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SUMMARISING STUDIES ON THE IMPACTS OF CLEAN TRANSITION POLICIES ON EMPLOYMENT IN THE EUROPEAN UNION AND EU JUST TRANSITION POLICIES

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DRAFT

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Executive Summary

This report reviews ex-post empirical evidence on the labour market impacts of clean transition policies, focusing on Europe and advanced economies where results are mostly externally valid. Firstly, the report provides a concise overview of the empirical strategies employed in the reviewed literature, highlighting the methodological approaches through which the cited studies identify and quantify policy impacts. Then, it provides an overview of the evidence. Across instruments, the central finding is that employment effects are heterogeneous but generally modest: most policies do not cause major job losses, though transitional costs emerge for specific industries, regions, and worker groups. Policy design, revenue recycling, and skills support strongly shape outcomes.

Studies of the EU Emissions Trading System (EU ETS) demonstrate that the scheme reduced emissions substantially while leaving aggregate employment largely unaffected (Dechezleprêtre, Nachtigall & Venmans, 2018). Employment declines were observed in a few carbon-intensive sectors such as paper, mining, and utilities, and regional analyses show modest losses in provinces with high ETS exposure (Hernandez-Carballo et al., 2025). These findings suggest that ETS achieves decarbonisation goals at low employment cost (low impact on employment), though vulnerable industries and less developed regions face adjustment challenges. For carbon and environmental taxes, evidence from the UK, Sweden, British Columbia, and cross-European studies confirms that emissions reductions can be achieved without damaging overall employment (Martin et al., 2014; Andersson, 2019; Metcalf & Stock, 2020). Revenue recycling plays a decisive role: in British Columbia, tax cuts funded from carbon revenues boosted service-sector jobs (Yamazaki, 2017), although some groups such as less-educated male workers experienced temporary unemployment and wage losses (Yip, 2018).

Renewable energy deployment has been a major source of net job creation. EU-wide modelling estimates that the transition generated around 530,000 net jobs, concentrated in manufacturing, services, and construction, though with uneven distribution across member states (Markandya et al., 2016). Local case studies highlight that most opportunities are temporary construction jobs, while community-owned projects provide more durable benefits (del Río & Burguillo, 2009; Susser & Kannen, 2017). Broader welfare gains are also evident, with renewable deployment lowering electricity prices and raising consumer surplus [1](Liski & Vehviläinen, 2020; Petersen et al., 2024). Feed-in tariffs (FiTs), central to Germany's Energiewende, initially stimulated large employment gains but later generated mixed results as imports displaced domestic production (Pahle et al., 2016; Pestel, 2019). International evidence is similarly varied, with Portugal and Japan experiencing job creation, Ontario showing net losses, and China revealing gender-differentiated effects.

Investment subsidies and tax credits also play a critical role in job creation and firm upgrading. Evidence from Germany and Italy demonstrates that such incentives are particularly effective

[1] Consumer surplus refers to the welfare gain that consumers obtain when they can purchase goods or services at a market price lower than the maximum amount they would have been willing to pay. It is commonly used in policy evaluation to capture the benefits to consumers from lower prices, improved access, or enhanced choice.

for small firms and disadvantaged regions, significantly increasing investment and employment (Lerche, 2025; Cingano et al., 2023). Spain's environmental investment credits likewise supported green job creation, though sudden policy shifts created short-term disruptions (Tchorzewska, 2024). These measures also stimulate innovation and skills development, strengthening long-run employment gains.

Eco-innovation represents another pathway through which the transition generates jobs. Innovative production processes especially cleaner production technologies are consistently associated with stronger employment effects than incremental end-of-pipe solutions (Biggi, Mina & Tamagni, 2023; Zhang et al., 2024). Studies show that product innovations and voluntary eco-innovations create more green jobs than compliance-driven process changes (Cecere & Mazzanti, 2017; Elliot et al., 2024). However, concerns remain regarding the quality of green jobs, with evidence from Portugal indicating weaker safety protections and higher accident rates compared to conventional employment (Moreira et al., 2018).

Other regulatory and price-based measures show mixed but generally modest employment impacts. Command-and-control regulations are effective in reducing emissions and have mostly neutral net effects (Cole & Elliot, 2007; Kahn & Mansur, 2013). Nevertheless, transitional costs for workers can be substantial: in the United States, Clean Air Act compliance reduced regulated workers' lifetime earnings by around 20% (Walker, 2013). Rising energy prices similarly produce sector-specific pressures, with losses concentrated in energy-intensive industries, though firms often adapt through efficiency measures and self-generation (Marin & Vona, 2021; von Graevenitz & Rottner, 2024). The phase-out of fossil fuel subsidies appears less disruptive than carbon taxation, generating fiscal space and competitiveness gains (De Bruin & Yakut, 2023), but mine and plant closures still impose acute local unemployment shocks (Mark et al., 2024).

The literature also underscores that employment outcomes are highly sensitive to the design, sequencing, and supporting measures that accompany environmental interventions. Well-designed policy mixes can deliver net job gains, while poorly implemented measures risk transitional unemployment, regional disparities, and widening inequality. Based on the evidence, two sets of actions are critical: maximising positive outcomes and minimising negative or unequal effects.

To fully harness the job-creation potential of the transition, governments should pursue integrated strategies that combine fiscal, innovation, labour market, and regional interventions. Revenue recycling from carbon and environmental taxes is particularly effective: channeling revenues into labour tax reductions, investment incentives, R&D support, and upskilling mitigates regressive effects while boosting green employment, as illustrated by British Columbia's revenue-neutral carbon tax. Targeted and stable investment subsidies and tax credits—especially for cleaner production technologies and SMEs—stimulate eco-innovation and productivity growth, while avoiding abrupt phase-outs is essential to preserve policy credibility. Careful sequencing of policies also matters: a "carrot-first, stick-later" approach, where subsidies precede carbon taxes, strengthens adoption of green technologies and employment spillovers. Predictable renewable energy deployment, embedded in community-owned or locally anchored projects, ensures durable jobs and domestic economic benefits while avoiding boom-bust cycles. Complementary labour market and skills policies—reskilling, targeted training, and certification—are indispensable to smooth reallocation and prevent skill mismatches. Industrial and regional strategies, including place-based investments through the EU's Just Transition Mechanism, and support for SMEs and innovation ecosystems, further spread the benefits of transition across regions and groups.

At the same time, proactive measures are required to mitigate transitional costs. Fossil-intensive sectors and regions face concentrated job losses, requiring Just Transition support packages that combine income support, retraining, job search assistance, and redeployment pathways into low-carbon industries. Safeguarding job quality is also essential: green jobs must meet occupational health, safety, and bargaining standards to avoid risks of low wages or precarious conditions. To prevent inequalities, green employment programmes should embed gender and inclusion targets, ensuring equal access for women, youth, and underrepresented groups. Policy stability and smoothed timelines reduce the volatility of green employment, while climate strategies must address carbon leakage risks through e.g. border adjustment mechanisms and competitiveness policies that secure domestic employment.

In sum, clean transition policies achieve substantial environmental benefits with limited aggregate employment costs. Where job losses occur, they are concentrated in carbon-intensive sectors, disadvantaged regions, and vulnerable worker groups. By combining targeted incentives and revenue recycling with measures to protect communities and workers at risk, governments can turn the green transition into both an environmental and social success.

I. Chapter 1: Background and motivation

Understanding the employment effects of clean transition policies is essential to ensuring that environmental and climate goals translate into inclusive, resilient, and sustainable economic outcomes (OECD, 2024; European Commission, 2025). While considerable research has evaluated the effectiveness of climate policies—especially in reducing emissions and improving energy efficiency—their labour market effects remain less systematically explored. Yet, employment is a central dimension of social and economic well-being, particularly in a context of structural transformation and growing inequality across regions and labour market groups.

As the European Union moves forward with ambitious clean transition strategies—including the Green Deal, the European Climate Law, the Fit for 55 package, and national-level decarbonisation plans- there is also a growing EU Just transition policy framework including the Council Recommendation on ensuring fair transition towards climate neutrality, the Just Transition Mechanism and Fund, the Social Climate Fund and the Clean Industrial Deal including the Quality Jobs Roadmaps which aims to improve the way to anticipate and manage employment opportunities and risks of climate policies. (Council of the European Union, 2022). At the heart of this challenge is the imperative to ensure a just transition—a concept first articulated in the 1970s by labour unions and social movements in response to the employment implications of new environmental regulations. As emphasized by Godinho (2022), contemporary policy and academic debates have further developed the framework, often emphasizing three dimensions of justice: distributional (who bears the costs and receives the benefits), procedural (who participates in decision-making), and recognitional (how different interests and identities are acknowledged). While widely referenced in principle, empirical evaluations applying the just transition framework remain limited, particularly at the firm level.

A better understanding of how firms make employment decisions under the influence of environmental policies is therefore critical. These decisions—whether to hire, retain, lay off, or relocate workers—are shaped by both internal firm-level dynamics (such as size, productivity, access to capital, or technology adoption) and external conditions, including product demand, energy prices, regulatory pressure, and fiscal incentives (Horbach & Rennings, 2013). Firms do not operate in a vacuum; they respond to signals from the broader macroeconomic and policy environment. As such, clean transition policies—ranging from carbon pricing to renewable energy subsidies—may affect employment not only directly (through cost and compliance effects), but also indirectly, by influencing investment behaviour, innovation trajectories, and competitiveness.

Moreover, these policies are rarely implemented in isolation. In practice, they function as part of broader policy mixes, combining market-based instruments (e.g., carbon taxes or emissions trading), regulatory standards, and public support schemes (e.g., investment subsidies, feed-in tariffs, or tax credits). These interactions can be synergistic or conflicting (Stechemesser et a, 2024), even when analysed in sequence (Tchorzewska et al., 2025). Understanding how such interactions play out at the firm and sectoral levels is crucial for identifying optimal policy combinations—those that both accelerate decarbonisation and safeguard or enhance employment.

Against this backdrop, this report examines the employment impacts of clean transition policies in the European Union, with a particular focus on ex-post empirical evaluations. It synthesizes available evidence on how individual clean transition policies and policy combinations influence employment across sectors, regions, and firms. It identifies the aggregate impacts, the distributional impacts across sectors, but also effects on vulnerable groups. It aims to inform the design of labour-sensitive climate policies that promote environmental and social goals simultaneously, as well as the accompanying social and employment policies.

This report complements previous studies and analyses run by the European Commission aiming at better understanding labour market dynamics and investment needs in the context of the transition towards climate neutrality. [2] The Directorate-General Employment, Social Affairs and Inclusion (DG EMPL) and the Joint Research Centre (JRC) of the European Commission have a long-standing cooperation in this respect in the context of the AMEDI projects "Assessing and monitoring employment and distributional impacts of the Green Deal"[3], which combine macro-economic modelling work and micro-economic modelling approaches, with the ultimate goal of enhancing the Commission's modelling and analysis capacities for assessing and monitoring employment, social and distributional impacts of climate, energy and environmental policies.

This report is organized as follows. Chapter 2 gives an overview of the tools and methodologies used in the empirical literature assessing the impacts of clean transition policies in the EU labour market. Chapter 3 provides a synthesis of the empirical findings, dividing the literature into separate aggregated sub-groups: carbon pricing, renewable energy deployment, energy prices and fossil fuel subsidy phase-outs, biodiversity, policy-mixes. Chapter 4 aims at deriving useful policy implications for maximizing positive effects and minimizing potential negative impacts of clean transition policies, while Chapter 5 concludes.

II. Chapter 2: Tools and methodologies used in assessing the impacts of clean transition policies in the EU labour market

The ex-post empirical evaluations of the impacts of clean transition policies on employment in the European context have employed a wide range of methodological approaches. These vary depending on data availability, policy type, country context, and the specific employment outcomes under investigation (e.g. number of employees, unemployment level, job creation, wage changes, relocation across countries, plant exit). Broadly, the methods fall into two main categories: macroeconomic modelling approaches and econometric/quasi-experimental

[2] See for instance European Commission: Directorate-General for Employment, Social Affairs and Inclusion, Fulvimari, A., Garaffa, R., Kunertova, L., Van Der Vorst, C. et al., Estimating labour market transitions and skills investment needs of the green transition – A new approach, Publications Office of the European Union, 2025, https://data.europa.eu/doi/10.2767/4332366

[3] Assessing and Monitoring Employment and Distributional Impacts (AMEDI) - European Commission

empirical methods. Each comes with distinct strengths and limitations, offering complementary insights.

A. Macroeconomic Modelling Approaches

Macroeconomic models—especially Computable General Equilibrium (CGE) models, Input–Output (IO) models, and multi-regional hybrid models—have been widely used to assess the aggregate, economy-wide employment impacts of green policies. Within those in the literature review carried out, a few were used more commonly than others.

Input–Output (IO) models are particularly useful for estimating the direct, indirect, and induced employment effects of environmental investments or renewable energy deployment. For example, Markandya et al. (2016) used a multi-regional IO model to assess the employment impacts of the EU's energy transition, showing positive net effects both within and outside the EU due to supply chain interactions.

Hybrid approaches, such as those employed by Ortega et al. (2015) and Vachon and Meunier (2023), combine IO analysis with additional features like trade adjustments, skill requirements, or life-cycle stages of technology deployment. These models allow for more granular projections and sectoral disaggregation (e.g., by skill, gender, or occupation).

CGE models, used for example by Böhringer et al. (2012) in the Canadian context, offer a more dynamic perspective by simulating equilibrium adjustments in the economy in response to green policies. They can incorporate price responses, behavioural changes, and substitution effects across factors and sectors, but often rely heavily on assumptions and calibration parameters.

These models, while well-suited for scenario building and ex ante policy design, they unfortunately depend on structural assumptions and do not evaluate what actually happened after a policy was implemented. That is why, this summarizing report focuses mainly on ex-post empirical evaluations.

