may need to make a transition from the sectors in decline to another sector, including those in growing demand. On top of this, regardless of whether the green transition leads to expansion or contraction of employment in these sectors, the transformation of skills and occupations could increase the importance of workers being mobile across or within sectors, as well as geographically.

Box 1: An overview of the framework and approach for exploring sectoral transitions

The sectoral angle is preferred in the analysis as decarbonisation takes more direct impact on sectors rather than occupations. Recent works by Causa et al. (2024) and OECD (2024) provides novel findings on occupational transitions in the economy greening.

Definition of 'transforming sectors'

This paper explores transitions out and into sectors defined in this paper as 'transforming sectors'. This category includes the selection of sectors that (i) are key to transition to climate neutrality for their role in implementation of climate targets (e.g. the electricity, gas, steam and air condition supply sector), or (ii) are expected to experience significant employment-related changes due to decarbonisation (e.g. construction, mining and quarrying), or both. The employment-related changes can be either positive (net growth in employment demand), neutral (no net change in employment demand but considerable changes to skills or tasks are expected) or negative (loss in demand for employment). The sectors considered under this definition are selected based on the NACE Rev. 2 Level 1 and include *mining and quarrying (B)*, *manufacturing (C)*([22]), *electricity, gas, steam and air conditioning supply (D)*, *water supply, sewerage, waste management and remediation activities (E)*, *construction (F)*, and *transportation and storage (H)*. The analysis takes note that parallel changes of opposing directions may be experienced among sub-sectors within the broader economic activity at NACE 1-digit level due to the decarbonisation's requirements, such in the case of manufacturing where growth in demand for labour (e.g. linked to manufacturing of equipment linked with low-energy produce) as well as decline in demand in some carbon-intensive manufacturing (e.g. metals) is anticipated. Nevertheless, due to data availability in the LFS, the report provides analysis at the broadest sector level (NACE 1-digit). Because of the particular sensitivity of the mining and extraction sector to the energy transition, the results for this sector are occasionally discussed in this paper in additional detail.

([18]) Tamba et al. (2022).

([19]) Cedefop (2021).

([20]) European Commission (2018, 2020b and 2024c).

([21]) Eurofound (2023a).

([22]) This includes also manufacture of motor vehicles, trailers and semitrailers (C29), the manufacturing subsector relevant to transformation to electromobility.

Framework for sectoral transitions

Sector-to-sector transitions represent one type of transitions that may occur in the labour market, next to occupational transitions, transitions out and into employment or inactivity, transitions across different contractual arrangements and wage transitions. The analysis of sectoral transitions in 'transforming sectors' provided in the section 2.2.3 makes use of standard EU LFS variables on workers' retrospective self-reported employment data (sector, employment status) of the year before. ([23]) Labour market transitions are estimated to track the movement of individuals between each possible sector-pair combination on a yearly basis and per Member State. The methodology is repeated for different releases of the LFS between 2010 – 2020, taking note of the fact that the results for 2020 may be sensitive to the impact of the COVID-19 crisis. Hence, 2019 is considered the main year of reference. The analysis is not possible for subsequent years as the retrospective question used to assess the transitions has been discontinued from the LFS.

2.2. Labour market transitions and demographical composition in 'transforming sectors'

2.2.1. Characterisation and demographical composition of EU 'transforming sectors'

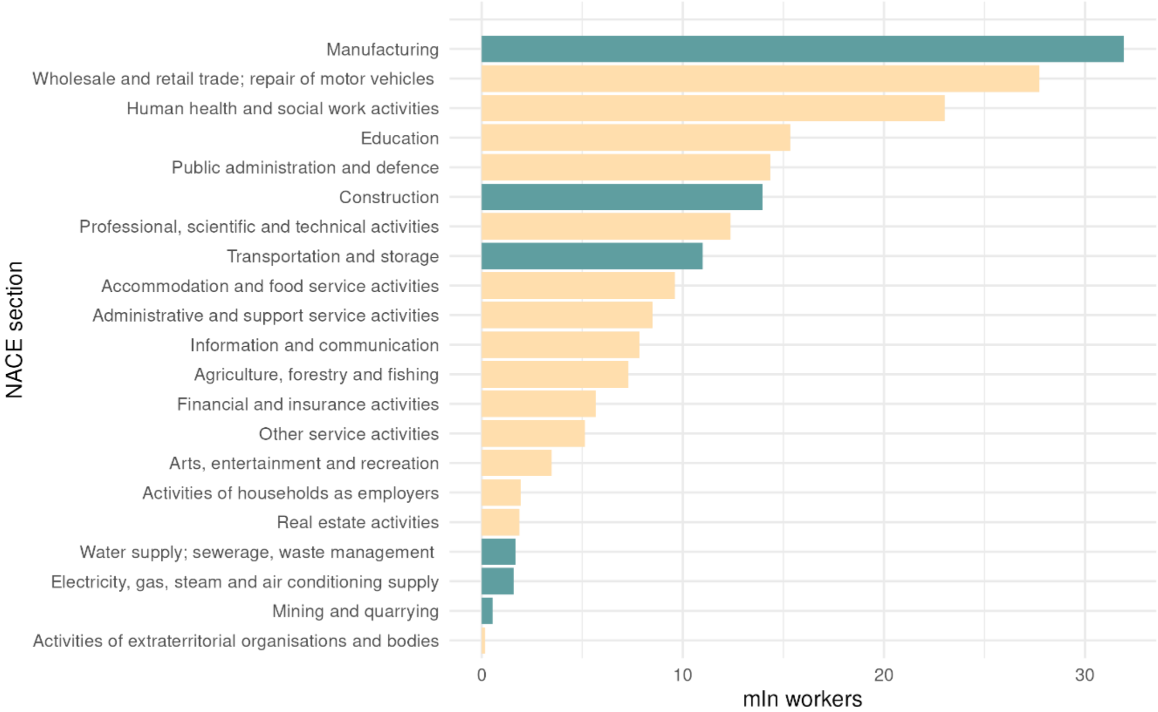
Employment in 'transforming sectors' across the EU

Overall, the 'transforming sectors' made up around 30% of the European labour market in 2023 (Figure 1). Of the different 'transforming sectors', *manufacturing* employs the most workers across the EU, with over 30 million workers in 2023. The second largest transforming sector in terms of employment is *construction*, with almost 15 million workers in 2023. The sectors *mining and quarrying*, *energy*, and *water supply and waste management* make up a much smaller share of the European labour market, jointly representing around 3.8 million workers.

There are differences across Member States in the relative importance of each of the 'transforming sectors' for employment, although the overall pattern remains the same. Figure 2 displays the relative employment in the NACE 1-digit sectors within the total 'transforming sector' group for each Member State. While *manufacturing* employs most workers in most Member States (often over 50% of the workers in 'transforming sectors'), Cyprus and Luxembourg are exceptions to this, with a higher concentration of workers in the *construction* sector. *Transportation and storage* accounts for approximately 20-25% of workers in 'transforming sectors' across most Member States. Lastly, *mining and quarrying* employs the least amount of workers (less than, or around 1% in most Member States with the exception of Bulgaria and Poland), following a declining trend over the past few decades.

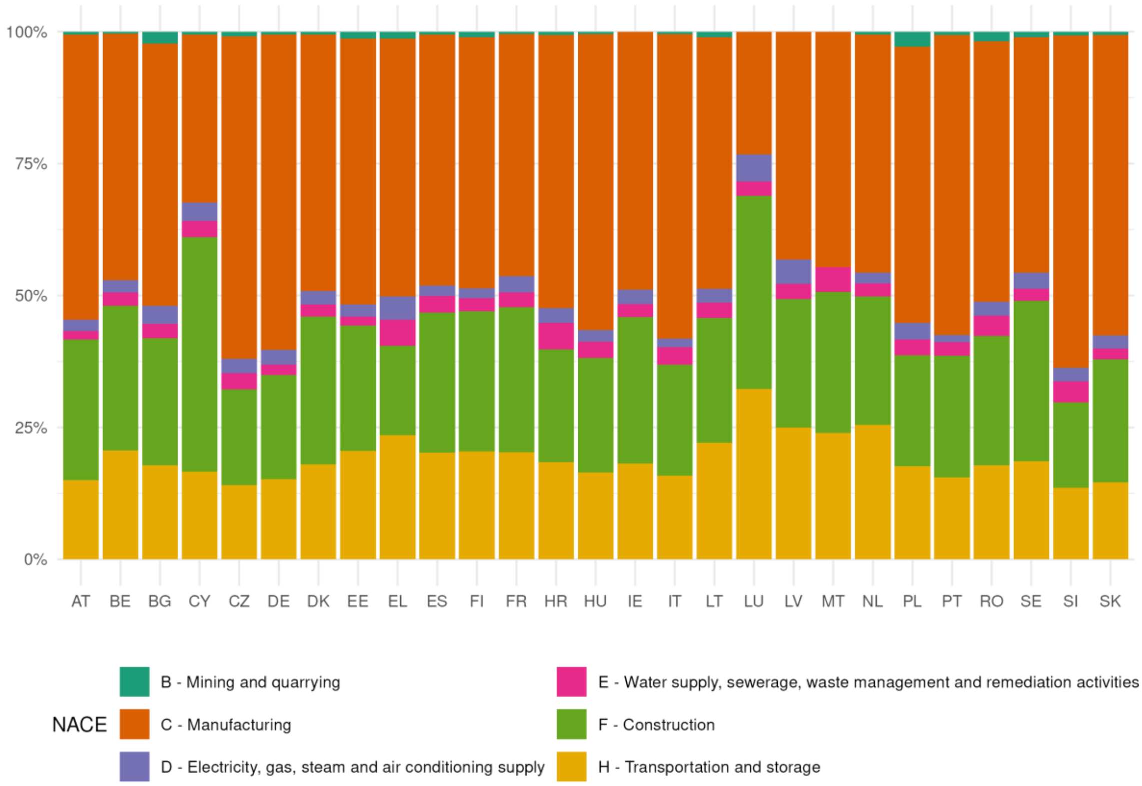
([23]) The analysis in this section makes use of both yearly and quarterly LFS variables which are weighted using the yearly weighting factor (COEFFY) rather than the quarterly weighting factor (COEFFQ).

Figure 1: Employment in millions of workers in EU27 per NACE sector, 2023



Source: Eurostat, variable « lfsa_eisn2 ».
Notes: 'Transforming sectors' are visualised in green.

Figure 2: Share of workers employed in different 'transforming sectors' per Member State, 2022



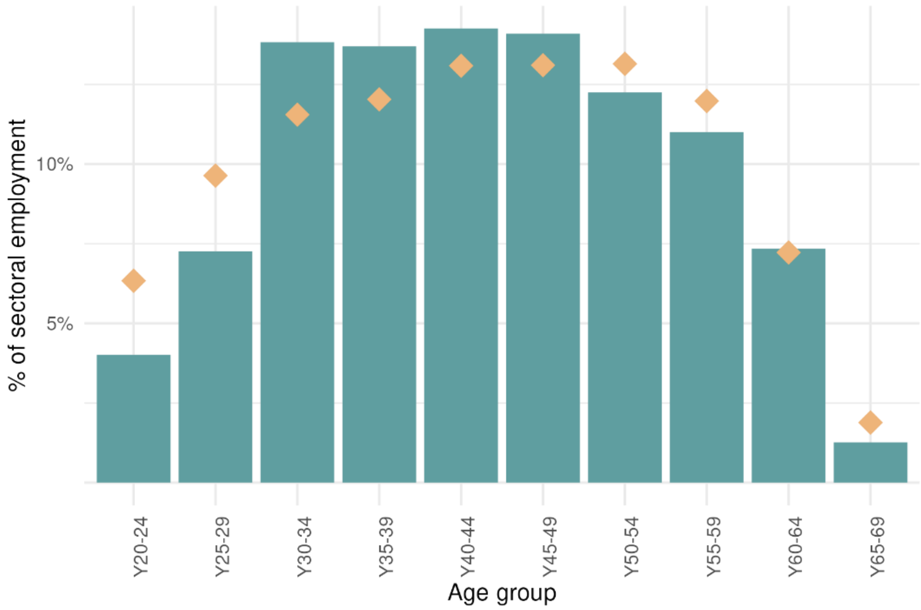
Source: Own calculations based on EU-LFS microdata (2022 wave).

Demographic profiles of workers in 'transforming sectors' in the EU

In the EU, 'transforming sectors' have a fairly balanced representation of different age groups across the 'transforming sectors' (Figure 14 in Annex). However, in certain Member States, there is a higher prevalence of workers from middle-aged or older age groups, including Greece, Spain, Italy, Luxembourg, Romania, and Slovenia. Compared to these Member States, Estonia, Croatia, and Lithuania have slightly younger workforces within these sectors. While *water supply, sewerage, waste management* is the oldest transforming sector across the EU (with a median age of 46 years, Figure 14 in Annex), the *mining* and *construction* sectors have a slightly younger workforce (with a median age of 43 years, Table 2 in Annex).

