

# Skill Resilience 4EU

---

**SkillResilience4EU**  
Resilience through re-skilling and upskilling for European labour  
markets in transition

**D1.2 – Twin Transition Matrix in EU Regions**

**DISCLAIMER:  
THIS DELIVERABLE IS  
PENDING EU APPROVAL.**



**Funded by  
the European Union**

**Project information**

<b>Project acronym:</b>	SkillResilience4EU
<b>Full title:</b>	Resilience through re-skilling and upskilling for European labour markets in transition
<b>Grant agreement:</b>	101177821
<b>Programme and call:</b>	HORIZON-CL2-2024-TRANSFORMATIONS-01-03 - Minimise costs and maximise benefits of job creation and job destruction
<b>Project coordinator:</b>	HVL
<b>Contact:</b>	<a href="mailto:SkillResilience4EU@hvl.no">SkillResilience4EU@hvl.no</a>
<b>Project duration:</b>	36 months
<b>Project website:</b>	<a href="http://SkillResilienceEU.EU">SkillResilienceEU.EU</a>

**Deliverable information**

<b>Deliverable number:</b>	D1.2
<b>Deliverable title:</b>	Twin Transition Matrix
<b>Dissemination level:</b>	PU - Public
<b>Deliverable type:</b>	R — Document, report
<b>License:</b>	CC BY-NC-SA
<b>Status:</b>	Submitted
<b>Due date:</b>	30/06/2025
<b>Submission date:</b>	30/06/2025
<b>Work Package:</b>	1
<b>Lead Beneficiary:</b>	Universiteit Utrecht

**Disclaimer**

Funded by the European Union. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union. Neither the European Union nor the European Research Executive Agency can be held responsible for them. All SkillResilience4EU consortium members are also committed to publish accurate and up to date information and take the greatest care to do so. However, the SkillResilience4EU consortium members cannot accept liability for any inaccuracies or omissions, nor do they accept liability for any direct, indirect, special, consequential or other losses or damages of any kind arising out of the use of this information.

**Copyright and license information**

All intellectual property rights are owned by the Skillresilience4EU consortium members and are protected by the applicable laws. Unless otherwise indicated, all materials created by the Skillresilience4EU consortium members are licenced under Creative Commons Attribution-Non Commercial-Share Alike 4.0 International (CC BY-NC-SA).



## Revision History

Date	Version	Author	Comment
01/05/2025	V0.01	Benjamin Cornejo-Costas, UU	Creation of document outline
17/06/2025	V0.02	Benjamin Cornejo-Costas, UU	First draft
24/06/2025	V0.03	Benjamin Cornejo-Costas, UU Deyu Li, UU Ron Boschma, UU	Second draft
27/06/2025	V0.04	Alexandra Sandu, LSE Ridvan Cinar, HVL	Peer review
29/06/2025	V0.05	Benjamin Cornejo-Costas, UU Deyu Li, UU Ron Boschma, UU	Third draft addressing the comments of the reviewer
30/06/2025	V0.06	Risk and Quality Manager, HVL	Final check and approval for submission
30/06/2025	V1.0	Coordinator, HVL	Final check and submission to the granting authority

## Author List

Institution	First name and Name	Contact information
UU	Benjamín Cornejo-Costas	<a href="mailto:b.j.cornejocostas@uu.nl">b.j.cornejocostas@uu.nl</a>
UU	Deyu Li	<a href="mailto:d.li1@uu.nl">d.li1@uu.nl</a>
UU	Ron Boschma	<a href="mailto:r.a.boschma@uu.nl">r.a.boschma@uu.nl</a>

## Abbreviations and acronyms

Abbreviation or acronym used in this document	Explanation
NACE	Statistical Classification of Economic Activities in the European Community
GEI	Green employment index
DEI	Digital employment index
Eurostat	Statistical office of the European Union

**Glossary**

Term	Definition used or meaning in the Acronym project	Reference or source for the definition if applicable
Greenhouse gases	CO <sub>2</sub> , N <sub>2</sub> O in CO <sub>2</sub> equivalent, CH <sub>4</sub> in CO <sub>2</sub> equivalent, HFC in CO <sub>2</sub> equivalent, PFC in CO <sub>2</sub> equivalent, SF <sub>6</sub> in CO <sub>2</sub> equivalent, NF <sub>3</sub> in CO <sub>2</sub> equivalent	Eurostat
Emerging digital technologies	New generation of digital technologies such as electric vehicles, self-driving cars, drones, wearable devices, artificial intelligence, augmented/virtual reality, internet of things, 3D printing, and blockchain.	Prytkova et al. (2024)

## Executive Summary

The transition towards a green and digital economy has been on top of the policy agenda of European Commission for its new growth model. However, despite the increasing policy and academic interests in ‘twinning’ the digital transition and the green transition for sustainable prosperity, fairness and competitiveness, their interconnections remain less explored, especially on whether and how they could jointly influence the future of work and the labour market resilience in Europe.

in this report, we aim to provide a common taxonomy of all the European regions and sectors according to their ability to transform through the twin transition. More specifically, we classify European regions and sectors by their progress, their capabilities, their potential to diversify in green and digital industries.

The results of this report reveal a clear and concerning pattern that the progress and potential of European regions and sectors in green and digital transition differ significantly. Regions that are already well-positioned in the green and digital transitions regarding their current employment structure tend to be the same regions with high potentials in further diversifying into industries with low greenhouse gas emissions and high level of digitalization.

Conversely, regions that are lagging behind face significant structural barriers. These regions often struggle to identify closely related industries that can serve as stepping stones toward industries with lower greenhouse gas emissions and higher level of digitalization. This structural gap risks locking these regions into a cycle of limited transition progress, reinforcing existing territorial inequalities across Europe.

## Table of Contents

<b>1</b>	<b>Introduction .....</b>	<b>7</b>
<b>2</b>	<b>Data and Methodology .....</b>	<b>9</b>
2.1	Data .....	9
2.2	Green Employment Index (GEI) .....	9
2.3	Digital Employment Index (DEI).....	10
2.4	Green and digital transformative potentials .....	10
<b>3</b>	<b>Results.....</b>	<b>11</b>
3.1	Top industries in greenhouse gases emissions and digitalization, weighted by number of employees.....	11
3.2	Regional progress and potential in green transition .....	12
3.3	Regional progress and potential in digital transition.....	14
3.4	Twin transition taxonomies.....	16
<b>4</b>	<b>Conclusions .....</b>	<b>20</b>
4.1	Main results and implications.....	20
4.2	Limitations and future research.....	21
	<b>References .....</b>	<b>22</b>
	<b>Annex 1: The Consortium .....</b>	<b>25</b>
	<b>Annex 2: Project Summary .....</b>	<b>26</b>

## List of Figures

<i>Figure 1 : Top industries in greenhouse gases emissions and digitalization, weighted by number of employees .....</i>	<b>11</b>
<i>Figure 2 : Average Green Employment Index between 2008 to 2020. ....</i>	<b>13</b>
<i>Figure 3: Average Green Transformative Potential between 2008 and 2020.....</i>	<b>14</b>
<i>Figure 4: Average Digital Employment Index between 2008 and 2020.....</i>	<b>15</b>
<i>Figure 5: Average Digital Transformative Potential between 2008 to 2020. ....</i>	<b>16</b>
<i>Figure 6: Twin Transition Taxonomy based on GEI and DEI. ....</i>	<b>18</b>
<i>Figure 7: Twin Transition Taxonomy based on Green and Digital potentials. ....</i>	<b>19</b>

## 1 Introduction

The transition towards a green and digital economy has been on top of the policy agenda of European Commission for its new growth model<sup>1</sup>. However, despite the increasing policy and academic interests in ‘twinning’ the digital transition and the green transition for sustainable prosperity, fairness and competitiveness, their interconnections remain less explored, especially on whether and how they could jointly influence the future of work and the labour market resilience in Europe (Aloisi, 2025).

