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The Impact of Green Technologies on GDP and Employment in the EU

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Abstract

Increasing production of green technologies in the EU holds great potential for the European economy. This study uses trade data and input-output tables to estimate the impacts on GDP and employment of reshoring to the EU the production of five major green technologies: photovoltaics, wind turbines, batteries, electric motors and electric vehicles. Our findings show that reshoring these five technologies would increase EU GDP by EUR 18.4 billion, or 0.13% of EU GDP, and create 242,728 new jobs. The same shift of imports to EU production would have had roughly half of the impact in 2010. We also find significant spillover effects on other sectors of the economy, particularly for metal products, wholesale and retail, professional, scientific and technical activities, and administrative and support services. To make the most from the transition, we argue that EU green industrial policy should put more emphasis on manufacturing capacities and innovation to meet the targets of the Net Zero Industry Act, remain internationally competitive, and reduce strategic dependencies.

Keywords: green transition; photovoltaics; batteries; electric vehicles; GDP; employment

JEL classification: Q55, Q56, F14, O25

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1. INTRODUCTION

'*The transition to a climate-neutral, clean economy and the corresponding overhaul of our energy system present significant opportunities in terms of developing the net-zero technology sectors and creating quality jobs and growth. The global market for key mass-manufactured net-zero technologies is set to triple by 2030 with an annual worth of around EUR 600 billion. Our partners and competitors have grasped this opportunity and are deploying ambitious measures to secure significant parts of this new market*.' (European Commission, 2023: p.1).

These are the first sentences of the regulation establishing the **Net Zero Industry Act** (NZIA). More recently, Mario Draghi's speech[1] on the future of EU competitiveness (which reveals some of the insights in the competitiveness report, due to be published in June) reinforced the message that the green race will determine the future **competitiveness** of the EU and that this is intimately related to how the EU will position itself within these value chains. As Mr Draghi has put it, the green agenda 'has to be combined with a plan to secure our supply chain'. Other global players (China, and increasingly also the United States) use government policy tools to 'attract high-value domestic manufacturing capacity' within their national borders, focusing particularly on green and advanced technologies. As other regions gain market shares, the EU becomes progressively more **dependent** on imports to advance its green agenda.

Faced with the active use of green industrial policies in China and the US, Europe cannot sit back and observe the unfolding of this 'green race'. And this is not just in order to defend Europe from the threat of other global players. A deeper EU involvement in these value chains could create new business opportunities and ignite a new wave of innovations and investment. This is even more the case when we consider the **ambitious EU targets** in terms of the green agenda. However, if Europe does not have the industrial capacity to manufacture these products, it would not fully appropriate the benefits of these policies. On the contrary, imports would increase, leaving the EU more vulnerable to external shocks and geopolitical tensions. Such a scenario would also contribute to a loss of competitiveness in yet another technology. The obvious outcome that could be foreseen is the replication of the history of photovoltaics (PVs). Until the mid-2000s, the value chain for PVs was concentrated in the US, Germany, and Japan – with Germany playing an important role (partly because of generous government support). Over time, however, manufacturing capacities moved almost completely to China. By 2010, China accounted for 82% of the manufacturing capacity of ingots and 78% of crystalline PV modules (Carvalho et al., 2017).

This study contributes to the debate on the **co-benefits of the green transition**. It estimates the impact on EU GDP and employment of increasing the production of five of the most debated climate technologies: electric vehicles (EVs), PVs, wind turbines (WTs), batteries and electric motors. In particular, we use trade data and input-output tables to test the scenario in which the EU would stop

[1] https://www.thewatcherpost.eu/politics-economics/mario-draghi-speaks-as-a-european-constituent-his-report-on-competitiveness-the-complete-version/

importing those green technologies and produce them within its borders. Although we acknowledge that this is an unlikely and extreme scenario, increasing manufacturing capacity for green technologies is the key goal of the NZIA and a strategy currently being pursued by other global players, including the US.

Because of the pragmatisms implicit in our exercise, our results should be taken as a signal of the business opportunity that the green transition represents for the EU, rather than as an exact measure of the benefits of producing green technologies. This is even more the case when we consider that there are many more green technologies than the limited sample we analyse here and also that, even within the technologies we are analysing, for the sake of simplicity, we are not accounting for all inputs and components that make up for these products. Moreover, because our analysis is a static one, it does not take into account the impacts of the expected demand surge and new innovations that can be expected in the future.

Despite these caveats, the technologies investigated here can be enumerated among the most ‘representative’ green technologies that we monitor today. Indeed, these technologies are chosen because of their significant role in the green transition and beyond. First, the adoption of these technologies has been extremely rapid in the past years. Second, the EU industrial policy currently supports these products. Third, new innovations are still shaping these industries, creating business opportunities and attracting the interest of many global players.

2. MOTIVATION

Although green technologies are today highly strategic, Europe is dependent on foreign imports to satisfy its internal demand. This is despite the fact that EU exports of these technologies are growing (Figure 1).

Looking at the technologies one by one, imports of EVs rose more than threefold from 2017 to 2020 and almost fivefold from 2020 to 2022. However, **EU exports of EVs increased even more rapidly than imports**. This trend reflects an upsurge in EU demand for EVs and the important role played by EU producers, some of which can be considered pioneers in this market.

