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## Green Jobs: A critique of the occupational approach to measure the employment implications of the green transition

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2025/02

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# Green Jobs. A critique of the occupational approach to measure the employment implications of the green transition

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## Abstract

The green transition is set to transform labour markets, yet its impact remains difficult to measure. This paper critically examines the occupational approach—based on task-based measures—which is the most widely used framework among researchers and institutions for estimating green employment. First, we identify theoretical shortcomings in this approach, emphasizing that its reliance on occupational titles leads to false positives by misclassifying non-green jobs as green, while also producing false negatives by excluding key contributors to the green transition. Second, we highlight methodological issues, such as inconsistent categorizations, arbitrary task definitions, outdated classifications, and the flawed assumption that occupational content remains stable across time and countries. Third, we apply the occupational approach using the O\*NET framework to quantify green employment in 24 European countries from 2011 to 2022. Our analysis reveals that, according to this method, there has been virtually no net creation of green jobs in Europe. Moreover, we find no meaningful correlation between the presence of green jobs and various aggregate and sectoral environmental indicators. These findings underscore the fundamental limitations of the occupational approach, suggesting that it is an inadequate tool for assessing the labour market effects of the green transition. We discuss how this measure is suitable for policy benchmarking in the context of the European green transition.

**Keywords:** ONET, Green Jobs, Green employment, Occupations, Green transition

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## **Executive Summary**

The green transition is reshaping labour markets by driving demand for new skills, changing the nature of existing jobs, and influencing employment across sectors. However, accurately measuring these labour market effects remains a significant challenge. This paper critically evaluates the occupational approach, the most widely used framework for estimating green employment, and highlights its **conceptual, methodological, and empirical shortcomings**.

The occupational approach—often operationalized through the O\*NET Green Jobs framework—classifies jobs as "green" based on occupational titles and task-based measures. While widely adopted by researchers and policymakers, this approach suffers from serious limitations that undermine its usefulness for assessing the labour market effects of the green transition.

1. **Conceptual Shortcomings** – The approach assumes that workers in certain occupational titles are inherently green, without effectively measuring whether their work contributes to environmentally beneficial production or the green transition. This results in **false positives** (misclassifying non-green jobs as green) and **false negatives** (excluding workers who contribute significantly to the green transition but do not have explicitly green job titles).
2. **Methodological Limitations** – The occupational approach relies on arbitrary classifications, outdated frameworks, and flawed assumptions about job stability. Additionally, the framework assumes that task composition remains constant over time, without considering to account for how the green transition continuously reshapes job roles. Moreover, inconsistent aggregation methods introduce further measurement errors, making cross-country comparisons challenging.
3. **Empirical Findings** – Applying the occupational approach to 24 European countries (2011–2022), we find virtually no net creation of green jobs, despite substantial investments in green policies and industries. The share of employment classified as green remains largely unchanged over time. Furthermore, **green job estimates derived from this approach show no correlation with environmental and sustainability indicators**, such as reductions in greenhouse gas emissions, investments in energy efficiency, or the share of renewable energy in national energy mixes. In our view, these results suggest that the occupational approach to green employment does not capture the labour market dynamics of the green transition.

## **1 Introduction: the green transition and its implications for European labour markets**

Record-breaking temperatures and extreme weather events caused by climate change are more and more common, and their environmental and societal effects are already tangible and set to increase in frequency and intensity over the coming years and decades (Keramidas et. al. 2023, Intergovernmental Panel on Climate Change 2023). This increasingly visible impact of climate change underlines the importance of making progress towards the implementation of the Paris Agreement, signed in 2015 to limit global temperature increases to 1.5°C above pre-industrial levels. According to the Intergovernmental Panel on Climate Change (IPCC), crossing the 1.5°C temperature increase threshold above pre-industrial levels risks unleashing far more severe climate change impacts, including more frequent and severe droughts, heatwaves and rainfall (IPCC, 2023). The need for tangible results is clear: the UNFCCC estimates that, in order to limit global warming to 1.5°C above pre-industrial levels, greenhouse gas emissions must peak before 2025 at the latest and decline by 43% by 2030. However, much remains to be done<sup>1</sup>, and policy action is therefore more urgent than ever as the IPCC underlined in its last synthesis report, stressing that current mitigation and adaptation actions and policies are not sufficient, both at global and national level (IPCC, 2023).

When we look at recent trends the overall picture is however not so dire, in the light of the enormous progress that has been made in the past years to address climate change thanks to international climate agreements and rising national ambitions and public awareness. Mitigation policies have contributed to a decrease in global energy and carbon intensity, and low-emission technologies are becoming much more affordable (IPCC, 2023). This last factor, particularly the sheer pace of adoption of renewable energies, electric vehicles and clean technologies across the globe, which has accelerated in recent years, leaves plenty of room for optimism (Ritchie, 2024). The International Energy Agency estimates that investment in clean energy has risen by 40% since 2020, and not only thanks to policy action (IEA, 2023). The fact that there is now a strong economic case for mature clean energy technologies is a decisive factor that may definitively accelerate the energy transition in the years and decades to come: clean energy deployment is starting to bend the emissions curve, thanks largely to solar energy wind power and electric vehicles (IEA, 2023). As a result, in parts of the developed world the reduction of CO2 emissions is already underway, and what is more important, it is now clearly decoupled from economic growth.

### **1.1 The green transition in the European context: the European Green Deal**

At European level, these recent trends are also a reason for optimism, but this does not hide the need for urgent policy action, like elsewhere in the world. A major green agenda has shaped EU regulation and policy measures in the last 5 years to fight climate change and reduce emissions. The European Green Deal, announced in 2019, has been since then a major policy priority for the EU and has led to the adoption of a large amount of legislation and the creation or reshaping of major investment programs to support green policies. In particular, the European Green Deal involves extensive measures to reduce greenhouse gas emissions, promote renewable energy, and increase energy efficiency. A key initiative under the Green Deal is the Fit for 55 package to reduce greenhouse gas emissions. Under the Fit for 55 package a major milestone in the European Green Deal has been the European climate law regulation, which turns the political ambition of reaching climate neutrality by 2050 into a legal obligation for the EU. By adopting it, the EU and its Member States committed to cutting net greenhouse gas emissions in the EU by at least 55% by 2030, compared to 1990 levels. This target is legally binding.

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<sup>1</sup> At the end of 2023, COP28 (the conference of the parties monitoring the Paris Agreement under the United Nations Framework Convention on Climate Change UNFCCC) underlined that, despite overall progress, collective efforts towards the implementation of the Paris Agreement are not on track yet.

From the very beginning the European Green Deal was presented not just as a means to fighting climate change, but also as a new growth strategy for the EU, a set of transformative policies that would give new impetus to the EU economy, making it more sustainable and fairer. Also from its very inception, the grand vision behind the European Green Deal embedded a logic of “transition”, implying a process to “transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use” (European Commission, 2019). This notion of a “green transition”, also linked to the need to make it just and inclusive, was present in the European Commission communication outlining the European Green Deal, and was taken up by the Council conclusions of December 2019 which talked about a “transition to climate neutrality” that would bring new opportunities for growth, jobs and technological development. The Commission work programme for 2020 further reinforced the transition narrative by presenting this green transition towards a climate-neutral Europe in combination with the digital transition (European Commission, 2020), coining the term “twin transition” which has been widely present in EU policy discussions in recent years. This notion of a clean, just and competitive transition remains central in the priorities of the EU for 2024-2029.

In the European policy context, we can therefore talk about a “green transition” that refers to the process through which Europe is set to become climate neutral. From this perspective the EU has presented the green transition as a broad transformation of the European economy and society to achieve climate neutrality, sustainability, and environmental protection. This involves a shift towards a low-carbon, circular, and resource-efficient economy, with a focus on reducing greenhouse gas emissions, increasing the use of renewable energy, and promoting eco-friendly technologies and practices. The policy approach followed in Europe in recent years builds on a literature that emphasises the critical role of government policies in achieving sustainability goals and stresses the importance of developing and implementing effective policy mixes that can facilitate environmental objectives, stressing the government's role in guiding and supporting sustainable transitions (Soderholm, 2020).

Indeed, many of the European policies have gone in the direction of raising the price of CO<sub>2</sub> and other GHG emissions in line with Nordhaus (2019) to accelerate the transition towards cleaner forms of energy. In other countries green policies have also been significantly reinforced in recent years. In the USA, the Inflation Reduction Act has become a massive public scheme to support investment in clean energies through tax incentives and subsidies, while in China there has been a major push to invest in clean energies, electric vehicles and key technologies to support the clean transition based on state support. In these countries green policies can best be characterised as green industrial policies in the sense of Rodrik (2014) who build a theoretical case in favour of using industrial policy to facilitate green growth on the basis of stimulating and facilitating the development of green technologies.

## **1.2 The broad-ranging socio-economic implications of the green transition: what impact on labour markets?**

Climate change, its immediate effects and the policies implemented to address them can have wide-ranging socio-economic implications, and it is obvious that there is also an impact on labour markets to be expected. This is because climate change can directly affect the economy, creating jobs in certain sectors and destroying them in others. In addition to these direct effects on the sectoral composition of the economy, the policies implemented to mitigate climate change and adapt to it can also have implications for the economy and society, and therefore an impact on employment. Moreover, the green transition is also likely to induce market-driven effects in terms of new technologies, innovations and economic transformation which will also impact on the labour market. For example, reducing emissions by phasing out fossil fuels and promoting renewable energies will naturally reduce employment in the former and increase it in the latter, and this transition can have important distributional consequences. Furthermore, policies to increase the



price of CO<sub>2</sub> have been shown to have relevant implications in terms of inequality (Drupp et. al. 2021). The EU has recognised the importance of addressing the relevant employment and social aspects linked to the green transition in a comprehensive manner. The Council recommendation on ensuring a fair transition towards climate neutrality<sup>2</sup> encourages Member States to support people most affected by the green transition with measures in the field of employment to stimulate the creation of quality jobs and facilitate access to safe working conditions. It also puts a focus on education and training measures, fairness of tax-benefit and social protection systems and on ensuring access to affordable essential services and housing for people and households most affected by the green transition.

Overall, the impact on employment of the green transition, either already realised or potential, is suspected to be substantial but little is known about it. This is because it is particularly difficult to come up with robust methodologies to analyse this aspect of the green transition, due to the complex nature of the potential impacts, the lack of conceptual clarity about the characterisation as “green” of economic activities, sectors or jobs and the operational and methodological difficulties in quantifying the labour market implications of such “green” or sustainable activities.

At the same time, as the fight against climate change intensifies and the green transition accelerates it becomes urgent to address the increasingly tangible consequences for the economy and the labour market, calling increased attention to this issue by policymakers and citizens, and creating an increased demand for robust data and evidence that is currently not met. For example, the Council recommendation. This approach includes also the so-called task approach. As it will become clearer below, while leading to different results in other domains of implementation, the distinction between the task and occupational approaches is mostly nominal and their estimation does not entail a substantial difference in theoretical or methodological terms. For this reason, in the context of this report these approaches can be grouped into one family, which we identify as the occupational approaches.