One of the key challenges is that the progress and potential of European regions and sectors in green and digital transition differ significantly. The impact of green and digital transitions differs across sectors and regions (OECD, 2023b, 2024b). On the one hand, the impact of digital and green transition on the labour markets of European regions is conditioned on the regional industry structure (OECD, 2023a, 2024a). For example, regions with significant energy intensive industries are exposed or vulnerable to energy transition (Guarascio, Reljic, & Zezza, 2025; McDowall et al., 2023), whereas regions specializing in labour-intensive manufacturing industries, e.g. many regions in Eastern European countries, are more likely to experience labour displacement (Guarascio, Reljic, & Stöllinger, 2025). On the other hand, the regional industrial structure also conditions the potential of regions in green and digital transitions. The evolutionary economic geography literature has highlighted the importance of local capabilities in related industries in the creation of new industries (Boschma, 2017; Henning et al., 2025; Neffke et al., 2011), including digital and green industries (Apostol & Hernández-Rodríguez, 2024; Barbieri & Consoli, 2019). Furthermore, Farinha (2025) also suggested that the regional capabilities can mitigate the impact of automation.

Another key challenge is the uneven progress and potential of European regions and sectors in digital and green transitions (Bachtrögler-Unger et al., 2023; Fazio et al., 2025; Romero et al., 2025). For example, Bachtrögler-Unger et al. (2023) found that more developed EU regions are better equipped for developing technologies that digitize and green the economy. Developed regions also stand out in that their highest potential is concentrated in high-complex rather than low-complex green and digital technologies, such as battery technologies and artificial intelligence. This gives more developed regions a significant competitive advantage, as complex technologies are difficult to master and to imitate for other regions and therefore create higher economic returns. In contrast, transition regions and less developed regions in Europe are responsible for modest shares of twin transition patents. Their technological profiles also look different: their potential is in green rather than digital technologies, and more often in low-complex rather than high-complex technologies. Those regions find it hard to develop twin transition technologies as relevant capabilities are often missing: local firms tend to lack absorptive capacity, the regional work force tends to have inadequate skills, and/or regional institutions tend to be weak.

However, these studies on the geography of twin transitions mostly relied on the patent data, providing limited insights into the industry and employment dynamics at the regional level. To fill the gap and inform about the transformation level in the different European regions and sectors in digital, green and twin transitions, in this report, we aim to provide a common taxonomy of all the European regions and sectors according to their ability to transform through the twin transition. More specifically, we classify European regions and sectors by their progress, their capabilities, their potential to diversify in green and digital industries.

---

<sup>1</sup> European Growth Model, [https://ec.europa.eu/commission/presscorner/detail/en/ip\\_22\\_1467](https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1467)

First, we quantify the level of digitalization and greenness of European industries (2-digit NACE rev.2) using the exposure score to emerging digital technologies calculated by Prytkova et al. (2024) and the intensity of greenhouse gas emissions from Eurostat respectively. Second, we quantify the progress of European regions (NUTS-2) in digital and green transitions by weighting the level of digitalization and greenness at the industry level with the employment share of industries in each region. Third, we calculate the relatedness density of regions in each industry to proxy their potential in diversifying into these industries following Hidalgo et al. (2007). Finally, we map European regions into four types based on their progress and potential in digital and green transitions.

The remaining of this document is structured as follows. Section 2 describes the data and methodology used in estimating the exposure of European industries and regions to green and digital transitions. Section 3 presents the results and the taxonomies of European regions in digital, green and twin transitions. Section 4 concludes and discusses the implications and limitations of this report.

## 2 Data and Methodology

### 2.1 Data

This subsection outlines the data and methodology we used to construct two indicators at the regional level in Europe: the **Green Employment Index (GEI)** and the **Digital Employment Index (DEI)**. These indices quantify, respectively, how environmentally sustainable and how digitally advanced the industry structure of a region is, based on the composition of its employment across industries. We use the number of employees in 68 NACE (rev.2) 2-digit industries and 288 NUTS-2 regions in 27 member states of the European Union, United Kingdom, Norway and Iceland over the period 2008-2020 from the European Structural Business Statistics<sup>2</sup>.

To measure the greenness of industries, we use the annual emission intensity of greenhouse gases from the Eurostat's air emissions accounts<sup>3</sup>. The dataset documents the emission intensity of greenhouse gases of NACE 2-digit industry at the national level for European countries.

To measure the level of digitalization of industries, we rely on the exposure score to emerging digital technologies constructed by Prytkova et al. (2024). The dataset includes the level of exposure to emerging digital technologies for each NACE 2-digit industry between the period 2012-2021. The exposure score were calculated base on the semantic similarity between the description of NACE industries and the text of patents in emerging digital technologies. Higher level of exposure indicates the focal industry is more relevant for emerging digital technologies<sup>4</sup>.

### 2.2 Green Employment Index (GEI)

We calculate the Green Employment index of European industries and regions in three steps. First, since the data on the intensity of greenhouse gases emissions of 2-digit NACE industries is only available at the country level. We regionalize the intensity using the share of employees in an industry in a region. This method assumes that, within a given country and NACE 2-digit industry, emissions are roughly proportional to employment across regions in the focal country.

$$EmissionsIntensity_{rft} = AverageEmissions_{fc} * \left( \frac{Employees_{rft}}{\sum_{r \in c} Employees_{rft}} \right)$$

Where  $AverageEmissions_{fc}$  is the average intensity of greenhouse gases emissions of the industry  $f$  in country  $c$  across all years available.  $Employees_{rft}$  is the total number of employees in the industry  $f$  in region  $r$  in year  $t$ . This regional-specific estimation ensures that national (and regional) variations in technology, environmental regulation, and production processes are reflected in the emissions attributed to each industry. For example, a given industry like

<sup>2</sup> European Structural Business Statistics,

[https://ec.europa.eu/eurostat/databrowser/view/sbs\\_r\\_nuts06\\_r2/default/table?lang=en&category=reg.reg\\_sbs](https://ec.europa.eu/eurostat/databrowser/view/sbs_r_nuts06_r2/default/table?lang=en&category=reg.reg_sbs)

<sup>3</sup> Air emissions accounts by NACE Rev 2. activity,

[https://ec.europa.eu/eurostat/databrowser/view/env\\_ac\\_ainah\\_r2/default/table?lang=en&category=env.env\\_air.env\\_air\\_aa](https://ec.europa.eu/eurostat/databrowser/view/env_ac_ainah_r2/default/table?lang=en&category=env.env_air.env_air_aa)

<sup>4</sup> Note that the term exposure used in Prytkova et al. (2024) is neutral. It does not suggest automating or displacement effect. In fact, Prytkova et al. (2024) found that European regions facing higher exposure to emerging digital technologies experienced higher employment growth between the period 2012-2019.

metallurgy may be more polluting per worker in one country than in another, due to differences in fuel mix, production intensity, or mitigation practices.

We then obtained the average Green Employment Index (GEI) at the regional level by summing up the multiplication of the negative value of  $EmissionsIntensity_{rft}$  with the share of employees of the focal industry in the region. The inversion of scale allows us to capture the greenness of the employment structure in region. Higher GEI indicates that more employees in the region are in industries with lower intensity of greenhouse gases emissions.

$$GreenEmploymentIndex_{rt} = \sum_f -1 * EmissionsIntensity_{rft} * \left( \frac{Employees_{rft}}{\sum_r Employees_{rft}} \right)$$

### 2.3 Digital Employment Index (DEI)

We follow the same approach in calculating the Digital Employment Index as the Green Employment Index by weighting the annual exposure scores of NACE 2-digit industries to emerging digital technologies with the employment share of a given industry in a given region in a given year.

$$DigitalEmploymentIndex_{rt} = \sum_f DigitalScore_{ft} * \left( \frac{Employees_{rft}}{\sum_r Employees_{rft}} \right)$$

Where  $DigitalScore_{ft}$  is the exposure score of industry  $f$  emerging digital technologies at year  $t$ .  $Employees_{rft}$  is the total number of employees in the sector  $f$  in region  $r$  in year  $t$ . Higher DEI indicates that more employees in the region are industries with higher level of digitalization.