Batteries are the most valuable component of EVs, representing 30-45% of the cost of an EV,[2] and an increasingly strategic technology with strong global competition. **The imports of batteries, which were roughly ‘under control’ until 2021, skyrocketed during 2022**. As a consequence of this rapid growth, and although EU exports increased, the gap between imports and exports is widening. Indeed, as demand for batteries gained momentum in previous years, producers, particularly in China, increased their capacities. Consequently, **China today accounts for 74% of the world’s battery manufacturing capacity** (Strategic Perspectives, 2023a). Its largest producers are also moving away from the simple role of producers and becoming leading innovators.[3]

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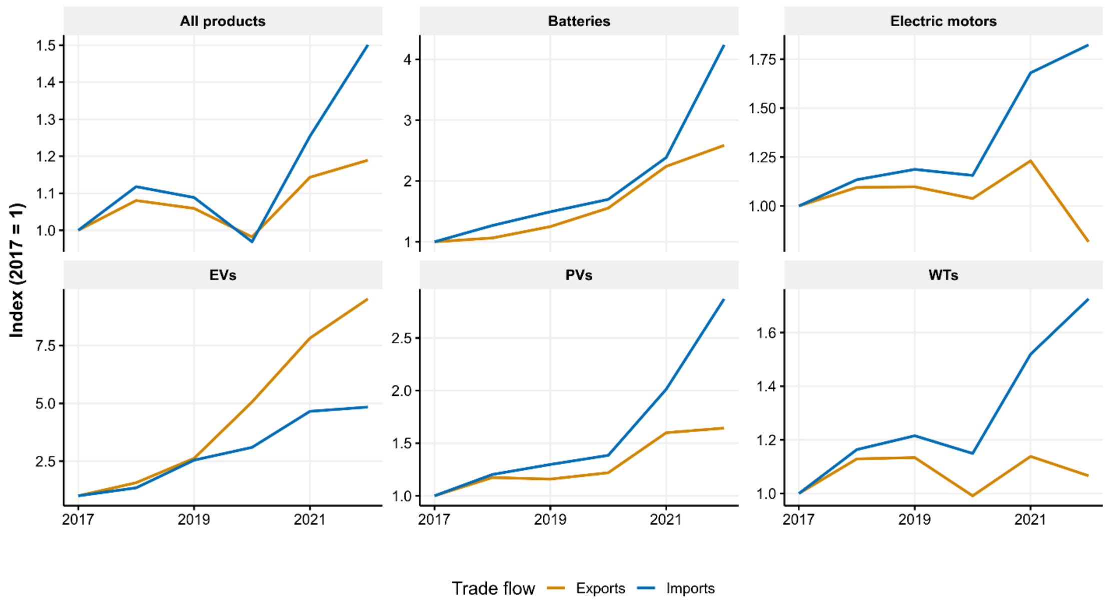
2 https://www.forbes.com/sites/jenniferdungs/2023/08/17/china-has-perfectly-tangled-the-battery-value-chain-with-electric-vehicles-leading-to-a-combo-the-us-and-europe-will-find-hard-to-beat/

3 https://www.bloomberg.com/news/newsletters/2024-04-12/china-already-makes-as-many-batteries-as-the-entire-world-wants

PVs have also become an important import item since 2020, with EU export growth stalling. With a value chain comprising roughly 80 companies, EU producers have progressively lost ground to Chinese competitors.[4] Heavy subsidies, which allowed price undercuts and over-capacity, are often cited as the factors behind the Chinese takeover of this industry. Today, according to the European Commission, solar energy is the fastest-growing renewable energy sector in the EU. Annual installations of PVs increased from around 28 GW in 2021 to 41 GW in 2022 and 56 GW in 2023. However, **the bulk of the demand for PVs in Europe is covered by imports, with 97% of the solar panels coming from China.**[5] EU PV producers are facing almost unprecedented difficulties: while EU producers together have an annual production capacity that could cover only 25% of all solar panels installed in the EU in 2023,[6] they are currently shutting down production lines instead of expanding them.

In wind turbines and electric motors, the EU has faced significant import growth and stagnating exports. According to the European Clean Tech Tracker,[7] the global WT industry is dominated by ten companies, five of which are European: Vestas, Siemens Energy, Enercon, Nordex SE and GE Renewable Energy. Manufacturing facilities are located in several countries, especially in Germany, Denmark and Spain. Today, the EU is a net exporter of wind technologies, and 83% of its market can be covered by EU manufacturers (Strategic Perspectives, 2023a; Widuto, 2024). As a result, imports of WTs have increased since 2017, but much less rapidly than the other technologies. For electric motors, Europe retains a significant presence in this market too, owing to a long tradition in the auto component industry. Although imports of electric motors have risen since 2020, they have increased at almost the same pace as overall imports.

Figure 1 / EU imports and exports from 2017 to 2022, indexed in 2017



Source: Authors, based on BACI data.

4 https://esmc.solar/press-release-race-against-time-safeguarding-the-european-solar-industry-is-still-possible/

5 https://energy.ec.europa.eu/news/commission-supports-european-photovoltaic-manufacturing-sector-new-european-solar-charter-2024-04-15_en

6 https://foreignpolicy.com/2024/03/22/europes-solar-industry-panels-energy-strategy/

7 https://www.bruegel.org/dataset/european-clean-tech-tracker

This analysis shows that European imports of green technologies have increased remarkably over the past few years. For some technologies, import growth has outpaced export growth. Europe suffers significant strategic dependencies, which are likely to deepen further as the green transition accelerates. At this critical juncture, boosting EU manufacturing capacity is essential if the EU is to reduce its dependencies and be a leading player in green technologies.

In line with the NZIA, the EU target is to manufacture within EU borders 40% of its annual deployment needs by 2030. The investments needed to reach this goal are huge. To take just one example, the EU today produces less than 3% of the solar panels needed to reach its 2030 target for solar power. With its Solar Photovoltaic Industry Alliance, the EU is already aiming at scaling up to 30 GW of annual solar PV manufacturing capacity by 2025, adding EUR 60 billion of GDP every year and creating more than 400,000 new jobs (direct and indirect). This suggests that to meet these targets, the EU would need to scale up its manufacturing capacities.

3. DATA AND METHODOLOGY

Our analysis uses **trade data and input-output tables** to estimate the impact of increasing the EU production of green technologies. For the sake of simplicity, we test the scenario in which the EU would end its imports from non-EU countries and internalise that demand through domestic production. Although we acknowledge that this is an unlikely and extreme scenario, we use this simple framework to assess the potential impacts of the green technologies without making assumptions about the direction. of future demand or trends in the manufacturing capacities of different world countries. Because of this pragmatic approach, our exercise and its results are suggestive of what is at stake for the EU, rather than providing a solution of how the EU will implement the green transition.