B. Quasi-Experimental and Econometric Approaches

Evaluating the effectiveness of clean transition policies requires methodological approaches capable of credibly **identifying causal impacts in the absence of randomized trials**. Researchers rely on quasi-experimental and observational econometric methods (simple OLS, spatial econometric models or others) to assess the effects of environmental measures on firms, regions, and economies, with the choice of method shaped by policy design, data availability, and the nature of the outcomes being studied. Scholars try to rely on sudden policy changes, eligibility criteria and other quasi-experimental settings. Very often they also combine methods together to arrive at more robust findings.

Difference-in-Differences (DiD) and panel fixed effects models are among the most widely applied approaches. These techniques estimate the effect of a policy by comparing changes in outcomes over time between treated and untreated units, while accounting for unobserved, time-invariant characteristics. They are widely used due to their transparency and relatively modest data requirements. For example, Martin et al. (2014) assess the impact of the UK's Climate Change Levy using a DiD framework combined with Instrumental Variable (IV) estimation, while Dechezleprêtre et al. (2018) apply matching and DiD to evaluate the European Union Emissions Trading System (EU ETS). The main limitation of these methods lies in the parallel trends assumption, which requires that treated and control units would have evolved similarly in the absence of the policy. Staggered implementations or time-varying confounders can violate this assumption and bias the results.

Instrumental Variable (IV) strategies provide another avenue for causal identification when policy participation is endogenous to firm or regional characteristics. A valid instrument must influence treatment while affecting outcomes only through that treatment. For example, Yip (2018) and Alecke and Mitze (2023) employ IV approaches to address selection into environmental policy programs and to estimate impacts on firm performance. IV methods are particularly useful in contexts where greener or more productive firms are disproportionately likely to adopt or qualify for environmental measures. However, their reliability depends on the strength and validity of the chosen instrument, and resulting estimates often reflect Local Average Treatment Effects, which may not be generalizable.

Regression Discontinuity Design (RDD) is a quasi-experimental method that exploits cut-off rules—such as thresholds in policy eligibility—to estimate causal effects. Units just above and below the threshold are assumed to be similar, so differences in outcomes can be attributed to the treatment. While this report does not cite classic RDD applications in the context of green transition policies and employment, Kahn and Mansur (2013) apply a geographic RDD to study environmental regulation, and Bronzini & Iachini (2014) use it to evaluate the effects of R&D subsidies on firm investment.

Matching methods, such as Propensity Score Matching (PSM) and Coarsened Exact Matching (CEM), are also frequently employed to improve comparability between treated and untreated units. By aligning firms or regions on observed characteristics, matching reduces selection bias and enhances the credibility of subsequent regressions or DiD estimations. Wolverton et al. (2022), for instance, use CEM to examine the employment effects of Renewable Portfolio Standards in the United States. While useful, matching approaches can only account for observed confounders, leaving the potential for unobserved heterogeneity to bias results.

Synthetic control methods have become increasingly influential for policy evaluations at the regional or national level. By constructing a data-driven counterfactual that replicates the pre-policy trajectory of the treated unit, this approach isolates the impact of the intervention from broader macroeconomic trends. Andersson (2019), for example, uses synthetic controls to evaluate the effects of Sweden's carbon tax on emissions. Synthetic controls are particularly valuable when only one or a few units are treated, as in national-level policies, and do not require the parallel trends assumption. However, they demand long pre-treatment periods, a rich donor pool of comparison units, and rely on permutation-based inference rather than standard statistical tests.

Categorical treatment matching, have been more recently used by researchers and used for policy-dosage models evaluations. They are especially useful to study the impact of complex policy mixes and heterogeneous policy intensity. These methods allow for multiple levels of treatment and can allow for impact assessment between different doses of treatment. Tchorzewska et al. (2022) use such models to assess the effects of environmental policy mixes on firm productivity through eco-innovation investment. They look not only at the policy mix between environmental taxation and investment subsidies but also for different doses of those environmental policy instruments.

Sequencing analysis has also gained traction, with Lenihan et al. (2022) and Tchorzewska et al. (2025) applying it to evaluate how the order and combination of general innovation and environmental policies influence technology adoption, respectively. These approaches allow nuanced insights into policy complementarities and timing effects but demand extensive data and careful modeling assumptions.

Econometric models, including panel OLS and spatial econometric frameworks, continue to play a role in the evaluation of environmental policies, particularly in capturing cross-regional spillovers and diffusion effects. Spatial models are valuable in studying green technology adoption, which often spreads geographically. Nonetheless, when used in isolation, these approaches are limited in their ability to support causal claims – they mostly provide information about strong correlations - and are best combined with quasi-experimental techniques to strengthen inference.

Qualitative research methods are often employed when high-quality panel data are unavailable or when researchers seek to capture social dynamics that quantitative approaches alone may overlook. These methods typically rely on surveys, interviews, focus groups, and case studies to explore how communities experience and perceive policy interventions. While qualitative evidence cannot establish causality in the econometric sense, it provides crucial insights into mechanisms, distributional effects, and the lived experiences of affected groups. For example, Cormack and Kurewa (2018) and Ortega et al. (2015) show that renewable energy deployment does not always generate stable, high-quality employment, with many jobs proving short-lived or precarious. Conversely, community-owned renewable projects have been found to produce more durable local benefits. By complementing econometric evidence with local perspectives, qualitative research enriches our understanding of the broader social and economic impacts of environmental policies.

In summary, each method entails trade-offs between data demands, interpretability, and causal credibility. Difference-in-Differences and fixed-effects models remain the workhorses of environmental policy evaluation, especially in settings with clear treatment and control groups. Increasingly, the most robust studies combine multiple methods, leveraging their complementary strengths to deliver credible evidence for evidence-based clean transition policy.

Chapter 3: Impacts of various clean transition policies on employment in developed economies – evidence by policy area

This section focuses on studies conducted in Europe and in advanced economies such as the United States, Canada or China, where external validity is more likely to be present. Clean transition policies were segregated into several categories, within which we deal with the literature one by one[4].

A. Carbon pricing (ETS, Carbon and environmental taxes)

1. Emissions Trading Schemes (ETS)

Ex-post evaluations of the employment effects of emissions trading schemes (ETS) are increasingly available and quantitatively rich, although they face certain empirical limitations—particularly regarding internal and external validity. As of 2025, there are 36 countries operating purely national ETSs. Overall, the empirical literature presents a mixed picture regarding ETS impacts on employment, underlying significant heterogeneities present.

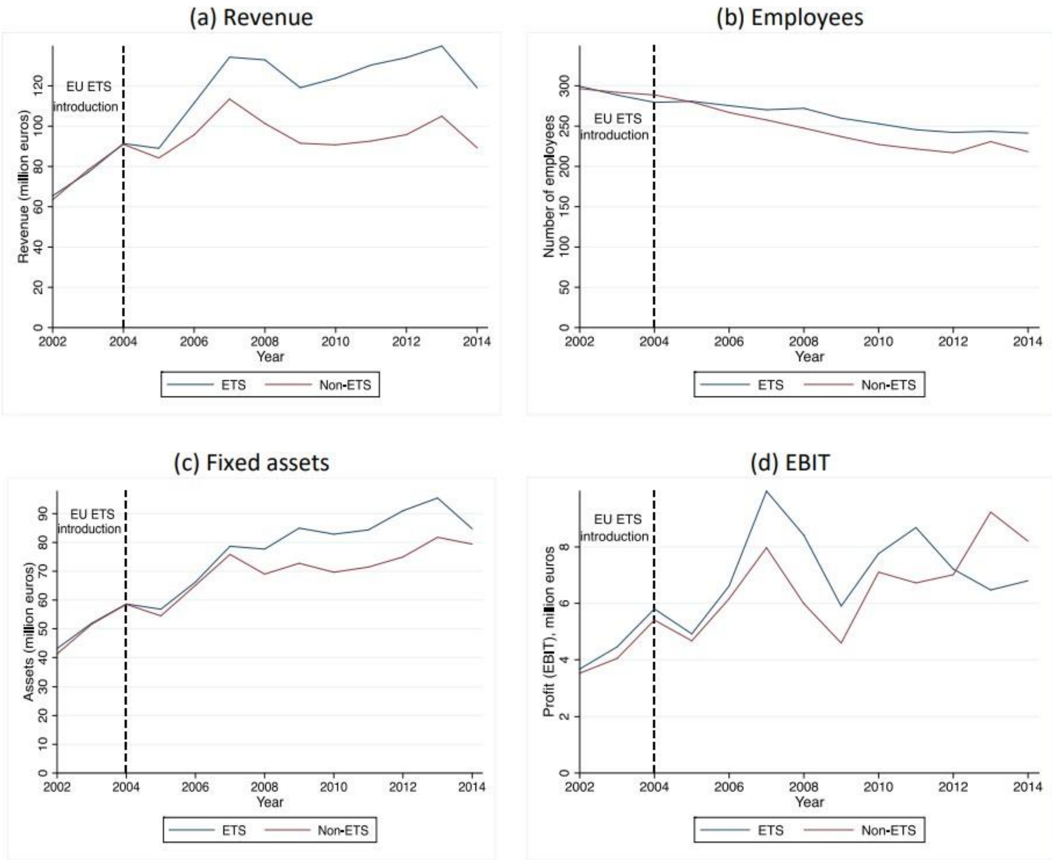
A relatively recent study, using data from Germany by Gupta, Shah, Kaul, and Gupta (2021) used a combined DiD and matching approach with a stochastic production frontier framework to assess ETS effects on manufacturing firms. Their results showed **no significant overall employment effects**, although some sectors—particularly paper manufacturing—exhibited modest improvements in economic performance. In China, Zhang and Zhang (2020) evaluated the country's 2007–2017 ETS pilots and found a **2.4% increase in rural employment**, attributing this to ETS-induced support for forestry-related economic activities.

The emergence of bigger administrative datasets has allowed for broader, more representative assessments. Dechezleprêtre, Nachtigall, and Venmans (2018) examined firm-level data across all EU ETS countries from 2005–2012 using a matching strategy that compared regulated and unregulated firms. They found that CO_2 emissions fell by 10%, yet **no negative employment effects** were detected. In fact, some regulated firms saw **increases in revenues and fixed assets**, consistent with investments in carbon-saving technologies and thus with the Porter's Hypothesis[5], as can be seen in Figure 1.

[4] Building upon the literature review carried out by Godinho (2022).

[5] Porter's Hypothesis suggests that well-designed environmental regulations can stimulate firms to innovate in ways that not only reduce pollution but also improve efficiency and competitiveness. Rather than creating only compliance costs, regulation can encourage technological and organizational improvements that offset those costs and, in some cases, enhance productivity and growth.

Figure 1. Impacts of the introduction of the EU-ETS on ETS and non-ETS firms in Europe between 2002-2014 on revenue, employees, fixed assets and earnings before interest and taxes (EBIT).



Note: Graphical representation of the difference-in-difference approach. The effect of the EU ETS is assessed statistically in the regressions by comparing the different trends between matched ETS firms and non-ETS firms.

Source: Dechezlepretre et al (2018)

A more recent and very comprehensive study by Kalantzis et al., (2025) merged ORBIS[6] data with OECD environmental policy stringency indicators and EU Allowance (EUA) prices, covering roughly 1 million firms across 12 EU countries (1,870 ETS firms) from 1995–2020. They found **negligible average employment effects.** Interestingly, during periods of high EUA prices, regulated firms experienced economic strain, and indirect effects were observed in non-regulated firms—likely reflecting higher input costs.

[6] ORBIS is a large international firm-level database compiled by Bureau van Dijk. It provides standardized information on the financial accounts, ownership structures, industry classifications, and geographic locations of millions of companies worldwide. The dataset is widely used in economic and policy research because it enables cross-country comparisons, the study of firm behavior and performance, and analysis of issues such as productivity, innovation, and taxation.

One of the earliest European studies was conducted by Wagner et al. (2014), who analyzed a rich plant-level administrative dataset from French manufacturing sectors, covering Phase I (2005–2007)[7] and Phase II (2008–2009/10)[8] of the EU ETS. They found that participation in the ETS led to an average **7% decline in employment in regulated firms**, while value-added and exports were largely unaffected. Emission reductions were achieved mainly through fuel switching and energy efficiency improvements. Their analysis employed a semi-parametric difference-in-differences (DiD) strategy with nearest-neighbour matching on emissions, employment, and carbon intensity—a robust design for isolating treatment effects. Similarily, Hanoteau and Talbot (2019), using Canadian firm-level data and a similar DiD approach, estimated a **6.8% employment decline** in regulated firms.

At the regional level, Hernandez-Carballo et al. (2025) used a synthetic difference-in-differences approach on a panel of 900 European provinces (2008–2020) to evaluate Phase III of the EU ETS. They have investigated how implementation of the program affected local communities in terms of employment, gross value added and productivity. Their results indicate that provinces with the highest ETS exposure (quintile 5) **saw a 1.6% decline in total employment, and a 3.6% drop in employment in carbon-intensive sectors specifically**. The strongest impacts were observed in **mining and quarrying, utilities** (electricity, gas, steam, and AC supply), and **water supply**. The regional breakdown suggests disparities were rather mild. It seems that in less developed regions, negative employment impacts were concentrated in construction and agriculture. In mid-developed regions, losses were mostly in carbon-intensive sectors, while in in highly developed regions, modest negative effects also appeared in manufacturing employment.

In summary, the ex-post literature on ETS and employment shows heterogeneous and generally modest impacts. While some studies detect small negative effects, others find no significant impact, and in certain contexts, effects may even be positive. When employment losses occur, they are typically limited to carbon-intensive industries or specific regions, while broader labour market impacts remain mild.

2. Carbon and environmental taxes

Compared to ETS, carbon and environmental taxes are more widespread. As of May 2025, at least 43 countries operate national-level carbon taxes. The empirical literature on their employment effects is similarly mixed but generally suggests neutral or modest impacts.