The age distribution in the *mining* sector in 2022 (Figure 3), showing that workers are mainly between the ages of 30 – 50, may reflect a high proportion of workers going into early retirement possibly because of the difficult working conditions. Additionally, this sector shows fewer workers between the ages of 20 – 30 than the EU average across all sectors, which may reflect that the shrinking mining sector is less attractive to younger workers who enter the labour market for the first time. To give an example, in Poland which has the highest share of the workforce in the EU working in this sector (1.1% in 2022 according to LFS data), the average age of a miner worker is 39 years, while the statutory pension age for workers in hard mining is 50. [24]

Figure 3: Age distribution in mining in the EU27, 2022



Source: Own calculations based on EU-LFS microdata (2022 wave).
Notes: Yellow dots indicate the EU average across all sectors.

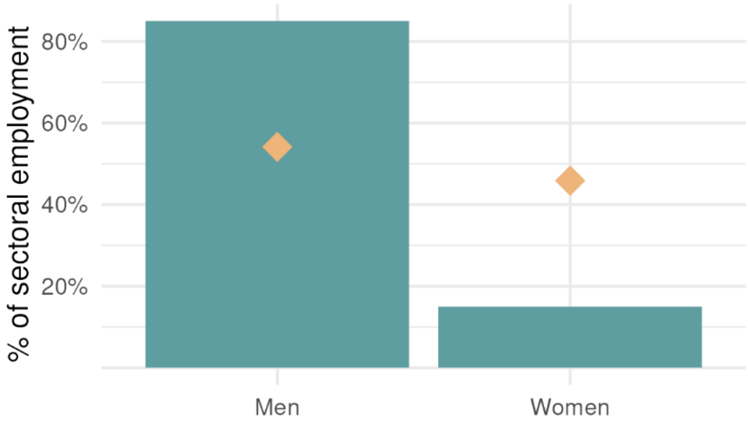
Women are widely underrepresented in the 'transforming sectors' in all Member States, representing between 20-30% of the workforce in these sectors. This is much lower than the European average across all sectors in 2023, where women made up 46.5% of the labour force. [25] Luxembourg, Belgium and Greece have the largest gender gaps for the

[24] Frankowski et al. (2020).

[25] Eurostat (2024d).

'transforming sectors', with women making up only 20% of the workforce (Figure 15 in Annex). Conversely, the gender gap is the smallest in Lithuania and Bulgaria, with women making up 31% of the workforce in the 'transforming sectors'. Women constituted as little as 14% of all persons working in mining in 2022 (Figure 4), while the gender ratio is slightly higher in some of the manufacturing industries for computers, electrical and optical equipment, and chemicals (around 30% in 2017). ([26])

Figure 4: Gender composition in mining in the EU27, 2022



Source: Own calculations based on EU-LFS microdata (2022 wave).
Notes: Yellow dots indicate the EU average across all sectors.

The share of women in the *energy* sector has been steadily increasing over the past decade (+12% since 2013), yet women made up only 26.7% of the total energy workforce in 2023 (according to LFS data). Variation exists depending on the type of energy production. Worldwide, there is a larger share of women employed in renewable energy sectors (32%) compared to the oil and gas sector (22%). ([27]) Across the renewable energy sectors, there are relatively more women in the solar PV industry (40%) compared to the wind industry (21%). ([28])

At the same time, looking through the gender lens, the uneven gender composition of 'transforming sectors' creates two-fold implications of the labour market changes in the green transition. While job losses due to the transition to a net-zero economy are expected mainly in sectors primarily occupied by men, such as *mining*, employment gains are expected in sectors of *construction* or *waste management* where men are also more represented. To this end, increasing women's employment in the clean energy sector that constitutes an important share of the new emerging jobs in the green transition is a key step to ensure a successful and gender-neutral energy transition. ([29])

([26]) IEA (2022).

([27]) IRENA (2022).

([28]) IRENA (2022).

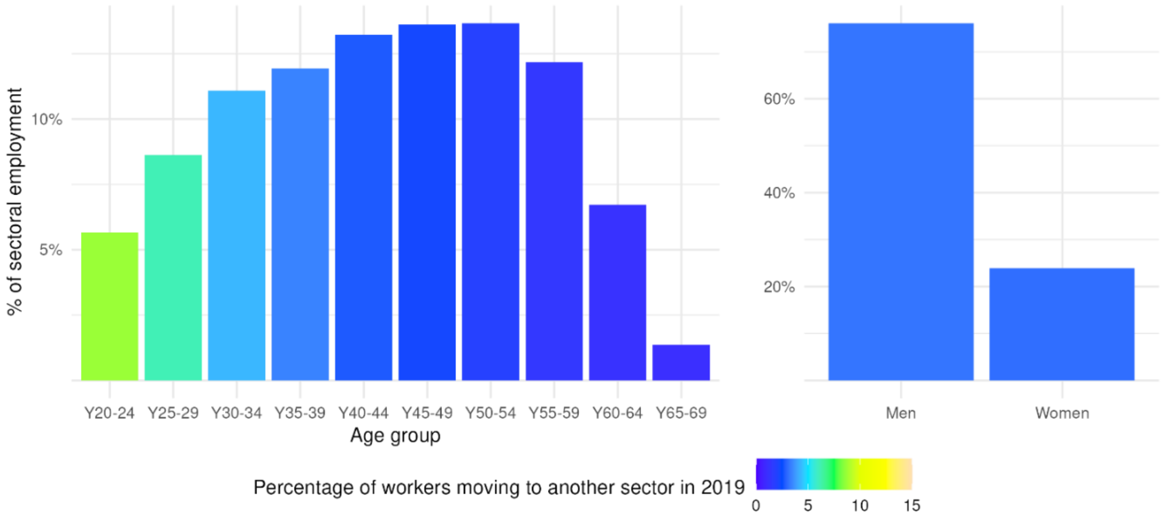
([29]) Murauskaite-Bull et al. (2024).

2.2.2. Sectoral transitions in the total economy in the EU

In the EU, most of the sector-to-sector transition rates in the overall economy fall between 1.8% – 3.9% (Figure 16 in Annex). [30] In many Member States, the transition rates remained relatively stable over the observed period (2010-2019), while a slight upward trend that could be observed around the year of 2016 in some countries. For example, in Estonia, Finland, Hungary, Luxembourg, Malta and Slovenia, there were years with increases in the rate of sectoral transitions after 2017. [31]

Worker characteristics can typically influence one's sectoral mobility. Workers at various career stages may encounter different circumstances when considering a shift in their sector of employment. For example, the opportunities for sectoral mobility may differ based on whether a worker is entering the labour market for the first time, has a few years of experience, or is nearing retirement age. Figure 5 presents sector-to-sector transitions of workers of different age groups in the EU (Figure 14 in Annex for Member States breakdown).

Figure 5: Age and gender distribution in 'transforming sectors' (*magnitude of the bars*) and sectoral mobility across all sectors of economy (*colours of the bars*) by age or gender, EU



Source: Own calculations based on EU-LFS microdata (2019/2022 waves).
Notes: The magnitude of the bars indicates the share of workers employed in 'transforming sectors' by age groups. Colour indicates sector-to-sector mobility per age or gender group, based on sectoral transitions across all sectors of the economy.

Overall, the descriptive analysis indicate that older workers tend to make fewer sector-to-sector transitions in the EU. However, there are variations among countries. For instance, workers in Estonia and Finland appear to be generally more mobile across sectors compared to other countries. On the other hand, some countries exhibit significant discrepancies between the mobility of younger and older workers, including Cyprus,

(30) The calculation of sector-to-sector labour market transitions employs a method based on two LFS variables. The method involved creating "labour market transition matrices" that track the movement of individuals between all possible sector-pair combinations within NACE rev. 2 Level 1 sectors on a yearly basis and per Member State. The sector-to-sector transition rates were calculated using the following LFS variables: the current sector of employment (NACE1D) and the sector of employment one year prior to the survey (NACE1Y1D), available until 2021. By comparing these variables, the method allowed for the identification of common sector-to-sector transitions and the calculation of transition rates (the percentage of individuals who changed sectors from one year to the next, out of all individuals who were employed in both years). The analysis made use of the LFS' yearly weighting factor (COEFFY).

(31) Notably, the percentage of sectoral transitions in Germany in 2020 was much higher than the average (around 8%), possibly influenced by the COVID-19 crisis.

Estonia, Finland, France, and Hungary. Notably, there are countries where sector-to-sector transitions are relatively limited, such as Germany, Greece and Romania. While further research on labour mobility at Member State is required, the data seem to suggest that in these countries, workers are less likely to move between different sectors, potentially indicating more stable employment patterns in the economic activity, specific structural factors influencing cyclicality, or even a more rigid labour market. ([32])

Our data show no substantial differences in the mobility for men and women across all sectors of the economy across the EU (see Figure 5 above and Figure 15 in Annex for Member States breakdown). One exception is Estonia, where women seem to make slightly more sectoral transitions than men. Zooming in on other than sectoral labour market transitions, recent evidence finds that women are flowing out and into employment more frequently than men as they are more likely to drop out of the labour force due to caring responsibilities, but are also less likely to transition into another job within the same industry, ([33]) while other research from US suggests this trend has been historically improving. ([34])

The ease of transitioning specifically from a job in a more polluting sector to a job in a less polluting sector may also differ from one country to another. For example, Lim et al. (2023) found that workers in the US fossil fuel industry might possess transferable skills applicable to green energy sectors but that there are geographical barriers to sectoral transitions because the fossil fuel industries are not necessarily located in the same place as the green energy sectors. These geographical barriers, including associated moving costs, may vary from country to country, potentially posing greater challenges in geographically larger countries such as Spain compared to smaller countries like Estonia.

On the other hand, OECD (2024) suggests that the ease of transitions from more to less polluting sectors varies between the low-skilled and high-skilled workers, finding that the skillsets of workers with low-skilled background are less compatible with 'greener' opportunities relative to their high-skilled counterparts. ([35]) Moreover, workers in some regions with higher dependability on a limited number of traditional emission-intensive sectors may face higher barriers to sectoral transition, making the transition costs more significant.

2.2.3. Transitions out and into 'transforming sectors'

Sectoral mobility is affected by several factors, including seasonality, cyclicality, structural changes such as digitisation or decarbonisation, exogenous events like climate change or COVID-19, but also phenomena such as job upgrading. ([36]) Moving from sectoral transitions in the overall economy to those occurring across 'transforming sectors' we find that most of the sectoral transitions occur between *manufacturing* and *construction*, with a comparable level of transitions in both directions. Additionally, there is a fair amount of mobility between the sectors of *manufacturing* and *transportation*, equally in both directions. Figure 6 presents the different sectoral connections between the 'transforming sectors' in the EU

([32]) Existing literature has already established that there is much variation in sector-to-sector mobility across different countries and over time. For instance, Cardi and Restout (2015) estimated the labour market mobility in 14 OECD countries, revealing substantial frictions within each country, with notable differences between them. Among the countries analysed, the US displayed the highest labour market mobility, while the Netherlands exhibited a more rigid labour market.

([33]) Causa et al. (2024).

([34]) Molloy et al. (2016).

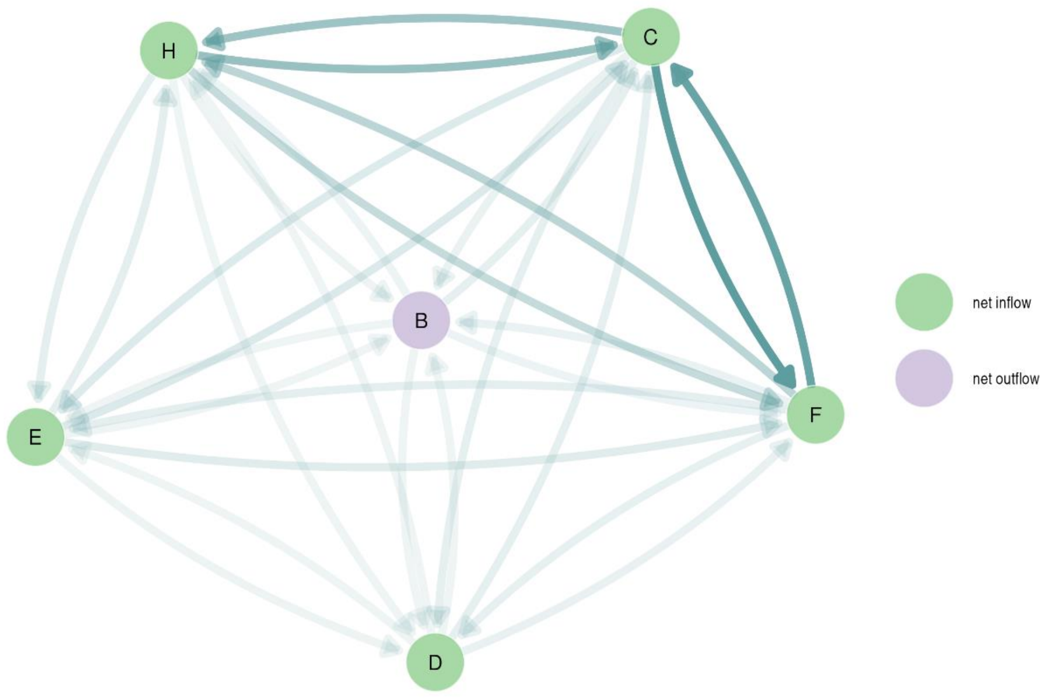
([35]) OECD (2024).