The report is structured as follows. Section 2 proposes a taxonomy of the different approaches currently used to measure the impact of the green transition on employment, distinguishing between organisation-based and occupation-based approaches. It then explains in detail the concepts and rationale behind the O\*NET Green Jobs framework, which has become the dominant operationalisation of the occupation-based approach, and the most frequently used one in both research and policy. Section 3 then delves further into this approach by presenting a critical appraisal of the method, explaining its main conceptual and methodological shortcomings, while Section 4 provides empirical applications of the method for the EU. Section 5 discusses the policy dimension of the green jobs concept and explains the reasons why neither the concept itself nor the occupation-based approach appear to be robust ways to gain a full understanding of the implication of the green transition for labour markets. Section 6 concludes and proposes future research lines.

## **2 How to measure the impact of the green transition on employment?**

For the purposes of this paper, we can simply define the **green transition** as a transformation of economic activity that makes it more environmentally sustainable, in particular by reducing greenhouse gas emissions. This requires a number of critical changes, such as shifting from fossil fuels to renewable energy sources, increasing energy efficiency, adopting technologies and methods of production and transport which have a lower environmental impact, increasing the circularity of production and consumption patterns (recycling more and wasting less) and in general reducing the amount of waste and pollution associated with economic activity. Analytically, it is useful to distinguish **two key dimensions of this green transition from the perspective of economic activity**:

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<sup>2</sup> <https://data.consilium.europa.eu/doc/document/ST-9107-2022-INIT/en/pdf>

- **First, the green transition entails producing at large scale some products and services which contribute directly or indirectly to decarbonisation and environmental sustainability.** Some examples of the products and services that have to be produced at large scale for the green transition are renewable energy technologies and infrastructures, sustainable buildings and transportation systems, waste and recycling management systems, etc. This first dimension of the green transition can be called **“greening economic outputs”**. It is important to note that, given that some economic outputs are inputs into other economic activities, there may be *indirectly green* economic output: products and services which do not directly contribute to the green transition, but which are necessary to the production of green outputs and therefore contribute to the green transition through the value chain. An example of this would be the mining of critical raw materials that are necessary for building solar panels or batteries: although they do not contribute directly to decarbonisation or environmental sustainability, they are critical for products which do and therefore can also be considered as “indirectly green output”.
- **Second, the green transition requires changing the technologies and methods of economic activity so that they become more environmentally sustainable.** For instance, independently of what a factory produces (be it green output or not), it can do it using internal combustion engines powered by fossil fuels or using electric motors powered by renewable sources of energy. The green transition does not only require producing more solar panels and electric cars but producing them (and everything else) in a way which is itself more environmentally sustainable. This second dimension of the green transition can be called **“greening economic processes”**.

**The first dimension (greening economic outputs) refers to what is necessary to produce for the green transition, while the second (greening economic processes) refers to how it is necessary to produce for the green transition.** As usually happens, both dimensions are intertwined. Green economic outputs such as green devices and infrastructures (solar panels, batteries, electrical grids) are critical components for the greening of economic processes. If we see the entire economy as a single big economic process, we could even collapse the two dimensions into one, referring to the greening of the entire (global) economic process (which would be in practice a synonym of the concept of the green transition itself). However, the distinction between the *what* and the *how* of the green transition is very important in practical terms. Green products can be produced in non-green ways, and there can be green production processes which nevertheless generate harmful outputs from an environmental perspective. This does happen in practice, often affecting different areas of the planet in a different way, as a result of the interaction of global markets and different environmental regulations. For example, solar panels are sometimes produced in developing economies in very polluting ways<sup>3</sup> (generating environmental degradation and even high carbon footprints in the area), while internal combustion engine vehicles are often produced in developed economies in pristinely green ways. This is why the two aspects (the *what* and the *how*) of the green transition have to be taken into account: a successful green transition requires significant progress in both dimensions.

What is the role of labour in all this? Labour is a crucial input into all economic activity, playing a key role in both the *what* and the *how* dimensions of the green transition. On the one hand, a significant amount of labour has to be redeployed towards the production of greening economic inputs (and away from polluting ones). On the other hand, labour needs to adapt to and operate with green technologies and methods. Given that labour is qualitatively differentiated by skills and

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<sup>3</sup> Often, clean energy technologies require a wide range of minerals and metals with very energy-intensive and unsustainable production and processing methods (IEA, 2022).

specialisation, the redeployment of labour towards green output and its adaptation to green processes require important changes in the skills and specialisation of workers. This has two important implications for policy:

- First, developing new **skills and specialisation** takes time. Depending how different the skills and specialisation required by the green transition are from pre-existing ones, this time can be significant. If they concern the kind of foundational skills provided by the educational system, they would require changes in this educational system and time for a new generation of workers to be educated by them. If they require just an adaptation of existing professional skills to new products, tools and methods, they may be provided via life-long learning and occupational training programs in a relatively short period of time. Or they may even require very little or no adaptation at all if, as suggested by some studies, the main labour requirements of the green transition concern traditional sectors and activities (Hentzgen and Orand, 2023). In any case, it is important to assess the type and scope of skills required for the green transition to ensure that labour does not become a bottleneck for change.
- Second, jobs requiring different skills and specialisation tend to also be very different in terms of **job quality**<sup>4</sup>, and provide differential access to economic resources and life chances. The redeployment of significant amounts of labour from polluting to green activities will therefore probably reshape the distribution of socio-economic inequality. As with skills, it is important to take this into account and assess the socio-economic impact of the green transition from this perspective, to ensure that it is socially fair and beneficial for all. A green transition which generates unfair socio-economic consequences for some groups of the population is obviously less desirable, and probably also less politically sustainable (as it can generate a backlash).

For these two reasons, it is important for policy to be able to identify and measure the employment implications of the green transition, differentiating these implications according to the types and levels of skills required to the extent that it is possible, and taking into account the further socio-economic impact of these changes.

## **2.1 Defining and measuring green employment**

How can we define and measure green employment? Following the previous differentiation of the what and how of the green transition from an economic perspective, there are two ways to define green employment:

- **First, we can define it as employment that contributes to the production of green goods or services.** This can be limited to employment that contributes directly to the production of green outputs (e.g., people working in a solar panel factory), or it can be extended to those that contribute also indirectly (e.g., people working in mines that extract minerals and metals which are used for the production of solar panels). This is sometimes called the “**output approach**” to define green employment.
- **Second, we can define it as employment that contributes to green production processes.** For instance, people working in recycling for a retail company, or environmental specialists in a car production factory. This is sometimes called the “**process approach**” to define green employment. One can include in this approach a more “passive” concept of

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<sup>4</sup> In line with Eurofound’s widely accepted definition, by job quality we refer here to all the characteristics of work and employment that have been proven to have a causal relationship with health and well-being.

green employment, referring to employment that contributes to activities that do not actively harm the environment. For instance, jobs in education may not contribute to greening production processes, but they do no significant environmental harm (in contrast with jobs that contribute directly to polluting economic processes). However, this “passive” concept of green employment from a process approach is rarely used in practice, so we will not consider it in this paper, focusing instead on the “active” concept which focuses directly on jobs that themselves contribute to greening production processes.

These two definitions are by no means incompatible, and ideally, we would want to measure both types of green employment because, as previously argued, both are critically important for the green transition. In fact, it should be possible to combine both definitions into a single measure that captures all employment contributing to the green transition, although it would certainly be useful to distinguish in which way they contribute.

How can we identify and measure green employment according to these two definitions? The specialised literature has followed **two broad approaches** in this respect (for a review, see Apostel and Barslund 2024): organisation-based and occupation-based.

First, the **organisation-based approach** uses productive organisations as the unit of analysis, classifying them by their greenness. Therefore, according to this approach green employment is defined as *employment within green organisations*. There are two main ways in which this approach has been applied in the literature:

- The first one classifies individual organisations directly by their greenness, relying on information from surveys, company-level registers or other databases. Then, all (or part, if there is detailed information on the workforce characteristics) of the employment in green organisations is identified as green.
- The second way in which the organisation-based approach has been applied in the literature uses the economic sector of the organisation as the criteria for classification (drawing on pre-existing classifications of greenness by economic activity), thus identifying as green employment that belongs to organisations in green sectors.

Secondly, the **occupation-based approach**, which is the main focus of this paper, tries instead to classify employment by its greenness in a more direct way, using the existing occupational classifications as a basis. Occupational classifications have been used for many decades for employment research, and they consist of detailed lists of occupational titles that classify jobs by their similarity in terms of task content and skill level. In the occupation-based approach, some of these occupational titles are classified as green, which then allows to classify the associated employment accordingly. Within the occupation-based approach, we can differentiate two main applications:

- The first one uses a *discrete* categorisation of occupations, which allows a simple but effective counting of green employment (or *green jobs*) in the different categories. As we will see in the next subsection, this is for instance what the most widely used proposal (the O\*NET<sup>5</sup> Green Jobs framework) does: on the basis of desk research and expert assessments, a series of detailed occupational titles are classified as “green” in three different categories

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<sup>5</sup> The Occupational Information Network (O\*NET) is the US’s primary source of occupational information. The O\*NET database contains hundreds of standardized and occupation-specific descriptors on almost 1,000 occupations covering the entire U.S. economy. The database is continually updated from input by a broad range of workers in each occupation.

(existing occupations whose demand will grow because of the green transition, existing occupations whose task content will change because of the green transition, and new and emerging occupations associated with the green transition).

- The second approach, which is in practice a derivation of the first one, uses a *continuous* index of greenness to characterise each occupational title, on the basis of information on the task content of each occupation. This second approach allows computing an even more nuanced estimate of green employment, corresponding to the share of overall labour input that goes into green tasks within green occupations. In this paper, we will also discuss in detail this task variant of the occupational approach.

Although there have been some alternative proposals that we will briefly discuss later, the O\*NET Green Jobs framework has become the dominant operationalisation of the occupation-based approach to measure green employment (in both the discrete categorisation and the continuous index variants). Most of the empirical estimations of green jobs from an occupational perspective in recent years, both in the US and Europe, and both by academic and policy researchers, use the O\*NET Green Jobs framework in one way or another (e.g. Bowen et al., 2018; Consoli et al., 2016; Elliott et al., 2021; Peters, 2013; Vona, 2021).

In the policy arena, international institutions and national governments resort to different approaches to define and measure green employment, although the occupation-based approach has become the most frequently used in recent years, and particularly its operationalisation through the O\*NET Green Jobs framework. There is indeed a significant body of policy reports and grey literature that builds on the concept of green jobs following O\*NET, and important institutions such as the OECD and the IMF have adopted this approach (OECD, 2023, 2024; IMF, 2022; Cedefop, 2023; Eurofound, 2022). It is important to note however that the European Union has not used this approach so far for policy benchmarking purposes. Outside international organisations there is additional literature that follows an occupational-based approach. For instance, a 2021 report by the LSE fully embraces the O\*NET operationalisation by characterising jobs as being directly or indirectly green, depending on whether jobs contain explicitly 'green' tasks (Valero et. al. 2021). Other institutions such as the UN, ILO, Eurostat, the European Environment Agency or the International Renewable Energy Agency have relied on a diversity of organisation-based approaches (Eurostat 2016a, 2016b, 2018a, 2018b; ILO 2016, 2023).