The first European study to assess employment effects was Martin et al. (2014), focusing on the UK's Climate Change Levy (CCL)—an energy tax with differentiated rates across fuels. Firms that signed Climate Change Agreements (CCAs) paid only 20% of the standard rate if

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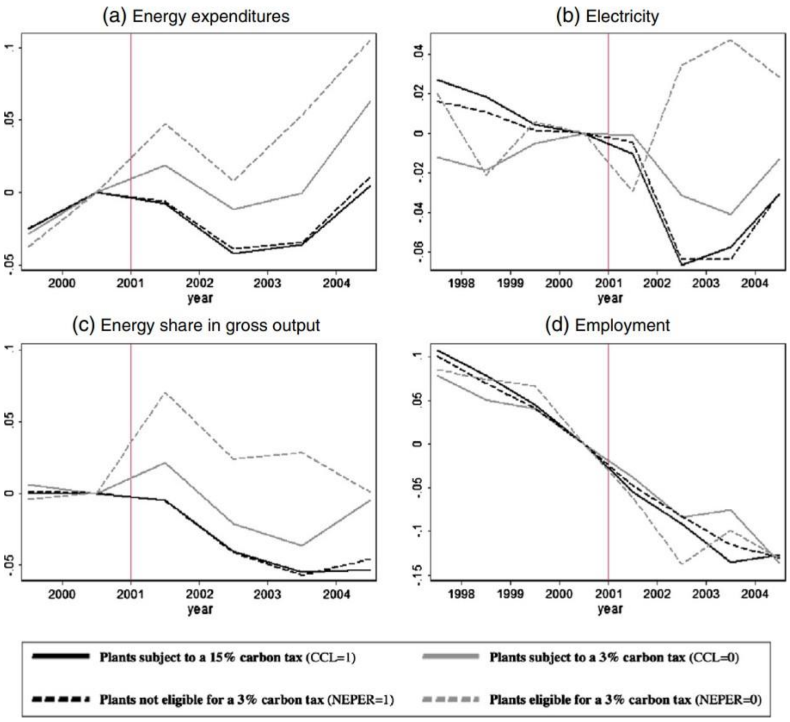
[7]The pilot phase of the EU ETS established the system's basic architecture, with allowances allocated almost entirely for free by Member States. While it successfully created the first large-scale carbon market, it was characterized by an oversupply of permits and limited trading volumes, which drove allowance prices close to zero by the end of the phase.

[8] Building on lessons from Phase I, Phase II tightened the emissions cap, expanded coverage to additional gases and sectors, and aligned with Kyoto Protocol commitments. Although free allocation still dominated, monitoring and reporting were improved, and the system experienced higher and more volatile allowance prices, reflecting increased scarcity and stronger compliance obligations.

they committed to energy efficiency targets. Using a DiD approach with plant fixed effects and an IV for CCA eligibility, the authors found that the policy reduced electricity use by 22.6% and energy intensity by 18.1%, corresponding to CO_2 reductions of 8.4–22.4%. Importantly, **employment, revenue, total factor productivity, and plant exit rates were not significantly affected (Figure 2)**.

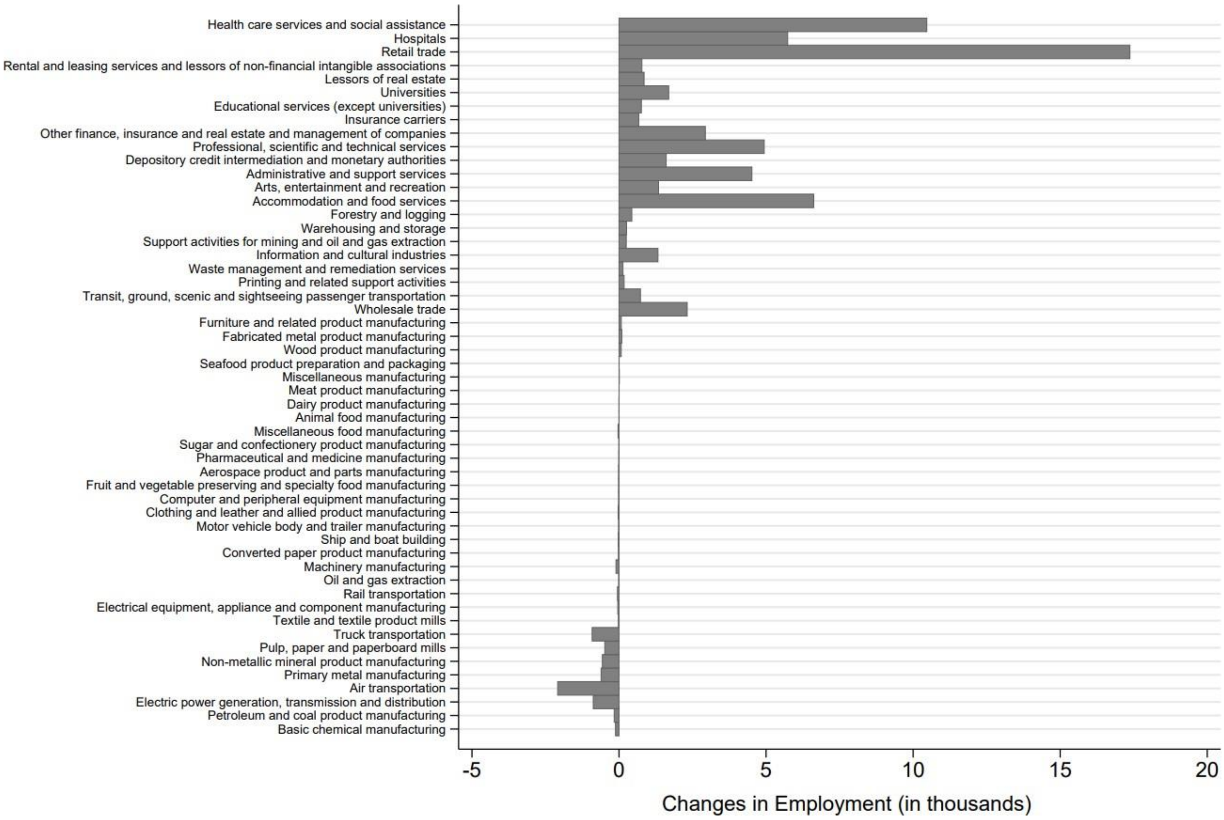
Figure 2. Impacts of a carbon tax in the UK on energy expenditures, electricity, energy share in gross output as well as employment between 1998 and 2004 (with coefficients on the Y-axis).



Source: Martin et al (2014)

However, evidence from British Columbia's revenue-neutral carbon tax (2008–2013) is particularly informative. Yamazaki (2017) found a **0.74% increase in annual employment**. He used industry-level DiD and compared British Columbia to the rest of Canada. This positive effect likely **stems from recycling tax revenues into labour and corporate tax cuts**, which **supported job creation in service sectors like healthcare, retail, and education (Figure 3)**. However, carbon-intensive and trade-sensitive industries experienced employment declines – such as air and truck transportation, power generation and transmission, metal, non-metal, pulp and paper - those reductions are not as large as the increases in other sectors. At the macro level, Köppl & Schratzenstaller (2023) confirmed this, by reviewing ex-post carbon tax studies from the EU region and Canada and concluded that most carbon taxes do not harm employment, often showing neutral or slightly positive effects when they are recycled to reduce labour taxes.

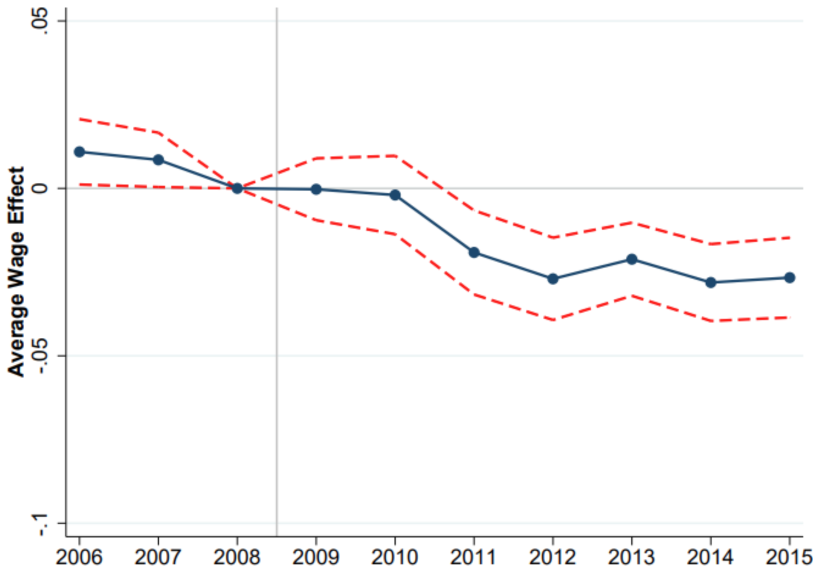
Figure 3. Changes in employment at 10 USD/ton of CO2.



Source: Yamazaki (2017)

In fact, to our knowledge, there is only one study that showed a negative effect of carbon tax on employment, in contrast to Yamazaki (2017) it did not account for the recycling of the carbon tax. Yip (2018) studied the revenue-neutral British Columbia carbon tax (2008–2013) using Canadian Labour Force Survey microdata and a province-level difference-in-differences with Coarsened Exact Matching. He found that the tax **increased unemployment by 1.3 percentage points relative to other provinces,** with **stronger effects for lower-educated and male workers (up to 2.4 pp)**. **Average hourly wages fell by 2.4%, concentrated among new hires**, whose starting wages declined by 4.4–4.9%. Impacts were **most pronounced in energy-intensive industries**, and wage declines persisted longer (Figure 4.), particularly for new hires (Figure 5.) than the initial unemployment increase (Figure 6.). Importantly, we can see **unemployment returning to its initial level after 6 years.**

Figure 4. The dynamics of the average wage effect between 2006-2015 (July 1st 2008 the tax was introduced – the vertical gray line).

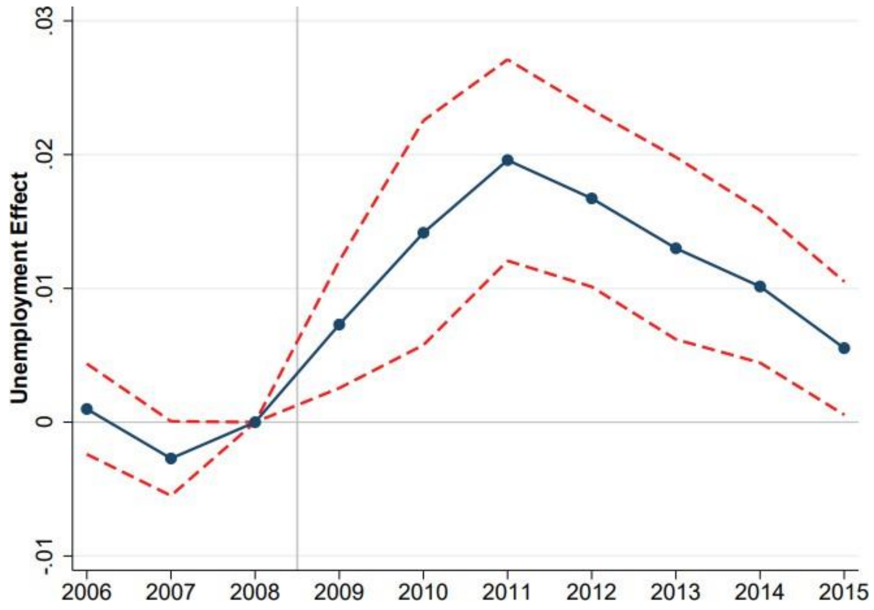


Source: Yip (2018)

Figure 5. The dynamics of the average hiring wage effect between 2006-2015 (July 1st 2008 the tax was introduced – the vertical gray line)

Source: Yip (2018)

Figure 6. The dynamics of unemployment effects between 2006-2015 (July 1st 2008 the tax was introduced – the vertical gray line).



Source: Yip (2018)

Renewable energy deployment, renewable energy support (via feed-in-Tariffs and Subsidies/tax credits)

1. Renewable energy deployment

A growing body of empirical literature examines the employment and welfare impacts of the European Union's transition towards renewable energy and reduced carbon intensity.

a. Net employment effects of the clean transition

Markandya et al. (2016) conducted the first comprehensive analysis of the net employment impacts of the EU's energy transition, which involved shifting from carbon-intensive energy sources toward natural gas and renewables. Using a multi-regional input–output (IO) model covering the period 1995–2009, the authors found that the **transition generated 530,000 net jobs within the EU**—equivalent to approximately 0.24% of total employment in 2009—and an additional 645,000 jobs outside the EU, mainly due to supply chain effects.

However, the impacts were uneven across member states. The primary beneficiaries were Germany, Hungary, Italy, and Spain, while Ireland, Lithuania, France, and Czechia experienced net employment losses. The uneven distribution of employment effects across member states stems from a combination of **pre-existing energy dependencies, and integration into European and global supply chains**. Winners (Germany, Spain, Italy, Poland, Hungary) had either strong renewable industries or benefitted from natural gas transitions, while losers (Ireland, Lithuania, France, Czechia) were more reliant on carbon-intensive sectors or less connected to the renewable supply chain dynamics. Sectoral outcomes were similarly heterogeneous and we can observe the division of the sectors between "winners" and "losers". We can observe that the winners report much higher employment gains, than losers report employment losses. Sectors with the largest job gains included machinery and business services (159,000), electricity and supply (64,000), as well as construction, community and social services, and inland transport (approximately 40,000 each). While, sectors with job losses included mining and quarrying (−28,000), public administration (−10,000), and coke, refined petroleum, and nuclear fuel (−3,000 each).