Keeping in mind this pragmatism, we identify the ‘green’ products associated with the five technologies under scrutiny and, building on WTO, ITC, and UNCTAD (2019), we trace product codes for them (all product codes are detailed in the Annex). It is worth highlighting here that for EVs, we account only for the **final products**, rather than for the parts and components that comprise the final product. For the other four technologies, we account for at least some of the components as detailed in WTO, ITC and UNCTAD (2019), although we recognise that, for simplicity, not all components and inputs are included in this list.

Using trade data from the CEPII BACI database,[8] we calculate the import share of these products (i.e. imports of EU27 countries importing from non-EU27 countries) in the total of the relevant ISIC 2-digit code. These import shares are then used in the ‘partial global extraction method’ (PGEM) calculation.[9] Using input-output data from the OECD Inter-Country Input-Output (ICIO) tables[10] and the import shares, we calculate the absolute value of imports. This total value of imports is then redistributed to the EU27 countries as domestic demand. With the input-output framework, we can then translate this increased final demand into changes in value added and (through employment multipliers) in employment.

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8 See http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=37

9 We refer the interested reader to Reiter and Stehrer (2023) for a detailed explanation of the necessary steps.

10 See http://oe.cd/icio

In so doing, this exercise mimics a counterfactual situation where these products are not imported but produced domestically (i.e. within EU27 borders), thus delivering an estimate of the potential benefits if the production took place in the EU.

For reporting, we aggregate these country-industry results up to country or industry level.

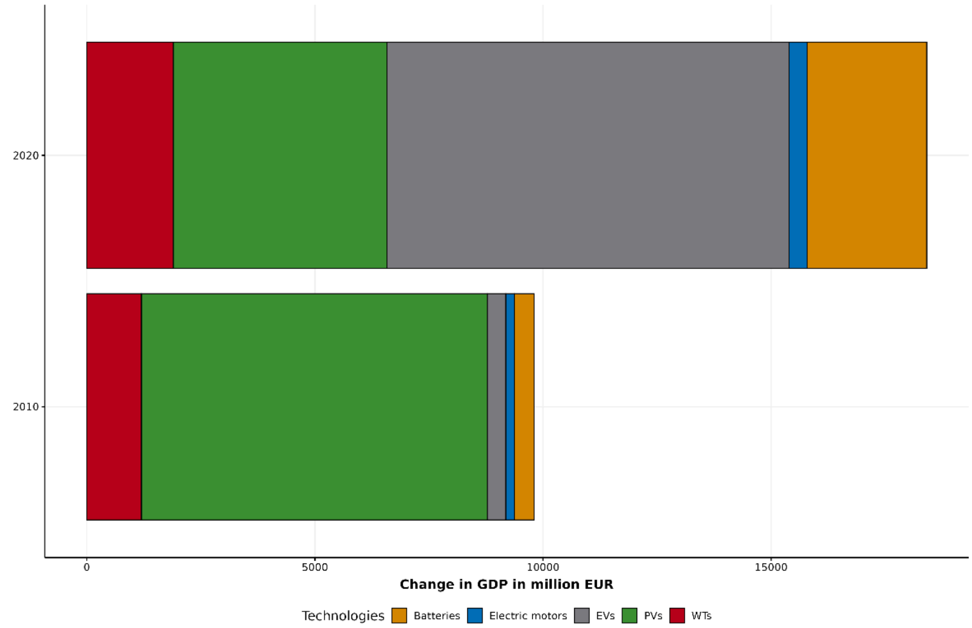
4. RESULTS: THE IMPACT OF GREEN TECHNOLOGIES ON GDP AND EMPLOYMENT IN THE EU

This chapter presents the key results of our analysis, showing the impact of the increased EU production of these green technologies on GDP and employment and the indirect impacts on the industries linked to them.

4.1. The impact on GDP and employment

Our analysis indicates that increasing the production of these five green technologies would increase **EU GDP by EUR 18.4 billion** (Figure 2). This equals half the amount of state aid disbursed by EU member states for environmental protection in 2022 (European Commission, 2024), the funds requested for the Innovation Fund, which reinvests the funds generated by the EU's Emissions Trading System (ETS), or the total amount of public investments required by the NZIA (European Commission, 2024). The same shift of imports to EU production would have had roughly **half of the impact in 2010**, generating EUR 9.8 billion of GDP. This indicates the greater relevance of green technologies over the past decade and also suggests the potential magnitude of these impacts in the next decade. Indeed, as the green transition is expected to gain further momentum in the future, a stronger investment in these technologies is expected to generate even stronger impacts on GDP.

Figure 2 / Impact of increased EU production on EU GDP (in million EUR)



Source: Authors, based on OECD ICIO and BACI data.