([36]) See JRC Publications Repository - Global Shifts in the Employment Structure (europa.eu) for more details on job upgrading.

from 2018 to 2019 ([37]), with the intensity of the arrows indicating the frequency of sectoral transitions in this direction.

Mining is the only sector that experienced a net outflow of workers between 2018 and 2019 in the EU out of the 'transforming sectors' considered. This sector is characterised by high emission-intensity and is expected to face a marginal net job loss in the transition towards net-zero by 2030. Remaining sectors experience net inflows, with the volumes of transitions notably reflecting sectoral size. While the *energy* sector recorded a net inflow of workers, it should be noted that the figure may conceal a considerable within-sectoral variation in labour mobility, as the sector category under NACE currently includes all types of energy production, including low-carbon energy (renewables) as well as high-carbon energy (production of gas from coal or manufacture of gaseous fuels) that may be experiencing marginal shrinking.

Figure 6: A network visualisation of the most frequent sector-to-sector transitions in the 'transforming sectors' in the EU from 2018-2019



Source: Own calculations based on EU-LFS microdata (2019 wave).
Notes: The colour indicates whether sectors had a net inflow or outflow of workers, based on sectoral transitions between all sectors of the economy. B - Mining and quarrying, C - Manufacturing, D - Electricity, gas, steam and air conditioning supply, E - Water supply; sewerage, waste management, F - Construction, H - Transportation and storage. The different shades of the arrows indicate more frequent (darker green) and less frequent (lighter green) sector-to-sector transitions.

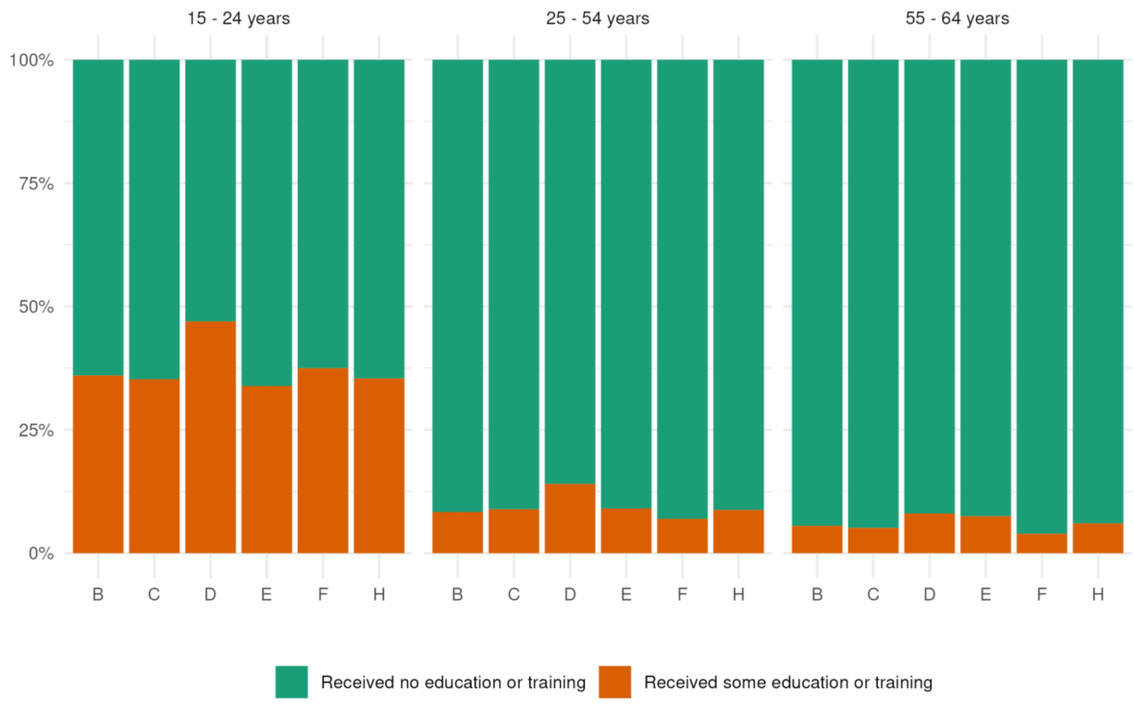
Compared to some of the services sectors, the 'transforming sectors' seem to retain relatively more workers, with the exception of *water supply, sewerage, waste management* where slightly more workers leave for other sectors (Figure 17 in Annex). The study of Artuç and McLaren (2015) provides more detail regarding where workers who are leaving different

([37]) As mentioned in *Box 1* the variable used to calculate sectoral transitions was discontinued from the LFS in 2020. In this paper it was decided to use 2019 data instead of 2020, to avoid using a wave much influencfed by the Covid-19 pandemic.

sectors may be moving when they make sectoral transitions. For example, the authors find relatively more mobility from sectors such as utilities, retail trade, and entertainment into sectors such as transportation, communication, and finance.

The energy transition will require a significant amount of re-skilling and/or up-skilling in the 'transforming sectors', and hence we also explore whether workers are already engaging in lifelong learning. Figure 7 shows the share of workers according to their age group that have received training or education in 'transforming sectors' in the EU. (38)

Figure 7: Percentage of workers in 'transforming sectors' in the EU that has received training or education in the four weeks prior to participating in the LFS, 2022



Source: Calculations based on EU-LFS microdata (LFS, 2022).
Notes: B - Mining and quarrying, C - Manufacturing, D - Electricity, gas, steam and air conditioning supply, E - Water supply; sewerage, waste management, F - Construction, H - Transportation and storage

Younger workers do not only make more sector-to-sector transitions on average, they also participate much more frequently in education and training on average in all sectors of the economy (39), as shown in Figure 8. As workers get older, the participation rate decreases in all sectors. Within each age group, participation in education and training is relatively similar across the different sectors. Nonetheless, workers in the energy sector receive slightly more education and training in all age groups. The participation rate is around 50% for individuals aged 15 – 24 (40) and remains at around 10% for those aged 25 – 54 in energy, which is almost twice the participation rate for 25 – 54 year olds in some of the other sectors. Kuokkanen (2023) equally finds that workers in the energy supply services participate more often in education and training compared to workers in manufacturing.

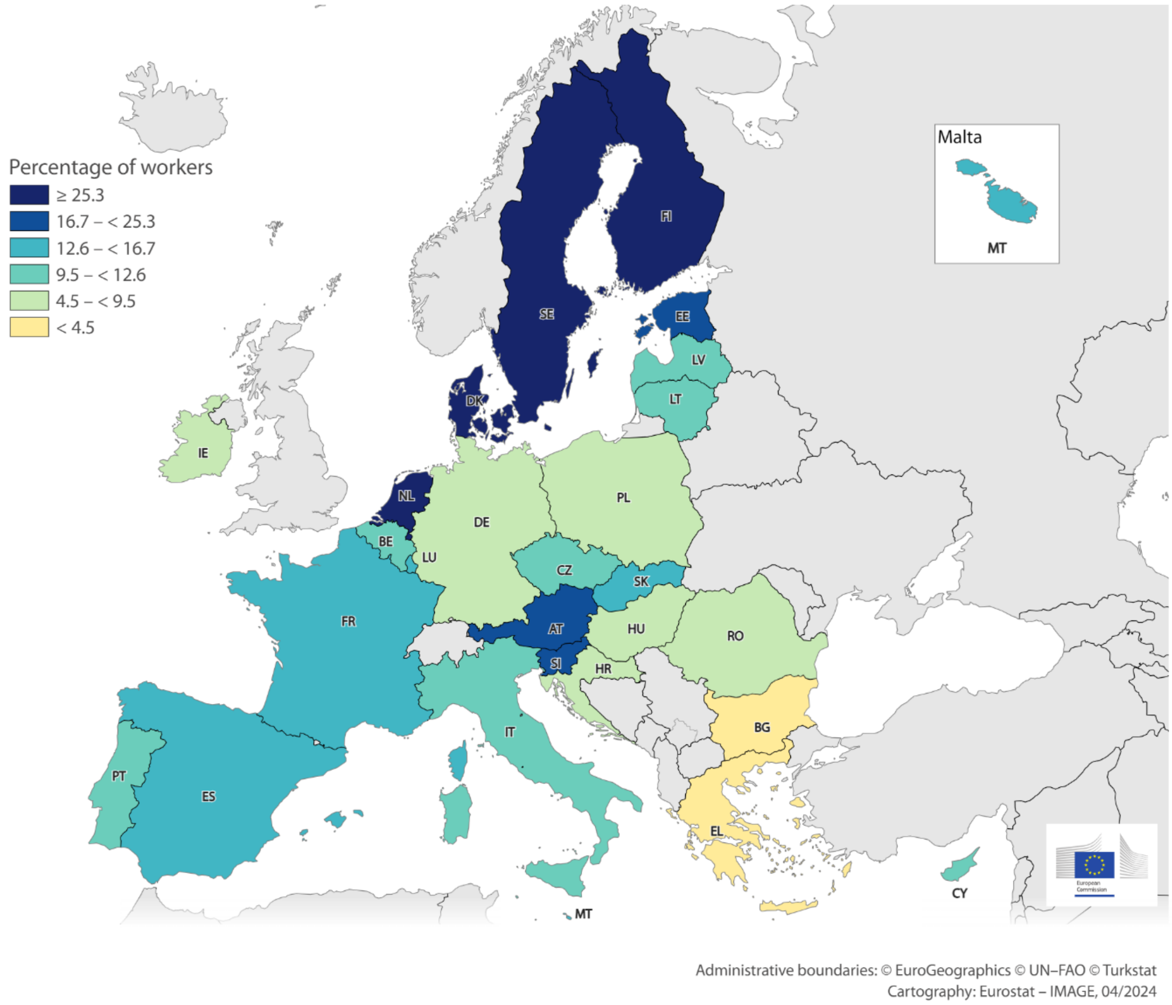
(38) This includes any formal or non-formal education training received during the reference period. This LFS variable is used as the measure for the 'adult learning' indicator in the EU.

(39) However, it should be noted that the 15 – 24 age group is potentially also capturing some workers who are employed while being enrolled in formal education programmes.

(40) The high value can be likely explained by the fact that the employed persons in this age group are typically still enrolled in different forms of formal education.

While this trend is consistent across all Member States, the average participation rates vary widely. Figure 8 shows that, in Finland and Sweden, more than 24% of workers in the 'transforming sectors' participate in education and training, compared to less than 5% in Bulgaria, Croatia, Greece, Romania and Slovakia. These results are in line with findings from previous studies. Kuokkanen (2023) finds that for energy supply services and manufacturing, workers in Sweden, the Netherlands, Denmark and Finland have the highest participation rates (20-40%) while this rate is much lower in countries such as Bulgaria, Greece and Hungary (1-5%).

Figure 8: Percentage of workers in 'transforming sectors' that has received training or education in the four weeks prior to participating in the LFS, 2022



Source: Own calculations based on EU-LFS microdata (2022 wave).

Box 2: Labour market transitions in 'energy-intensive industries'

We now introduce a second category of industries for analysis, the so-called 'energy-intensive industries' (EII). (41) This group is a subset of the 'transforming sectors' and includes industries that can be characterised by high-emission intensity and are particularly susceptible to economic transformation. To obtain granularity, the emission-intensive industries are grouped together based on the NACE Rev.2 Level 2, covering

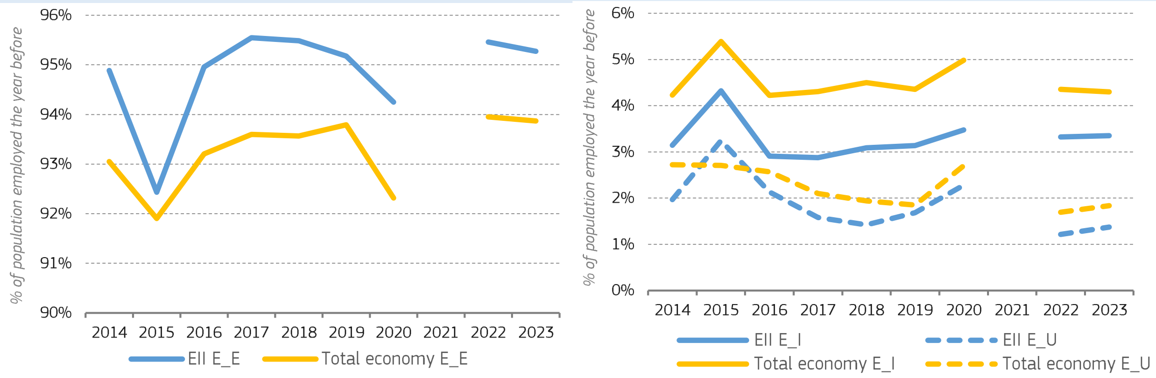
(41) To be noted that while an official definition on EII does no exist, there are different criteria to the one proposed in Box 1 to define this group of sectors. For example, the Annual Single Market Report of 2021 (page 209) includes other manufacturing sectors among EII (i.e. NACE codes 16, 17, 19, 20, 22, 23, 24).

mining and quarrying (B05-09), *manufacture of chemicals and chemical products (C20)*, *manufacture of other non-metallic mineral products (C23)*, *manufacture of basic metals (C24)*, *manufacture of motor vehicles, trailers and semi-trailers (C24)*.