### 2.4 Green and digital transformative potentials

We proxy the transformative potential of European regions in the green and digital transitions with the extent to which industries in each region are more closely related to industries with lower emission intensity of greenhouse gases and higher level of digitalization in three steps.

First, following Hidalgo et al. (2007), we calculate the *Relatedness Density* of a given industry to the rest of the industries that are present in a given region. We calculate the pairwise relatedness  $\phi_{f,j,t}$  between two 2-digit NACE rev.2 industries ( $f, j$ ), for the whole set of 68 industries that we have in our sample. This measure is calculated based on the co-occurrence of specialisation in the same region, and it can be interpreted as a measure of proximity between each pair of industries. We then computed how proximate each industry ( $f$ ) in region ( $r$ ), in period ( $t$ ) is to the specialisations ( $j$ ) currently present in the same region:

$$RD_{frt} = \frac{\sum_j^t RTA_{r,j}^t * \phi_{fj}}{\sum_j^t \phi_{fj}}$$

Where  $\phi_{f,j,t}$  is the pairwise relatedness between two NACE 2-digital industries  $f, j$ .  $RTA_{r,j}^t$  is a binary variable that takes value 1 if an industry/region/year has more employees than the average of all other regions in the whole NUTS-2 regions in the analysis. This can be expressed as follows:

$$RTA_{rf}^t = \begin{cases} 1 & \text{if } \frac{employees_{r,i}^t / \sum_i employees_{r,i}^t}{\sum_r employees_{r,i}^t / \sum_r \sum_i employees_{r,i}^t} > 1 \\ 0, & \text{otherwise} \end{cases}$$

$RD_{f_{rt}}$  takes values between 0 and 1. It is 0 when there are no industries related to industry  $f$  in region  $r$  at time  $t$  and 1 when all industries are related to industries  $f$  in region  $r$  in time  $t$ .

Finally, we calculate the average Relatedness Density weighted by the intensity of greenhouse gases emissions and exposure to emerging digital technologies respectively to proxy the transformative potential in the green and digital transitions.

$$GreenPotential_{rt} = \sum_f -1 * EmissionsIntensity_{rft} * RD_{f_{rt}}$$

$$DigitalPotential_{rt} = \sum_f DigitalScore_{ft} * RD_{f_{rt}}$$

### 3 Results

#### 3.1 Top industries in greenhouse gases emissions and digitalization, weighted by number of employees

Figure 1 presents the top industries regarding the intensity of greenhouse gases emissions (left) and the level of digitalization (right) in Europe, both weighted by the number of employees. This approach provides a more realistic picture of the challenges and opportunities these industries are facing in the green and digital transitions regarding the needs for upskilling and reskilling of their workforces. The top industry in terms of the intensity of greenhouse gases emissions weighted by share of employees is D35 Electricity, gas, steam and air conditioning supply whereas the top industry in terms of the level of digitalization weighted by share of employees is G47 Retail trade.

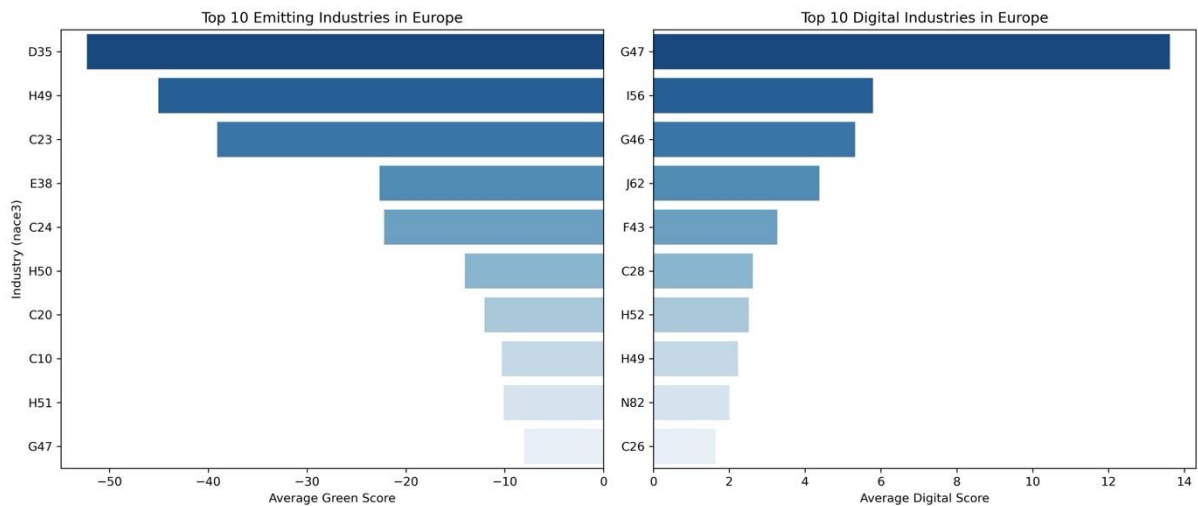


Figure 1 : Top industries in greenhouse gases emissions and digitalization, weighted by number of employees

The results reveal an important and somewhat paradoxical pattern. At least two industries rank prominently in both domains, highlighting the complex, and at times conflicting, nature of the twin transitions. Notably, land transport and transport via pipelines (H49) emerges as the second-highest emitting industry in Europe when adjusted for employment, while also ranking as the seventh most digitally exposed industry based on the same employment-weighted measure. Similarly, retail trade (G47), is the leading industry in terms of exposure to emerging digital

technologies, yet also ranks among the top ten emitting industries, again considering the size of its workforce.

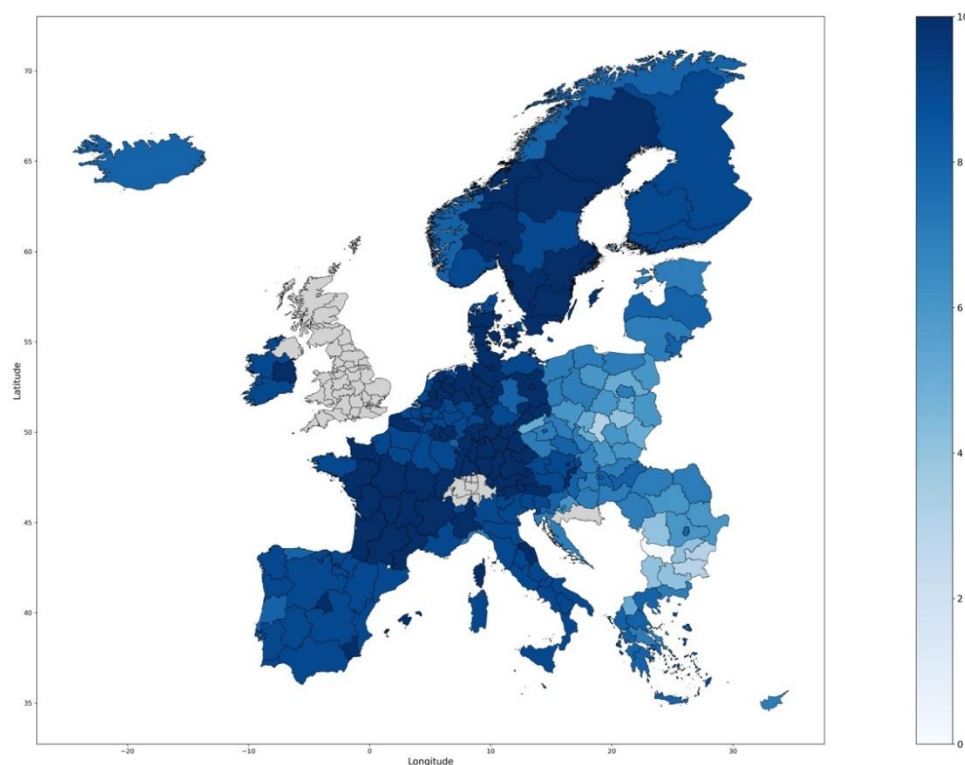
This dual positioning of industries such as transport and retail trade provides critical insight into the structural tensions that regions face in navigating the green and digital transitions. On the one hand, the high level of digitalization of these industries signals potentials for technological transformation and productivity gains. On the other hand, their significant contribution to emissions suggests that digitalisation alone does not automatically align with environmental sustainability.