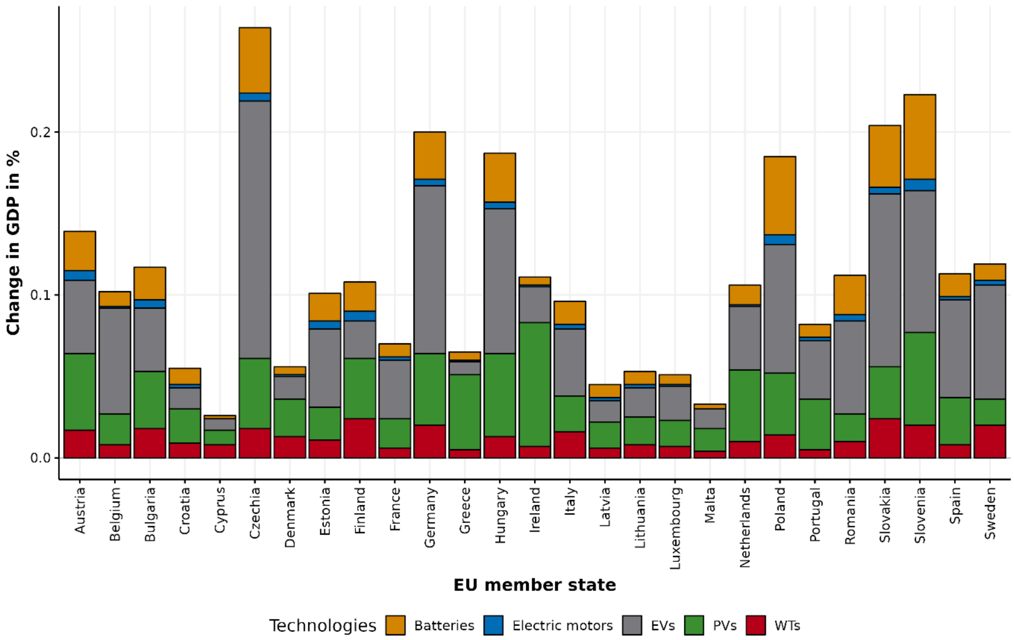
Today, EVs would contribute the most to GDP growth, adding EUR 8.8 billion to EU GDP and almost equalling the entire effect of all five technologies in 2010. PVs would be next, contributing EUR 4.7 billion. **In 2010, PVs would have been the largest contributor**, with all other technologies playing only a marginal role.

An impact of EUR 18.4 billion amounts to 0.13% of EU GDP in 2022 (Figure 3). Although apparently small, this is a sizeable impact when compared with other green policies. Indeed, green or trade policies usually exert much less significant effects. For example, the Carbon Border Adjustment Mechanism (CBAM), which requires countries to compensate for their carbon emissions, is expected to have an impact on EU GDP of around 0.05% (Korpar et al., 2022). Looking at the impact of more technologies and running a full modelling exercise, other studies found that the transformations produced by the European Green Deal could increase EU GDP by 0.4% by 2030 (Strategic Perspectives, 2023b).

When we look at how these impacts are distributed across EU member states (Figure 3), we see that the manufacturing hubs in Central and Eastern Europe would benefit the most from these changes (for obvious reasons). Beyond Central and Eastern European economies, other manufacturing-focused economies, most notably Germany, would capture a high share of this additional production. **With an impact of 0.14%, the impact on Austria would be of the same magnitude as the overall impact on EU GDP**. In terms of magnitude, this is similar to the impact on Sweden or Ireland.

A more prominent involvement in the production of EVs would yield the strongest results for EU GDP: 0.05% of the overall impact of these five technologies is due to EVs. After EVs, PVs are the technology with the largest impact (0.03%), followed by batteries (0.017%). The majority of EU economies would benefit most strongly from increasing their production of EVs, although several (including Austria) would benefit almost equally from the production of more EVs and PVs.

Figure 3 / Impact of increased EU production on EU GDP (% of GDP)

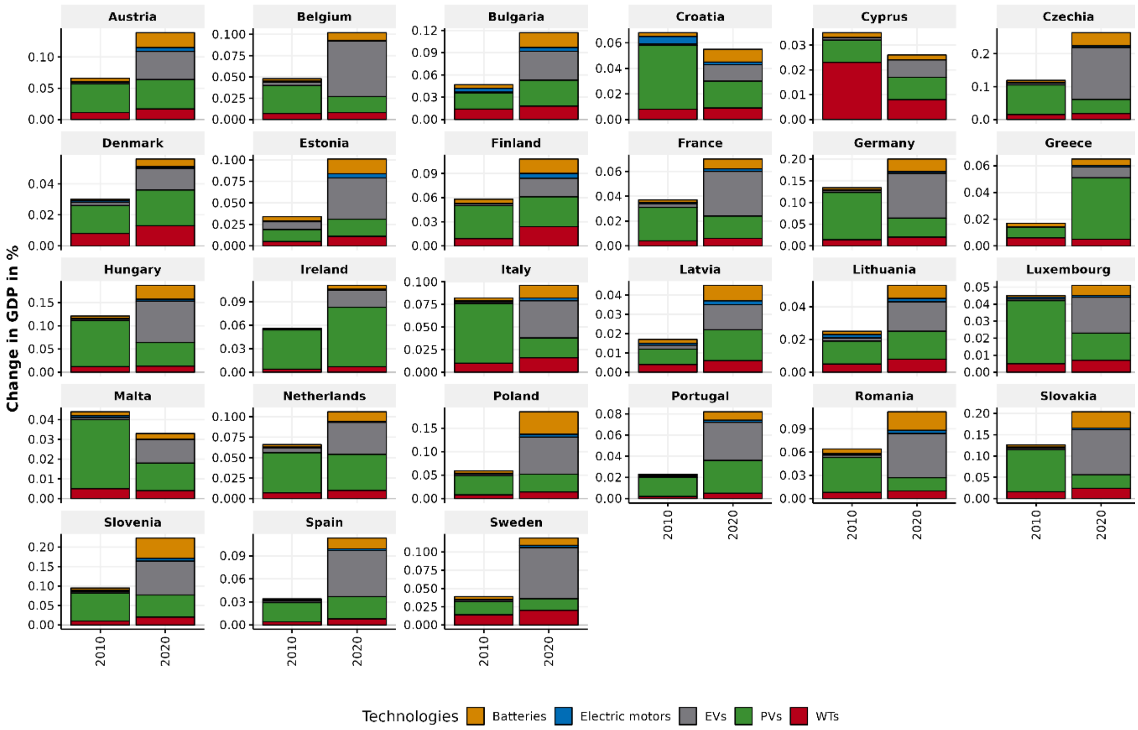


Source: Authors, based on OECD ICIO and BACI data.

BOX 1 / LOOKING BACK: WHAT WOULD HAVE BEEN THE IMPACT ON GDP IN 2010?