In this Box we use the Eurostat's 'labour market transitions' statistics ([42]) for the custom category of EII subsectors. The 'labour market transitions' are experimental statistics derived from the longitudinal component of the EU-LFS data. They identify the flows between different labour market statuses between consecutive quarters.

The data show that that 'energy intensive industries' (EII) ([43]) are overall less dynamic than the total economy, both when it comes to remaining in employment, and when considering transitions from employment towards inactivity and unemployment (Figure 9). During the 10-year time span analysed, from 2014 to 2023, the share of workers in EII who remained in employment (although not necessarily in the same sector of activity) between one year and the next was constantly above that for the total economy. The overall trend of both groups, however, is very similar (left-hand side in Figure 9). At the same time, workers in EII experienced less outflows into inactivity and unemployment (right-hand side in **Figure 9**).

Figure 9 Transitions from employment to employment (left) and employment to inactivity and unemployment (right) in 'energy-intensive industries' (EII) and in the total economy, 2014-2023, EU27



Notes: For the sake of this chart 'energy intensive industries' (EII) are defined at the NACE 2-digit level as: mining and quarrying (B05-09); manufacturing of other non-metallic minerals (C23); manufacturing of basic metals (C24); manufacturing of chemicals (C25); and manufacturing of motor vehicles, trailers and semi-trailers (C29). The full methodology is explained on the Eurostat website (https://ec.europa.eu/eurostat/cache/metadata/en/lfsi_long_esms.htm). "E_E" indicates employment to employment transitions meaning people employed either in EII or in the total economy in *t-1* who remained employed in *t* (but not necessarily in the same NACE sector); "E-I" indicates transitions from employment to inactivity between *t-1* and *t*; "E_U" indicates transitions from employment to unemployment between *t-1* and *t*. Due to limited reliability 2021 data cannot be presented.

Demographic profile of the workforce in EII is likely to be a factor behind the relative lower mobility into unemployment and inactivity as they are relatively male dominated. Nevertheless, less employment mobility in EII also corroborates the fact that these sectors are characterised by a high degree of labour market stability, which is positive for workers in terms of perceived job security, and can possibly be explained by the fact that these are relatively well-paid industries in which wage premiums are reported in some

([42]) Labour market transitions - LFS longitudinal data (lfsi_long) (europa.eu)

([43]) Based on the greenhouse gas (GHG) emissions levels of their production or products, sectors considered energy intensive are: mining and quarrying (B05-09); manufacturing of other non-metallic minerals (C23); manufacturing of basic metals (C24); manufacturing of chemicals (C25); and manufacturing of motor vehicles, trailers and semi-trailers (C29).

Member States, [44] although recent evidence by OECD shows that high-emission industries are also characterized by a higher incidence of low pay. [45]

Analysis by OECD based on linked employee-employer data also shows that when changing employment, workers from high-emission industries are slightly more likely to change a sector, but their destination is highly likely to be another emission-intensive occupation. [46] Re-skilling and up-skilling as well as broader and comprehensive employment support is thus needed to address challenges to sustainable employment outcomes of workers in the sectors that are affected and need to adapt to advance towards climate neutrality. Moreover, recent work by Causa et al. (2024) shows that workers in high-carbon jobs face higher displacement risks than workers in non-high-polluting occupations, with 20% higher odds of unemployment.

3. Estimating skills investment needs of the green transition

The green transition has substantial implications for human capital, which can be defined as the stock of skills that the labour force possesses. [47] The EU climate ambition will accelerate this transition, affecting the number of skilled workers in a range of activities, in particular those related to renewable electricity generation. The labour market impacts directly translate into training needs for both workers and jobseekers, but with markedly differences across sectors and regions.

Figure 10 visualises the evolution over time of the participation of works in education and training per sector in the EU. Overall, there appears to be a slight increase in the share of workers receiving education and training over time, with a sharp drop during the COVID-19 crisis and a recovery from 2021 onwards. Workers in the *energy* sector (NACE D) participate much more frequently in training and education compared to other sectors. The two sectors that consistently see some of the lowest share of workers participate are *mining* (NACE B) and *construction* (NACE F). Achieving the EU Green Deal targets in 2030, will heavily require skilled workers in the *construction* sector (e.g. installation of heat pumps, solar panels, construction of wind farms, new civil engineering skills, etc.), hence it is noteworthy that relatively few workers in this sector participate in training. In particular, the participation rate in the construction subsector that includes heat pumps' installation (specialised construction activities, NACE Division 43) is similar to that of the overall construction sector, as illustrated by the dashed blue line in Figure 10.

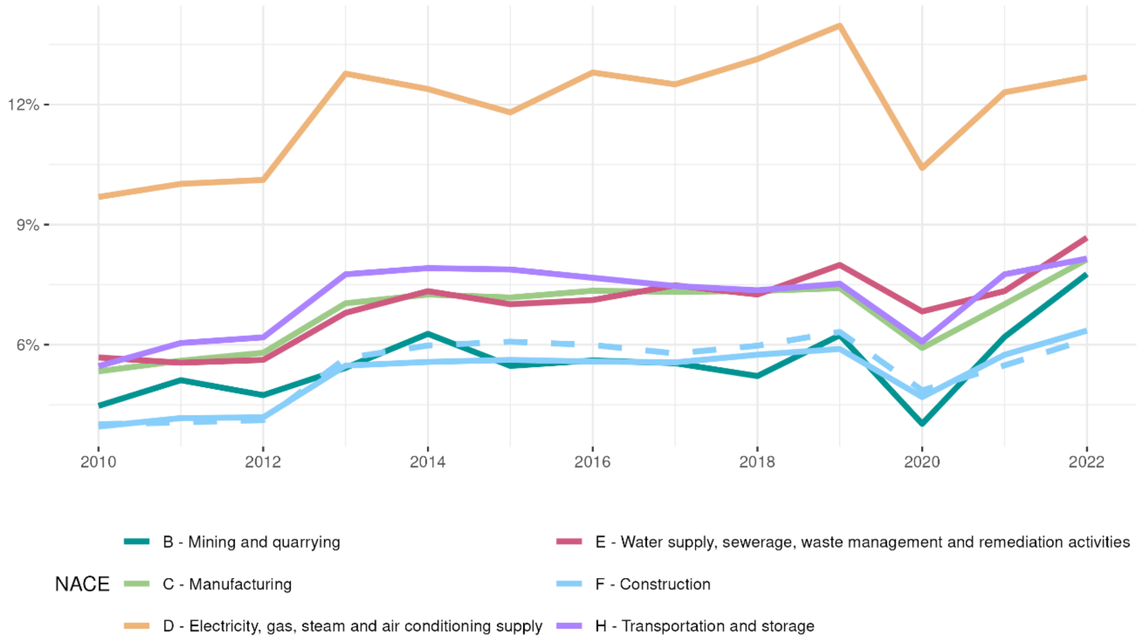
(44) European Commission (2023c); OECD (2024).

(45) OECD (2024).

(46) OECD (2024, Chapter 3).

(47) Goldin (2019).

Figure 10: Percentage of workers in the EU that has received training or education in the four weeks prior to participating in the LFS, by NACE Section (workers aged 25 – 65)



Source: Own calculations based on LFS microdata *(LFS,* 2010 – 2022).
Notes: Includes workers aged 25 – 65. The dashed blue line represents workers in the construction subsector "specialised construction activities" (NACE Division 43), which also includes activities such as electrical installation and heat and air conditioning installation.

There is also considerable variance across Member States in the participation rate in education and training. For instance, when looking at 'energy-intensive industries' (sectoral coverage defined in Box 2), the participation rate in education and training has increased to 10.9% in 2023 (9.4% in 2015) but remains below the whole economy average in the EU (12.7%). Croatia, Hungary, Poland and Czechia (3.1%, 7.6%, 7.9% and 8.2% respectively) rank lowest in terms of participation rate in education and training in 'energy intensive industries', while Sweden, Denmark, Finland and Netherlands report the highest shares (above 23%). (48) (49)

In this section we focus in two relevant sectors for the green transition. Our interest is in estimating the number of jobs related to the deployment and installation of wind and solar power generation, with respect to job creation across the whole value chain. We pay particular attention to the effects on construction, services and transport, as sectors that contribute the most to the number of jobs generated due to the deployment of wind and solar power generation. Compared to previous analyses (50), here the focus is in estimating those figures by Member States. Beyond providing a closer look at the number of additional jobs created due to the deployment of wind and solar PV, we estimate the related investment needs for re-training/re-skilling/up-skilling workers at Member States level.

(48) High variance also exists in yearly changes as the variable used to monitor adult learning in EU-LFS data ('Participation in education and training of the age group 25-64') uses 4 weeks as the reference period.

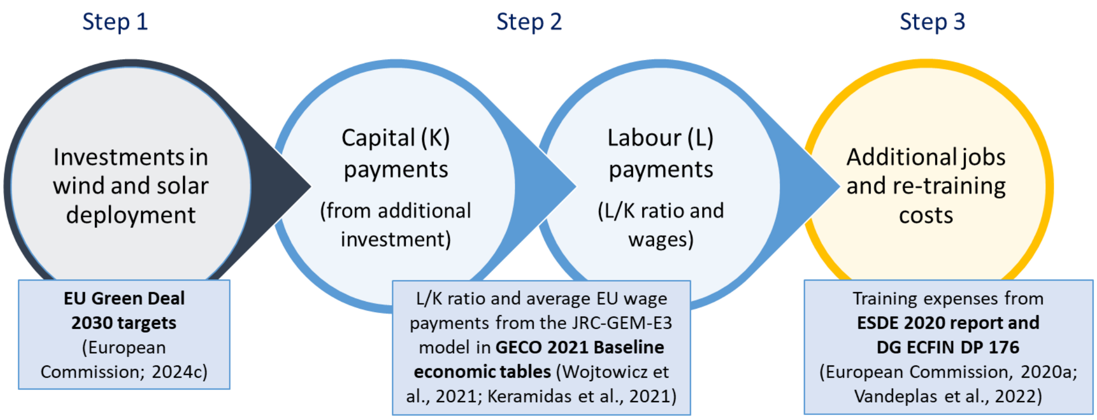
(49) Data is unavailable for BG, EL, LV, MT, IE, CY, LU due to limited sample size of the observed workforce in these industries under EU-LFS data.

(50) European Commission (2022a and 2022b).

3.1. Data used and calculations

Following the steps presented in Figure 11, this section describes the calculations and presents the data sources used to estimate the skills investment needs of the green transition. We take the wind and solar capacity expansions to calculate the additional investment needed to deliver on the European Green Deal 2030 targets. From the additional investment needs, we further obtain the additional jobs and re-training costs related to deployment of wind and solar power generation technologies by Member States in 2030.

Figure 11: Flowchart – steps used in the calculations of additional jobs and re-training costs in 2030



Source: Own elaboration.

Step 1: As a starting point, we take the installed capacity reported at the ENTSO-E Transparency Platform ([51]) to obtain the current power generation installed capacity by Member States. ([52]) Precisely, we take the average installed capacity additions for wind and solar power generation (i) by Member State (r) over 2021-2023 $(ENTSOE\_Cap_{i,r}^{2023})$, which we assume as a proxy of what is the current annual rate of deployment of these technologies (in MW/y).

Next, we need to calculate what is the additional installed capacity projected to be consistent with the EU Green Deal targets. For that we use the average installed capacity over 2025-30 $(AddCap_{i,r}^{2030})$ informed by the energy models that include the policy impacts of the 'Fit for 55' and RePowerEU packages. We use information from both PRIMES and POTEnCIA energy models ([53]) to calculate the annual capacity additions for wind and solar power generation by Member States $(GDtarget\_Cap_{i,r}^{2030})$, averaging across both models. Using the information from both energy models reduces the uncertainty in the projections at Member States level, as the models have different characteristics ([54]). It also provides a range (min-max) of the average annual capacity additions, hence of the additional jobs and associated re-training expenses. In Equation 1a, the capacity additions of wind or solar power

([51]) ENTSO-E (2024).

([52]) Table 14.1.A of the ENTSO-E platform shows the historical installed net generation capacity equalling to or exceeding 1 MW effectively installed on January 1st of a given year.

([53]) European Commission (2024a).