The retail trade sector (G47) can be a useful example to represent the complexities and paradoxes that the twin transition brings. Its strong digital footprint implies that this industry could play a key role in driving digital adoption, fostering innovation, and supporting technological upskilling. Yet, at the same time, its high emissions profile raises concerns regarding its compatibility with regional and national green transition objectives. Furthermore, industries like retail trade are among those most susceptible to automation, posing additional labour market challenges, particularly in regions heavily dependent on these sectors.

### **3.2 Regional progress and potential in green transition**

We plot the average Green Employment Index to reflect the progress of European regions in the green transition. It is important to note that Figure 2 is designed to reflect the overall “greenness” of the employment structure of a region, rather than its absolute greenhouse gases emissions. Regions with higher GEI means the higher share of employees in the industries with less emission intensity of greenhouse gases, thus better progress in green transitions regarding the labour market transitions.

As we can see from the map, regions in Eastern European regions show on average lower levels of greenness, meaning that the employment composition of the industries present in those regions is characterised by higher intensity of greenhouse gases emissions. This can be explained by the high number of employees working in the greenhouse gases intensive industries such as mining and coal industries. This map resonates with the findings by Rodríguez-Pose & Bartalucci (2024) in which they constructed a multi-dimension green transition vulnerability index.



*Figure 2 : Average Green Employment Index between 2008 to 2020.*

As discussed in Section 2.4, one of the core aims of our analysis was to examine whether the existing employment structure within each region supports or hinders progress in the green transition. Specifically, we sought to understand whether lagging regions could leverage their current industrial capabilities to create greener employment opportunities and transition toward sustainability—or, alternatively, whether they remain locked into high-emission trajectories due to the nature of their existing industry structure. To explore this, we use the concept of relatedness density—a measure of how closely connected industries are within a region based on shared capabilities, technologies, and labour inputs. When this is combined with each industry's greenhouse coefficient, we can assess the extent to which a region's industrial ecosystem is conducive to a shift toward greener sectors.

The results, presented in Figure 3, indicate that in many cases, regions that are already falling behind in the green transition face structural constraints that limit their ability to diversify into greener activities. This is because the industries which are most closely related to those already present in the region tend to be similarly greenhouse gases intensive. In other words, high-emission sectors are often embedded within regional economies in ways that make transitioning difficult—not simply due to policy or investment gaps, but because of the inherent path-dependence in polluting industries. Regions with a strong presence of greenhouse gases intensive industries—such as heavy manufacturing, fossil-fuel-based energy, or extractive sectors—often share similar infrastructure, skills, and supply chains with other greenhouse gases intensive industries. These reinforcing linkages can lock regions into polluting trajectories, creating what can be described as structural inertia: a situation where diversification is

technically possible but practically constrained by the historical evolution of the local industrial base.

In this sense, relatedness density serves as a double-edged sword. High relatedness might suggest a strong industrial network, but if that network is dominated by green-intensive sectors, it actually indicates fewer internal pathways toward green transformation. As such, regions with lower GEI and high relatedness density to other high-emission sectors face the risk of being trapped in brown industrial ecosystems—where even adjacent industries offer little relief in terms of sustainability.

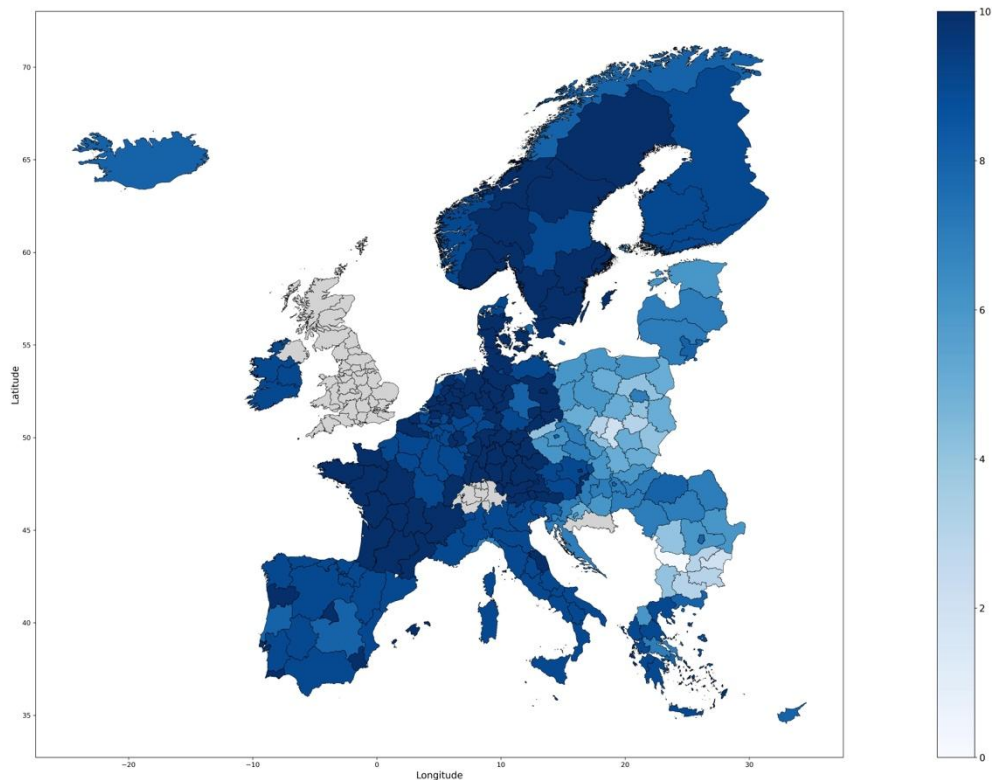


Figure 3: Average Green Transformative Potential between 2008 and 2020.

### 3.3 Regional progress and potential in digital transition

Following the same approach used for analysing the green transition in NUTS-2 regions, we also mapped the results for the digital transition.

As shown in Figure 4, industries with high Digital Employment Index are more widely distributed across the continent. However, there is a noticeable concentration in capital regions, as well as in Ireland, parts of Germany, and Scandinavian countries. In contrast, many regions in Eastern Europe—and some peripheral areas elsewhere—remain characterised by labour markets with relatively low level of digitalization in their employment structure.