A more recent study focused on the employment impacts of coal transitions alone (EC JRC, 2025) shows that Poland is the most negatively affected country experiencing 55% of the total potential employment in transition in direct terms, while 37% in terms of total indirect employment. Conversely, Germany is more substantially affected indirectly (28%) than directly (11%). More specifically, a Silesia region in Poland is expected to close around 90,000 jobs (5% of total employment) associated to coal based activities. The study uses a comprehensive CARMEN model developed by the European Commission's Joint Research Centre.

Connolly et al. (2016) adopted a hybrid approach that combines bottom-up survey data with top-down official statistics for Scotland (2004–2012). They reported overall positive green employment growth but highlighted that **green jobs** (defined as low carbon environmental goods and services – including a wide range of renewable, low carbon and environmental activities) **were more volatile than aggregate employment** (both green and non-green). This means they showed greater sensitivity to the business cycle and a slower recovery from the Great Recession. This suggests that the green sector remained more vulnerable to economic shocks than the broader labour market.

b. Welfare impacts of renewable energy deployment

The welfare implications of renewable energy expansion, particularly of wind power, have also been investigated. Liski and Vehviläinen (2020) examined the Nordic electricity market—characterized by high renewable penetration and energy storage potential[9]. They found that renewable deployment reduces electricity prices, which increases consumer surplus enough to offset the cost of subsidies. Specifically, a 10% market share of wind generation resulted in an approximately 40% reduction in consumer expenditure, effectively transferring surplus from existing producers to consumers.

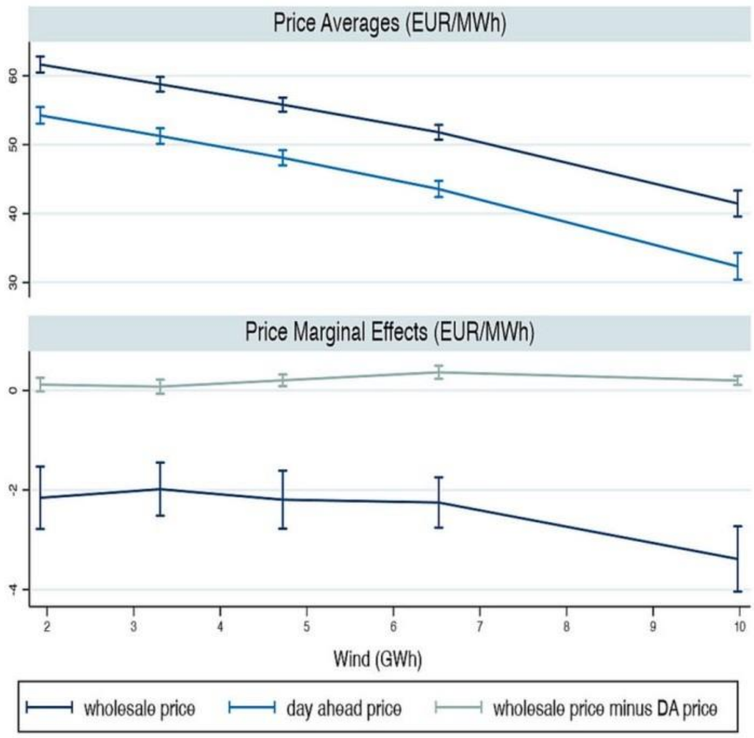
Abrell et al. (2019) evaluated welfare impacts of renewable energy deployment in Germany and Spain, estimating that the cost of abating 1 ton of CO_2 through Spanish wind power subsidies ranged from €82 to €258. While these subsidies imposed costs on producers, they benefited consumers. Since subsidies increased costs for electricity producers by reducing wholesale prices and revenues (merit-order effect), they benefited consumers by lowering

[9] High renewable penetration in the Nordic electricity market reflects the dominant role of hydropower and growing wind capacity, with renewables covering the majority of generation. The region's large hydropower reservoirs also provide significant storage potential, functioning as flexible "natural batteries" that balance intermittent supply and stabilize the system.

market prices and providing more stable, low-carbon supply. Similarly, Petersen et al. (2024) analyzed operational welfare effects of wind integration in the Spanish electricity market (2009–2018), leveraging hourly grid data and the 2014 regulatory reform that shifted subsidies from output-based feed-in tariffs to capacity-based payments. Their cost–benefit analysis combined consumer and producer surplus, benefits in terms of emission reductions, and subsidy costs, concluding **that wind power improved overall welfare despite intermittency costs**—primarily through lower consumer prices (Figure 7, Figure 8.), climate benefits, and stable returns to wind producers (Figure 8).

Although these studies focus on welfare rather than employment directly, they suggest how **cost-effective renewable deployment indirectly supports job creation** by enabling stable market expansion.

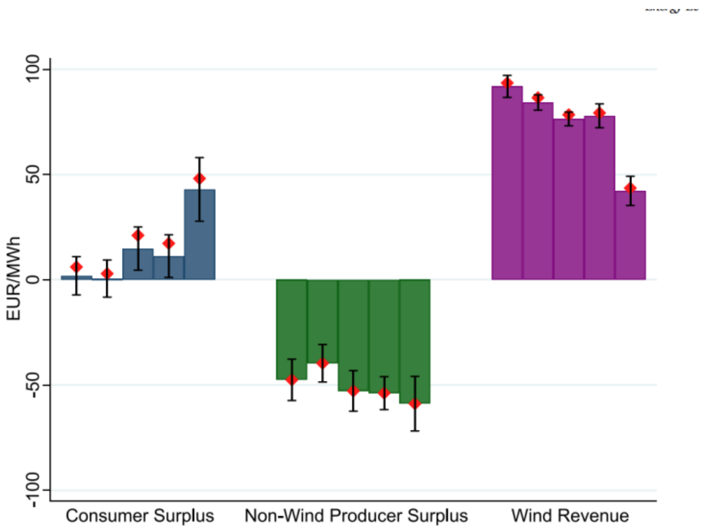
Figure 7. Consumer price averages and price marginal effects of electricity[10] in EUR/MWh after wind power deployment in Spain.



Source: Petersen et al (2024)

Figure 8. Cost-benefit analysis following wind power deployment in Spain, divided into consumer surplus, non-wind producer surplus and wind revenue.

[10] Price marginal effects of electricity refer to the change in electricity demand, supply, or welfare outcomes resulting from a one-unit change in the electricity price, holding other factors constant. In empirical studies, these effects capture how sensitive consumers, producers, or policy outcomes are to variations in marginal electricity prices.



Source: Petersen et al (2024)

c. Local employment and community impacts

Case studies emphasize that employment gains from renewable energy projects are often concentrated and unevenly distributed. For example, del Río and Burguillo (2009) analyzed three Spanish projects: a wind farm in Maranchón, a biofuel plant in Tarancón, and a photovoltaic plant in La Puebla de Montalbán. The wind farm generated 150 temporary construction jobs, 12 full-time operational jobs, and 5 indirect administrative jobs. The biofuel plant created 23 direct jobs, with additional benefits to local agricultural employment. The photovoltaic plant offered 10 short-term construction jobs and 1 operational job. In all cases, **higher skill levels (technical or university training) were required, underscoring the need for local workforce reskilling**.

Qualitative research similarly finds that renewable energy deployment does not always yield long-term, high-quality local employment. **Jobs may be short-lived, lower-wage, or less secure** (Cormack & Kurewa, 2018; Ortega et al., 2015). Conversely, **community-owned renewable projects tend to produce more durable local benefits**. Susser and Kannen (2017), through surveys and interviews in Germany, found that community renewables mitigate youth outmigration and enhance social cohesion by creating local opportunities. Lantz and Tegen (2009) reached similar conclusions in the US, showing that community wind projects generate construction and operational employment and broader regional economic development.

d. Broader positive impacts of renewable energy deployment

There exist also several studies which extend the analysis to broader context, using various methodologies. Wang et al. (2013) used an IO model to evaluate employment effects of Clean Development Mechanism (CDM) renewable projects in China's power sector. They reported **net employment gains of ~2.98 million jobs**, with losses of 99,600 direct jobs in traditional sectors offset by large indirect gains in manufacturing, supply chains, and services such as engineering, logistics, and maintenance.

Ortega et al. (2015) introduced a novel EU-wide methodology covering wind and solar PV deployment (2008–2012), integrating trade adjustments, dynamic learning, and life-cycle employment. They **confirmed overall positive employment effects but showed that five countries—Germany (39%), Denmark (12%), Italy (12%), Spain (10%), and the UK (6%)—captured most job creation, concentrated in manufacturing (56%) and installation (27%).**

Proenca and Fortes (2020) used panel data with country fixed effects for EU-28 (2000–2016), finding a **robust positive correlation between renewable deployment and national employment (0.48% for each 1% in renewable power generation capacity)**. They argued that renewable policies can support both climate objectives and labour market resilience, especially during economic downturns. Cerny et al. (2021) projected to 2050 using a multi-regional IO model (EU-27 + UK), disaggregated by sector, occupation, skill, and gender. Their 100% renewable scenario shows a **significant increase in labour demand in the first stage, concentrated in manufacturing, construction, and services**. However, they caution that **skills mismatches and gender imbalances will likely persist without targeted interventions.** They model that it would significantly increase labour demand in most EU27+UK countries, rising sharply at the beginning of the transition and peaking around 2030 followed by either a slight decline or a steady state continuation. The major 'winners' by 2050 would be Hungary and Cyprus (over eleven and ten times more jobs in electricity sectors than in 2015), followed by Latvia (over seven times), Lithuania (a little more than four times) and Belgium (approximately three times as many). Romania would be the only country that would lose jobs related to the electricity sectors by 2050 (-10 per cent). Countries such as Hungary, Cyprus, Latvia, Lithuania, and Belgium are projected to gain most because they start from lower renewable shares, require large employment-intensive investments in new infrastructure, and benefit from higher labor intensity in renewable generation compared to their existing energy mix.

Lastly, two recent studies deal with this topic using data from Portugal (Costa & Veiga, 2021) and Denmark (Gavard et al., 2025). Costa and Veiga (2021) use municipal data between 1997-2017 and estimate the local labour impacts of wind power investment. They find that there exist short-term effects during the construction phase. Specifically, they estimate **a decrease of**

0.05 pp in the total unemployment rate for each KW per capita installed. These effects are **confined to unskilled labour and male workers**. The spatial analysis suggests that workers are willing to commute up to 30km, but not migrate. Similarly, using Danish municipal data and quasi-experimental setup, Gavard et al (2025) find that the deployment of wind power contributed to the increase in personal income for entrepreneurs and reduced dependence on social benefits. They find only negligible effects on employment in some sectors, and the aggregate local employment does not change significantly.

This body of evidence collectively indicates that renewable energy deployment in Europe supports net job creation, delivers consumer welfare gains, and contributes to climate objectives, but also requires careful policy design to address regional disparities, labour market volatility, skills mismatches, and local benefit distribution.

2. Renewable energy support via feed-in-Tariffs

Among tools to encourage renewable energy deployment Feed-in tariffs (FiTs) represent one of the most widely implemented renewable energy support instruments worldwide. Consequently, several studies have examined their economic and labor market effects, though the scope and depth of empirical analyses vary significantly across countries.

a. Evidence from Germany

The richest body of research is situated in the German context, where FiTs were central to the Energiewende before the gradual shift to competitive auctions under the EEG[11] reform. Much of this literature is descriptive, but several ex-post empirical papers provide insights into the employment implications of FiTs. Empirical evidence varies in the results.

On one hand, Pahle et al. (2016) report mixed labor market outcomes. **While early phases of the German FiTs stimulated job creation, later stages saw a slowdown** as domestic solar panel production was increasingly displaced by cheaper imports, reducing local employment gains. Frondel et al. (2008) convey a similar message, arguing that high FiTs for solar electricity were inefficient and calling for an "immediate and drastic reduction" of their magnitude due to limited net job creation.

In contrast, some scholars find evidence of substantial green employment growth (Sopher, 2015; Pegels & Lütkenhorst, 2014). They document that **renewable energy jobs in Germany doubled between 2004 and 2013**, with the largest increases in solar PV, wind installation, operations, maintenance, and equipment manufacturing. However, these gains were accompanied by higher energy costs for energy-intensive industries and residential consumers. Pestel (2019) provides a comprehensive synthesis of the ex-post empirical literature. His review concludes that FiTs drove a rapid expansion of renewables and clear job creation in green sectors, yielding **overall positive but modest net employment effects**. Gains in renewable energy employment were partially offset by losses in other parts of the economy (mostly energy intensive).

b. Evidence from other countries

Behrens et al. (2016) applied a hybrid energy–economic input–output model to simulate counterfactual scenarios without FiTs. They estimate that Portuguese **FiTs created approximately 160,000 jobs between 2000 and 2010**, driven by the expansion of renewable energy capacity. Fraser & Chapman (2018) employed a qualitative approach to study the role of FiTs in supporting Japan's mega-solar plant boom. They found that most host communities experienced minimal local benefits in terms of municipal revenues, employment, or general economic impacts, despite the visible infrastructure expansion. Böhringer et al. (2012) used a computable general equilibrium (CGE) model to simulate the 2010 Ontario FiT program. Their results indicate gross job creation in renewable energy production and manufacturing, but also

[11] The German Renewable Energy Sources Act (EEG), first enacted in 2000, has undergone several reforms (notably in 2004, 2009, 2012, 2014, 2017, and 2021). These shifted support for renewables from fixed feed-in tariffs toward more market-oriented mechanisms such as competitive auctions, with the aim of containing costs, aligning with EU state aid rules, and integrating renewables more efficiently into the electricity market.

net employment losses due to reductions in labor demand in other sectors. The program increased green jobs but did not reduce overall unemployment, highlighting the distributional nature of labor market effects. Lastly, Xu & Jiang (2025) analyzed panel data for 31 Chinese provinces (2008–2021) using a difference-in-differences design with continuous treatment, where exposure was determined by cumulative wind capacity reductions following FiT subsidy cuts in 2014. They found that **female employment declined significantly in high-exposure regions, while male employment remained largely unaffected**, revealing a gendered dimension to the labor impacts of green policy reforms.