([54]) There are several reasons why energy models may take different decisions on where to install the additional capacity of wind and solar. Here we refer to the models' documentation for further details, because it is out of the scope of this work to go specifically into their features. Nonetheless, an example of potential drivers of those differences is how the electricity market balance is achieved and what the role electricity trade plays across the EU27 Member States in a context of intermittent renewable sources.

generation (i) by Member State (r) represent the expansion rate of installed capacity additions needed to deliver on the European Green Deal targets by 2030.

$$AddCap_{i,r}^{2030}\left(\frac{MW}{y}\right) = GDtarget\_Cap_{i,r}^{2030}\left(\frac{MW}{y}\right) - ENTSOE\_Cap_{i,r}^{2023}\left(\frac{MW}{y}\right) \quad (1a)$$

$$INV_{i,r}^{2030}\left(\frac{€}{y}\right) = AddCap_{i,r}^{2030}\left(\frac{MW}{y}\right) * CAPEX_{i,EU27}\left(\frac{€}{MW}\right) \quad (1b)$$

To conclude the first step of our calculations, in Equation 2b we multiply the projected average installed capacity additions in 2030 ($AddCap_{i,r,m}^{2030}$) by the investment cost in wind and solar ($CAPEX_{i,EU27}$) underlying the EU 2020 Reference scenario [55], to obtain the additional investment needed for the deployment of such technologies to deliver on the European Green Deal targets [56] by 2030 ($INV_{i,r,m}^{2030}$). Therefore, our estimates capture the additional jobs required by 2030, while we further refer to re-training expenses in 2030 as we use annual re-training costs estimates, hence assuming a one-time off expenditure in 2030.

The capacity additions trigger investment upstream of the value chain of these technologies. For example, investment in the wind energy sector requires the manufacturing sector to produce equipment goods (e.g., nacelle, rotors and generators) and the construction sector to build the physical infrastructure (e.g., construction workers to clean and prepare the construction sites, welders to merge metal parts). Differently from the analysis done in the context of the Net-Zero Industry Act policy proposal [57], where equipment goods' manufacturing could happen in different places, here the technology deployment actually happens in the EU Member States. Therefore, we focus on a subset of upstream sectors (namely construction, services and transport), related to the installation of wind and solar power generation technologies. These are upstream sectors whose economic activity is positively affected by investments in these power generation technologies.

Step 2: In the second step of our calculations we move to the additional investment needed. First, we calculate the labour share in total value added for the EU27 ($LVA_{j,EU27}$) using the input-output (IO) tables projected for the year 2025 in the Global Energy and Climate Outlook (GECO) 2021. [58] [59] Next, we obtain the share of investment supplies ($INVSH_{j,EU27}$) to wind or solar power generation from the investment matrix of the JRC-GEM-E3 model for the EU27. [60] Therefore, the parameter $INVSH_{j,EU27}$ informs what is the share of the investment supplied by upstream sectors given one unit of investment in the investing sectors (wind and solar). Finally, we obtain the share of labour payments ($LABSH_{j,EU27}$) in the upstream sectors (j) as described in Equation 2a. For example, if the labour share in

(55) In line with the EU Reference 2020 scenario and RePowerEU (European Commission, 2021; 2022), here we assume a CAPEX of 1,250 EUR/kW for wind and of 600 EUR/kW for solar power generation in the EU27. The information is available for more disaggregated technologies in the file REF2020_Technology Assumptions_Energy.xlsx (Power&Heat sheet) of the EU Reference 2020 scenario (European Commission, 2021). As a simplification, we assume that the same CAPEX applies to all EU Member States.

(56) While Member State specific targets for renewable deployments would be a preferred source, the draft updates of the National Energy and Climate Plans (NECPs) submitted in 2023 are not yet sufficient to reach the 2030 climate target (European Commission, 2023b). Therefore, here we rely on scenarios incorporating the relevant Fit for 55 and RePowerEU policies to meet the EU climate target for 2030. For more details of the policies represented, see Annex 6, Section 3.1.1 of European Commission (2024c).

(57) European Commission (2023a).

(58) In GECO 2021, we calibrate the JRC-GEM-E3 model to the base year 2014 using the GTAP10 database (Aguiar et al., 2019). The input-output tables are further projected in 5-year intervals over 2015-50. To perform the calculations of additional jobs in 2030, we take the year 2025 IO table, as investment decisions in JRC-GEM-E3 are based on the capital stock of the previous period. See Keramidas et al. (2021) for more details.

(59) Wojtowicz et al. (2021), Keramidas et al. (2021).

(60) Norman-López et al. (2023).

total value added of the construction sector is 18% and the share of investment supplied by the construction sector in the installation of a wind mill is 12%, then we obtain a 2.2% share of labour payments to the construction sector.

$$LABSH_{\ j,EU27}\ (\%) = \ LVA_{\ j,EU27}\ (\%) * INVSH_{\ j,EU27}\ (\%) \qquad (2a)$$

$$LAB_{\ j,EU27}\ \left(\frac{worker}{€}\right) = \frac{LABSH_{\ j,EU27}\ (\%)}{AvgWage_{\ j,EU27}\ \left(\frac{€}{worker}\right)} \qquad (2b)$$

Next, using the share of labour payments ($LABSH_{\ j,EU27}$) and the average wage of the upstream sectors in the EU27 from the JRC-GEM-E3 model ($AvgWage_{\ j,EU27}$), we calculate a job intensity indicator ($LAB_{\ j,EU27}$), expressed in number of workers per labour compensation, as described in Equation 2b. Therefore, this indicates the job intensity, from the capacity additions of wind and solar, to the delivery on the EU Green Deal targets.

Step 3: In the final step, by multiplying the additional investment needed for the technology deployment by the job intensity, we calculate the number of additional jobs by 2030 ($Jobs_{j,r}{}^{2030}$) in upstream sectors (j) by Member State (r). Hence, Equation 3a informs the number of jobs implied by the additional installed capacities of wind and solar power generation:

$$Jobs_{j,r}{}^{2030}\left(\frac{worker}{y}\right) = \underbrace{INV\left(\frac{€}{y}\right)}_{\text{Investment}} * \underbrace{LAB_{\ j,EU27}\left(\frac{worker}{€}\right)}_{\text{Job intensity}} \qquad (3a)$$

$$Skills_{j,r}{}^{2030}\left(\frac{€}{y}\right) = Jobs_{j,r}{}^{2030}\left(\frac{worker}{y}\right) * ReSkill_{\ j,EU27}\left(\frac{€}{worker}\right) \qquad (3b)$$

After calculating the additional jobs created, in Equation 3b we take re-training costs estimates at the EU level ($ReSkill_{\ j,EU27}$) per person per year ([61]) to calculate the corresponding investment needs for re-training/re-skilling/up-skilling by Member States ($Skills_{j,r}{}^{2030}$). The re-training costs ($ReSkill_{\ j,EU27}$) are scaled to the Member States by service worker wage using the labour cost levels from Eurostat (2023). For example, if the training cost is EUR 1 000 for the EU average, then for a Member State with 80% wage level relative to the EU average, we reduce the cost by 20% to reach a training cost 800 euro, assuming that the training can be done in the same time in all Member States but at a lower cost.

3.2. Additional jobs and re-training costs in 2030

In this section we present the results of the calculations described in section 4.1. In addition to the projected additional jobs and re-training costs in 2030, we show indicators of the current share of renewable energy in power generation and the projected capacity additions to better contextualise our findings. We also develop two further indicators that show the number of additional jobs and the value of re-training costs per person in the labour force by Member States.

Table 1 shows the projected number of additional skilled workers needed for the deployment of wind and solar energy and the investment in skills by EU Member State in

([61]) European Commission (2020a), Vandeplas, A. et al. (2022).

2030. Overall, we find that the installations of wind turbines and solar panels would require about 130 000 to 145 000 additional skilled workers in construction, services and transport sectors in 2030 (Table 1). The number of additional skilled workers is in line with, if not more optimistic, than figures in the Employment and Social Developments in Europe (ESDE) 2023 review, which estimated 100 000 additional workers ([62]), based on the scenarios from the Net Zero Industry Act. Eurofound ([63]) estimates 204 000 additional jobs when accounting for the full range of investments needed for the implementation of the Fit for 55 package (i.e., not only wind and solar PV related investments). These figures are also in the range of the additional 286 000 jobs in the energy sector to deliver on the EU Green Deal targets in 2030 projected by Cedefop. ([64]) According to our analysis, the main sectors affected by the investment in wind and solar power generation are the construction and services sectors, where the bulk of these jobs are concentrated on (about 90%). These sectors are followed by the transport sector, where the additional jobs come mainly from the infrastructure development for the installation of windmills.

At the Member States level, Germany and Italy stand out as the countries where additional skilled workers would be the most needed for the deployment of wind and solar energy. This reflects the higher expansion rate of installed capacity additions in these countries compared to other Member States. Although economies of scale and scope are present when installed capacity expands (e.g., logistics and transportation costs may not increase proportionally to the installed capacity expansion), this result reflects the investment needs associated to deliver the installed capacity rates projected by the energy models ([65]) – about 17GW/year and 15GW/year, for Germany and Italy, respectively, by 2030. On the other hand, smaller economies (e.g., Cyprus, Malta) and Member States where renewables have gone through faster deployment in the past years (e.g., Denmark, Sweden) show expansion rates lower than 1GW/year, meaning that investment and, hence, job creation are not projected to be as high as in e.g. Germany and Italy in the coming years. The capacity additions per capita nonetheless suggest Member States gravitating around the EU27 average of 0.15 GW/capita in 2030, with the exception of Luxemburg, due to its small population size (Table 1).

([62]) European Commission (2023c).

([63]) Eurofound (2023a and 2024a).

([64]) Cedefop (2021).

([65]) European Commission (2024a).

Table 1: Projected number of additional skilled workers needed for the deployment of wind and solar energy and investment in skills (in million Euro) by EU Member State and EU27 total in 2030. Average share of renewable energy sources in electricity generation over 2020-2022 (%)

Member State	Capacity additions		Additional jobs (000 jobs)		Re-training costs (in million EUR)		Share of renewables (*avg.2020-22*)
	GW / year	*GW / capita*	*min*	*max*	*min*	*max*	(%)
Austria	2.0	0.22	3.5	4.4	45.5	56.8	75.6
Belgium	2.4	0.21	4.2	6.1	47.9	59.9	26.7
Bulgaria	0.5	0.08	0.7	1.7	3.7	4.7	21.7
Croatia	0.4	0.09	0.2	1.2	1.1	1.3	54.3
Cyprus	0.3	0.29	0.4	0.6	1.4	1.8	14.6
Czechia	2.2	0.20	2.3	6.6	9.8	12.2	14.9
Germany	16.9	0.20	32.7	36.6	379.0	473.7	45.2
Denmark	0.1	0.01	0.2	0.8	9.7	12.1	71.8
Spain	3.5	0.07	7.2	12.9	44.2	55.3	46.6
Estonia	0.2	0.14	0.3	0.6	1.4	1.7	28.9
Finland	0.9	0.16	0.2	3.6	2.3	2.9	42.4
France	4.4	0.06	4.5	13.3	142.8	178.5	25.6
Greece	2.0	0.19	3.0	5.1	19.3	24.2	38.1
Hungary	0.4	0.04	0.6	1.4	1.7	2.2	13.6
Ireland	1.3	0.25	2.6	2.8	25.4	31.7	37.4
Italy	15.1	0.26	25.8	33.8	199.2	249.0	37.1
Lithuania	0.3	0.12	0.1	1.5	0.4	0.5	22.6
Luxembourg	0.3	0.52	0.3	1.1	3.6	4.5	14.7
Latvia	0.3	0.18	0.5	1.0	1.7	2.1	52.7
Malta	0.1	0.10	0.1	0.1	0.4	0.5	9.8
Netherlands	3.3	0.19	3.4	11.4	121.3	151.7	33.2
Poland	3.2	0.08	5.1	9.0	16.6	20.7	18.1
Portugal	1.7	0.16	2.8	3.5	11.9	14.8	59.1
Romania	2.0	0.11	2.0	6.0	4.9	6.2	43.3
Slovakia	0.5	0.09	1.0	1.3	3.9	4.9	22.8
Slovenia	0.3	0.16	0.2	1.0	1.4	1.7	35.7
Sweden	0.9	0.08	0.8	2.4	8.8	11.0	77.9
EU27	65.4	0.15	130.2	144.7	1,109.4	1,386.7	38.8

Source: Own calculations; share of renewables in electricity from Eurostat (2024b).
Notes: Number of additional jobs obtained from JRC-GEM-E3 calculations using the input-output (IO) tables projected for the year 2025 in the Global Energy and Climate Outlook 2021 (Wojtowicz et al., 2021; Keramidas et al., 2021). Training costs estimates per person per year from European Commission (2020a) and Vandeplas et al. (2022). Capacity additions, additional jobs and re-training costs for the EU27 are the sum of the individual Member States, while the share of renewables in electricity reflect the EU average over 2020-22 from Eurostat (2024b).