Figure 4 provides a comparison of the impacts on GDP in 2010 and 2020 in percentage terms by country. It clearly shows that **the impact in 2010 would have been much smaller than in 2020 in virtually all EU member states**. This is particularly evident for countries such as Austria, Czechia, Spain, Poland, Slovenia and Sweden. What also emerges from the comparison is that in 2010, the largest impacts would have been produced by the PV industry, rather than by EVs, as in 2020. This pattern certainly reflects different demand growth trends and possibly also the role of policy incentives, which in 2010 were more generous for PVs, while turning increasingly towards EVs in recent years.

Figure 4 / Impact on EU GDP in 2010 and 2020, %

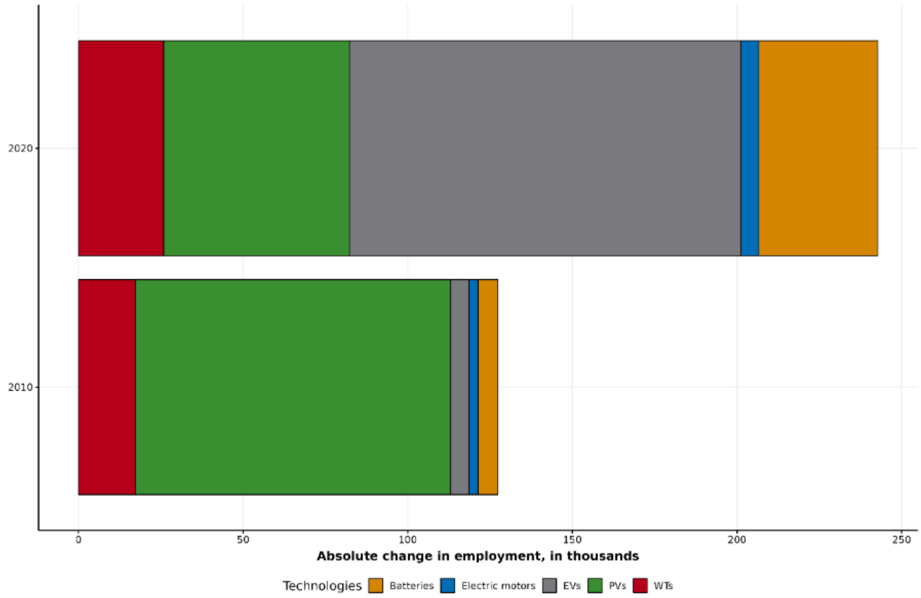


Source: Authors, based on OECD ICIO and BACI data.

Such an increase in production of green technologies would also create new jobs: **a total of 242,728 jobs would be created in the EU, 116,000 more than in 2010**. To put this number in perspective, it is worth considering that the European Commission (2023) expects the NZIA to create 350,000 jobs through new investments in wind energy, PVs, heat pumps, battery cells and electrolysers.

Mirroring the results for GDP, EVs would produce the highest number of new jobs (roughly 119,000). In 2010, however, PVs would have created the largest number of jobs (about 95,000).

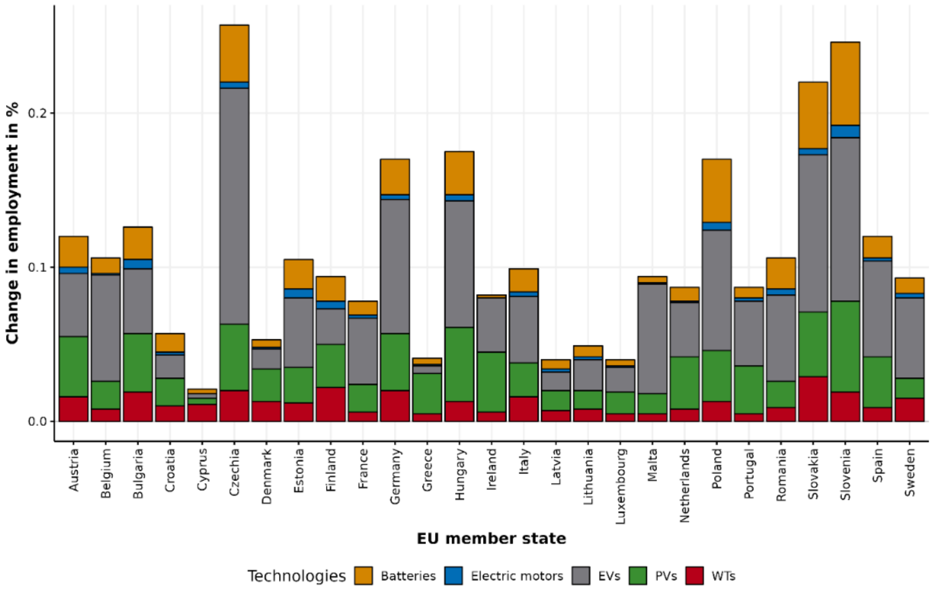
Figure 5 / Impact on EU jobs ('000)



Source: Authors, based on OECD ICIO and BACI data.

When we consider these numbers in relation to the workforce of the EU and its member states (Figure 6), we see that increasing the production of these five technologies would increase employment by 0.12%, with peaks of 0.257% for Czechia, 0.246% for Slovenia and 0.22% for Slovakia. The impacts are also significant in other EU manufacturing hubs, such as Poland, Hungary and Germany. As for Austria, this increased production would generate an impact on employment of 0.12%. As is the case for GDP, **EVs would have the most significant impact**.