3. Green investment via subsidies/tax credits for deployment of cleaner production technologies

Despite the growing prominence of green subsidies and tax incentives used to encourage adoption of cleaner production technologies among manufacturing firms (World Bank, 2024), empirical evidence on their employment effects remains surprisingly limited. Much of the existing literature focuses on the broader impact of general subsidies and tax incentives on firm investment and job creation, but it can be providing insights that can be instructive for the design of environmental policies also.

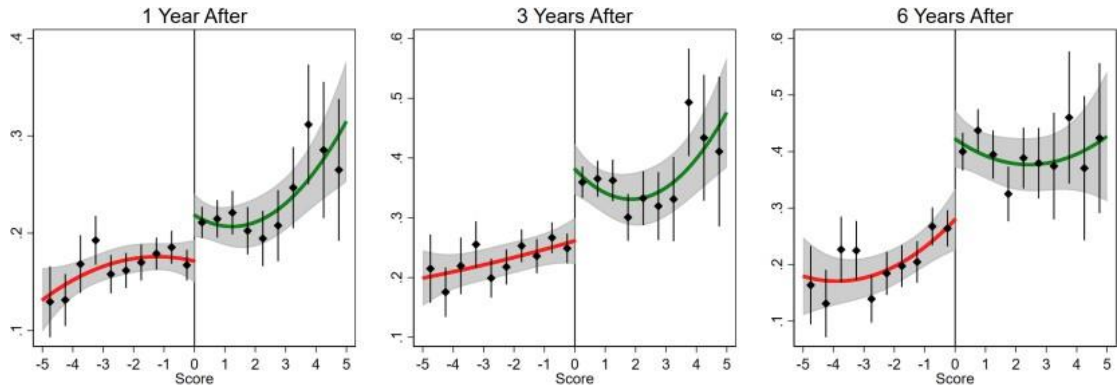
a. General investment tax incentives

Most recent evidence from Germany illustrates the potential of targeted investment tax credits to support employment. Lerche (2025) analyzed the post-reunification corporate tax credit system, with a particular focus on the 1999 reform. The scheme provided a 20% tax credit to manufacturing firms with fewer than 250 employees, while larger firms received 10%. Exploiting this discontinuity, the author applied a difference-in-differences approach comparing firms just below and just above the 250-employee threshold. The results showed that the **20% investment tax credit increased employment by 12%, capital stock by 17.7%, and sales by nearly 10%**.

The literature also highlights that smaller firms, firms in economically disadvantaged areas, and firms operating during recessions often experience stronger employment and investment effects from fiscal incentives. Cingano et al. (2023) studied a **public subsidy program (L488[12]) for firms in Italy's disadvantaged regions and found that it increased investment by 39% and employment by 17% over six years** (Figure 9). The effects were particularly pronounced for younger and smaller firms. Similar patterns are observed in other contexts: Dechezleprêtre et al. (2023) document **stronger responses among small firms** to R&D tax credits, while Criscuolo et al. (2019) and Bronzini and Iachini (2014) also find significant effects concentrated in smaller enterprises.

[12] L488 (Law 488/92) was the largest investment subsidy programme Italy implemented, providing roughly €26 billion (constant 2010 prices) to firms between 1996 and 2007. It financed nearly 77,000 private-sector projects across 35 open calls, allocated via open regional bids based on combined objective scoring ("rules") and local political discretion ("discretion"), with co-funding from EU structural funds

Figure 9. The effect of the L488 subsidy (standardized score obtained in firm applications for L488 fund) on firm employment in Italy.



Source: Cingano et al. (2022)

b. Channels of impacts of subsidies

Subsidies for green technology adoption influence firms in multiple ways. By reducing the cost of adopting environmentally friendly technologies, such policies can challenge the dominance of traditional production methods and prompt firms to reassess their established practices. This often requires new equipment, new processes, and employees with specialized skills. Public support for technology adoption may thus lower production costs and indirectly stimulate private investment in environmental R&D (Popp, 2002).

Green R&D investment but also eco-innovations differ fundamentally from simple technology adoption because it is more intangible, riskier, and often far from immediate commercialization. While the adoption of subsidized environmental technologies does not always stem from a firm's own R&D efforts, it can foster collaborations with external innovators. As Popp (2006) notes, the diffusion of new green technologies enables experiential learning through practical application, which can trigger further internal innovation. These processes ultimately carry indirect employment effects, as firms expand their capabilities and labor demand.

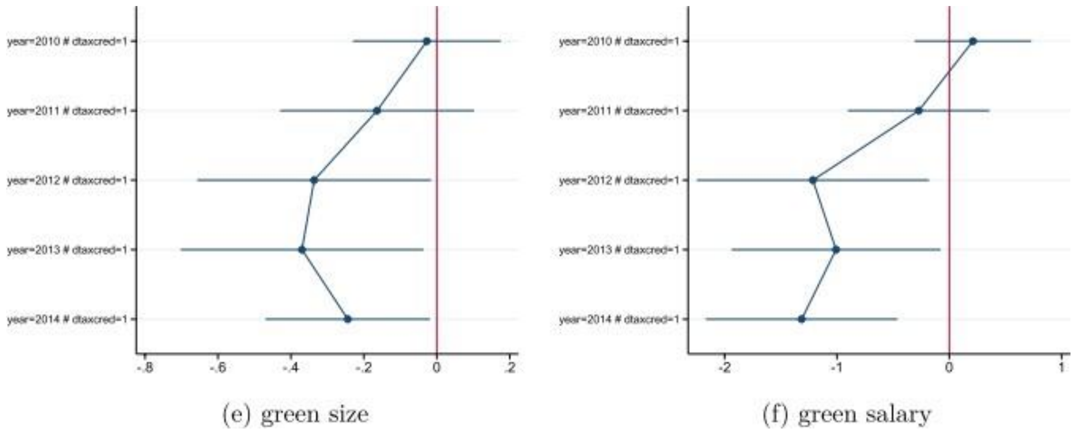
c. Environmental Investment (EI) tax credits

Spain provides valuable evidence on the employment impacts of environmental tax incentives. Tchorzewska (2025) shows that **higher environmental investment tax credit rates are associated with an increase in the number of green employees** (employees dedicated to environmental protection activities), with total firm size remaining stable or slightly increasing. Similarly, Martinez-Ros and Kunapatarawong (2019) find that Spanish environmental investment and **R&D tax credits have positive effects on employment, with stronger impacts in micro-firms** compared to larger SMEs.

Tchorzewska (2024) examines the sudden reintroduction of the EI tax credit during the financial crisis, after it had been scheduled for phase-out. This **unexpected policy shift produced a temporary decline in the number of green employees and in their associated**

salaries, likely reflecting short-term adjustment costs. At the same time, the measure successfully increased investment in energy-efficient technologies, especially among the smallest firms (fewer than 50 employees). Using a panel of approximately 2,500 firms over 2008–2014 and a difference-in-differences strategy, the study concludes that the reintroduction likely prevented sharper employment declines that might have occurred had the credit been discontinued as planned, though the precise counterfactual remains unknown.

Figure 10. The dynamic DiD effects of the tax credit reintroduction (2011) on the number of green employees (green size) and the salaries of green employees (green salary).



Source: Tchorzewska (2024)

d. Regional investment programs and employment

Complementary evidence comes from Germany's Gemeinschaftsaufgabe Verbesserung der regionalen Wirtschaftsstruktur (GRW), a regional investment grant program targeting economically lagging areas. Alecker and Mitze (2023) exploit exogenous variation in grant generosity resulting from policy reforms, applying a difference-in-differences with instrumental variables approach. They find that **increasing the generosity of investment grants led to higher firm-level investment and positive employment effects**, again with particularly strong impacts on small firms.

In sum, evidence from Germany, Italy, and Spain suggests that green subsidies and environmental tax credits can be effective tools for both technological upgrading and job creation, particularly when carefully targeted and consistently implemented. Across literature, several themes emerge. Firstly, targeting matters. Employment and investment effects are consistently stronger for smaller and younger firms, as well as in disadvantaged regions and during recessions. Secondly, green subsidies have indirect effects. They not only lower the cost of technology adoption but also stimulate learning, innovation, and the creation of green jobs. Thirdly, policy stability is crucial. Sudden changes, such as the reintroduction of Spain's EI tax credit, may create short-term disruptions in green employment, while predictable and sustained support generates more durable effect.

4. Indirect link between eco-innovation and green jobs

The creation of green jobs and the development of new skills are closely linked through the complementarity between technology and human capital (Horbach & Rennings, 2013; Cecere & Mazzanti, 2017). Green employees inherently possess higher levels of "green skills" (Vona, 2023; Vona, 2021), making it crucial to assess whether eco-innovations—such as the adoption of green technologies—disproportionately benefit green jobs. As Cecere and Mazzanti (2017) observe, "there is still a lack of specific evidence on the effects of eco-innovation[13] on employment and on green jobs in particular."

So far, we have seen that subsidies affect employment, and that green investment, development of green infrastructure affects employment. Now, it is also important to point out that the level of innovativeness at the firm level and specifically their innovativeness directed at greening their production processes is also relevant and indirectly affects employment itself. Eco-innovations not only support environmental objectives but can upgrade the skill structure of firms, indirectly prompting the demand for highly skilled labour. Empirical evidence suggests that eco-innovations increase the need for skilled workers to implement and manage new technologies effectively (Rennings et al., 2004; Aldieri et al., 2019). Firms undertaking such transformations require employees with the capabilities to integrate advanced environmental technologies and manage associated organizational changes.

a. *Evidence on the effects of eco-innovation on employment*

The literature on the employment effects of eco-innovation is limited, with only a few studies focusing specifically on green jobs. Two notable contributions—Cecere & Mazzanti (2017) and Elliot et al. (2024)—rely on relatively small survey datasets in a specific country and adopt different methodological approaches.

Cecere & Mazzanti (2017) analyze 7,457 European SMEs in 2013 to examine how microeconomic factors (technological and organizational innovation) and sectoral features affect green job creation. Using a binomial model, they find that the introduction of **green services and product innovations stimulates the creation of green jobs**, whereas the adoption of environmental management systems has no significant effect. They also highlight path dependency: successful green products and services reinforce future green job demand.

Elliot et al. (2024) adopt a task-based perspective and merge several datasets covering Dutch firms for 2006–2010. Using an endogenous switching model with cross-sectional data, they conclude that eco-innovation does not affect overall employment, but **product eco-innovations increase green jobs, whereas process eco-innovations do not[14]**. They also

[13] Eco-innovation refers to the development or adoption of products, processes, services, or organizational methods that reduce environmental impacts, increase resource efficiency, or support sustainability goals. It encompasses both technological changes (e.g., cleaner production methods, renewable technologies) and non-technological changes (e.g., new business models or practices) that contribute to environmental improvement while also enhancing firm performance.

[14] Product eco-innovation refers to new or significantly improved goods and services with reduced environmental impact across their life cycle, while process eco-innovation involves cleaner and more resource-efficient methods of production or delivery. Within process innovation, a common distinction is between **cleaner production**, which integrates environmental improvements directly into production processes (e.g., using less energy or materials), and **end-of-pipe technologies**, which are add-on measures designed to control or treat pollution after it has been created (e.g., filters, scrubbers, wastewater treatment).

distinguish between voluntary eco-innovations and policy-driven ones, showing that the effects differ depending on the drivers of innovation. These studies collectively suggest that the employment impact of eco-innovation is heterogeneous, depending on the type of innovation and whether it is voluntary or regulation-induced.

b. Types of eco-innovation and employment implications

The literature emphasizes the importance of distinguishing between end-of-pipe (EP) and cleaner production (CP) technologies when assessing employment effects (del Río, 2005; Horbach & Rennings, 2013). End-of-pipe technologies (EP) involve incremental, add-on solutions such as scrubbers or waste treatment equipment, while cleaner production technologies (CP) entail more transformational process changes, such as energy and material efficiency improvements. If eco-innovations increase demand for highly skilled workers capable of performing green tasks, CP technologies are expected to drive stronger green job growth than EP solutions. Moreno-Mondejar et al. (2021) argue that “the more radical the change, the higher the skills of the workers that will be needed and therefore, the higher the number of green employees at the firm level.” There are several papers that provide empirical evidence to support this distinction. Horbach & Rennings (2013) show that **innovative German firms experience larger employment growth**. Gagliardi et al. (2016) find that green innovation in Italian firms—measured through environmental patenting—has a stronger long-run job creation effect than other forms of innovation. Zhang et al. (2024) report that energy-reducing (CP) innovations positively affect total firm employment, whereas pollution-reducing (EP) innovations are not significant. Biggi, Mina & Tamagni (2023), using Spanish firm-level data for 2003–2016 and a quasi-experimental identification approach, confirm that **resource-saving (cleaner production) innovations drive positive employment effects**, while EP technologies do not. They also provide evidence that voluntary eco-innovations are more strongly linked to employment gains than regulatory compliance-driven changes. While empirical evidence is still limited, first mover advantage and enhanced organizational learning and capabilities seem to play a role. There exist also a recent working paper by del Rio et al (2025) using a confidential unbalanced firm-level dataset of 4,244 companies between 2010-2020 from Spanish statistical institute. They find that cleaner production technologies indeed have positive impacts on green jobs. The **elasticity[15] regarding the effects of investments in clean technologies is lower in the short term than in the long term**.

c. Beyond quantity – the quality of green jobs

While most studies focus on the quantity of green jobs, some research addresses their quality. Moreira et al. (2018), studying Portugal, show that **green jobs receive less occupational health and safety coverage, suffer higher incidence and severity of workplace accidents, and are often filled by less qualified or skilled workers**. These findings raise concerns about

[15] Elasticity measures how responsive one variable is to a change in another, expressed as the percentage change in the dependent variable relative to a one percent change in the independent variable. In economics, common examples include price elasticity of demand (sensitivity of quantity demanded to price changes) and income elasticity of demand (sensitivity of demand to income changes).

the sustainability and social desirability of some green jobs, suggesting that **job creation policies should also consider job quality, training, and worker protection** alongside employment numbers.