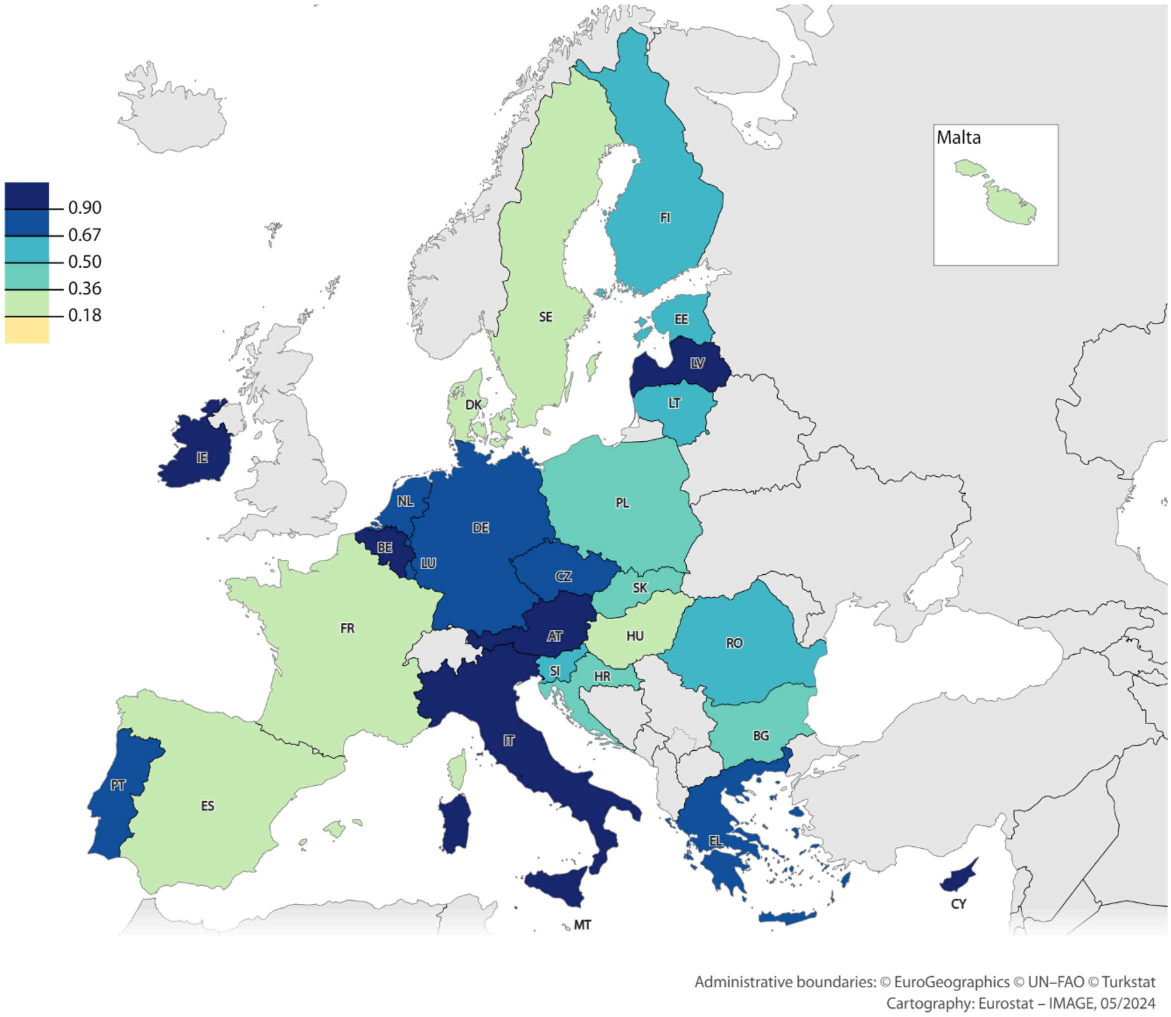
In general, the literature estimates employment factors for the construction and installation ranging from 2.0 to 6.2 (full-time equivalent) jobs/MW of wind power installed, and from 3.5 to 13.0 jobs/MW of solar power installed. (66) These estimates are typically derived from bottom-up technology models and provide a useful reference to cross-check the employment factors obtained in our Input-Output (IO) estimates. In our analysis, we find 2.4 jobs/MW installed of wind power and 2.1 jobs/MW installed of solar power when looking at the EU27 average. While the employment factors for wind are within the range observed in the literature, we note that our results for solar are conservative compared to the existing literature.

The deployment of wind and solar energy affects human capital, as more trained workers are needed to support the capacity expansion of these technologies. Following our calculations, we find that the additional installed capacities of wind and solar to deliver on

(66) Cameron and Van der Zwaan (2015), Fragkos and Paroussos (2018), Ortega et al. (2020), Pai et al. (2021), European Commission (2022a and 2022b).

the EU Green Deal targets may require at minimum an investment in skills of EUR 1.1 to 1.4 billion by 2030 (Table 1). The investment in skills is also similar to the ESDE 2023 estimate of EUR 0.9 billion by 2030, which was based on the Net-Zero Industry Act policy proposal scenarios (European Commission, 2023a). (67) Putting it into perspective, the investment is about 1% of the average annual investment needs in power plants (142 billion EUR) projected in Europe's 2040 climate target impact assessment report for the period 2031-2050 (European Commission, 2024c).

Figure 12: Job creation per thousand people in the labour force for the deployment of wind and solar power generation by EU27 Member State (in 2030)



Source: Own calculations based on European Commission (2021; 2024a) and Eurostat (2023).
Notes: Number of additional jobs obtained from JRC-GEM-E3 calculations using the input-output (IO) tables projected for the year 2025 in the Global Energy and Climate Outlook 2021 (Wojtowicz et al., 2021; Keramidas et al., 2021).

The job creation in 2030 negatively correlates with the current share of renewables in power generation. The correlation coefficient between jobs created and the current share of renewables is not substantially high (-0.16), nonetheless indicates that job creation in 2030 should occur more prominently in Member States with a lower share of renewables today. This result becomes more evident when looking at Figure 12, in which we use the average

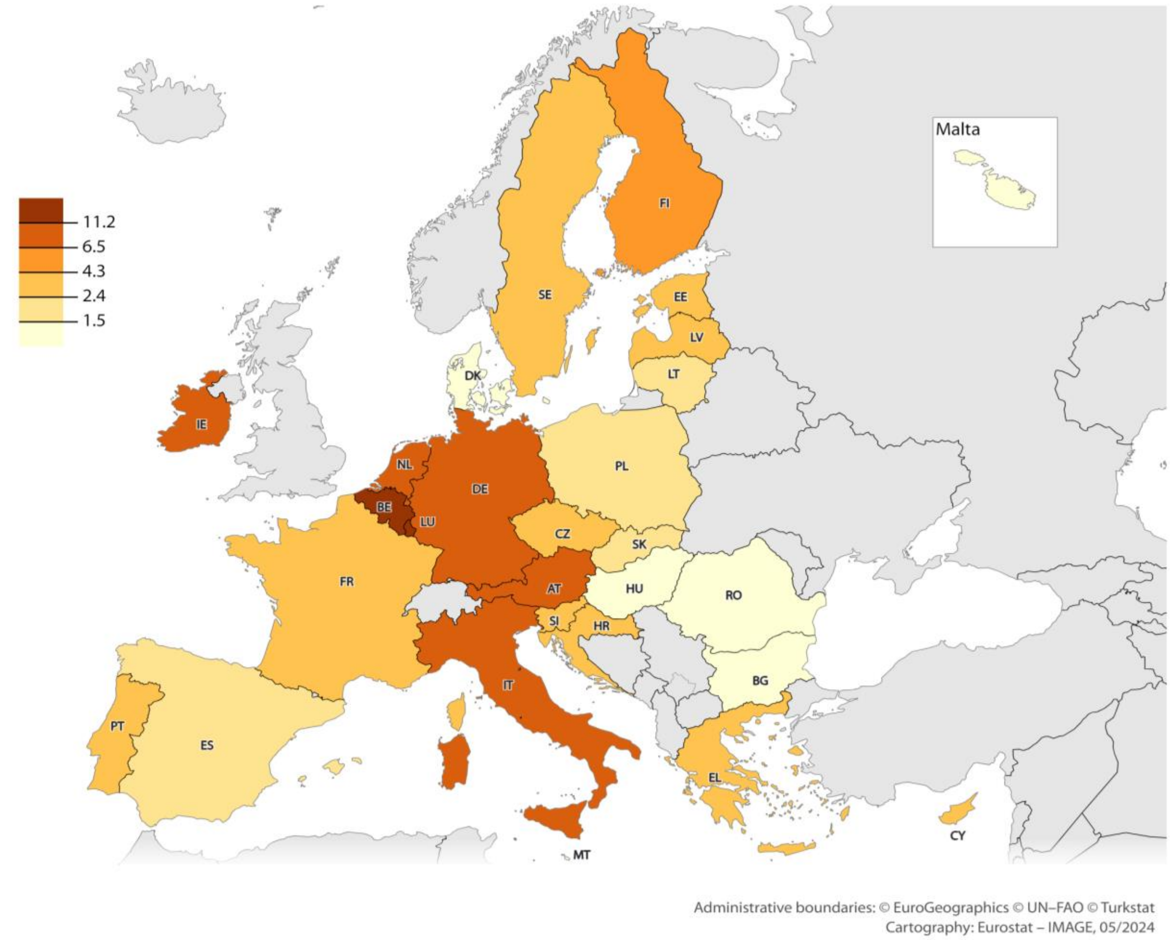
(67) European Commission (2023c).

installed capacity informed by the two energy models to calculate the job creation per person in the labour force by Member States. In

Figure 12, we observe countries like Belgium, Italy and Ireland with about 1 job created per thousand people in the labour force in 2030, due to the deployment of wind and solar power generation. When looking at the share of renewables obtained from Eurostat (2024b), the average share between 2020 and 2022 shows a range of 26.7% to 37.7% for these countries (last column in Table 1). Conversely, job creation should be close to 0.4 jobs per thousand people in Portugal or Sweden, which currently have a higher share of renewables in power generation (59% and 78%, respectively).

When looking at re-training costs per person across the EU labour force, Figure 13 shows a similar regional pattern as observed in Figure 12. In general, Member States with relatively higher installed capacity today show lower re-training expenses per person in the labour force as additional job creation is not as high as in other Member States. For instance, Belgium, Italy or Ireland apparently undergo a ‘catching-up’ process in terms of wind and solar deployment over 2025-30. These Member States are typically exploring their available renewable potential and increasing the share of wind and solar in the power mix, hence stimulating different skillsets and tasks in those sectors (e.g., drivers bringing blades for wind power generation on site or service workers doing site permitting). On the upper range of the distribution, we calculate values between EUR 10 (Italy) to EUR 13 (Belgium) per person in the labour force as re-training expenses in 2030.

Figure 13: Investments in skills: re-training costs in EUR per person in the labour force (in 2030)



Source: Own calculations based on European Commission (2021; 2024a) and Eurostat (2023).
Notes: Training costs estimates per person per year from European Commission (2020a) and Vandeplas et al. (2022).

On the other hand, Eastern Member States feature more prominently in the lower range of the distribution. For instance, re-training expenses range around EUR 1 (Bulgaria, Hungary) per person in the labour force in 2030. Although we also observe this 'catching-up' effect, this result seems to be mainly driven by the relatively lower training costs in those Member States, as training expenses are scaled by country-specific labour cost levels.

4. Conclusions

While the green transition will affect the entire economy, it will lead to significant transformations in some specific sectors, the so called 'transforming sectors', which include *mining and quarrying*, *manufacturing, energy* industries, *water supply and waste management, construction* and *transportation.* The sectoral transformations will have an impact on the demand for overall labour, skills, occupations and wages in the sectors. Ultimately, this may cause some workers to make sectoral labour transitions. In this paper, we employ the EU LFS data to gain more insight into sectoral and employment mobility in the 'transforming sectors', the sectors that are likely to be affected by the transition one way or other, in combination with other factors such as age, gender or participation in education and training. ([68])

Based on the data available, which unfortunately were discontinued in 2020, we found that on average across the whole economy, the rate of workers making year-on-year sector-to-sector transition falls between 1.8 – 3.9 in the EU and this is relatively stable over time, following a slightly increasing trend around the year of 2016 in some Member States. From 2018 – 2019, there was a net inflow of workers into all of the 'transforming sectors' except for *mining and extraction* in the EU. In all Member States, older workers make less sectoral transitions compared to younger workers, but no significant difference in sectoral transitions can be observed between men and women. Women are still heavily underrepresented in the 'transforming sectors'. Although the share of female workers in *energy* industries has risen over the past decade, it amounted to only 26.7% in 2023. The smallest share of women can be found in the *mining* sector (14%). In the case of 'energy-intensive industries', ([69]) we find that workers in these industries overall make less transitions towards non-employment (inactivity or unemployment) than those working in other sectors.