At country level, there are different approaches. The German IAB institute, for example, has developed a task-based approach, the Greenness of Jobs Index (GOJI), to measure green employment (Janser, 2018; Bachmann et. al., 2024). In contrast, the United Kingdom, a green jobs taskforce set up by the Government opted in 2021 for a sector-based definition by which the term green job is used to signify "employment in an activity that directly contributes to - or indirectly supports - the achievement of the UK's net zero emissions target and other environmental goals, such as nature restoration and mitigation against climate risks" (Green Jobs Taskforce, 2021). In France, a 2023 report commissioned by the government to assess the employment implications in France of the fight against climate change also takes a sectoral approach, looking through modelling tools at the sectors that are most likely to be positively and negatively impacted by the green transition (Hentzgen and Orand, 2023).

## **2.2 The O\*NET Green Jobs framework and its applications**

The O\*NET Green Jobs framework was developed in 2009 by a group of US occupational experts, building upon a detailed review of existing literature on green economy activities. It was carried out in an iterative expert-driven process of refining, combining and validating occupational lists to develop a 3-category classification of 202 green occupations, out of the total list of nearly 1,000 occupations available in the O\*NET-Standard Occupational Classification (SOC) full occupational taxonomy of 2006. The three categories are defined as follows (Dierdorff et al., 2009, p. 5):

1. **Green increased demand (GID)** occupations: this category includes 64 existing occupations from the 2006 O\*NET-SOC taxonomy whose demand is expected to increase significantly in the green transition, according to the O\*NET occupational experts. However, the occupations in this category are not expected to change in any way in their task content, implying that they do not require any green-specific skill or specialisation. An example of this category of GID occupations is electricians: because of the increasing use of renewable energy sources and the increasing need for energy-efficient electrical systems, electricians are likely to see growing demand for their services as a result of the green transition. However, according to the O\*NET occupational experts, this growing demand will not require any additional skills or specialisation specific to the green transition.
2. **Green enhanced skills (GES)** occupations: this category includes 60 existing occupations from the 2006 O\*NET-SOC taxonomy whose demand is also expected to increase, but whose task content will change in significant ways, requiring additional skills and specialisation. An example of this category of GES occupations is roofers: according to O\*NET experts, roofers will see an increasing demand for their services in the green transition and they will need to acquire new skills to install and maintain environmentally sustainable roofing systems, such as solar panels, green roofs and energy-efficient roofing materials.
3. **Green new and emerging (GNE)** occupations: this final category includes 78 occupations which are specifically green in their content, 45 of which were already included in the existing 2006 O\*NET-SOC taxonomy and 33 of which were newly created by the Green Jobs framework. As example of an existing GNE according to the O\*NET classification, we can mention fuel cell engineers. As an example of a new GNE occupation, we can mention solar photovoltaic installers.

In a subsequent document (O\*NET 2010), the O\*NET experts provided a detailed description of the specifically green task content associated with the 138 GES and GNE occupations, after another process of literature review and expert consultation. This involved an expansion of the task content of occupations already present in the existing 2006 O\*NET occupational taxonomy, adding a total of 1079 new green tasks, and marking as green 290 already existing tasks. For reference, the total number of tasks (green and not green) identified for all the 138 occupations marked as green in O\*NET 2009 (GES and GNE) was 3074.

An example can help clarify what these green task descriptions are. The occupation “automotive engineers” (classified as “existing green new and emerging”) is described by a total of 25 tasks in the O\*NET framework. Of these, 17 are non-green tasks (“conduct automotive design reviews”, “perform failure, variation or root cause analysis”, among others), 2 are classified as existing green tasks (“design control systems for purposes such as energy management or emissions management”) and 6 are newly created green tasks (“create design alternatives for vehicle components to increase fuel efficiency”, “develop specifications for vehicles powered by alternative fuels or power methods”, among others).

Table 1 provides an overview of the distribution of green occupations and tasks by type. Whereas the 33 new GNE occupations only have green task content (the assumption being that these are fully green occupations), the 45 existing GNE occupations have on average 6.9 green tasks out of a total of 23.7 tasks on average (meaning that around one third of the task content of existing GNE occupations is actually green), and the 60 GES occupations have on average 7.2 green tasks out of a total of 23 (so they would also have around a third of green task content overall). Given that, by definition, the occupations identified as GID (green increased demand) do not see any changes in their task content as a result of the green transition, none of their tasks are marked as green. And of course, all of the other occupations not marked as green at all in the O\*NET framework also have zero green task content.

*Table 1. Distribution of green occupations and tasks by type.*

Type of occupation		Number of occupations	Average number of tasks	Average number of green tasks
Increased demand occupations (GID)		64	-	-
Green enhanced skills occupations (GES)		60	23.0	7.2
New and emerging green occupations (GNE)	Existing Green N&E	45	23.7	6.9
	New Green N&E	33	19.0	19.0

*Source:* Own elaboration based on O\*NET.

The O\*NET Green Jobs framework provides a rather complete toolbox for measuring the employment implications of the green transition from an occupational (and tasks) perspective and, as previously mentioned, it has been very extensively used for this purpose. There have been two main uses of this framework for employment analysis.

First, the most simple and common application has been to use the discrete categorisation of occupational titles in the 3 green categories explained above to estimate the number and share of green jobs for countries, sectors, or any other relevant aggregate of the employed population. The fact that the identification of greenness is carried out by detailed occupational titles allows relating green employment thus measured to other aspects of employment of policy or research interest. In particular, it allows relating green employment with skills demand (given that the occupational classification is itself constructed according to types and levels of skills demanded by the different jobs) and to job quality and socio-economic inequality (given that different occupational levels tend to be systematically associated with different levels of job quality and life chances).

Second, the 2010 task expansion of the O\*NET classification allowed for a further and slightly more sophisticated application of the occupational approach that has also been widely used for the US and Europe (Scholl et al., 2023; Vona, 2021). This variant is based on computing, for each occupation identified as green, a continuous (0/1) index of “greenness” by simply dividing the number of green tasks by the total number of tasks (Vona, 2021). In the example given above for the occupation “automotive engineers”, this index would be 0.32 (the result of dividing 8 green tasks by 25 tasks in total identified by the O\*NET experts for this occupation). By construction, all occupations not classified as green in O\*NET or classified as GID would get a value of 0 in this index (zero green tasks); all occupations classified as new GNE would get a value of 1 (given that all of their tasks are green); and occupations in the GES and existing GNE would get a value between 0 and 1 corresponding to the share of their tasks explicitly identified as green by O\*NET experts.

In concluding this section, it should become clear why the so-called green task approach is largely equivalent to a job or occupational approach. The procedure followed by O\*NET consisted in, first, isolating a list of job titles that were considered to be crucial for the green transition. Then, the corresponding green tasks performed by these occupations were identified (for those new green N&E occupations new tasks are created and assigned to those jobs). The result is a list of green occupations that are assumed to perform specific green tasks. This circular reasoning has important consequences in practical terms. Analysts that use this approach simply retrieve the occupational titles of green occupations, assign them a green content (whether binary or continuous, as in Vona, 2021, OECD 2024) and quantify their presence in the economy. The role of tasks is, at best, only secondary. Occupational titles are essentially what matters for empirical estimations.

### **3 Conceptual and methodological problems of the occupational approach**

The occupational approach to measure the impact of the green transition on labour markets has many appeals. In principle, it measures simply and directly what we want to measure (the employment impact of the green transition), in a way that allows a fine-grained analysis of the implications for skills and socio-economic inequality and drawing on occupational employment data which is readily available and regularly updated. However, **this approach suffers from a series of problems that make it, in our view, inadequate for the measurement of the employment impact of the green transition, especially from a policy perspective.** In the following two subsections, we will discuss in detail conceptual and methodological problems of the occupational approach. Although many of these points will be explicitly referred to the O\*NET Green Jobs framework and its applications (because of its centrality in this literature and in policy), most of them apply equally to other proposals also using an occupational approach.

#### **3.1 Conceptual problems**

The biggest problem of the occupational approach lies at the core of the concept of green employment. Following most of the literature, we have defined green employment as employment that contributes to green outputs or processes. This definition makes clear that employment is with respect to the green transition *a derived variable*: green employment is not defined by its intrinsic characteristics, there is nothing intrinsically green or not in any kind of labour input. What makes employment green in some cases is the fact that it *contributes to* outputs or processes which are (in this case, intrinsically) green. But the occupational approach is built on the assumption that the greenness of employment can be identified directly *ex ante* according to the type of labour input it entails (measured by occupation or by occupation and tasks). This is inconsistent with the concept of green employment itself (as previously stated) and leads to several significant problems that seriously challenge the validity of this approach.

The way the O\*NET Green Jobs framework was developed betrays this problem. Even though it is a classification of occupations, it was built, validated and identified with a list of 12 green sectors.<sup>6</sup> After the concept of greening of occupations and the three categories of green jobs were defined, a detailed review of 12 green sectors was carried out and their occupational implications were discussed (listing specific occupations potentially affected). Building on this preparatory work and after a detailed review of different materials, a list of candidate occupations was proposed. This list was validated by mapping them back into the 12 green sectors used in the initial preparatory work, resulting in the final list of green jobs in the three categories previously discussed. In the final taxonomy provided by O\*NET, all the occupations included in the green jobs classification (for all three categories) are mapped into one or more of the 12 green sectors. But despite the central role that these 12 green sectors played in the creation, validation and identification of the green occupations, they are completely ignored in any later use of the O\*NET green jobs classification. Once the occupations are classified as green jobs in one of the 3 categories of the O\*NET framework, they are used on their own to classify employment as green, independently of whether they contribute to those 12 activities or not. This is problematic, because even if the O\*NET validation procedure implies that only occupations contributing to those 12 activities could be considered as green, those occupations also exist (and very significantly!) in other sectors. For instance, the occupation “robotics technician” is one which is classified as an “existing new and emerging green job” within the sectors “research, design and consulting services” and “manufacturing”. But there are also many “robotics technicians” in other sectors, including in very

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<sup>6</sup> These sectors are: Renewable Energy Generation, Transportation, Energy Efficiency, Green Construction, Energy Trading, Energy and Carbon Capture, Research Design and Consulting, Services, Environment Protection, Agriculture and Forestry, Manufacturing, Recycling and Waste Reduction, Governmental and Regulatory



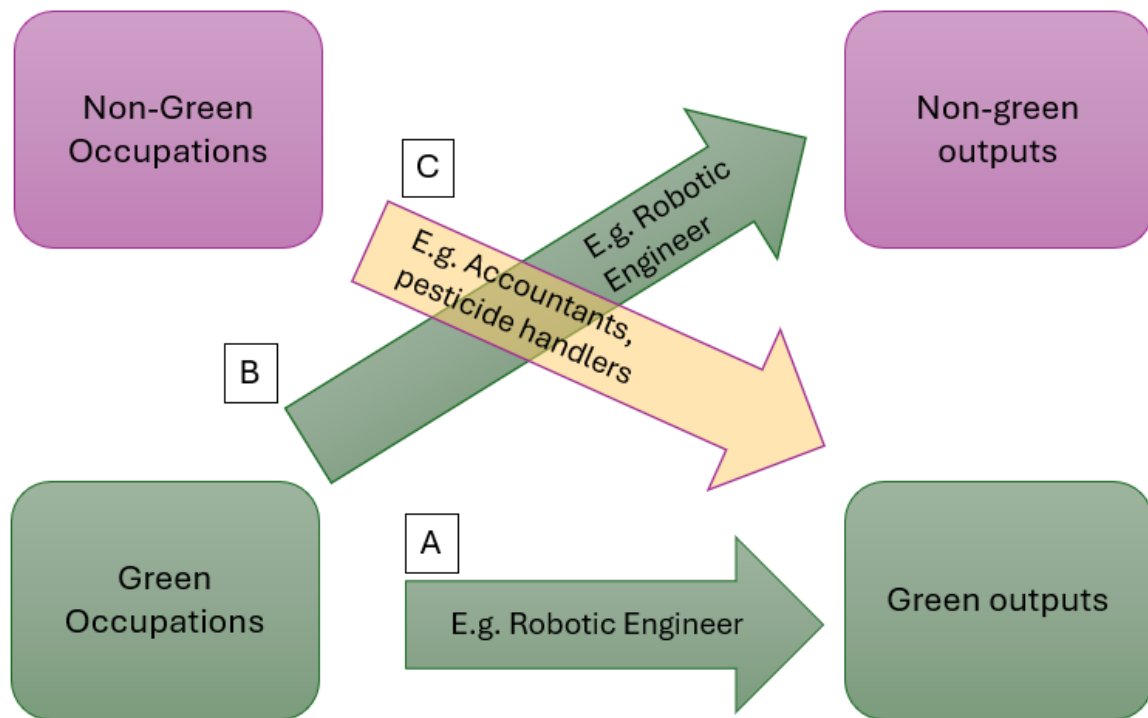
polluting sectors such as for instance in oil extraction and refining. Given that once the classification has been done only the occupation is used as a criterion for identifying green employment, also “robotics technicians” working in oil extraction and refining (and in any other sector) are considered as green jobs, which makes little sense.