Figure 6 / Impact of increased EU production on EU employment (as % of employment)



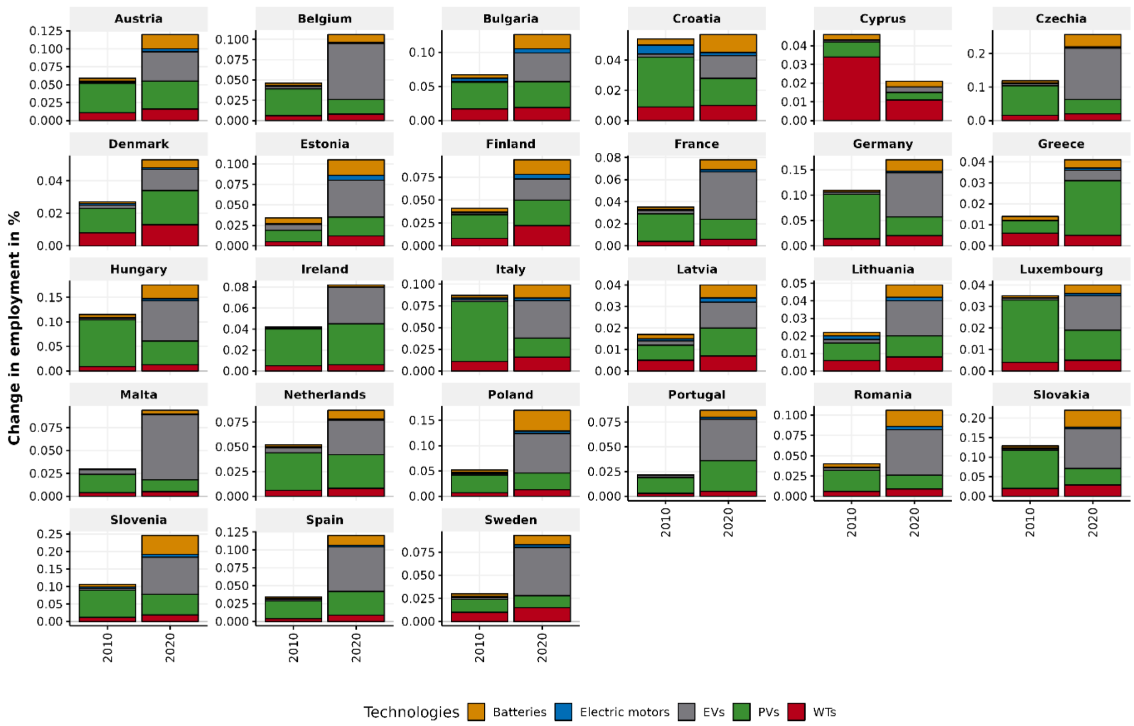
Source: Authors, based on OECD ICIO and BACI data.

BOX 2 / LOOKING BACK: WHAT WOULD HAVE BEEN THE IMPACT ON THE EMPLOYMENT IN EACH EU MEMBER STATE IN 2010?

The answer to this question can be seen in Figure 7. As with the results for GDP, the impacts on employment in 2010 would have been smaller than in 2020 in virtually all EU member states. In Austria, for example, the impact in 2010 would have been less than half of that in 2020; in Poland, one-third and in Sweden roughly one-quarter. This indicates the relevance that green technologies have gained over the past years. The comparison also hints at the larger impacts that the same analysis is likely to yield 10 years from now. Indeed, accounting for the expected demand growth for green technologies (arising from changes in consumer preferences, but also induced by public policies and incentive schemes), it is obvious that the magnitude of these impacts is likely to increase in the future.

As for GDP, in 2010 the largest impacts would have been produced in the PV industry, rather than in EVs, as in 2020.

Figure 7 / Impact on EU employment in 2010 and 2020, %



Source: Authors, based on OECD ICIO and BACI data.

4.2. The indirect impacts on linked industries

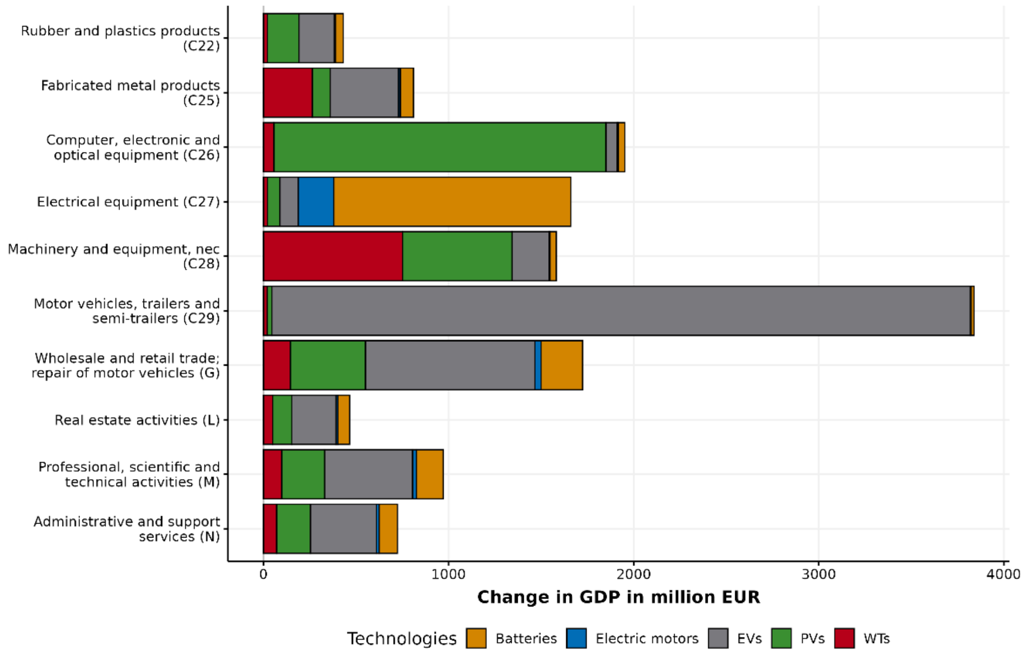
All economic sectors are linked to one another by being suppliers and buyers of inputs, intermediate and final products. In the case of these technologies, for example, PVs use thin silicon wafers, an electronic product, as well as lithium and a huge variety of other products and services. The same applies to EVs, which source inputs from virtually all sectors of the economy. Because of these linkages, expanding the production of these green technologies creates direct positive impacts on GDP and employment in the industries producing these products and indirect impacts in the industries producing inputs (in the form of intermediate products and services) which are then bought by producers of green products. Moreover, because the EU is a well-integrated economy, the spillovers can be found across industries, but also across countries. Therefore, increased production in Czechia has positive effects on the production of Austria, for example. The relevance of these indirect impacts on EU GDP is illustrated in Figure 8. The figure highlights a few interesting results.