To conclude, complementarity between technology and human capital is central in the sense that firms adopting eco-innovations need highly skilled labour. Having said that, employment effects are heterogeneous. We can see different employment outcomes across firms investing in product vs. process innovations, or EP vs. CP technologies. Even voluntary vs. compliance-driven innovations have different impacts on green job creation. The empirical literature agrees that radical, cleaner production innovations, that change the production process show the strongest long-term employment gains.

B. Environmental regulation (command and control policies)

a. Net employment impacts of environmental regulation

Empirical evidence on the labour market effects of environmental regulation shows that, similar to market-based instruments such as carbon taxes, emissions trading schemes, or subsidies, the overall net impact on employment is generally limited or mildly positive. However, negative consequences can occur through transitional costs—such as plant relocations, temporary unemployment, or lost benefits—that often disproportionately affect certain groups of workers (Walker, 2013).

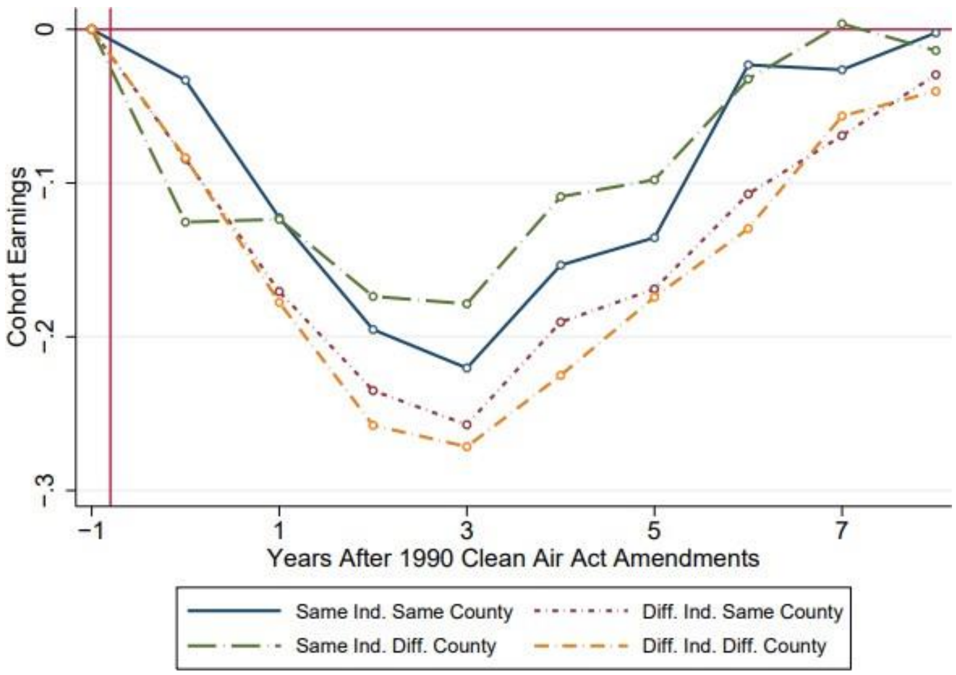
For instance, analysing British data from 1999–2003, Cole and Elliot (2007) find no evidence that pollution abatement costs reduce overall employment. In the United States, Kahn and Mansur (2013) apply a regression discontinuity design comparing adjacent county pairs with differing regulatory statuses. Their findings indicate that **pollution-intensive industries are sensitive to air quality regulation: counties designated as non-attainment under the Clean Air Act host fewer workers in high-emission industries than their more lightly regulated neighbours**.

Firm-level behaviour further illustrates how environmental stringency affects employment dynamics. Cui and Moschini (2020), using a probit model for U.S. data, show that **multi-plant firms exhibit greater flexibility under strict environmental controls**. Multi-plant firms can strategically absorb and respond to environmental regulations by reallocating production and closing less profitable plants, particularly when those facilities are geographically distant from the parent company or situated in highly competitive regions, whereas single-plant firms face fewer options and may bear regulatory costs more directly. Closure probabilities increase when firms also operate plants in neighbouring, less regulated areas, indicating that firms strategically adjust their production footprint in response to regulatory pressures.

b. Firm location responses – pollution haven effect

Evidence from other countries supports these patterns. Wang et al. (2019), analysing firm location choices in China with a conditional logit model including province fixed effects, find that **heavily polluting firms tend to avoid provinces with stringent environmental regulation**—consistent with the "pollution haven"[16] hypothesis.

Figure 11. The effect of sector level regulation on earnings (decomposed based on sectoral transitions).



Source: Walker (2013)

c. Transitional labour market costs

Transitional costs for workers can be significant. Walker (2013), in an analysis of the 1990 Clean Air Act in the United States, finds that sectoral reallocation imposed substantial earnings losses (Figure 11). On average, **workers in regulated sectors experienced cumulative earnings declines of approximately 20% of their pre-regulation income**, driven largely by periods of unemployment and lower wages in subsequent jobs. **Losses were notably higher for women**, measured as a proportion of prior income. Furthermore, the study highlights that workers in regions with higher baseline unemployment faced substantially greater earnings losses, underscoring the importance of local labour market conditions in mediating the social costs of environmental transition. **Earnings returned to their original level only after 7 years**.

C. Energy prices and fossil fuel subsidy phase-out

[16] The pollution haven hypothesis suggests that firms may relocate production to countries or regions with weaker environmental regulations to lower compliance costs, leading to the concentration of polluting industries in these jurisdictions.

1. Energy prices

In parallel with studies on environmental regulation, a growing body of literature examines the impact of energy prices on employment, as these effects often mirror the consequences of fuel or carbon taxes and broader energy transition costs.

Hille and Möbius (2019) use a comprehensive firm-level dataset of approximately 500,000 firms across 27 OECD countries (2000–2014) to evaluate both employment responses among surviving firms and entry–exit dynamics. Their results indicate that, for manufacturing sectors alone, **increases in both market and shadow energy prices[17] do not significantly affect net employment**. However, when considering the entire economy, the average employment effect becomes positive, driven primarily by larger positive cost effects that offset negative demand and factor-shift effects.

a. Sectoral heterogeneity in employment impacts

Several studies demonstrate that the employment effects of higher energy prices are highly sector-specific. In France, Marin and Vona (2021) find that a **10% rise in energy prices leads to an average 0.9% reduction in employment**, with the impact concentrated in **energy-intensive and trade-exposed sectors.** While in the United States of America, consistent with the evidence on regulatory stringency, Kahn and Mansur (2013) show that employment is higher in counties with lower energy prices, highlighting the sensitivity of local labour markets to energy cost differentials.

b. Firm relocation and energy price sensitivity

Energy prices can also influence firm location decisions. Panhams et al. (2017) compile a dataset of 634 firm relocation events within and outside the EU. Their analysis reveals that firms are **more likely to relocate to countries with lower industrial electricity prices, with energy-intensive firms nearly twice as price-sensitive as less intensive firms**. Interestingly, the effect is asymmetric. Increases in domestic energy prices have little influence on whether firms move abroad. What matters more are price differences between countries: if energy is significantly cheaper elsewhere, foreign firms are about 70% more likely to relocate in response (elasticity of 0.7).

c. Energy transition policies and employment outcomes

Two recent studies explore the interaction between renewable energy policies, electricity prices, and employment. In the US, Wolverton et al. (2022) analyse plant-level data from 1992–2015 and apply coarsened exact matching to study the effects of Renewable Portfolio Standards (RPS). They find that RPS policies increased electricity prices by 2%, resulting in modest employment and hours reductions of 0.15–0.2%, reflecting the resilience of the manufacturing sector. While in Germany, Cox et al. (2014) find that higher electricity prices reduce

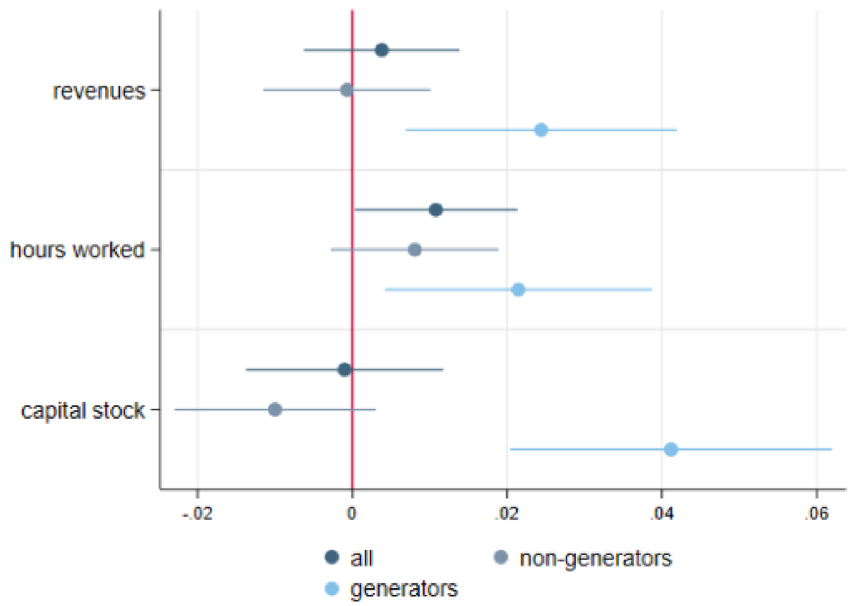
[17] Shadow energy prices refer to implicit or effective energy costs faced by firms due to environmental regulations or market mechanisms (such as emission trading schemes or taxes). Unlike market energy prices, which reflect the direct cost of purchasing fuel or electricity, shadow prices capture the additional regulatory burden associated with energy use, often expressed as the opportunity cost of constrained emissions.

manufacturing employment, with employment elasticities ranging from −0.06 to −0.69, depending on skill levels, and energy-intensive industries experiencing the largest negative impacts.

d. Energy Prices, Industrial Adjustment, and Competitiveness

The most recent evidence by von Graevenitz and Rottner (2024) shows that rising electricity prices in German manufacturing led to a reduction in external electricity procurement, with an own-price elasticity of −0.4 to −0.6 on average. Importantly, **many firms compensated by generating electricity onsite, contributing to a decentralisation of industrial power suppl**y. Despite these adaptations, the authors find **no statistically significant negative effects on competitiveness indicators such as hours worked, revenues, or capital stock**.

Figure 12. The effect of energy price increases on revenues, hours worked and capital stock in Germany.



Source: von Graevenitz and Rottner (2024)

The empirical evidence suggests that rising energy prices and energy transition policies have, on average, modest effects on net employment, with impacts varying substantially across sectors and firm types. Aggregate employment effects are limited or slightly positive. Impacts are concentrated in energy-intensive and trade-exposed industries. Lastly, labour market resilience matters. The capacity of the labour market to absorb structural changes influences how transitional costs materialise, with potential distributional consequences for vulnerable workers.

2. Fossil fuel subsidies phase-outs

The literature highlights that phasing out fossil fuel subsidies (FFS) can significantly affect energy prices, with effects often comparable to those of carbon taxation. However, the price increases resulting from subsidy removal can be particularly sharp, sometimes exceeding 100%, depending on initial subsidization rates (Rentschler & Bazilian, 2016; Rentschler et al., 2017). Such abrupt changes can generate both economic opportunities and transitional challenges for labour markets.

a. Macroeconomic and employment effects

Recent modelling evidence illustrates the potential economic and employment impacts of FFS reforms. De Bruin and Yakut (2023) apply a dynamic intertemporal CGE model to Ireland, comparing two scenarios: (i) removing eight fossil fuel subsidies, and (ii) increasing the carbon tax to €100/ton by 2030. Both achieve similar emission reductions, but **fossil fuel subsidy removal generates lower negative impacts on employment, stronger public revenues, an improved trade balance, and lower public debt than carbon pricing**. In contrast, carbon taxation tends to distribute effects more evenly across sectors and households. Excluding household-targeted subsidies from the reform package can mitigate distributional pressures while maintaining environmental effectiveness.

When revenues are recycled via tax reductions, the phase-out of subsidies can deliver a double dividend, combining environmental gains with economic efficiency. However, income inequality may worsen unless complementary redistribution or social protection measures are implemented.

b. Effects on Energy Use, Competitiveness, and Investment

Low fossil fuel prices encourage overconsumption and can discourage investments in energy-efficient and low-carbon technologies, ultimately reducing long-term competitiveness (Ley et al., 2016). By contrast, **subsidy removal aligns energy prices with true costs, incentivising firms to upgrade to more efficient and cleaner technologies**.

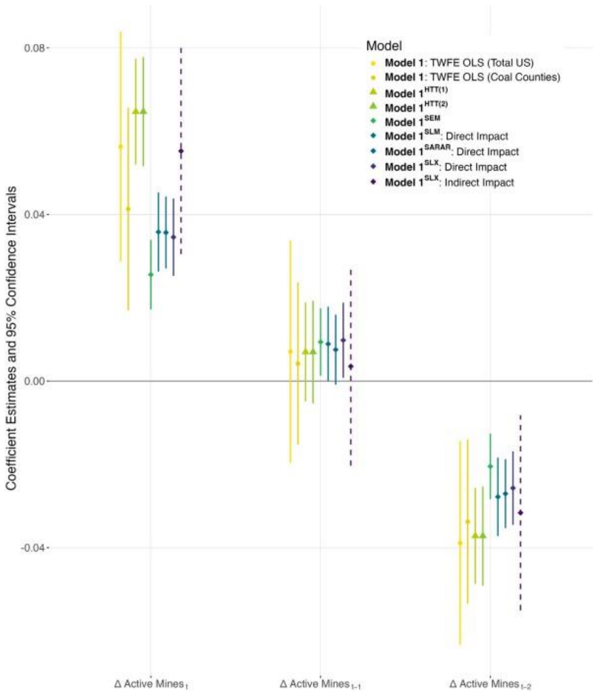
However, some short-term adverse effects are also noted. A form of the "Green Paradox" can occur if fossil fuel producers accelerate extraction upon learning that subsidies will end, temporarily raising emissions before the long-term benefits of the reform materialise.

c. Local Labour Market Impacts of Fossil Fuel Plant Closures

The phase-out of fossil fuel subsidies can indirectly trigger plant closures, with significant local employment effects. Mark et al (2024) provide a spatial econometric analysis of 3,072 U.S. counties (2002–2019) and find that each **coal mine closure raises the local unemployment rate by 0.056 percentage points** in the same year. **When spatial spillovers to neighbouring counties are considered, the effect quadruples**, highlighting the **regional interconnectedness** of labour markets. Although the unemployment **spike typically fades within 2–3 years**, the short-term dislocation is substantial (Figure 13. and Figure 14.).