In other words, the occupational approach tries to infer contribution to green outputs (and processes) from the occupational title, but this simply cannot be done because by construction occupations classify different types of labour in terms of skills and specialisation, not in terms of the types of outputs and processes to which they contribute. While it is true that some occupational titles may be regarded as “inherently” green (e.g. a solar panel engineer), this does not work in most cases. We can go back to the example of a robotic engineer, a green occupation according to the O\*NET task-based approach. In this approach all robotic engineers are to be accounted as green workers, but only some of them contribute to green outputs and/or within green processes. Many of them do not, but with this approach they will be classified as green. In other words, this approach classifies as “green” workers which should not be classified as green, generating **false positives**.

This problem is compounded by the fact that labour is always an input into a bigger economic process. Jobs are part of organisations which produce outputs with particular technologies and methods. To try to measure a phenomenon that pertains to the organisation level (the environmental impact of its outputs and processes) at the level of individual job contributions is simply wrong, and it will necessarily lead to measurement error. For instance, even occupations which are in themselves ostensibly non-green such as accountants, or pesticide handlers (to give two examples not classified as green in O\*NET) may be very important contributors to green outputs and/or processes when seen from an organisational perspective (solar panel factories also need accountants, and a pesticide handler may in fact work in an organisation that focuses on reducing the amount of pesticides in farming). Hence, this approach will not classify as “green” workers that are part of the production function of goods and services critical for the green transition. This aspect has also a crucial importance in policy terms. By excluding, *ex ante*, some workers that are crucial for the green transition, it is not possible to assess correctly the demand for skills that are needed for the transition. In short, the occupational based approach does not classify as “green” workers that contribute to the green transition, generating **false negatives**.

**In a nutshell, the occupational-based approach includes as “green” some workers that contribute to the production of non-green output, and at the same time excludes others that are key for the green transition, generating both false positives and false negatives. These conceptual shortcomings underline the unreliability of this approach for benchmarking purposes.** Figure 1 synthetises these points.

*Figure. 1. Main conceptual problems of the occupational based approach*



Note: A is the relationship that the occupational based approach is meant to measure, i.e. workers that contribute to the production of green outputs, such as robotic engineers. However, since the approach classifies as green *all* the employment in occupations classified as green, it will also consider as green B, which are those workers in “green” occupations that contribute to non-green outputs (a false positive). At the same time, the occupational based approach ignores C (for example accountants or pesticide handlers contributing to green outputs), i.e. those workers that contribute to the production of green outputs but do not have an explicit green occupational title (false negative).

*Source: own elaboration*

A related but slightly different problem of the occupational approach is that **it ultimately relies on occupational/job titles which can only imperfectly approximate what people actually do at work**, which is what is relevant for the green transition. Even if the occupations were initially well classified according to their contribution to green outputs and processes (ignoring for a moment the problems mentioned above), nothing guarantees that in practice they will correspond to what people actually do in their jobs. In occupational research, there are well-known phenomena such as title inflation (Martinez et al. 2008) or social desirability bias (Goulart et al. 2022) that suggest that occupational titles can sometimes provide a biased perspective of actual occupational content. There are even specific reasons to expect this kind of bias with respect to occupational titles related to the green transition. On the one hand, the green transition is strongly driven by policy requirements and there is a strong social desirability attached to green practices. On the other hand, green activity often involves high economic costs to companies. This combination of regulation/desirability and economic costs may create an incentive for some companies to create green-sounding positions that in practice contribute very little to the green transition. This is related to the phenomenon of “green washing”, and it should be taken seriously from a policy perspective because it can radically undermine effective progress in the green transition.<sup>7</sup>

<sup>7</sup> Some recent proposals of measuring green employment using online job vacancies data are even more problematic in this respect. For example, the Skills Online Vacancy Analysis Tool for Europe (Skills OVATE), developed by CEDEFOP

Ultimately, all these conceptual problems can be considered as problems of **validity** of the occupational approach. In Social Sciences, validity refers to how accurately a measure reflects the concept or reality it intends to measure. As previously explained, green employment can be simply defined as employment that contributes to green outputs and processes, and this is something that cannot be measured by classifying occupations by their greenness and then measuring the levels of employment across the different occupational categories.

### **3.2 Methodological problems**

On top of the conceptual problems discussed in the previous section, the occupational approach poses some important methodological challenges that we will discuss in this section. Because these methodological challenges concern the operationalisation of the occupational approach into a measurement framework, the discussion in this section will be more directly addressed at the O\*NET proposal and its different implementations. However, many of the methodological challenges discussed in this section can be generalised to other similar proposals.

**A first operational problem of the O\*NET framework is that it is inconsistent in its underlying logic**, a problem that probably derives from trying to infer green outputs from the type of labour input, as discussed in the previous section. We already saw that the O\*NET Green Jobs framework identifies and categorises green occupations and then uses those occupations to infer green outputs without taking into consideration the sector where the organisations operate, as if the type of labour input somehow determined the type of output. A related problem is that the O\*NET framework purports to be output-oriented only (in other words, measuring only employment contributing to green outputs), but a quick look at some of the occupations listed as green shows that some of them can only be considered as green from a process perspective (i.e., occupations whose tasks involve dealing with green technologies or methods across all kinds of organisations, irrespective of their output). For instance, “energy auditors” or “sustainability officers” are occupations typically involved in greening productive processes rather than in producing green outputs. This also applies to the task descriptions: as shown by Table 2, many of these “green tasks” clearly refer to green processes rather than (contributions to) green outputs. By construction, any occupation-based classification will necessarily relate as much to process as to output, because in fact occupations are relatively orthogonal to sectors and thus the same occupations can contribute to very different outputs.

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gathering more than 100 million online job advertisements in 28 European countries, has been used to study the trends in the requirements of green skills and tasks (e.g. CEDEFOP, 2023). However, these approaches also have different limitations. For example, it is not possible to verify if the descriptions of the jobs included in the online job ads used as a source correspond to a real job content. Companies could overemphasize green task content, green skill requirements, or even use green job titles because of the social desirability and attractiveness associated with them (see Sostero and Fernández-Macías 2022 for a discussion of possible sources of bias in this kind of data).

*Table 2. Examples of process-oriented green tasks in the original O\*NET green-task classification.*

O*NET SOC Code	O*NET-SOC Title	Green task description
13-1199.01	Energy auditors	Calculate potential for energy savings.
		Analyze energy bills including utility rates or tariffs to gather historical energy usage data.
		Determine patterns of building use to show annual or monthly needs for heating, cooling, lighting, or other energy needs.
11-3071.02	Storage and Distribution Managers	Plan, develop, or implement warehouse safety, security, or environmental programs and activities.
		Plan or adjust routes based on changing conditions, using computer equipment, global positioning systems (GPS) equipment, or other navigation devices to minimize fuel consumption and carbon emissions
53-3032.00	Truck Drivers, Heavy and Tractor-Trailer	Drive electric or hybrid-electric powered trucks or alternative fuel-powered trucks to transport and deliver products, livestock, or other materials.
		Operate idle reduction systems or auxiliary power systems to generate power from alternative sources, such as fuel cells, to reduce idling time, to heat or cool truck cabins, or to provide power for other equipment.
		Plan or adjust routes based on changing conditions, using computer equipment, global positioning systems (GPS) equipment, or other navigation devices to minimize fuel consumption and carbon emissions

*Source: Own elaboration based on O\*NET.*

**A second operational problem of the O\*NET classification is that it incorporates many arbitrary choices for which there is no clear explanation** (or explicit logic) and which can be easily challenged, an implementation problem which is also probably related to the underlying conceptual contradictions of this approach. To some extent, this is unavoidable in a classification which was ultimately done based on (well informed) expert judgement, but this is obviously problematic for the applications of this framework, especially for policy benchmarking. This apparent arbitrariness of the original O\*NET taxonomy is reflected both in terms of the three defined categories (see previous section) and in terms of the task content of the green occupations:

- First, the distinction between “green enhanced skills” and “existing new and emerging green occupations” is very thin, and it often seems unclear why a given occupation is in one or the other category. For instance, “heating engineers” are in “green enhanced skills” but “energy engineers” are in “existing new and emerging” –they could easily be the other way around, or both in either category. Something similar happens between “green enhanced skills” and “green increased demand”: for instance, construction labourers are in the former, but construction carpenters are in the latter, even if both would require similar re-skilling (if any) for contributing to green construction.
- Second, a similar arbitrariness seems to affect the task descriptions of the green occupations. Each occupation is described with a varying number of tasks, and with varying levels of detail, without any clear logic as to why that is the case. In many cases, the newly specified “green tasks” seem to be just a reformulation of some pre-existing tasks but

adding some green aspect. In the previously used example of “automotive engineers”, five of the six specifically green tasks are defined as follows: “design alternatives for vehicle components to increase fuel efficiency”, “design vehicles to improve fuel efficiency”, “develop specifications for vehicles powered by alternative fuels” and “research green automotive applications”. Given their degree of similarity, could not these tasks be merged with each other? To what extent are these tasks really different from each other? And more broadly, are those different tasks from the same ones without the “green” added aspect? Is the level of detail of these tasks equivalent to the other (non-green) tasks? These questions are particularly poignant because the share of green versus non-green tasks has been widely used as a quantitative indicator of the green content of the occupations, an approach which would require a level of precision in the measurement of tasks which does not seem available

An additional technical but important operational problem of the O\*NET framework is that, **because it is defined at a very detailed level of disaggregation of the occupational classification, it necessarily requires aggregation to be usable for employment analysis**. The underlying classification of the O\*NET Green Jobs typology is O\*NET-SOC at 8-digit level, which differentiates around 1,000 different occupational titles for the US. Roughly 200 of those occupational titles were classified as green in one category or other. However, this level of detail is not available on any employment databases, neither in the US or Europe. At the 6-digit level, the US SOC classification has around 800 occupations, but the most frequent level of detail available in employment databases is 4 (which covers around 400 occupations) or even 3 (around 100). In Europe, the International Standard Classification of Occupations (ISCO) is only available in practice at the 3-digit level for employment analysis. What this means is that for using the O\*NET typology, it is necessary to aggregate it considerably, which adds noise and imprecision in the analysis.