The industry that would benefit the most is motor vehicles, trailers and semi-trailers. This is not surprising, as the production of EVs is part of this industry. The other industries directly involved in the production of these technologies – computer, electronic and optical equipment, and electrical equipment – would also benefit greatly. Owing to their strategic and technological relevance, various products within the computer, electronic and optical equipment industry are targets of industrial policy in the EU. As the Commission aims to accelerate the **twin transition**, i.e. a transition towards a greener and more digital economy, our findings suggest that pushing for the production of green technologies would stimulate the production of digital products too.

Beyond these industries, **significant spillover effects are visible for three services: wholesale and retail; professional, scientific and technical activities; and administrative and support services.** This indicates that the effects of increased production of green technologies would reach many parts of the economy. Considering the different types of activities that these services entail, **both higher-tech (e.g. professional and technical business services) and lower-tech activities (e.g. retail services) would benefit from the additional production.**

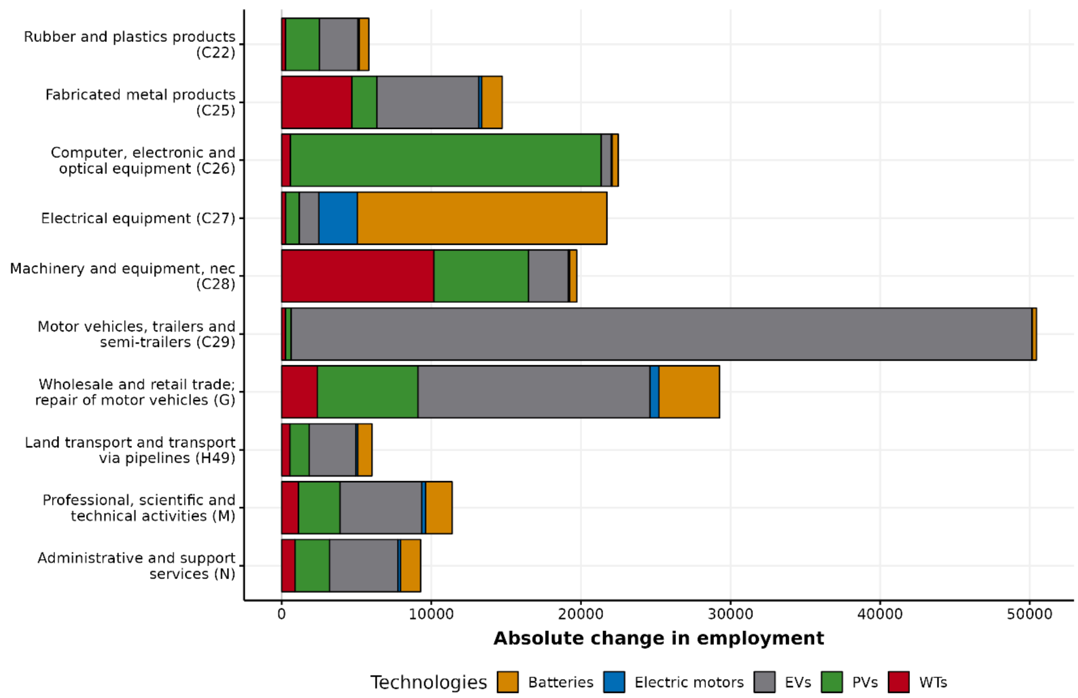
The impact on wholesale and retail services is even more pronounced for jobs (Figure 9). As this is a very labour-intensive activity, the indirect impact on its employment is second only to that for motor vehicles. Although just over 50,000 new jobs would be created in the motor vehicles industry, 30,000 jobs would be generated in wholesale and retail. **Fabricated metal products** would also be positively affected, with roughly 15,000 new jobs, created mostly because of the growth in EV production but also benefiting from the expansion of WT production. **Professional, scientific and technical activities and administrative and support services** would also see roughly 10,000 new jobs each, owing to EVs and PVs. This mix of activities also suggests that new job opportunities are likely to emerge for both unskilled workers (e.g. in wholesale and retail) and skilled workers (e.g. in professional, scientific and technical activities).

Figure 8 / Indirect impacts on EU GDP (in million EUR), top 10 industries with the highest effects



Source: Authors, based on OECD ICIO and BACI data.

Figure 9 / Indirect impacts on EU employment (no. of jobs), top 10 industries with the highest effects



Source: Authors, based on OECD ICIO and BACI data.

5. DISCUSSION AND POLICY IMPLICATIONS

Green technologies are helping to reduce the carbon footprint of economic activities and creating enormous business opportunities, spurring investments, spawning new firms and generating new innovations. All this translates into higher exports and competitiveness, higher GDP growth and jobs. As global demand grows rapidly and the focus of policies worldwide shifts towards the green transition, the heightened competition has created a 'green race' in terms of the adoption of green technologies, but also, and even more strategically, in terms of investment attraction.

Europe is contributing significantly to the global production and innovation of green technologies (see, for example, European Investment Bank, 2024; Strategic Perspectives, 2023a). Despite its role, Europe is now a net importer of most green technologies. In other words, it has become dependent on foreign imports to satisfy its domestic demand. Strategic dependencies, particularly from China, are becoming more pervasive (see, for example, Arjona et al., 2023; European Commission, 2021, 2022; Guadagno and Stehrer, 2024; Pindyuk, 2023; Reiter and Stehrer, 2021, 2023).