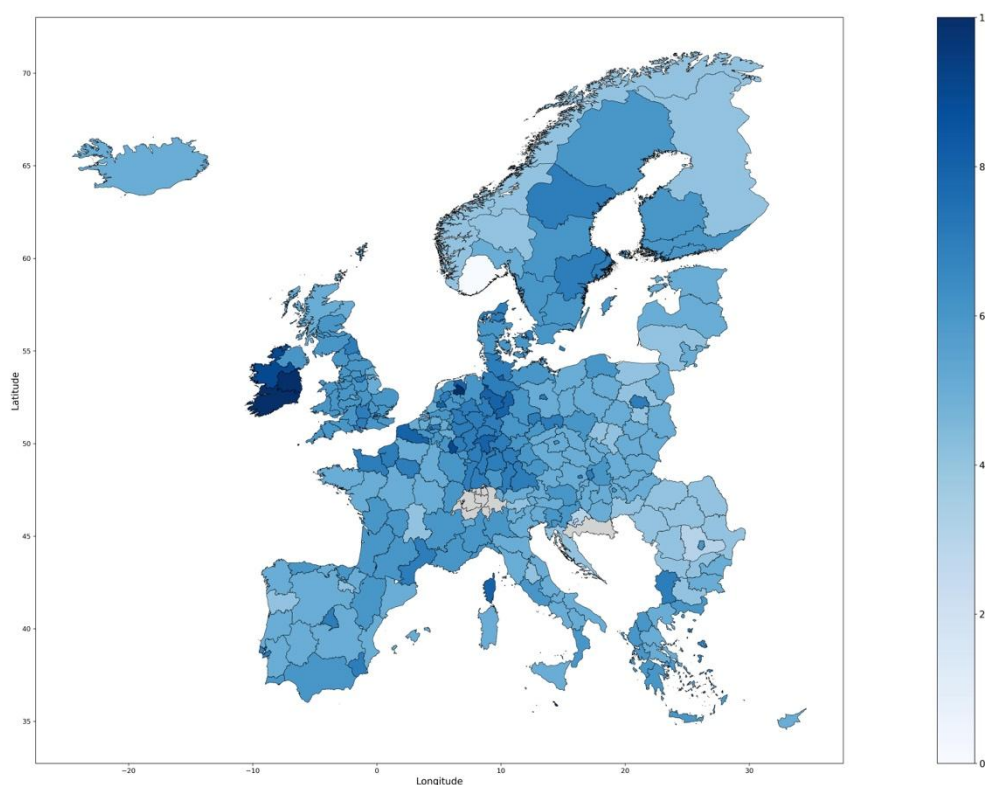


Figure 4: Average Digital Employment Index between 2008 and 2020.

In contrast to the patterns observed in Figure 3—where related industries within each region tended to mirror the region’s overall green profile, either being predominantly environmentally sustainable or heavily emitting—Figure 5 below presents a different dynamic in the context of the digital transition. Specifically, Figure 5 illustrates the average relatedness density of industries in each region, weighted by their exposure to emerging digital technologies. The findings in Figure 5 suggest a more optimistic scenario for many regions, particularly those currently lagging in the digital transition. Unlike the green transition, where high-emitting industries are often surrounded by similarly high-emitting industries, in the case of DEI, a greater number of regions appear to have industrial ecosystems that could serve as a foundation for advancing digitalisation. That is, even if certain industries are not yet highly digital, their proximity to digitally advanced industries—in terms of skills, technologies, or supply chains—offers a pathway for smoother and potentially faster digital upgrading.

This brings into focus the strategic importance of relatedness density: regions with dense networks of technologically or economically related industries are better positioned to absorb innovations and adapt to structural changes. High relatedness means that digital capabilities in one sector can more easily spill over into others, facilitating a broader transition.

However, this also introduces a double-edged dynamic. On one hand, regions with high digital potentials may harness these synergies to accelerate their digital transition. On the other hand, this same relatedness can also amplify risks—particularly in terms of automation and job displacement—if a significant portion of the workforce is concentrated in occupations vulnerable to digital disruption. Nonetheless, regions with a diverse mix of industries may be able to mitigate

these effects internally, as other related sectors might offer alternative employment opportunities within the same geographic unit. The insights from Figure 5 suggest that while the digital transition poses clear challenges, especially around automation, it also presents more accessible and tangible opportunities for structural transformation than the green transition, provided that regional policies are tailored to leverage industrial relatedness.

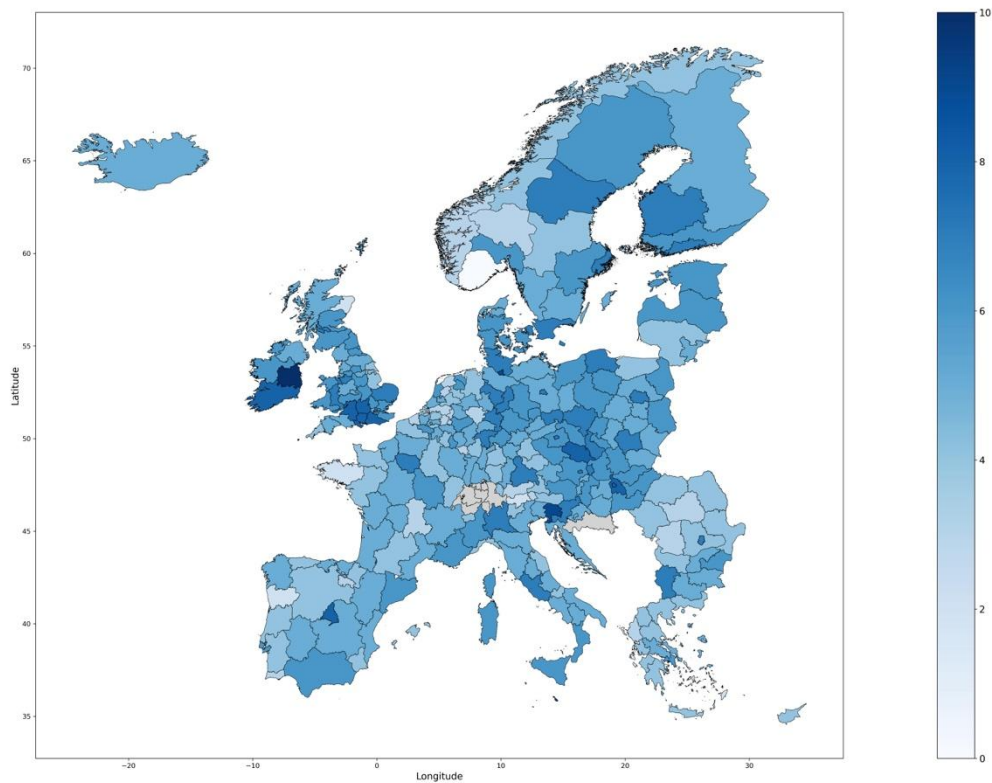


Figure 5: Average Digital Transformative Potential between 2008 to 2020.

### 3.4 Twin transition taxonomies

In addition to the sector-level analyses, we developed a quadrant map that classifies European regions based on the combination of GEI and DEI. This approach enables a comparative assessment of the progress of each region in the so-called twin transition, based on the proportion of its workforce employed in industries that are either green-intensive, digital-intensive, or both.

By intersecting these two dimensions—GEI and DEI—we constructed a map (shown in Figure 6) that visually captures the spatial distribution of twin transition taxonomy across Europe. This taxonomy is conceptualised in three broad tiers, determined by the share of employees working in industries at the forefront of the green and digital transitions. The quadrant map is divided as follows:

### ***Green and Digital Leaders***

Regions situated in the “top-right” quadrant exhibit both GEI and DEI. These regions represent the vanguard of the twin transition, where the structure of local labour markets already aligns with the requirements of a sustainable and digital economy. Unsurprisingly, these regions include many of Europe’s industrial and technological cores, capital cities, and innovation hubs, such as parts of Scandinavia, Ireland, and core European regions (Île-de-France, West-South Germany, the Netherlands, Lombardy).