The evidence gathered in this paper seems to broadly reflect the sectoral outlook in the changing economy in the green transition where anticipated employment losses are primarily accumulated in *mining* whereas other sectors experience mixed (or positive) employment changes in the long run. However, the analysis focuses on impacts of climate policies only, omitting any effects that the changing climate and increased occurrence of extreme weather events themselves may have on economic activity across different Member States, including on sectors that are more susceptible to these conditions such as tourism and agriculture. Further research could explore these aspects to provide the full spectrum of changes in sectoral employment induced by the climate change and related mitigation and adaptation policies. It is also important to recognise that several other significant structural and other trends are working in parallel in shifting sectoral employment patterns, including cyclicality and digitisation (accelerated due to COVID-19).

Contrary to the intuition, 'energy-intensive' industries that are generally considered as the most 'vulnerable' sectors into decarbonisation for their high GHG emissions, have seen their workforce flow out of employment significantly less than other sectors in the past

([68]) Additionally, at the detailed sectoral country-level, there were some instances where the low number of observations warranted notes about potential low reliability of results or even the removal of results to comply with LFS requirements.

([69]) These are the sectors that are expected to face some degree of loss in demand or substantial recompositing of their workforce. The definition includes mining and quarrying, manufacturing of automotives, minerals, chemicals and metals.

decade. Anecdotal evidence from some Member States ([70]) can suggest that the higher incidence of trade union density in these sectors may be one of the possible explanations. Another plausible factor may be that these male-dominated sectors see relatively less flows out of employment over time as men make relatively less employment transitions than women (due to their lower participation in care). ([71]) However, it should be noted that our descriptive analysis finds no difference in the frequency of transitions that men and women make between sectors. Yet, it is in some of the 'transforming sectors' that new job opportunities are expected in the twin green and digital transition context, including engineering, technician, maintenance and installation professions in clean energy technologies production and roll out.

Our paper also provides novel estimations on the additional amount of workforce needed and the associated training costs from renewable power generation deployment at Member State level in 2030. Our findings show that the additional installations of wind turbines and solar panels to deliver on the EU Green Deal targets would require about 130 000 to 145 000 additional skilled workers in the EU, with associated investment in skills reaching EUR 1.1 to 1.4 billion by 2030. This investment is about 1% of the average annual investment needs in power plants projected in Europe's 2040 climate target impact assessment report for the period 2031-2050 (European Commission, 2024c). Job creation nonetheless differs across Member States, and those with relatively higher shares of renewable installed capacity today may present lower re-training costs per worker in 2030. While we focus on sectors related to the installation of wind and solar power generation technologies (e.g., construction and services sectors), future studies may expand the sectoral coverage to assess job creation and re-training costs due to investments in other sectors in the EU (e.g., electric vehicles manufacturing) ([72]).

Yet, while crucial in ensuring inclusion and productivity in the changing EU labour market, training and education in some sectors that are key to the transition towards climate neutrality is lacking behind others. While *energy* records highest rates of participation in training and education out of the 'transforming' sectors, workers in *mining* and *construction* receive below-average training. Overall, participation in training in 'transforming sectors' is relatively similar across the different sectors per age group and follows a slightly increasing trend over time. Older workers receive least training across 'transforming' sectors. Although 'energy-intensive industries' are more exposed to employment restructuring in the green transition, only 10.9% of their workers received training in 2023 in the EU against an average of 12.7% in the whole economy. At the same time, growing skills and labour shortages hamper hiring into new green job opportunities, including for occupations relevant in *construction*, *energy production and distribution* or *transport* sectors which are key for advancing EU climate ambitions. Boosting upskilling and reskilling efforts in these sectors are therefore most urgently required to ensure a workforce equipped with the necessary competencies, and increased attention on participation rates in these sectors, and namely in *construction* with lowest adult learning scores, is needed to avoid protracting skills shortages in the future.

According to recent Commission assessment, re-skilling and up-skilling policies have been so far the most frequently used tool by Member States to navigate employment and social

([70]) Duell et al. (2023).

([71]) OECD (2024).

([72]) Some studies are available on national assessment of employment projections in automotive manufacturing in the green transition. See Černý et al. (2022) and Umweltbundesamt (2022) for analysis on Czechia and Germany where the car industry plays an important role. While marginal relative employment drop is typically found, findings also suggest that the shift towards electric vehicle manufacturing will result in job upgrading in the industry (Černý et al., 2022). See also Eurofound (2023) for horizontal analysis of sectoral employment changes resulting from 'Fit for 55' package and 2040 climate targets impact assessment (European Commission, 2024c).

outcomes in the transition towards climate neutrality. (73) Taking different shapes and centres of focus, often supported by EU funds such as the Just Transition Fund, Recovery and Resilience Facility (RRF) or European Social Fund Plus (ESF+), they encompass a wide range of measures to foster skills for the workforce. They include targeted training to promote employment of workers out of emission-intensive sectors or into green sectors, training provisions in relevant occupations (74), initiatives to green and broaden relevant formal or non-formal education curricula (75), programs to launch or adapt national skills anticipation strategies to better understand future demands in the green transition, or conceptualisation of key labour market elements in the green transition (including definition of 'green' jobs or skills).

But ensuring that workers are left with good employment outcomes in the economic transition cannot rely solely on skills. Promoting quality greener jobs in the labour market requires a comprehensive policy approach. This should focus on employment in a more well-rounded spirit, including on areas such as active support to quality employment and education (of underrepresented groups too). Policies should also promote hiring incentives in greener parts of the economy, fair and favourable tax-benefit and social protection systems, and increasing working conditions to attract workforce into professions that are instrumental to a sustainable and resilient society. (76) This includes not only jobs in green sectors, but also in the so-called 'white' jobs, such as in healthcare, education or hospitality, that have been facing widespread shortages in recent years.

Working conditions is an important aspect of exploring the employment changes in the transition towards climate neutrality. Recent foresight study by EU-OSHA (2023) finds that overall, renewable energy production carries significantly lower occupational health and safety risks than fossil-fuel heavy production. Yet, some risks emerge in demolition and other works related with phase out of the old production plants. (77) While the largest expansion of new green opportunities is mainly expected for middle-paying, middle skill jobs over the long run, (78) the category of occupations that has been found to grow the fastest so far also includes many high-skilled professions (including professionals and technicians) that tend to have a better job quality advantage. (79) Nevertheless, working conditions in 'green jobs' will not be of high quality by default. According to Eurofound (2024b), their quality is not homogeneous. While workers in high-skilled 'green' professions enjoy better working conditions, including pay, (80) working autonomy, flexibility of working hours or training, (81), the low-skilled jobs created in the transition towards climate neutrality seem to be associated with lower pay, (82) and, in some sectors, including waste and management in circular economy, poorer health and safety conditions. In a similar vein, the impacts of climate change, such as a rising frequency and intensity of weather extremes (e.g. heatwaves, wildfires, storms, floods), pose health and safety risks, in particular in outdoor occupations (e.g. construction, agriculture), and affect labour productivity, especially in

(73) Key messages from EMCO and SPC on the implementation of the Council Recommendation on ensuring a fair transition towards climate neutrality, 14 November 2023.

(74) e.g. Ireland, Italy, Luxembourg and Sweden in construction and zero-emission buildings.

(75) This includes vocational education and training.

(76) Recommendations 5-6 of the Council Recommendation on ensuring a fair transition towards climate neutrality.

(77) See the full report by EU-OSHA: [Foresight-circular-economy-key-findings_en.pdf (europa.eu)]

(78) SWD (2020) 176 final.

(79) OECD (2024).

(80) OECD (2024).

(81) Eurofound (2024).

(82) OECD (2024).

vulnerable regions, including in the tourism sector. ([83]) To this end, the quality of green jobs, equal opportunities, and job creation throughout the economy, play a pivotal role for ensuring a decent job standards in the context of the changing climate and green transformation.

([83]) García-León et al. (2021).

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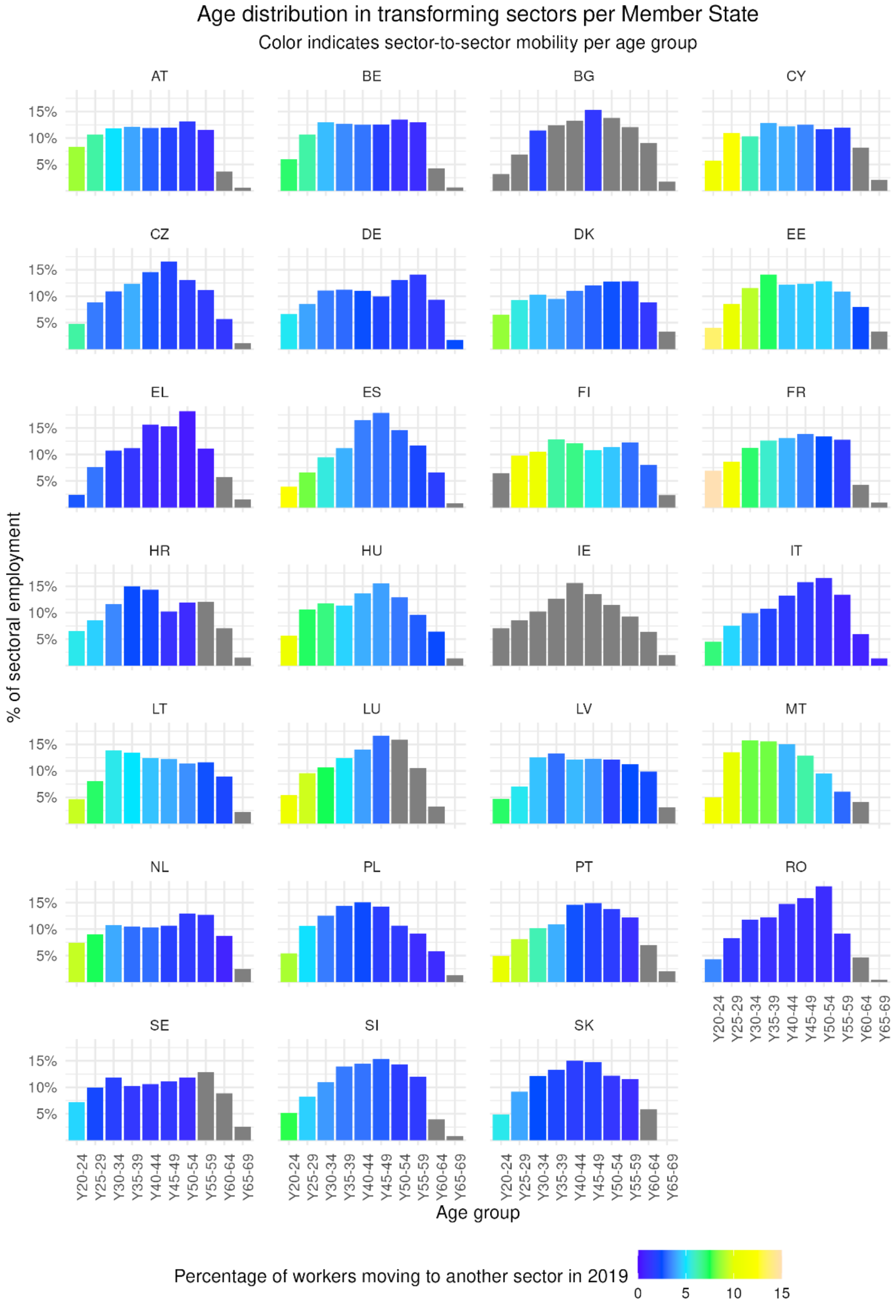
Annex

Figure 14: Age distribution in 'transforming sectors', and sectoral transitions across the whole economy, by Member State, 2022



Sources: Own calculation based on EU LFS micro-data 2019-2022. ([84])
Notes: The height of the bars indicates the share of workers employed in 'transforming sectors' by age groups. Colour indicates sector-to-sector mobility per age group, calculated based on sectoral transitions across all sectors of the economy. Grey indicates insufficient observations for reliable estimates. No sectoral transition data is available for Ireland.