It is useful to explain briefly how this aggregation is carried out, to understand its implications for the analysis of the implications of the green transition in terms of employment. For instance, the 8-digit occupation “Automotive Specialty Technicians” (code 49-3023.02), flagged as “green enhanced skills” has to be aggregated into the 6-digit occupation 49-3023 (Automotive Service Technicians and Mechanics). This 6-digit occupation includes two 8-digit occupations, automotive master technicians and automotive specialty technicians: given that only the latter is flagged as green, the aggregation means that the 6-digit occupation “Automotive Service Technicians and Mechanics” will have a value of 0.5 (implying that only half of employment in this occupation is flagged as green, the half that corresponds to “automotive specialty technicians”). Then, this code will in practice have to be further aggregated for employment analysis into 5, 4 or even 3-digit occupational codes. In the SOC classification at the 5-digit level, this means that the value of 0.5 for “automotive service technicians” will be merged with the values of 0 for “automotive body repairers” and “automotive glass installers”. Assuming that the employment of the 3 merged occupations would roughly be the same, then the value for the 5-digit occupation “automotive technicians and repairers” would be 0.167 (in reality, the aggregation within SOC codes from 6 digits upwards can be done with employment weights, so that the actual value will be slightly different). This value of 0.167 means that only 16.7% of employment within the occupation “automotive technicians and repairers” is considered to be green. And this aggregation has to continue upwards to generate 4 or even 3-digit codes that can be merged with employment data in order to do the analysis.

This need to aggregate the classification of green occupations to be able to use it for employment analysis has important implications that are not always fully appreciated. Even if in theory this approach uses a categorical method to measure green employment, which should in principle allow to simply “count” the number of green jobs, in practice this would only be true at the very detailed 8-digit occupational level which is not available in any traditional employment database. Using this classification for employment analysis requires aggregating into less detailed occupational categories, which means that in practice very rarely an entire occupational code is classified as fully green or not, but as only *partly green* as indicated by a continuous index of 0 to 1. Then, the

“counting” of green jobs is carried out by approximation, by aggregating the proportions of green employment across all occupational codes.

Given that the aggregation from 8 to 6 digit occupational codes cannot be done with employment weights, it is necessary to assume that all 8 digit occupational codes within a given 6 digit occupational group have equal employment (which is a rather implausible assumption especially given that many of the occupations classified as green were by definition new and thus likely to be smaller than pre-existing similar occupations within the same 6-digit occupational group). From 6 digits to 4 or 3 digits there are employment weights in the US SOC data which allow a more precise aggregation, but even in that case the aggregation introduces uncertainty because *we cannot know which jobs are specifically green within each occupational category* (we only know the share). For instance, if we want to know how many of the 16.7% of jobs in the category “automotive technicians and repairers” are held by women, we really cannot know precisely, because we do not know the socio-demographic composition of that value. We can only approximate that value assuming that the composition of employment by gender within the 8-digit occupations originally classified as green is identical to the composition of the 5-digits occupation in which it had to be aggregated.

**A final important problem of the O\*NET framework is that it is a measure of the labour market implications of the green transition which is very time and place specific and yet it is routinely applied to employment data of very different times and places.**<sup>8</sup> It is striking that the original classification was proposed in 2009 (and since then it has undergone only minor changes), more than 15 years ago and at a time when the green transition was certainly much less developed than now (in 2024), both in terms of policies and in terms of technologies and practices. This is a key but systematically overlooked shortcoming of using the O\*NET framework: the classification of occupations by their greenness (as well as their description in terms of green task content) is based on an assessment of green technologies, practices and regulations in the years prior to 2009. It is striking that such an outdated framework is still considered as valid for inferring what shares and types of employment are contributing to the green transition in 2024. Since 2009, for example, and looking only at the US, per capita CO2 emissions have declined significantly, the share of electricity production from coal has dropped while it has soared for solar, primary energy consumption from low-carbon sources has increased and the efficiency of renewable energy production has dramatically improved, with new technologies being discovered and developed in this period. Even if we discard the problems discussed in previous pages, it seems obvious that any occupational classification related to the green transition, a process that has mutated and evolved significantly in the last 15 years, should be updated on a relatively frequent basis, given the very fast pace of change in the technologies linked to renewable energies, decarbonisation, recycling and waste management, and so on. The very idea of a green transition refers to a rapid and profound transformation in the outputs, technologies and methods of economic activity: it seems impossible to monitor such a transition with classifications that do not change in decades.<sup>9</sup>

Even more problematic is the application of the O\*NET framework to European employment data. Many aspects of the green transition are location-specific, and therefore any green classification must consider country specificities, which are completely absent when using the O\*Net classification. For example, using this approach, we would obtain that a power plant operator (a green enhanced skill occupation in the O\*NET framework) in Sweeden, where 70% of energy comes from renewables, will be as green as it is in Belgium, where only 15% of total energy is produced

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<sup>8</sup> This is a type of concern that has often been raised when a given measure is applied outside its original time and place. For instance, Villani (2021) showed that the assumption of stability in time and space of the external financial dependency index do not hold, and that the update of the measure leads to very different estimates.

<sup>9</sup> The authors of the original report were aware of the necessity of updating this classification: “Because of its constantly evolving nature, the green economy will be researched continually in an effort to see how it is impacting the world of work and, in particular, O\*NET-SOC occupations and the emergence of new occupations” (p. 34). However, no significant updates to this classification have been carried out since then.

from renewable sources. For these reasons, using a US-based taxonomy for Europe does not seem to be a conceptually sound approach. In particular, the fact that the green transition is driven by regulation in many of its details, and the regulation of the green transition is very different in the US and Europe, makes the application of an outdated US-based classification of occupations and tasks to Europe very problematic. The use of technologies and the strategies of decarbonisation also differ significantly across the two sides of the Atlantic, and this can also affect the occupational structure. For instance, Europe has more ambitious climate targets than the US enshrined into legislation, it has implemented a carbon pricing mechanism whereas the US has not, and it has been traditionally more stringent in its regulatory framework with respect to agricultural activity or construction, while at the same time more conservative in its industrial policy approach to foster the development of decarbonisation technologies. It is logical to infer that these differences may have occupational implications: there may be some specific occupations related to these different environmental practices or policies, or specific implications for skills requirements or task contents.

A final technical problem of applying the O\*NET framework to European employment data concerns the international comparability of occupational classifications. On top of the need to aggregate the classification to the 3-digit level which is in practice available with European employment data, applying the US classification to Europe requires translating US to European occupational codes. While there are correspondence tables and crosswalk procedures available to translate from SOC to ISCO, the translation process necessarily involves many assumption-based aggregations and approximations that introduce a very significant amount of statistical noise and measurement error. Some studies have found that slightly different methods of translating the US to the EU codes can have very significant implications in terms of the estimates of employment implications of the green transition.

If in the previous section we concluded that the conceptual problems of the occupational approach seriously compromised its validity as a method for understanding the impact on labour markets of the green transition, in this section we can conclude that its operational and methodological problems seriously compromises its **reliability**. Using the occupational approach requires making many arbitrary operational decisions and implementing many dubious statistical assumptions, which are likely to lead to unreliable estimates. Small differences in those operational decisions or statistical assumptions can produce very different results under the same conditions. In the next section we illustrate some of these issues.

## 4 Empirical applications

In order to provide an illustration of the conceptual and methodological problems outlined in the previous sections, this section presents an empirical estimation of the distribution and evolution of green jobs in Europe on the basis of the occupational (O\*Net) approach. We computed the presence of green employment in each European country using data from the LFS for 24 European countries and 21 industries (1-digit NACE) over the period 2011-2022. The methodology employed reflects as close as possible the green jobs/tasks approach, with all the caveats discussed above. This exercise is helpful to illustrate and assess to what extent the occupational based approach to green employment can be fruitfully employed for policy analysis.

First of all, we look into the implications of different possible operationalisations of the approach. As presented in Section 2, even within the occupational (or task based) approach, there are three possible ways to estimate the presence of green jobs in the economy following the O\*Net Green Jobs framework:

- The most basic approach quantifies as green workers all those occupied in categories GID, GES and GNE. It is a binary approach, in the sense that a worker is considered fully green as

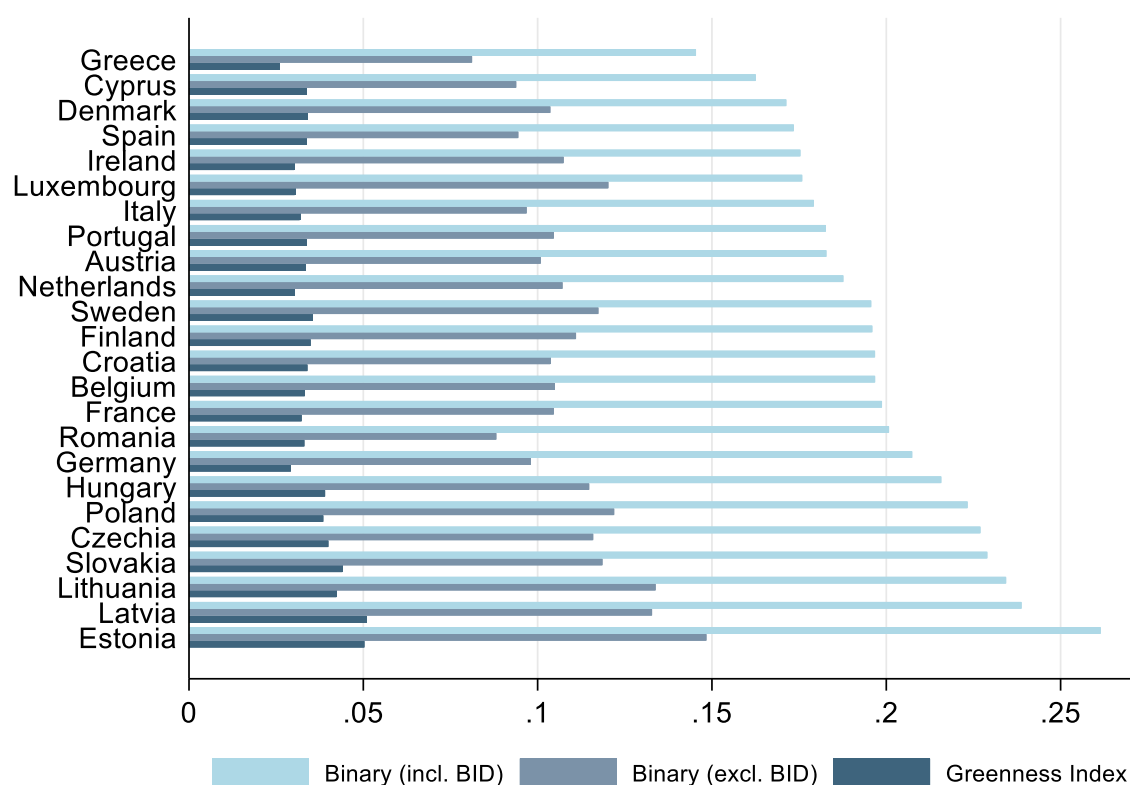
long as he/she belongs to any of these three occupational categories. This approach has been employed, for example, by the OECD (2024).