### ***Regions leading in green or digital transition***

The second and third quadrants capture regions where the labour market structure is tilted toward either the green or digital dimension, but not both. These regions occupy an intermediate tier, reflecting partial progress along one transition pathway, while still facing structural gaps in the other. Examples of these quadrants are some regions, such as parts of Northern Italy, Southern Belgium, and the French periphery that show relatively high employment shares in green industries but limited exposure to digital-intensive sectors. These areas may have successfully leveraged their industrial or environmental specialisations but lag in digitalisation, which could constrain long-term competitiveness. Conversely, regions including Lisbon, Lazio (Rome), and several Eastern European capitals exhibit high DEI but limited penetration of green-intensive industries. This suggests progress in technological transformation but limited alignment with environmental transition objectives.

### ***Twin Transition Laggards***

Finally, the “bottom-left” quadrant groups regions with low GEI and DEI. These areas face the most significant structural challenges, as their labour markets remain concentrated in emission-intensive, low-digital sectors. Typically, these regions are concentrated in parts of Eastern Europe, as well as some Southern European regions, where legacy industries, lower technological uptake, and historical underinvestment in innovation persist. For these regions, progress in twin transitions requires addressing deep-rooted structural barriers. This goes beyond merely attracting green or digital firms; it entails investing in workforce upskilling, modernising industrial infrastructure, fostering innovation ecosystems, and leveraging local relatedness density—the capacity of existing industries to support diversification toward greener and more digital sectors.

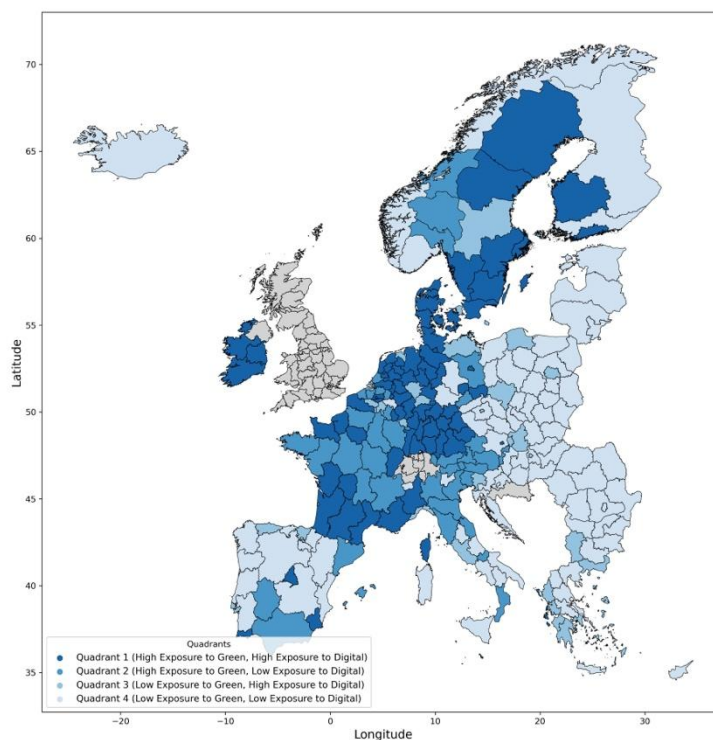


Figure 6: Twin Transition Taxonomy based on GEI and DEI.

We replicate the same exercise of plotting the four quadrants of regions but instead of using as threshold the median GEI and DEI, we use the green and digital transformative potentials we calculated. Put it differently, we plotter four different types of regions according to their related capabilities to industries with low greenhouse gases emissions and high level of digitalization. This approach provides a more refined, capability-oriented perspective on each region's potential to achieve the twin transition.

In essence, this version of the quadrant map does not merely reflect the current progress of regions in green and digital transitions, but rather captures the latent potential of regions to diversify towards these industries based on the industries that are already present and economically interconnected within the region. Put differently, the map reflects four types of regions according to their embedded industrial capabilities that can either support or hinder their trajectory towards the digital and green transitions.

The results of this exercise are visualised in Figure 7. Several key patterns emerge: First, we observe that many regions positioned in the intermediate quadrants—those with either high green transformative potentials or digital transformative potentials. A prime example of this is Catalonia, where related industries already embedded in the regional economy provide a foundation to simultaneously strengthen both transitions, provided the right policy incentives and investment strategies are in place.

More striking, however, is the case of many Eastern European regions, such as parts of Poland, Hungary, the Czech Republic, and the Baltic states. Although these regions currently display relatively low DEI and GEI, the presence of related industries suggests untapped potential,

particularly to advance the digital transition. Nevertheless, this scenario presents a double-edged sword. On the one hand, these related capabilities imply that, with strategic support, these regions could accelerate the development of digital-intensive industries. On the other hand, increased digitalization also brings with it heightened automation risks—particularly concerning in regions already characterised by weaker labour market resilience and socioeconomic inequalities compared to the European core.

Lastly, there remains a concerning group of regions—primarily in Romania, Bulgaria, parts of Greece, Portugal, and Spain—that not only lag behind in GEI and DEI but also lack the industrial fabric necessary to easily diversify towards these industries. The absence of related capabilities in these regions significantly constrains their potential to transition without significant structural transformation. For these regions, achieving the twin transition will likely require more ambitious, targeted, and externally supported interventions—ranging from skills development and infrastructure investment to attracting anchor industries capable of triggering positive path dependencies.

In sum, this capability-informed quadrant approach reveals the importance of looking beyond static employment structures and considering the evolutionary economic geography of regions—the pathways and constraints shaped by their existing industrial ecosystems. Incorporating relatedness density into this type of analysis provides a valuable framework to understand the dynamic, path-dependent nature of regional transformation in the twin transition context.

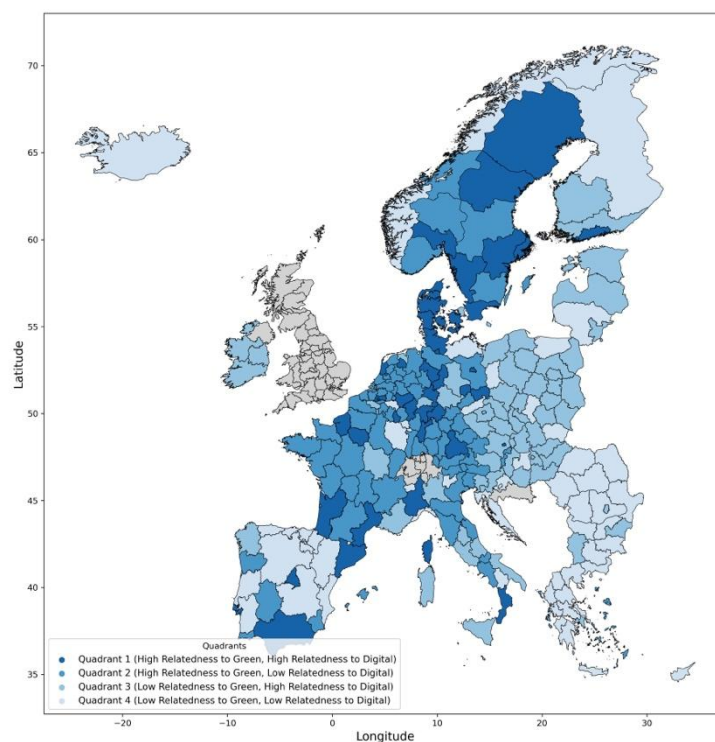


Figure 7: Twin Transition Taxonomy based on Green and Digital potentials.

## 4 Conclusions

### 4.1 Main results and implications

The results of this report reveal a clear and concerning pattern that the progress and potential of European regions and industries in green and digital transition differ significantly. Regions that are already well-positioned in the green and digital transitions regarding their current industry structure tend to be the same regions with high potentials in further diversifying into industries with low greenhouse gas emissions and high exposure to digital technologies. In other words, those regions also tend to possess local industrial structures that facilitate the absorption of new, greener and more digital jobs. This reflects a form of cumulative advantage, where existing economic structures, industrial diversity, and relatedness density create favourable conditions for further progress along the twin transition.