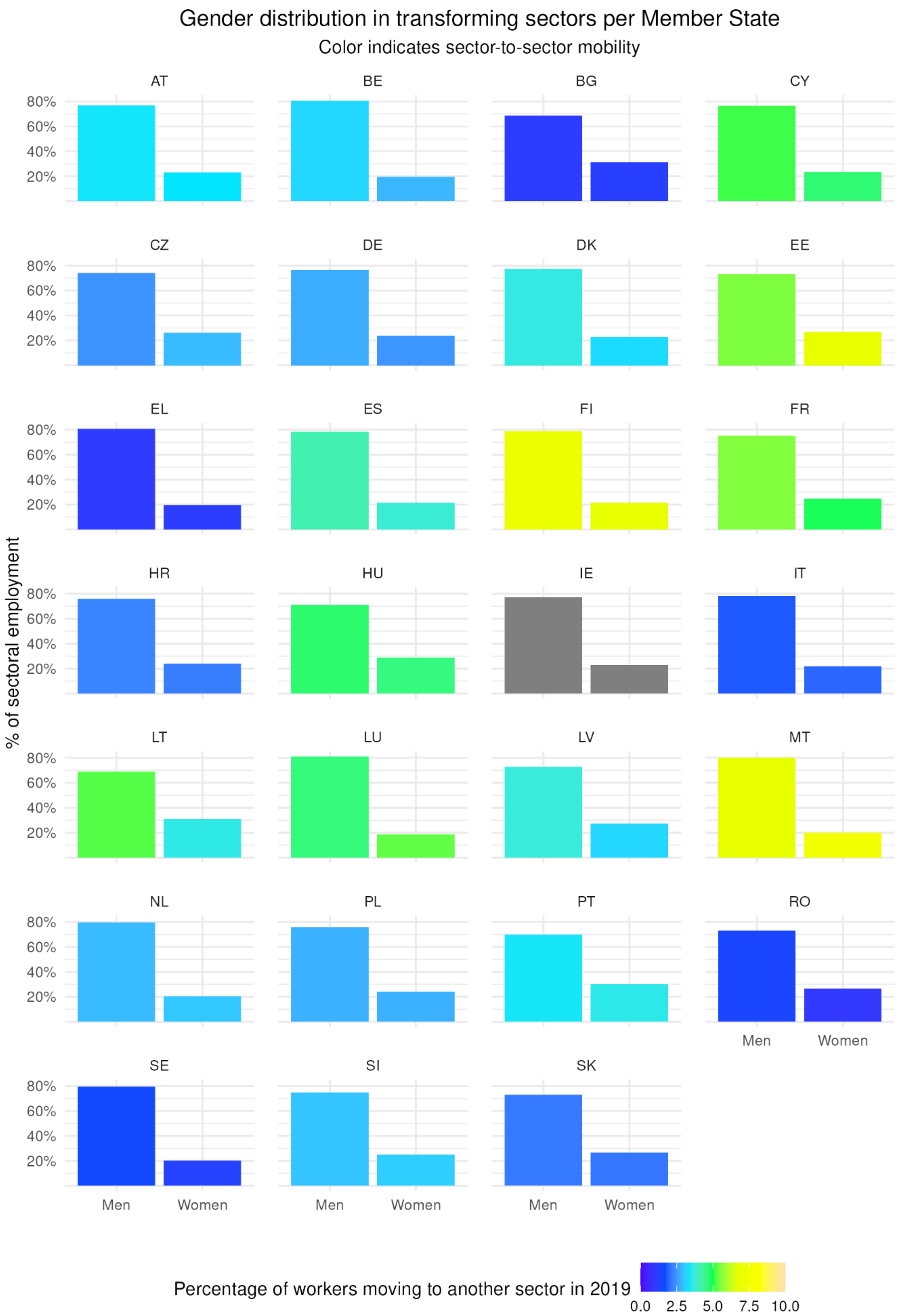
([84]) The data for sectoral transitions is calculated based on individuals from different age groups across all sectors of the economy (not just the 'transforming sectors'), measuring the proportion of workers that changed their sector of employment between 2018-2019. As mentioned above, 2019 was chosen as the reference year because it is the most recent year for which reliable sectoral transition data could be calculated. It is important to note that the data on these transitions, based on the LFS 2019, comes with certain limitations: Around half of the observations related to age-based mobility come with reliability warnings as defined by Eurostat. Additionally, the grey bars in Figure 14 indicate age groups in Member States for which the number of observations related to sectoral mobility fell below the minimum reliability limit and which are not sufficiently reliable for publication.

Table 2: Median age in the 'transforming sectors' per Member State in 2022

Member States	(B) Mining and quarrying	(C) Manufacturing	(D) Electricity, gas, steam and air conditioning supply	(E) Water supply, sewerage, waste management and remediation activities	(F) Construction	(H) Transportation and storage
AT	45	40	43	45	41	44
BE	36	44	42	43	40	43
BG	47	45	47	48	44	47
CY	34	43	50	42	43	43
DE	44	44	42	46	44	45
DK	51	46	44	50	41	47
EE	45	43	45	50	43	49
EL	39	44	44	50	46	46
ES	47	44	41	45	46	46
FI	38	43	41	42	42	43
FR	40	43	43	44	41	45
HR	43	41	48	44	42	44
HU	47	42	46	46	43	46
IT	45	45	43	49	46	46
LT	44	43	43	49	43	44
LU	NA	46	39	41	46	41
LV	40	44	47	54	41	49
PL	41	42	46	45	41	43
PT	49	44	45	50	46	44
RO	46	44	49	45	43	43
SE	40	45	46	43	40	46
SI	43	43	46	46	42	45
EU27	43	44	44	46	43	45

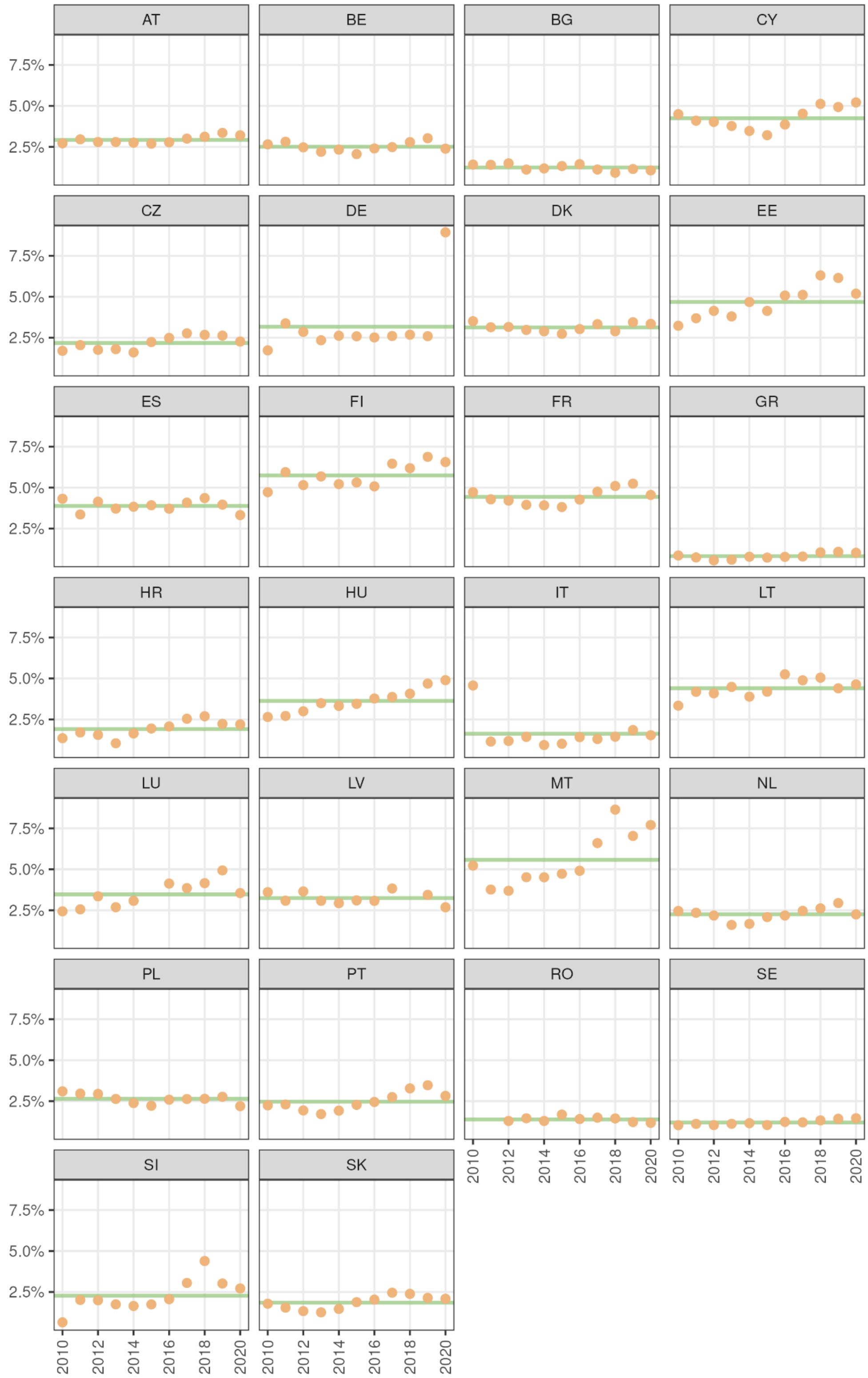
Source: Own calculations based on EU LFS micro-data (2022 wave).
Notes: Data not available for CZ, IE, MT, NL and SK.

Figure 15: Gender composition in 'transforming sectors' and sectoral transitions across the economy, by Member State, 2022



Source: Own calculations based on EU LFS micro-data 2022.
Notes: Colour indicates sector-to-sector mobility for men vs. women, calculated based on sectoral transitions across all sectors of the economy. Source: EU LFS 2019-2022. No sectoral transition data is available for Ireland.

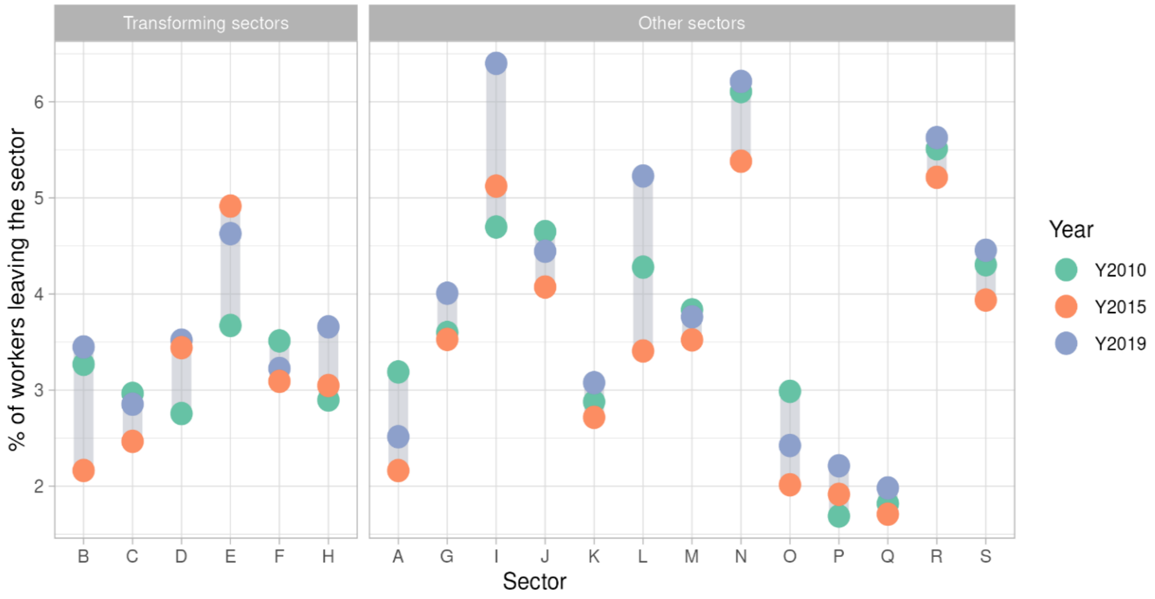
Figure 16: Yearly percentage of workforce making sector-to-sector transitions in the overall economy, 2010-2020



Source: Own calculations based on EU LFS micro-data (2010-2020 waves).
Notes: Percentages are calculated based on transitions across all sectors of the economy at NACE 1-digit level. The green line indicates the average. ([85])

([85]) For some Member States, the percentage of labour transitions is missing for certain years. This is because the number of observations of individuals making sector-to-sector transitions in this particular year fell below the

Figure 17: Percentage of workers leaving to another sector in different years



Source: Own calculations based on LFS microdata (LFS, 2010/2015/2019).
Notes: The figure displays outward sectoral mobility, i.e., the share of workers that leaves each of the sectors because they have found employment in another sector.

Figure 17 provides insight regarding the outward sectoral mobility of workers per sector in different years. Additionally, the figure serves as a kind of robustness check for the method and data used to calculate sectoral mobility in Section 2 of this paper. As described in Box 1, the calculations for sectoral mobility rely on LFS microdata and in particular an individual's self-reported current sector of employment as well as their sector of employment one year prior. Information on both the current and past sector of employment was not available for all individuals, which in some instances led to small sample sizes. As a result of these small sample sizes, some of the results in this report could not be displayed, or are displayed with a reliability warning, in accordance with Eurostat guidelines for LFS microdata. Hence, Figure 17 visualises outward sectoral mobility in different years so that the results can be cross-checked with other data sources. The results in the figure display overall lower sectoral mobility in 2015 compared to 2010 or 2019. This is in line with the data in the left-hand panel of Figure 7 in Section 2.3, which relies on a different data source and methodology (Eurostat experimental statistics on labour market transitions). Moreover, Figure 7 displays a spike in sectoral transitions in 2019, which is also mirrored in the results in Figure 17. This supports the robustness of the results for sectoral labour transitions in 'transforming sectors' in Section 2.

LFS reliability limit for this Member State and hence the results cannot be displayed. The results for Romania in 2010 and 2011 were removed from Figure 16**Error! Reference source not found.** as the percentages for these years were around 30%, which is an entirely different order of magnitude compared to other years for Romania or the results for other Member States. Hence, the results for Romania in 2010 and 2011 were treated as outliers and also removed from the calculations for the average over time.

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