- Another approach in the literature considers as green employment only workers belonging to GES and GNE occupational groups (e.g., Vona, 2021). This is also a binary approach but excludes GID occupations because these occupations are not themselves “green” (even if they are assumed to increase in demand as a result of the green transition), and probably also because O\*NET does not provide a list of green tasks for this group of occupations. This approach has the limitation of considering fully green even occupations which have only one green task. For example, for “securities and commodities traders”, only two out of twenty-two tasks are considered green tasks in the O\*Net Green Jobs framework: however, using this approach all workers in this category are considered to be fully green. Therefore, this approach is likely to result in an overestimation of green employment.
- The most refined indicator is the index of “greenness” that is obtained by dividing, for each occupation, the number of green tasks by the total number of tasks (Vona, 2021). This indicator addresses the main limitation of the binary methods. Different from the previous two indicators, the estimation of green employment provided by this approach cannot be simply interpreted as an estimation of the *number* of workers in green jobs. This is because with this approach an occupation classified as green is not necessarily “fully” green, but only a share of its labour input as indicated by their “greenness” index. This indicator can be interpreted as the *share* of total worked hours (or labour input) devoted to green tasks.

As could be expected, these different methods produce different estimations of green employment in Europe. As shown in figure 2, according to the first approach (considering as green all employment in the three green occupational categories of O\*Net), green employment oscillates between 14 (Greece) and 28% (Estonia) of total employment. The categorical approach that excludes GID (not-intrinsically green) occupations is more conservative, with a range of green employment comprised between 9% and 15%. Finally, the application of the task-based greenness index produces an estimation of total green labour input that ranges between 3 and 5% of the total. Such large variations across different applications of the O\*Net Green Jobs framework, although perhaps expected from a methodological point of view, is difficult to handle for policy purposes. The interpretation of these findings and their policy implications can vary significantly depending on the specific operationalisation, potentially leading to confusion and arbitrariness in policy analysis. This, as we will see in section 5, clearly compromises the usefulness of this approach for policy benchmarking.



Figure 2. Average employment shares by country, 2011–2022.

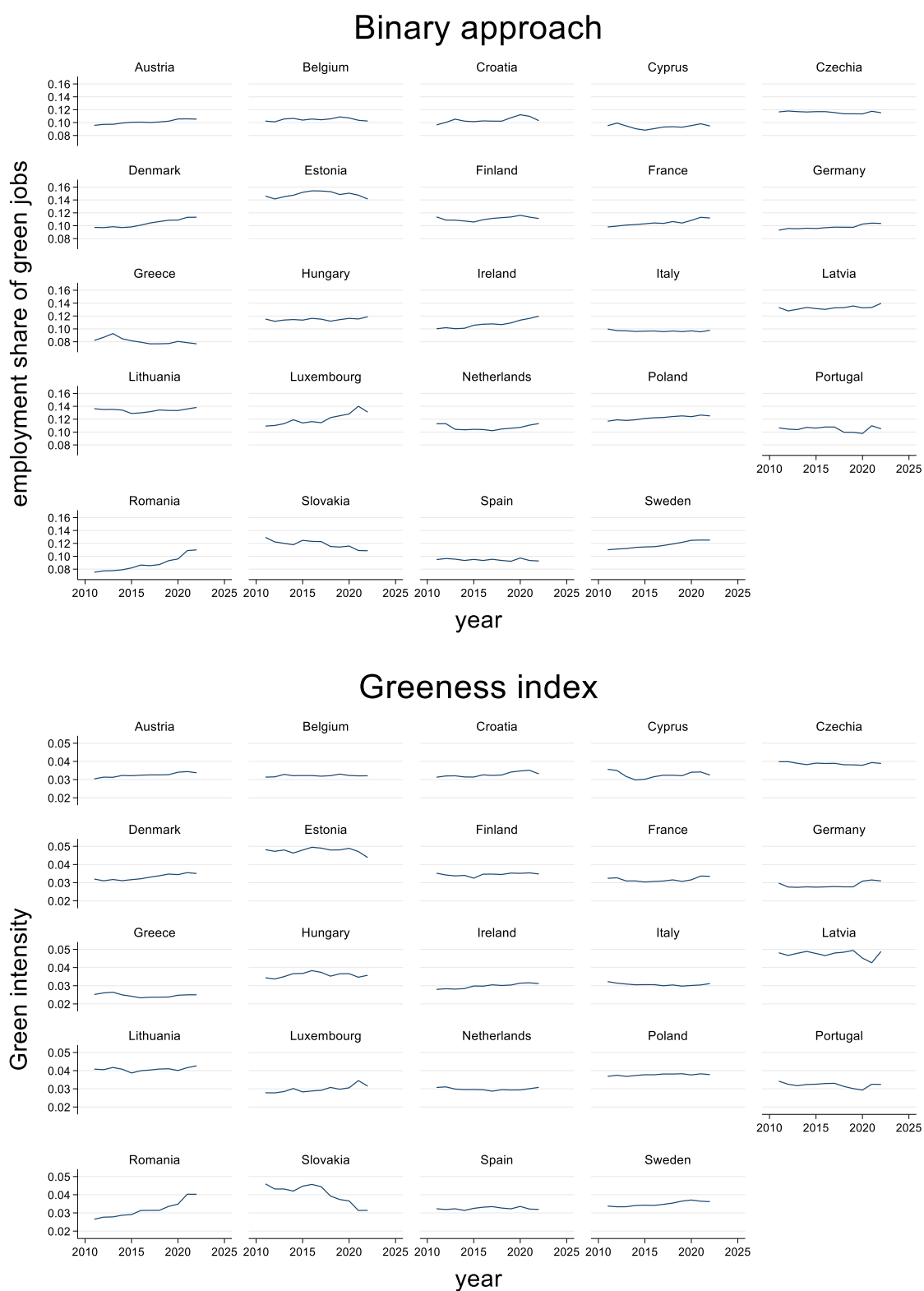


Source: own elaboration based on LFS data

To further investigate the green jobs in Europe using the occupational approach, figure 3 shows the evolution of green employment between 2011 and 2022, using the binary (which excludes BID occupations) and green task index estimations.<sup>10</sup> A striking feature of the graph that is the stability of green employment in most Member States, for both methods of estimation. Using the binary estimation (which can be simply interpreted as the percentage of employment in occupations classified as green in the O\*Net framework, excluding the “increased demand” category), Ireland, Luxembourg and Rumania are the countries that show a higher increase in the share of green jobs over the total, with increases that range between 2 and 5 percentage points of total employment. Slovakia is the only country that shows a negative trend, reducing its share of green jobs from 13 to 11% of the total. The shifts in the share of green labour input obtained using the green task index are much more contained. Apart from Romania and Slovakia (that show a more pronounced variation of approximately +/- 1.5 percentage points during the period), the share of green labour input in the economy has not changed significantly over the period (less than 0.5 percentage points increase).

<sup>10</sup> For the sake of simplicity, we focus only on the binary approach that excludes BID occupations, as it is the most common in the literature, and the greenness index approach, which is the most refined method of analysis.

Figure 3. Presence of green employment in Europe. Binary and greenness index estimations.



*Source: own elaboration based on LFS data*

Again, these results raise important concerns for the use of the green jobs estimations for policy. How is it possible that in the years witnessing the take-off of the green economy the share of green workers has remained essentially flat? Does the green transition imply no creation of green jobs? From our perspective, however, these surprisingly flat trends are to be expected given the methodology employed to estimate green employment from an occupational perspective. As discussed, this approach consists in simply counting the number of workers in occupations classified as green (with or without adjusting for green task content), in a given country/industry. Since the occupational structure is relatively stable, the estimation of green employment obtained with this method will necessarily be very steady too. Therefore, figure 3 should not be interpreted as evidence of a failure of the green transition in generating green employment. Rather, they reflect the conceptual and methodological problems of this approach, as extensively discussed in this paper. In other words, the occupational approach is a very problematic way to estimate the evolution of green employment over time in Europe.

To assess the external validity of this approach, we explore if the presence of green jobs in the European Union correlates with different green and environmental indicators (GEI).<sup>11</sup> Since the green-task approach aims at capturing the share of labour input involved in activities that have a positive environmental impact, it should be correlated with other indicators of greening and sustainability of the economy. To assess if this is the case, we correlate the presence of green jobs with environmental performance indicators at the country and, where possible, industry level. The indicators chosen for this analysis include the most common to evaluate the progress of the green transition (i.e. Greenhouse gases emissions) and other indicators that capture important information regarding the green and environmental sphere. Including a variety of indicators is important to test whether the presence of green jobs can be associated to specific factors of the green transition. Table 3 details the indicators employed.

It would be reasonable to expect that economies with a higher proportion of green jobs will exhibit better environmental performance, as such jobs are typically aligned with activities that reduce carbon emissions, improve energy efficiency, or promote sustainable resource use. This relationship reflects the assumption that green employment contributes directly to advancing a more sustainable economic structure. First, we correlate data on green employment in time  $t$  with the green and environmental indicator in the same year. The rationale behind this approach is to explore the contemporaneous relationship between green employment and environmental outcomes, capturing the potential immediate impacts of green jobs on ecological performance. However, it could be argued that the benefits of green labour input on the economy are not immediate and that are only visible after some time lag. For this reason, we compare the level of green jobs in 2016 with the level of GHG emissions in more recent years (2021 or 2022 depending on the indicator). By doing so, we can assess if the presence of green jobs could have tangible effects only after some years. Furthermore, it is possible that a relevant dimension is the relationship between the number of green jobs and the *change* of GEI. To address this point, we establish if the level of green jobs in 2016 and 2021 correlates with the change in GHG emissions and the share of EGSS production of GDP between 2016 and 2021 (the only indicators that covers this time span).

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<sup>11</sup> For the sake of simplicity, in the following pages we focus exclusively on the green task index. Results reached using other occupational-based indicators provide similar results.