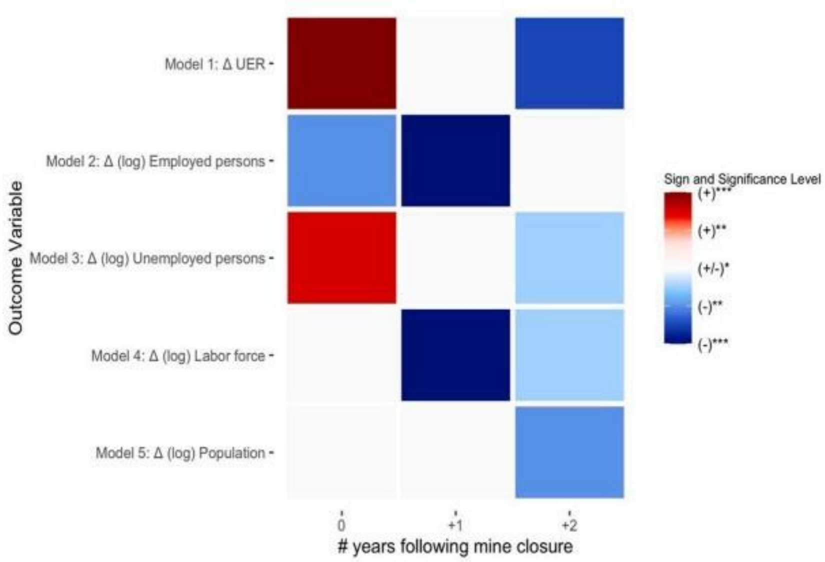
The study identifies key resilience factors, including economic diversification, higher educational attainment, and strong local institutions. Conversely, rural counties with low economic diversity and limited female labour participation face prolonged unemployment. The authors recommend targeted retraining programs, relocation support, and childcare subsidies to smooth the transition.

Figure 13. The effects of fossil fuel phase out on the change in active mines in t, t-1, and t-2.



Source: Mark et al (2024).

Figure 14. The effects of fossil fuel phase out on regional unemployment rate, employed persons (log), unemployed persons (log) and population (log), for 2 years following the coal mines closure.



Source: Mark et al (2024).

D. Biodiversity and environmental restoration

1. Biodiversity restoration

The growing focus on biodiversity protection and environmental restoration reflects the increasing recognition of nature-based solutions in achieving sustainable development and climate goals. While this policy field is developing rapidly, empirical evidence on its labour market impacts remains limited. To date, only very few studies have explicitly examined the employment effects of environmental restoration initiatives.

a. Employment Effects of Coastal Habitat Restoration

The first study, conducted by Edwards et al. (2013), provides a quantitative assessment of the employment generated by coastal habitat restoration projects financed under the American Recovery and Reinvestment Act (ARRA) of 2009, which was implemented by the National Oceanic and Atmospheric Administration (NOAA). The analysis covered forty shovel-ready projects across the United States and relied on actual expenditure data combined with input–output techniques to evaluate the multiplier effects of restoration spending. The projects created approximately 1,409 jobs within the first 18 months, corresponding to an average of 17 jobs per USD 1 million spent, though employment intensity varied depending on the specific restoration technique. Jobs were highly diverse, spanning scientists, engineers, boat operators, heavy equipment managers, technicians, and administrative personnel. Approximately **80 per cent of the roles offered median wages above the 2012 national average of USD 34,750**. Most of these **positions were temporary**, reflecting the project-based and construction-focused nature of restoration activities. However, the projects also generated indirect and **longer-term employment benefits by supporting fisheries, tourism, water quality improvement, and coastal resilience**.

b. Environmental Rehabilitation in Industrial Zones

The second study adopts a more qualitative approach, investigating environmental rehabilitation in contaminated industrial areas through two case studies (Battaglia et al, 2018). Drawing on survey data, publicly reported outcomes, and local authority information, the study finds that **rehabilitation efforts generated new green jobs, but on a modest scale**. Direct employment arose from activities such as soil removal, decontamination, and site restoration, while **indirect jobs were created in planning, engineering, environmental monitoring, reporting, and local administrative support**. Although these initiatives did not replace the scale of jobs lost in former industrial activities nor establish an entirely new regional economic model, they nonetheless delivered incremental employment benefits and contributed to the greening of local labour markets.

Taken together, the available evidence suggests that biodiversity and restoration initiatives can create meaningful local employment, particularly in the short term and across a broad range of skill levels. Positive outcomes are facilitated by strong stakeholder engagement, the creation of technological clusters and linkages between research and business, cross-sectoral policy approaches, and complementary investments in the local area. In contrast, bureaucratic delays, insufficient monitoring and evaluation, limited infrastructure investment, and uncertainty in international markets constrain the ability of restoration projects to translate into sustained labour market gains.

E. Policy-mixes

Research on the effectiveness of combined environmental policies remains in an early stage, primarily due to the challenges of accessing confidential firm-level data. The initial body of work on policy combinations originated in the economics of innovation literature. Early contributions, such as Mohnen and Roller (2005), examined the complementarity of innovation policies—including R&D tax credits—in stimulating overall innovation activity. This was followed by studies assessing the interactions and effectiveness of general innovation policies (Marino et al., 2016; Popp, 2006; Guerzoni and Raiteri, 2015), providing the first theoretical and empirical basis for understanding policy mix effects.

In contrast, the literature on clean transition policies is even more limited, although developing rapidly. Existing studies largely focus on firm-level productivity outcomes and green technology adoption, rather than direct employment effects, leaving a persistent gap in the literature (Dobbeling-Hildebrandt et al., 2024). Some scholars nonetheless suggest that **employment impacts tend to increase with the number of policies implemented concurrently** (Faulin et al., 2006; Yi, 2013). **Policy mixes can enable governments to pursue multiple objectives**, such as mitigating negative externalities, overcoming capital market failures, and addressing distributional concerns (Edmondson et al., 2019; Kern et al., 2019). As highlighted by Bouma et al. (2019), the evaluation of employment impacts in the context of clean transition policies must evolve to adequately capture these policy mix dynamics.

1. Evidence from Early Empirical Studies

One of the first studies to adopt a policy mix perspective was Costantini et al. (2018). The authors investigated how sectoral and national conditions influence employment dynamics in response to energy efficiency policies. They identified a negative correlation between energy efficiency gains and employment in energy-intensive sectors. However, when considering the interaction between efficiency-induced cost savings and energy taxation, they found that **countries with higher energy taxes (in aggregate) experienced net employment gains, as firms reinvested financial savings**. Their results suggest that a comprehensive policy mix—where efficiency measures are paired with taxation—can stimulate employment growth, underlining the importance of policy design and complementarity.

Additional evidence comes from regional case studies, such as Faulin et al. (2006), who examined how a combination of tax incentives, local investments, and industrial initiatives contributed to the creation of 1,800 renewable energy jobs in Spain's Navarra region in 2002. This accounted for more than half of Spain's total renewable energy employment at the time, illustrating the potential of locally embedded policy mixes to support job creation.

2. *Policy Mixes for Green Technology Adoption and Employment Implications*

The literature on environmental policy mixes in the context of green technology adoption has recently expanded along two complementary dimensions: 1) determining the optimal "dosage" of policies within a mix and 2) assessing the importance of sequencing or the order in which policy instruments are introduced (Tchorzewska et al., 2022; Tchorzewska et al., 2025). While these studies primarily examine firm level productivity outcomes e.g. green technology adoptions (eco-innovations) and green innovation, they have clear implications for employment, given the link between technology adoption and labour demand.

3. *Environmental policy-mix and dosage*

Tchorzewska et al. (2022), using firm-level data from Spain (2008–2014), apply categorical treatment matching to evaluate the joint effects of environmental taxes and public funding instruments (including subsidies and investment tax credits). The findings indicate that **low-level environmental taxes alone are insufficient** to stimulate green technology adoption alone. However, **combining even minimal environmental taxation with investment subsidies significantly increases the deployment of cleaner production technologies (superior more radical eco-innovations)—with stronger effects than subsidies alone**. These results highlight the role of policy complementarity in driving firm behaviour and indirectly suggest pathways to employment growth.

4. *Environmental policy-mix sequencing*

Building on this, Tchorzewska et al. (2025) explicitly examine whether the sequencing of environmental policies affects green technology adoption. They categorize instruments into three groups: environmental taxes, investment subsidies, and investment tax credits. **The study shows that sequencing of environmental policy instruments matters.** Introducing subsidies or tax credits first, followed by environmental taxes, generates the highest eco-innovation uptake across technology types, with particularly strong effects for cleaner production technologies. **Firms are more likely to invest in efficiency-enhancing innovations when they receive early support before facing tax pressure**. Conversely, when environmental tax is introduced first, with subsidy or a tax credit used later – there are no additional effects on green technology adoption. Additionally, when tax credits and subsidies are introduced simultaneously or with overlapping timelines, they tend to function as substitutes rather than complements, diminishing overall policy effectiveness.

Sequencing is especially critical for small and medium-sized enterprises (SMEs), which benefit the most from early incentives due to their limited internal capital and organizational resources. Larger firms, by contrast, are less sensitive to sequencing because they can more easily self-finance and manage policy compliance. These findings underscore the importance of strategic policy mix design for maximizing eco-innovation—and, by extension, potential employment gains in green sectors.

Overall, the emerging literature suggests that policy mixes can enhance employment outcomes indirectly by stimulating green technology adoption and sectoral transformation. Complementarity and sequencing play central roles in determining policy effectiveness. Well-designed policy mixes allow governments to capture synergies, balance short- and long-term impacts, and address market and institutional failures simultaneously. However, despite these promising insights, empirical studies linking policy mixes directly to employment outcomes remain extremely limited, highlighting a critical area for future research.

III. Chapter 4: Summary of the actions/policies put forward to maximise positive impacts of the clean transition policies on the EU labour market and actions aimed at minimizing potential negative impacts.

The literature on clean transition policies underscores that **employment effects are highly sensitive to the design, sequencing, and supporting measures** accompanying environmental interventions. While well-designed policy mixes can generate net job gains, poor implementation risks to induce transitional unemployment, regional disparities, and social inequalities. Based on the evidence reviewed, the following policy actions are recommended to maximize the positive labour market outcomes of the clean transition and to mitigate potential negative or unequal effects.

Maximizing the Positive Employment Effects of Clean Transition Policies

To fully harness the job-creation potential of the clean transition, governments should prioritize integrated strategies that combine technology deployment, labour market interventions, and regional support. Key actions include several steps as presented in Table 1.

Revenue Recycling from Environmental Taxes

Recycling revenues from carbon or environmental taxes into labour tax reductions, investment incentives, upskilling, and R&D support can mitigate regressive impacts and enhance net job creation. This approach aligns decarbonization incentives with broader economic and social objectives. It has already been implemented in British Columbia (Canada) in 2008. 100% of carbon tax revenue is returned via corporate income tax cuts. As a result, emissions fell but the growth and employment held up, with even small increases in firm level productivity.

Investment Subsidies and Tax Credits

Targeted subsidies and investment tax credits for green technologies, particularly for superior cleaner production (CP) technologies, are among the most effective tools to stimulate eco-innovation and productivity growth. Smaller and younger firms respond most strongly to such support, making them a priority. Abrupt changes or premature phase-outs of incentives should be avoided, as policy uncertainty can deter investment and slow job creation (Tchorzewska, 2024). Those subsidies and tax credits that are in line with international rules exist across Europe.

Policy-Mix Design

Empirical evidence highlights the importance of **combing instruments together such that they address different market failures simultaneously** e.g. a subsidy to address the capital market failure with a carbon tax to address the pollution (Stechemesser et al., 2024), but also sequencing policy instruments. A "**carrot-first, stick-later" approach**—where subsidies or tax credits precede environmental taxes—maximizes eco-innovation uptake by reducing initial investment barriers (Tchorzewska et al., 2025). Simultaneous overlapping policies e.g. overprovision of green subsidies, by contrast, can dilute effectiveness and confuse firm incentives. Careful policy mix design enhances firm adaptability and fosters stronger positive employment spillovers.

Renewable Energy Deployment

Investment in **community-owned renewable projects** generates both short-term construction jobs and long-term operation and maintenance (O&M) positions (Susser and Kannen, 2017). Additionally, stable and predictable deployment schedules are critical to prevent boom-bust employment cycles and to retain skilled labour. Local embedding of renewable projects also ensures that economic benefits are captured domestically rather than offshored. The empirical evidence from US and Germany presented in Chapter 3 supports this.

Labour Market and Skills Policies

Anticipating and addressing green skill needs is essential to avoid bottlenecks in the labour market. **Reskilling and targeted education programmes in renewable energy, energy efficiency, and environmental services** facilitate smooth labour reallocation and promote high-quality employment. Education about the fact that there exists a wage premium for geen intensive jobs could also be useful (Bergant et a., 2022; IMF).