Conversely, regions that are lagging behind face significant structural barriers. These regions often struggle to identify closely related industries that can serve as stepping stones toward industries with lower greenhouse gas emissions and more digitally intensive sectors. This structural gap risks locking these regions into a cycle of limited transition progress, reinforcing existing territorial inequalities across Europe.

However, the results are not entirely uniform, and some important nuances emerge: For regions with low level of digitalization of its employment structure, our findings suggest that there may still be pathways toward digital transition through industries already present in the region that, while not yet highly digital, are related enough to offer potential for technological upgrading.

In contrast, regions characterised by high levels of emissions face a more entrenched challenge. The principle of path dependency is particularly evident here: the industries which are most closely related to their existing economic base are themselves often greenhouse gases intensive. This industrial structure constrains the region's capacity to diversify into greener sectors, making the green transition significantly more complex.

The quadrant analysis, which mapped regions based on their progress in green and digital industries, offers further insight into the geography of the twin transition. It provides a tangible representation of how the composition of the labour force varies across European regions and how these differences intersect with transition progress. By distinguishing between regions that are already transitioning well, partially prepared, or significantly lagging behind, this typology highlights the uneven and complex spatial landscape of Europe's green and digital transitions.

The conclusion of this work is that Europe's twin transition is neither automatic nor evenly distributed. Instead, it is unfolding along lines shaped by deep-rooted industrial structures, workforce composition, and the relational fabric of local economies. Without targeted, place-based policies, these dynamics risk exacerbating territorial disparities, with some regions accelerating ahead while others remain structurally locked in.

In this context, several key policy considerations emerge:

- **Leveraging Local Relatedness:** Policy makers must identify and support industries within lagging regions that offer realistic pathways toward greener and more digital employment, even if those industries are not yet fully aligned with transition goals.
- **Breaking 'Brown' Lock-in:** Regions with entrenched high-emission industrial structures will require more than incremental change. Targeted investment, industrial

transformation policies, and support for workforce reskilling are essential to overcome path dependency.

- **Avoiding a Dual-Speed Europe:** If left unaddressed, the current patterns risk creating a “dual-speed” Europe, where leading regions reap the benefits of technological and environmental change, while others fall further behind.
- **Supporting Just Transitions:** Ensuring that all regions—regardless of starting point—have a fair chance to participate in and benefit from the twin transition should not only be an economic necessity but a social and political imperative for European countries.

## 4.2 Limitations and future research

While this study offers valuable insights into the progress and potential of European regions in the green and digital transitions, several important limitations should be acknowledged, which may influence the interpretation and scope of the findings.

First, the most significant limitation comes from the lack of comprehensive data that contains employment information at granular industry and regional level. The employment data we used from the European Structural Business Statistics contains information at 2-digit NACE industry level but it does not include the agricultural sector. This omission is non-trivial, as the agricultural sector remains a dominant source of employment in many European countries and regions. Moreover, the environmental impact of the agricultural sector, especially in terms of nitrogen emissions, is substantial. Some regions that appear well-positioned in the twin transition in our results—such as parts of North-West Germany or the Netherlands—may, in reality, face higher environmental challenges linked to agricultural activities. Alternatively, the European Labour Force Survey which contains the share of employment in the agriculture sector at the NUTS-2 regional level could be used. However, the European Labour Force Survey lacks detailed industry information (only at the 1-digit NACE industry level). Merging these two datasets is also challenging due to different sampling strategies. Compiling administrative linked employer-employee data from different national statistics offices would be the best way forwards (Barreto et al., 2024). However, it requires significant amount of coordination and administrative efforts.

Secondly, the methodology used to estimate exposure to green and digital labour markets has inherent conceptual limitations. Measuring the digitalisation of industries is particularly challenging. Although the exposure score to emerging digital technologies we adopted in this report offers valuable insights into, it does not represent the actual adoption of digital technologies in different industries. Furthermore, it does not fully capture the different impacts of digital technologies on jobs and tasks, e.g. displacement effect (automation) or productivity effect (augmentation) (Restrepo, 2024). Thus, the results should be interpreted with caution. High exposure to digital technologies might imply productivity effect for advanced regions or regions with related capabilities where digital technologies may complement with the existing capabilities in the region, but displacement effect in regions specializing in labour and routine task intensive industries (Farinha, 2025; Guarascio, Reljic, & Stöllinger, 2025)

Similarly, the average intensity of greenhouse gas emissions of NACE 2-digit industries does not directly equate to the “greenness” of employment within those sectors. Emissions data provides an important, but partial, proxy for the environmental footprint of industrial activities. However, they do not fully reflect the extent to which specific job roles within an industry contribute to or mitigate environmental impact. A more granular, occupation-based measure of green employment would strengthen the robustness of the analysis (Apostel & Barslund, 2024; Villani et al., 2025), but it was beyond the scope of this report. In addition, we also lack disaggregated data of greenhouse gas emissions of industries at the regional level.

Lastly, this study adopts a broad, pan-European perspective without delving into detailed, region-specific case studies. While the quadrant and relatedness analyses offer valuable macro-level insights, they cannot fully unpack the complex, place-specific dynamics that shape the twin transition and labour market resilience at the local level. Understanding how related industries, workforce skills, and institutional capacities interact within specific sectors in different regions would require a more granular, qualitative approach. Such region-focused analyses would be instrumental in identifying concrete pathways through which different types of regions leverage their existing capabilities to foster transformative change of key sectors in the digital, green and twin transitions.

## References

- Aloisi, A. (2025). *Integrating the EU Twin (Green and Digital) Transition? Synergies, Tensions and Pathways for the Future of Work* (No. JRC140964). European Commission: Joint Research Centre.  
[https://publications.jrc.ec.europa.eu/repository/bitstream/JRC140964/JRC140964\\_01.pdf](https://publications.jrc.ec.europa.eu/repository/bitstream/JRC140964/JRC140964_01.pdf)
- Apostel, A., & Barslund, M. (2024). Measuring and characterising green jobs: A literature review. *Energy Research & Social Science*, 111, 103477. <https://doi.org/10.1016/j.erss.2024.103477>
- Apostol, S., & Hernández-Rodríguez, E. (2024). Digitalisation in European regions: Unravelling the impact of relatedness and complexity on digital technology adoption and productivity growth. *Industry and Innovation*, 0(0), 1–30. <https://doi.org/10.1080/13662716.2024.2423731>
- Bachtrögler-Unger, J., Balland, P.-A., Boschma, R., & Schwab, T. (2023). Technological Capabilities and the Twin Transition in Europe. Opportunities for Regional Collaboration and Economic Cohesion. *WIFO Studies*.
- Barbieri, N., & Consoli, D. (2019). Regional diversification and green employment in US metropolitan areas. *Research Policy*, 48(3), 693–705. <https://doi.org/10.1016/j.respol.2018.11.001>
- Barreto, C., Fluchtman, J., Hijzen, A., Lombardi, S., Bennett, P., Bertheau, A., Chan, W., Gorshkov, A., Hambur, J., Johnstone, N., Lochner, B., Meekes, J., Mehdi, T., Muraközy, B., Nolan, G., Salvanes, K., Skans, O. N., & Vejlin, R. (2024). *The “clean energy transition” and the cost of job displacement in energy-intensive industries*. OECD. <https://doi.org/10.1787/abf614d1-en>
- Boschma, R. (2017). Relatedness as driver of regional diversification: A research agenda. *Regional Studies*, 51(3), 351–364. <https://doi.org/10.1080/00343404.2016.1254767>