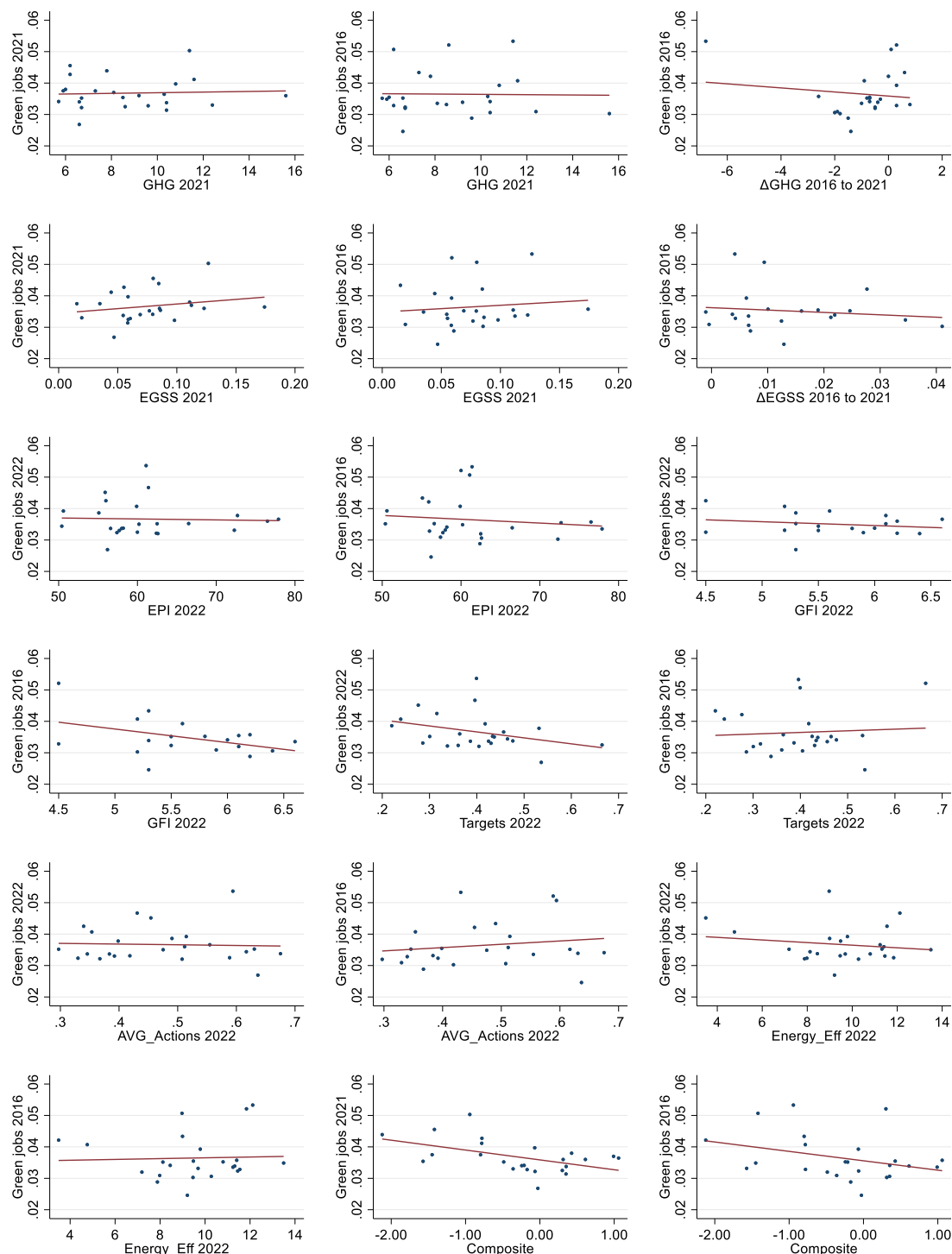
*Table 3. Green and environmental performance indicators.*

Indicator	Abbreviation	Definition
<i>Country level indicators</i>		
GHG per capita	GHG	Emissions of Greenhouse Gases (GHG) per capita
Share of EGSS over GDP	EGSS	Share of production in the environmental goods and services sector as share of GDP. Source: Eurostat
Green future index	GFI	The Green Future Index (GFI) measures the degree to which their economies are pivoting toward clean energy, industry, agriculture, and society through investment in renewables, innovation, and green policy. Source: <a href="https://www.technologyreview.com/2023/04/05/1070581/the-green-future-index-2023/">https://www.technologyreview.com/2023/04/05/1070581/the-green-future-index-2023/</a>
Environmental performance index	EPI	The Environmental Performance Index (EPI) assesses countries' environmental sustainability based on eleven indicators like air and water quality, biodiversity, and climate change. Source: <a href="https://epi.yale.edu/">https://epi.yale.edu/</a>
Targets for GHG emissions	Targets	Share of firms setting and monitoring targets for respective GHG emissions. Source: EIBIS
Average actions to reduce GHG emissions	AVG_actions	This composite indicator comes is the average of the values of five indicators that map to which extent firms invest and implement actions to reduce GHG emissions. I) Investing in new, less polluting business areas and technology; II) Investing in energy efficiency; III) Insite/offsite renewable energy generation; IV) Waste minimisation and recycling; V) Sustainable transport options. Source: EIBIS
Improvements in energy efficiency	Energy_eff.	Share (%) of investment directed towards measures to improve energy efficiency. Source: EIBIS
Composite indicator	Composite	This indicator is a synthetic indicator of all the above. Due to data availability, we compute it only for the year 2021 or 2022 (depending on data availability). The indicator is equal to the average value of the z-scores of each country's GHG (2021), EGSS (2021), GFI (2022), EPI (2022), Targets (2022), AVG_actions (2022), Energy_eff (2022).
<i>Industry level indicators</i>		
Share of renewable energy	Renewables	Share (%) of renewable energy over the total energy production. Source: Eurostat
Share of recycled waste	Recycling	Share (%) of recycled waste over the total. Source: Own elaboration using Eurostat data
Share of renewable energy in transports	Ren_Transports	Share (%) of energy from renewable sources used for transport. Source: Eurostat
Sectoral Composite indicator	Sectoral composite	This is a synthetic indicator of the three sectoral indicators. It is the average of the z-scores of each country's (1) Share (%) of renewable energy over the total energy production; (2) Share (%) of recycled waste over the total; (3) Share (%) of energy from renewable sources used for transport.

It can be appreciated that, regardless of the specification, there is no correlation between the share of green jobs in the economy and green and environmental indices (figure 4). One exception is the mild positive correlation between EGSS and the share of green jobs in 2021. This correlation,

however, is not statistically significant.<sup>12</sup> Overall, we do not find evidence of a relationship between green employment as measured by the occupational approach and environmental performance.

*Figure 4. Correlation between the share of green jobs at the country level and green and environmental performance indexes.*



Source: own elaboration based on LFS data

<sup>12</sup> The p-value of the regression between the two variables is 0.262.

Finally, we deepen the discussion by performing a similar analysis for specific industries, correlating the presence of green jobs in critical industries for the green transition with sectoral GEI. Green jobs may not correlate with GEI at the country level but could be more meaningful in some industries.

We focus on three industries:<sup>13</sup>

- The share of green jobs in the energy sector vs. the share of renewable energy over total energy production.
- The share of green jobs in the waste management and recycling industry vs. the share of recycled waste over the total.
- The share of green jobs in the transport sector vs. the share of energy from renewable sources used for transport.
- The average share of green jobs the three sectors (energy; waste management and recycling industry; transportation) vs. the average of the z-score of the sectoral GEI mentioned in the previous points.

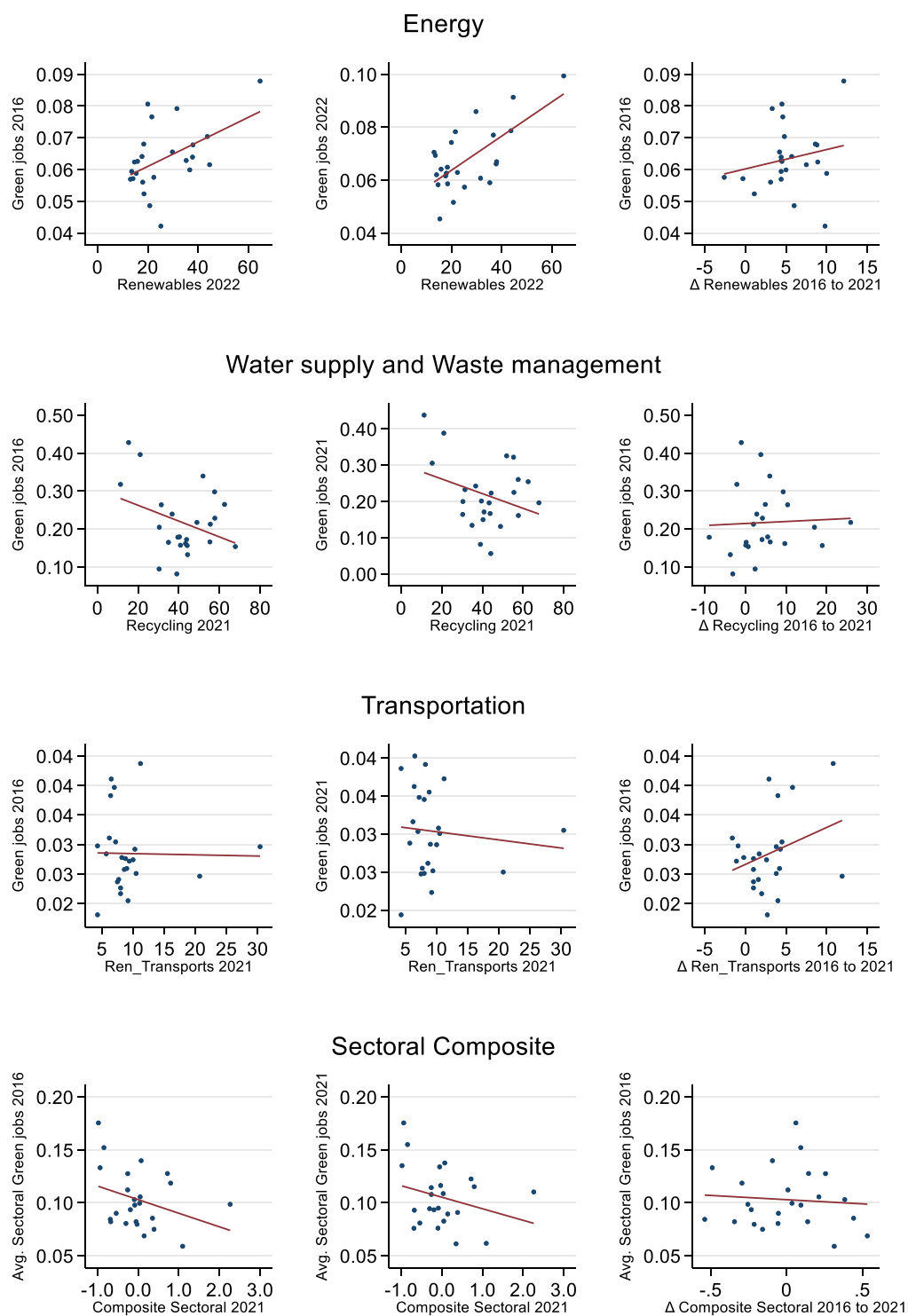
Also in this case, the correlation tends to be absent (figure 5). The only exception is the energy sector, where the share of green jobs is mildly correlated with the share of renewable energy. This finding may indicate that the green task occupational approach could provide some good insights about the share of green output in the energy sector. This may be explained by the fact that some occupations classified as green are indeed important for the production of green energy, such as photovoltaic and wind engineers. However, this result is only mild and contrasts with an almost complete lack of correlation between the occupational indicator of green labour input and all the other indicators of green and environmental performance.

Overall, the evidence provided in this section indicates that, according to the occupational approach, the relative presence of green employment has not changed in Europe since 2011. This finding openly contrasts with the important expansion of green activities and outputs in the same period. This evidence pairs with a conspicuous lack of relationship between green and environmental performance indicators and the share of green jobs in total employment according to the occupational approach. In our view, these results confirm that the occupational approach to measure green employment is flawed not only in theoretical and methodological terms, but also in capturing tangible outcomes of the green transition.

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<sup>13</sup> The choice of the industry is constrained by the availability of sectoral GEI.