Industrial and Regional Policy

Clean transitions can exacerbate regional inequalities if carbon-intensive areas are left behind. **Place-based green industrial strategies and targeted public investment**—such as through the EU's Just Transition Mechanism—can foster employment resilience and local economic diversification.

Support for SMEs and Innovation Ecosystems

Providing SMEs with tailored clean transition roadmaps and fostering partnerships with technology providers and universities accelerates the diffusion of eco-innovation. **Strengthening local innovation ecosystems increases both productivity and the creation of high-quality jobs** in emerging green sectors.

Table 1. Showing the actions/policies that should be put forward to maximise positive impacts of the clean transition policies based on the literature review.

Policy area	Key actions	Expected Benefits
Revenue recycling from carbon/environmental taxes	- Recycle carbon tax revenues into labour tax cuts or investment incentives. - Use them to support upskilling and R&D.	- Mitigates regressive effects. - Supports net job gains in clean sectors.
Investment subsidies and tax credits	- Provide targeted subsidies and investment tax credits to firms adopting green technologies, especially CP (cleaner production) technologies. - Prioritise smaller and younger firms which are more responsive to support. - do not phase-out/modify suddenly	- Stimulates technology uptake, firm productivity and job creation.
Policy-mix design	-Sequence policy instruments: *"carrot-first, stick-later"* (i.e., subsidies/tax credits first, then taxes). - Avoid simultaneous	- Promotes stronger eco-innovation adoption. - Reduces uncertainty and increases firm adaptability.

	overlapping policies which can reduce effectiveness.	
Renewable energy deployment	- Invest in community-owned or locally anchored renewable projects. - Maintain stable deployment schedules to avoid boom-bust cycles	- Generates short-term construction jobs and long-term O&M roles. - Increases local economic benefits and reduces job offshoring.
Labour market and skills policy	- Anticipate skill needs for green sectors and support reskilling/transition pathways. - Target education, training and certification programmes in RE, energy efficiency, and environmental services.	- Eases labour reallocation. - Prevents skill mismatches and facilitates high-quality employment creation.
Industrial and regional policy	- Support diversification in carbon-intensive regions through green industrial strategies. - Channel public investment into lagging regions (e.g., via Just Transition Mechanism).	- Mitigates regional inequalities. - Promotes place-based employment resilience.
Support for SMEs and innovation ecosystems	- Provide tailored clean transition roadmaps for SMEs. - Facilitate partnerships with technology providers and universities.	- Increases green technology diffusion and associated job creation. - Builds innovation capacity.

Mitigating potential Negative or Unequal Labour Market Effects

While the clean transition offers net employment gains in the long term, its disruptive effects can be significant in the short and medium term (up to 7 years), particularly for fossil-intensive sectors, vulnerable groups, and lagging regions. To ensure a just transition, the following measures are critical, presented in Table 2.

Addressing Employment Losses risks in Fossil-Intensive Sectors

Implement Just Transition **support packages combining income support, retraining, job search assistance, and mobility schemes**. These measures help address transitional unemployment, ease redeployment into low-carbon sectors, and protect communities dependent on legacy industries. A recent discussion paper by Vandeplas et al. (2022) underlines that policymakers need to address the distributional risks of climate policies, and the fact that "green", "brown" and "white" jobs are likely to be differently affected by the green transition. Acting in anticipation can improve policy effectiveness.

Addressing risks of Wage Losses and Job Quality Deterioration

Monitoring occupational health, safety, and job quality standards in new green jobs is crucial to ensure that the employment created is both sustainable and fair. Strengthening collective bargaining in emerging sectors mitigates the risks of low wages and precarious conditions.

Addressing risks of Gender and Social Disparities

Green employment programmes should **embed gender and inclusion targets, ensuring equal access to training and employment opportunities for women, youth, and other underrepresented groups**. This prevents the replication of existing labour market inequalities in the green economy. As underlined by the OECD Discussion paper written by Causa et al (2024) women are under represented in both green jobs, which are associated with higher education attainment.

Addressing Volatility of Green Employment

Regulatory stability and smoothed policy timelines are essential to reduce cyclical volatility[18] in green sectors, particularly in renewable energy. **Encouraging the creation of permanent roles—e.g., in O&M, environmental services, and domestic manufacturing**—enhances the durability of employment gains.

Addressing Carbon Leakage and Relocation Risks

Protecting against carbon leakage through border carbon adjustment mechanisms and innovation support can prevent offshoring of emissions and jobs. Finding synergies between clean strategies into industrial policy ensures that decarbonization strengthens, rather than weakens, domestic employment.

Table 2. Showing actions to mitigate potential negative or unequal labour market effects.

Challenge	Policy Response	Rationale
Risk of employment losses in fossil-intensive sectors	- Deploy Just Transition support packages, including income support, retraining,	- Addresses transitional unemployment and skills mismatches.

[18] Cyclical volatility refers to fluctuations in economic activity, such as output or employment, that follow the ups and downs of the business cycle. It captures how strongly a variable responds to expansions and recessions, with higher cyclical volatility indicating greater sensitivity to economic booms and downturns.

	and job search assistance. - Support redeployment into low-carbon sectors via mobility schemes.	- Protects vulnerable groups and regions.
Risk of wage losses and job quality deterioration	- Monitor occupational health and safety in new green jobs. - Promote collective bargaining and job quality standards in emerging sectors.	- Ensures that green jobs are also *good* jobs. - Avoids hidden costs of poor working conditions.
Risk of gender and social disparities	- Embed gender and inclusion targets in green employment programmes. - Promote access to training and employment in underrepresented groups.	- Prevents unequal access to new labour market opportunities.
Risk of Volatility of green employment	- Smooth policy implementation timelines and ensure regulatory stability. - Encourage permanent roles beyond the construction phase (e.g., O&M, services, manufacturing).	- Reduces uncertainty for firms and workers. - Increases durability of employment gains.
Risk of carbon leakage and relocation	- Protect against carbon leakage through border adjustment mechanisms and innovation support. - Promote clean industrialisation strategies.	- Prevents offshoring of emissions and job losses. -

IV. Chapter 5. Conclusions

The review of policy instruments and labour market effects highlights that well-designed clean transition policies can simultaneously drive technological innovation, productivity, and employment creation under specific conditions.

This chapter reviews the employment impacts of clean transition policies in Europe and other advanced economies, drawing on ex-post empirical evidence. Overall, the literature shows that while clean transition policies reshape labour markets, their aggregate effects on employment are modest—generally neutral or slightly positive—though sectoral, regional, and distributional disparities are clear.

More specifically, carbon pricing instruments, such as emissions trading schemes (ETS) and environmental taxes, are the most studied. Evidence from the EU ETS shows substantial emissions reductions with limited employment effects. Firm-level analyses across Europe found no aggregate job losses, and in some cases increased revenues and investment in cleaner technologies (Dechezleprêtre, Nachtigall & Venmans, 2018). More recent work confirms negligible average employment impacts, though high carbon allowance prices have strained regulated firms and indirectly affected unregulated ones (Kalantzis et al., 2025). In contrast, early plant-level studies in France detected employment declines of about 7% in regulated firms (Wagner et al., 2014). For carbon and energy taxes, evidence is more reassuring: the UK's Climate Change Levy cut electricity use without harming employment (Martin et al., 2014); Sweden's tax lowered transport emissions with no negative labour market effects (Andersson, 2019); and a cross-country study of 31 European nations found statistically insignificant impacts (Metcalf & Stock, 2020). In British Columbia, revenue recycling into tax cuts boosted service-sector employment (Yamazaki, 2017), though microdata suggest temporary unemployment spikes for less-educated workers (Yip, 2018).

Renewable energy deployment has generated significant net job creation, though unevenly. A multi-regional input–output model found 530,000 net jobs in the EU between 1995 and 2009, with gains concentrated in Poland, Germany, Hungary, Italy, and Spain (Markandya et al., 2016). Green employment in Scotland expanded but proved more volatile and sensitive to downturns than overall employment (Connolly, Allan & McIntyre, 2016). Local case studies show short-term construction jobs and modest long-term operational roles (del Río & Burguillo, 2009), while broader EU-wide studies confirm positive correlations between renewable deployment and employment (Proenca & Fortes, 2020). Welfare gains are also evident: renewable deployment lowered electricity prices in the Nordic and Spanish markets, increasing consumer surplus and offsetting subsidy costs (Liski & Vehviläinen, 2020; Petersen et al., 2024). Feed-in tariffs (FiTs) further spurred job growth in Germany (Pegels & Lütkenhorst, 2014; Pestel, 2019), Portugal (Behrens et al., 2016), and Japan (Fraser & Chapman, 2018), though imports reduced domestic benefits and some studies stress distributional inefficiencies (Frondel et al., 2008; Böhringer et al., 2012).

Green subsidies and environmental tax credits for cleaner production technologies also support employment by reducing the cost of adopting clean technologies. Evidence from Germany and Italy shows strong effects, especially for smaller firms and disadvantaged regions (Lerche, 2025; Cingano et al., 2023). Spain's environmental investment credits increased green employment, particularly in micro-firms, though sudden policy reversals created adjustment costs (Tchorzewska, 2024; Martinez-Ros & Kunapatarawong, 2019). These instruments also stimulate eco-innovation and skill upgrading (Popp, 2002; Popp, 2006).

Eco-innovation itself is linked to green job creation, especially when driven by cleaner production rather than end-of-pipe technologies (Horbach & Rennings, 2013; Biggi, Mina & Tamagni, 2023; Zhang et al., 2024; del Río et al., 2025). Product eco-innovations and voluntary innovations are particularly effective (Cecere & Mazzanti, 2017; Elliot et al., 2024). However, job quality issues remain: green jobs in Portugal were found to have weaker safety protections and higher accident rates (Moreira et al., 2018).

Environmental regulations and higher energy prices also yield limited aggregate employment effects. UK and U.S. studies suggest neutral or modestly positive outcomes overall (Cole & Elliot, 2007; Kahn & Mansur, 2013), but transitional costs are large: U.S. workers in regulated sectors lost around 20% of pre-regulation earnings following the Clean Air Act (Walker, 2013). Evidence on fossil fuel subsidy phase-outs indicates improved fiscal space and competitiveness, with fewer negative employment effects than carbon taxes (De Bruin & Yakut, 2023), but also highlights significant local shocks from coal mine closures (Mark et al., 2024).

In summary, clean transition policies in Europe and advanced economies generally achieve environmental goals without major job losses. Where employment declines occur, they are concentrated in carbon-intensive sectors, disadvantaged regions, and vulnerable worker groups. The right policy design is decisive: revenue recycling, targeted subsidies, predictable frameworks, and active labour market policies—particularly reskilling—can transform the clean transition into an opportunity for sustainable and inclusive employment growth. Several more specific conclusions emerge from the empirical evidence presented in this report.

1. Policy design and sequencing are decisive for employment outcomes.

Recycling carbon pricing to reduce labour taxes significantly was found to significantly increase employment gains. Additionally, investment subsidies and tax credits—especially when directed toward cleaner production (CP) technologies and targeted at smaller, younger firms—stimulate early adoption of green technologies and encourage firm-level productivity gains. However, the literature shows that sudden phase-outs or unpredictable changes can undermine firm adaptation and reduce employment benefits. A “carrot-first, stick-later” sequencing, in which fiscal incentives precede regulatory tightening or environmental taxation, appears to promote stronger eco-innovation adoption and smoother labour reallocation. Overlapping or poorly coordinated policies may, by contrast, dilute effectiveness.

2. Stable, place-based renewable energy deployment underpins durable job creation.

Renewable energy investments generate short-term construction employment and long-term operational and maintenance (O&M) roles, with additional benefits when projects are locally anchored or community-owned. Stable deployment schedules are crucial to avoid boom-bust employment cycles, which disproportionately affect vulnerable regions and workers.

3. Integrating labour market and skills policies is essential to prevent transitional costs.

The clean transition requires anticipating skill needs and supporting both upskilling and reskilling and mobility pathways for workers from fossil-intensive sectors. Without such measures, the literature points to risks of skills mismatches, wage losses, and job quality deterioration. Policy instruments such as Just Transition packages, targeted education and certification programmes, and job quality monitoring can ensure that green jobs are also good jobs, reinforcing both economic and social sustainability.

4. Equity, inclusion, and regional resilience must be embedded in clean transition strategies.

Employment benefits are unevenly distributed, with risks of regional inequalities, gender gaps, and social disparities if left unaddressed. Community-owned projects, place-based industrial and regional policies—particularly in carbon-intensive areas—combined with inclusion-focused labour programmes can help achieve a fairer distribution of green job opportunities. Revenue recycling from environmental taxation, whether via labour tax cuts or investments in R&D and upskilling, further supports net employment gains while mitigating regressive effects.

5. Gaps in evidence and evaluation limit the ability to guide optimal policy design.

Despite promising insights, the literature reveals several key limitations:

a. Causal inference is scarce especially in the context of job quality, as quasi experimental designs are difficult to find e.g. RDD; even more at firm-level, multi-country datasets are required, ideally merged across administrative, survey, and policy sources.

b. Policy-mix sequencing effects on employment remain understudied, despite evidence of "carrot-first, stick-later" benefits on other productivity measures e.g. eco-innovation.

c. Data on green jobs and job quality are still insufficiently precise, limiting the evaluation of whether new employment is sustainable, well-paid, and socially inclusive.

d. Central and Eastern European (CEE) countries remain under-researched, despite facing significant transitional risks and opportunities.

e. Few evaluations of Just Transition instruments exist, especially regarding their long-term effectiveness in preventing structural unemployment and regional decline.

In conclusion, achieving a net positive employment impact from the clean transition is feasible but contingent upon stable, sequenced, and socially conscious policy design. Future research should focus on generating granular causal evidence, improving metrics of job quality, and evaluating the real-world performance of Just Transition strategies—particularly in regions and countries where the stakes are highest.

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