- Farinha, T. (2025). Relatedness diffuses impacts from automation: A novel approach to estimate job risk in U.S. cities. *Industry and Innovation*, 0(0), 1–23.  
<https://doi.org/10.1080/13662716.2025.2499523>
- Fazio, G., Maioli, Sara, & Rujimora, N. (2025). The twin innovation transitions of European regions. *Regional Studies*, 59(1), 2309176. <https://doi.org/10.1080/00343404.2024.2309176>
- Guarascio, D., Reljic, J., & Stöllinger, R. (2025). Diverging paths: AI exposure and employment across European regions. *Structural Change and Economic Dynamics*, 73, 11–24.  
<https://doi.org/10.1016/j.strueco.2024.12.010>
- Guarascio, D., Reljic, J., & Zezza, F. (2025). Energy vulnerability and resilience in the EU: Concepts, empirics and policy. *Journal of Industrial and Business Economics*, 1–44.  
<https://doi.org/10.1007/s40812-025-00340-9>
- Henning, M., Eriksson, R., Garefelt, P., Martin, H., & Elekes, Z. (2025). Job relatedness, local skill coherence and economic performance: A job postings approach. *Regional Studies, Regional Science*, 12(1), 95–122. <https://doi.org/10.1080/21681376.2025.2459148>
- Hidalgo, C. A., Klinger, B., Barabási, A.-L., & Hausmann, R. (2007). The Product Space Conditions the Development of Nations. *Science*, 317(5837), 482–487. <https://doi.org/10.1126/science.1144581>
- McDowall, W., Reinauer, T., Fragkos, P., Miedzinski, M., & Cronin, J. (2023). Mapping regional vulnerability in Europe’s energy transition: Development and application of an indicator to assess declining employment in four carbon-intensive industries. *Climatic Change*, 176(2), 7.  
<https://doi.org/10.1007/s10584-022-03478-w>
- Neffke, F., Henning, M., & Boschma, R. (2011). How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions. *Economic Geography*, 87(3), 237–265.  
<https://doi.org/10.1111/j.1944-8287.2011.01121.x>
- OECD. (2023a). *Job Creation and Local Economic Development 2023: Bridging the Great Green Divide*. OECD Publishing.
- OECD. (2023b). *OECD Employment Outlook 2023: Artificial Intelligence and the Labour Market*. OECD Publishing. <https://doi.org/10.1787/08785bba-en>
- OECD. (2024a). *Job Creation and Local Economic Development 2024: The Geography of Generative AI*. OECD Publishing. <https://doi.org/10.1787/83325127-en>

- OECD. (2024b). *OECD Employment Outlook 2024: The Net-Zero Transition and the Labour Market*. OECD Publishing. <https://doi.org/10.1787/ac8b3538-en>.
- Prytkova, E., Petit, F., Li, D., Chaturvedi, S., & Ciarli, T. (2024). *The Employment Impact of Emerging Digital Technologies* (No. 10955). CESifo Working Paper. <https://doi.org/10.2139/ssrn.4739904>
- Restrepo, P. (2024). Automation: Theory, Evidence, and Outlook. *Annual Review of Economics*, 16, 1–25. <https://doi.org/10.1146/annurev-economics-090523-113355>
- Rodríguez-Pose, A., & Bartalucci, F. (2024). The green transition and its potential territorial discontents. *Cambridge Journal of Regions, Economy and Society*, 17(2), 339–358. <https://doi.org/10.1093/cjres/rsad039>
- Romero, O. Y., Boschma, R., Li, D., Kakderi, R. C., & Rizzo, U. (2025). *The geography of the green, digital and twin technological and scientific specialisation in Europe*. Zenodo. <https://doi.org/10.5281/zenodo.15552559>
- Villani, D., Vázquez, I. G., & Fernández-Macías, E. (2025). *Green Jobs. A critique of the occupational approach to measure the employment implications of the green transition* (No. JRC140967; JRC Working Papers Series on Labour, Education and Technology). European Commission.

## Annex 1: The Consortium

Short name	Full name	Homepage	Logo
HVL	Western Norway University of Applied Sciences	<a href="https://www.hvl.no/en/">https://www.hvl.no/en/</a>	
BOKU	BOKU University	<a href="https://boku.ac.at/en/">https://boku.ac.at/en/</a>	
LSE	London School of Economics	<a href="https://www.lse.ac.uk/">https://www.lse.ac.uk/</a>	
UoC	University of Crete	<a href="https://www.uoc.gr/en/">https://www.uoc.gr/en/</a>	
UW	University of Warsaw	<a href="https://en.uw.edu.pl/">https://en.uw.edu.pl/</a>	
UU	University of Utrecht	<a href="https://www.uu.nl/en">https://www.uu.nl/en</a>	
FHNW	University of Applied Sciences and Arts Northwestern Switzerland	<a href="https://www.fhnw.ch/en/">https://www.fhnw.ch/en/</a>	
BFI	Berufsförderungsinstitut Wien	<a href="https://www.bfi.wien/">https://www.bfi.wien/</a>	
Simplon	Simplon.co	<a href="https://www.simplon.co/">https://www.simplon.co/</a>	
MOP	Municipality of Platania	<a href="https://www.platanias.gr/en/">https://www.platanias.gr/en/</a>	

## **Annex 2: Project Summary**

### **SkillResilience4EU - Resilience through re-skilling and upskilling for European labour markets in transition.**

The twin transition (defined as the coexistence and interplay of the green and digital transitions) has enormous impacts on European labour markets. Because the green and digital transformations can feed into, facilitate, or hinder each other, it has been difficult to predict how labour markets will absorb and respond to changes and disruptions in employment conditions, skill needs and job availability and mobility. Other ongoing global challenges and macro-economic events, like the COVID-19 pandemic, also contribute to a profound reshaping of labour markets in Europe. New sectors emerge, existing sectors need to adapt and transform. New skills need to be developed or need to be transferred from other industries. Regions and sectors need to narrow labour market and skill mismatches to minimise the costs and to maximise the benefits of job destruction and job creation processes.

Different sectors and regions are affected in varying ways and intensities, either by green or digital transitions, or the combined impact of the twin transition. This unequal distribution of job creation and destruction processes may favour or leave behind places, sectors, and socio-economic groups and may threaten social cohesion and inclusion. The institutional and policy context needs to become more flexible and responsive to cope with the ongoing transformations and narrow down the labour market mismatches. Tailored and cost-effective policies and programmes for reskilling and upskilling, in particular for the most vulnerable and left-behind socio-demographic groups and places, need to be developed together with policy makers, VET providers, unions, public authorities, and other decision makers.

Funded by Horizon Europe, the European Union's Framework Programme for Research and Innovation, SkillResilience4EU will introduce a novel conceptual framework to describe and understand the impacts of the twin transition on European labour markets and will investigate the complex mechanisms, dynamics, and challenges that regions and institutions undergo by exploring selected sectors (tourism, food, transport, agriculture, and energy). The project will develop a management tool for policy makers to support them in managing labour markets in transition with recommendations for policy scenarios. SkillResilience4EU will also map and evaluate educational and training programmes for upskilling and re-skilling and will deliver recommendations and practical resources to support individuals and employers with specific focus on career guidance and development.

To achieve this ambition, the SkillResilience4EU consortium unites higher educational institutions (Western Norway University of Applied Sciences, Utrecht University, London School of Economics, University of Warsaw, University of Natural Resources and Life Sciences in Vienna, University of Crete, North-Western Switzerland University of Applied Sciences) one vocational training institute (BFI), one private training organization (Simplon.co) and a local public authority (Municipality of Platania). The partners cover a whole range of expertise: economic geography, innovation studies, regional development, sustainability transitions, qualitative research, institutional research, policy research, labour and behavioural economics, education, arts and design, social inclusion, VET and lifelong learning. Coordinated by Western Norway University of Applied Sciences, the project was launched on 1<sup>st</sup> January 2025 and will run for 3 years.