*Figure 5. Correlation between the share of green inputs at the sectoral level and green and environmental performance indexes.*



Source: own elaboration based on LFS data

## 5 Problems for policy benchmarking and implementation

A better understanding of the general socio-economic effects of the green transition is essential to inform future policies and ensure that measures to mitigate climate change and adapt to its effects do not have unintended economic and distributional consequences. Concerns about this are well reflected in the European policy framework. In this context, analysing specifically the impact of climate change and the measures to address it on employment and labour markets is of increasing importance, and coming up with appropriate ways to quantify this impact has become a relevant or even urgent policy need. However good policies should build on good evidence and sound indicators, and this in turn requires a strong and clear theoretical basis underpinning robust concepts. In the previous sections, we have argued that the occupational approach (and the O\*NET operationalisation of this approach, which is the most commonly used) suffers from critical conceptual, methodological and empirical problems.

In light of the previous discussion, in this section we will critically assess this approach from a different angle, that of policy benchmarking and implementation. In particular, we look at the criteria<sup>14</sup> normally employed to validate indicators for policy analysis and we assess against these criteria the indicators constructed using an occupational approach, in particular the O\*Net operationalisation discussed at length in the EU and beyond (Vona, 2021).

First, we consider if these indicators are relevant and accurately measure the concept or reality they intend to measure, along the lines of the idea of **validity** discussed in subsection 3.1 about the conceptual problems of the occupational approach. From our perspective, the arguments presented in 3.1 strongly question the validity of the occupational approach for the use case under analysis and show that these indicators can hardly be used to explain the corresponding policy area, namely the impact of the green transition on employment. Green employment is employment that contributes to green outputs and processes, and this is, in our view, cannot be measured by classifying occupations by their greenness and then measuring the levels of employment across the different occupational categories. The current formulation of the occupational-based approach simply gathers information about the presence of certain occupations in the economy. The original intent of this approach was to collect information about workers that, with their actions, actively contribute to the green transition. However, section 3 presented major conceptual and methodological flaws of this approach, which seriously harm the original intent. Section 4, then, showed that empirical estimations of green employment based on the occupational approach can hardly be informative to the policy maker. These results are the outcome of different factors. First, the importance of green employment measured with the occupational approach varies largely depending on the method employed to estimate them. Second, the presence of green employment measured using the occupational approach does not bear any significant relationship with our selected green environmental indicators.

Second, we focus on whether these indicators have a **clear and accepted normative interpretation**. This is not the case in our view, and this has to do with the fact that the indicators analysed in this report are not at all based on a clear definition and one that is commonly accepted.

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<sup>14</sup> Over time researchers and policy makers have developed criteria and guidelines on how indicators should be selected or constructed in order to provide a robust evidence base to inform policy, and these criteria are now widely applied by policymakers. In the European context, such key principles include Relevance (indicators should be closely aligned with policy objectives and should measure what is considered important for policy decisions and assessments); Accuracy and Reliability (the data used to construct the indicators should be accurate, ensuring that the indicators reliably reflect the reality they are intended to measure), Timeliness and Punctuality (indicators should be available in a timely manner and released according to a predetermined schedule that meets user needs, allowing for prompt policy analysis and decision-making), Coherence and Comparability (indicators should be coherent within a dataset and comparable across different geographical areas and time periods), Accessibility and Clarity (data and metadata used to construct indicators should be easy to access and understand, with clear explanations of methodologies and any limitations), Cost-efficiency (the cost of data collection and processing should be weighed against the expected benefits of the indicators), and Completeness (indicators should cover all relevant aspects needed to provide a comprehensive view of the policy area being measured).



The term “green employment” is often used to refer to different realities or phenomena (Valero et. al. 2021, Janta et. al. 2023, Apostel and Barslund, 2024). Valero et. al. (2021) underline that there is no agreed definition of a ‘green’ job and characterise the different existing approaches as either ‘top-down’ and ‘bottom-up’. OECD (2023) follows a similar taxonomy. In a similar vein Apostel and Barslund (2024) also recognise the diversity of definitions and concepts, adopting a conceptual framework distinguishing between output-based and process-based greenness, and entity-level and occupation-specific measurement techniques. As Urban et. al. (2023) underline, the absence of a common definition makes it almost impossible to gather and compare data on the number, trends, or needs of green jobs.

Third, we assess if these indicators are **accurate and reliable**. We have shown in sections 3 and 4 of the report that these indicators are far from meeting basic quality criteria in terms of robustness and external validity. Even if its quantification is possible, the occupational approach for estimating the implications for employment of the green transition is fraught with empirical issues that challenge its robustness and accuracy, calling for caution when interpreting the results. These issues have been highlighted in other existing studies (e.g., Vona, 2021), especially when attempting to translate the approach from the United States to Europe. Note that methodological problems are neither the only nor, probably, the most important ones. The theoretical problems discussed in section 3.1 would still be valid even if data with high granularity were available.

Fourth, we can consider the occupational approach to meet basic requirements in terms of **coherence and comparability**, assuming a consistent methodology is used. The figures shown in section 4 illustrate trends in the share of green employment across EU countries from 2011 to 2022 using the occupational-based approach. Most countries show relatively stable or slightly increasing trends which, however, are very contained (less than 1 percentage point over 2011-2022). However, this superficial comparability is seriously hampered by some of the methodological problems discussed in section 3.2. In particular, the lack of an international harmonised classification of occupations at the detailed level (8 or 6 digits) forces the analysis to rely on aggregations and crosswalks which introduce noise, imprecision or even potentially biases in the comparisons. The appearance of comparability in the cross-national figures (as shown in section 4), which conceals serious underlying comparability problems, is itself a problem of this approach, because it makes it difficult or nearly impossible to distinguish signal from noise.

Finally, the fact that the occupational approach ultimately relies on occupational titles makes it particularly prone to manipulation, and therefore unlikely to **be responsive to policy interventions**. Indeed, as explained in section 3, there the occupational approach is in fact particularly problematic in this regard, because it makes it easy for labour market actors (companies or even administrations) to use green-sounding job titles for purposes of “greenwashing”, or just for reasons of social desirability. Furthermore, it is not clear to which extent the indicators derived from the occupational-based approach can be considered sufficiently responsive to policy interventions: as indicated above, the estimations of green employment based on the occupational approach remain remarkably stable (and probably unresponsive) over time. As explained in previous sections, this stability is probably an artifact of the way these indicators were constructed following the occupational approach, not the result of faulty policy interventions.

Furthermore, if we take as a basis the country-specific trends shown in the previous subsection it is very difficult to attribute these heterogeneous national dynamics to specific factors or policies, further undermining also compliance with the first criterion. One could speculate on the relevance of economic factors such as the boom and bust of the construction and real estate sectors, as well as significant national reforms, including changes in legislation and privatisation. These factors particularly impact occupations like refuse workers and building trades workers and could be behind some of the results. For example, what policy interventions could explain the drop in the share of green employment in Slovakia in recent years? No significant exogenous factors appear to have had an impact, and one could expect the impact of heavy public investment, including cohesion policy, to be positive, as could be argued in other cases, for example to explain the positive trend in Romania

or the relatively high shares of green jobs in other Central and Eastern Member States. Conversely, it is also difficult to link the low shares of green jobs observed in countries such as the Netherlands or Germany to policy factors. As we showed in section 4, the estimation of green employment in the EU that we have developed using the occupational approach is not correlated to some key green environmental indicators. To sum up, it is the authors' view that the indicators of green employment in Europe obtained applying the occupational-based approach do not appear suitable to gain a full and accurate understanding of the employment implications of the green transition.

## **6 Conclusions**

The green transition posits numerous challenges. Addressing climate change is an urgent problem that requires urgent and concerted global action. It requires also complex policy mixes which can have negative socio-economic effects, and therefore a good understanding of these socio-economic implications is essential to design the most appropriate policies. In this context, a major challenge is to correctly identify and quantify those workers that are involved in the green transition. As we have seen in this report, in recent years several approaches have emerged to measure the impact of the green transition on employment.

If we define green employment as employment that contributes to green outputs or processes, we can infer that labour itself cannot be intrinsically green. As we explained in section 2, what makes employment in some cases green is the fact that it contributes to outputs or processes which are intrinsically green. However, the occupational based approach to measure the implications of the green transition for labour markets, which has become the most popular one in the academic literature and among institutions, follows a different and, in our view, misguided logic. Since green employment relates to green outputs and processes, it simply cannot be measured by classifying occupations by their greenness. This is the main fundamental problem with the occupational based approach.

Further to these conceptual issues, there are several methodological problems with this approach. We have discussed these problems in section 3.2, taking as a basis the most commonly used framework in the occupational approach (the one developed in the US by O\*NET, but applied widely in Europe and other countries): a lack of internal consistency, a set of dubious and arbitrary choices, imprecision and noise resulting from the necessary aggregation of the occupational classification to use it for employment analysis, and – last but not least – a time and place specificity (US in 2009) that makes it unsuitable for a good understanding of the employment implications of the green transition in Europe in 2024. However, the underlying conceptual problems persist even if we deal with the methodological problems.

Because of these shortcomings, we believe that the occupational approach is not a robust, and we have shown in section 4 that estimations developed under the occupational approach do not appear to have a reasonable empirical counterpart in environmental performance on the basis of the indicators selected. This is to be expected since, as we argued, the approach does not measure employment contributing to green outputs and processes but just reflects shifts in the occupational structure. Furthermore, as we have shown in section 5, the approach does not seem to comply in our view with some important quality standards for the development of indicators. For these reasons, the occupational approach does not seem to be, in our view, the most promising way forward to analyse the employment implications of the green transition in a comprehensive way.

On the other hand, the definition of green jobs as per the occupational approach could be more successfully employed to identify occupations whose content, either in terms of required tasks or available skills, is relevant for the twin transition. For example, it could be employed to map the specific set of skills that are required in a given occupation that is essential for the green transition (e.g. solar engineer), helping to ensure that workers are equipped with the necessary expertise to support the shift to a low-carbon economy. This could also facilitate targeted education and training programs, allowing for a more efficient alignment between labour market needs and the growing demand for green skills. The definition of the green content of an occupation is also relevant to the

analysis of job quality, which is an explicit goal pursued by the European Union over the next decade.

Other existing methods are methodologically robust but too narrow and still underdeveloped for comparative international analysis. For example, the Eurostat approach comprises industries that are relatively easy to define and distinguish with available data, typically focusing on environmental protection activities, related to reducing and preventing greenhouse emissions and other harmful environmental impacts, and resource management activities, which are usually related to energy (Eurostat, 2021). The European Environment Agency uses this approach to produce a set of indicators of employment in the environmental goods and services sector. However, we do not believe that this approach should be taken as reference or prioritised due to its important inherent constraints. Indeed, the approach is quite narrow as the indicators generated through it “pertain to easily identifiable, existing industries and jobs while ignoring larger but often more diffuse developments in the economy in general and the labour market in particular that are associated with low-carbon and environmentally sustainable activities” (Bowen et. al. 2019). A broader approach would potentially need to look at both green processes and products, deriving from that analysis the necessary implications for employment, but it is outside the scope of this report to develop in detail such a potential alternative.

The employment implications of the green transition are significant, and they should be well understood and closely monitored. Further efforts are needed in both research and policy to identify and agree on a robust, comprehensive approach to understand these implications. These efforts should be based on a comprehensive mapping of alternative methods which is currently ongoing in the JRC. Such alternatives will be further looked at to propose possible ways forward at the EU level in the future.

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