Amid this scenario, **Europe is today at a crossroads**. By continuing on the current path, it might have to rely on foreign products and innovations to push its green agenda. And this is not all. European industries are likely to be severely hit by the loss of competitiveness that would derive from this choice. Indeed, as foreign producers (particularly in China and the US) ramp up their investments, they will be likely to establish themselves as market leaders, wiping out (often long-standing) EU industries. The alternative route Europe could take is to prioritise investments and policy interventions so as to accelerate the transition and benefit economically from it. Although ambitious, the plan to become a world producer and innovator of green technologies is not incompatible with Europe's specialisation, capabilities and potential. Neither is it an unwise business consideration. On the one hand, EU companies are making sizeable investments to gain significant market shares and remain innovative. On the other hand, green technologies offer astonishing growth prospects, in terms of profits, returns on investments, stock prices, etc. (IEA, 2024a).

To contribute to the debate on the **co-benefits of the green transition**, our study estimates the impact on EU GDP and employment of an increase in EU production of five of the most discussed green technologies: PVs, WTs, batteries, electric motors and EVs. The key findings of our study can be summarised as follows:

1. Increasing the production of these technologies would **increase EU GDP by EUR 18.4 billion and generate 242,728 new jobs**, based on 2022 data.
2. **EVs would have the largest impact on GDP and employment**, accounting for EUR 8.8 billion of GDP and 119,000 jobs.
3. Beyond the industries directly involved in the production of these technologies, those to benefit most strongly would be **fabricated metal products; wholesale and retail; professional, scientific and technical activities; and administrative and support services.**

Although our estimates could be considered a sort of 'upper boundary' of the impact of reshoring these technologies (owing to the fact that reshoring of the entire production is neither realistic nor desirable from a global perspective), they are possibly a **'lower boundary' of the potential impact of green technologies for economic prosperity and jobs, especially when we think in prospective terms**. We are confident of this for a number of reasons.

First, even today there are **many more green technologies** than the limited sample analysed here. These include, for example, heat pumps – for which the global market is growing fast (Strategic Perspectives, 2023a), other renewable energies (such as hydropower), recycling technologies and new green materials, to cite only a few.

Second, in our analysis, we use only **data on final products and main components**[11] and conduct a static analysis, which **does not account for future demand trends**. Using a more complex methodological setting and accounting for more technologies, other studies have found, for example, that decarbonising the EU economy will produce 475,000 new jobs (Strategic Perspectives, 2023b). In a similar vein, others found that expanding the production of renewable energy and storage technologies will have an impact of around EUR 9.8 billion on Austrian GDP, while generating 100,000 new jobs in Austria by 2030 (Goers et al., 2020).

Moreover, as **demand is expected to grow much faster than in the recent past**, in prospective terms the effects of the green transition on GDP and employment are likely to be much higher. For example, according to SolarPower Europe's Annual EU Market Outlook 2022-2026, the EU member states saw PV capacity increase by 47% from 2020 to 2021. Even higher growth rates are expected in 2023, and capacities are expected to more than double by 2026.[12] EVs and batteries are also expected to enjoy extraordinarily high growth. According to the International Energy Agency (IEA, 2024b), global demand for EV batteries will go up sevenfold by 2030, while investments could reach USD 800 billion by 2030, up by 400% relative to 2023.[13]

Ambitious policy targets are also expected to spur the adoption of green technologies. The revised Renewable Energy Directive, adopted in 2023, set a renewable target for 2030 at a minimum of 42.5%, up from the previous 32% target, with an aspiration to reach 45% as mentioned in the REPowerEU plan.[14] For PVs, by 2030 the EU aims to reach the target of almost 600 GW of installed solar PV capacity, according to its Solar Energy Strategy, up from around 263 GW today (McWilliams et al., 2024). If this target is met, solar PV will become the largest source of electricity production in the EU. Similar plans (outlined in the RePowerEU) for wind capacity aim to reach 420 GW by 2030, up from 200 GW today.[15] Similarly, the

11 As the technologies that we are analysing are often made of hundreds of parts, and require a variety of machinery and tools, and complex equipment to be produced, tracing back all the products that would benefit from an increased production is an extremely interesting and equally challenging endeavour.

12 For more forecasts on the PV industry, see https://www.pv-tech.org/bnef-global-solar-additions-655gwdc-in-2024/ and https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/building-a-competitive-solar-pv-supply-chain-in-europe

13 https://www.eea.europa.eu/en/analysis/indicators/new-registrations-of-electric-vehicles

14 https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en

15 See the European Clean Tech Tracker: https://www.bruegel.org/dataset/european-clean-tech-tracker

Fit for 55 package requires all new cars and vans registered in Europe to be zero-emission by 2035, essentially phasing out the internal combustion engine (Delanote et al., 2022).[16]

Finally, and perhaps most fundamentally, most of the green technologies (including those not investigated in this study) are still young. **As the pace of innovation in green technologies is extremely fast, many possibilities for quality improvements and new product developments exist** (Ghodsi and Mousavi, 2023; McWilliams et al., 2024; Noailly, 2022). Such innovations would inevitably impact GDP and employment in the future. Moreover, as new green technologies are continuously introduced, estimating the future impact of the green transition is a particularly challenging exercise. The findings of our study partly hint at that. Looking at the 2010 findings, PVs were the technology yielding the largest results in terms of both GDP and employment. However, after only 10 years, EVs had completely taken over and had become a tremendously important market for the EU and globally.

The key policy messages stemming from our analysis can be outlined as follows.

First, the EU has put in place a range of policy initiatives to accelerate the green transition, but more emphasis is needed on manufacturing capacities, to meet the targets of the NZIA, remain internationally competitive and reduce strategic dependencies. As the European Commission (2023) noted, the EU would need investments of around EUR 92 billion over the period 2023-2030, and possibly as high as EUR 119 billion to meet the NZIA targets. Under the Green Deal, the EU has also mobilised hundreds of billions of euros through a variety of funds and facilities (Pisani-Ferry et al., 2023; Findeisen and Mack, 2023). Although much of the Green Deal is under implementation, or has still not been implemented, its fate appears rather uncertain at present, in view of elections to the EU Parliament in June 2024. Beyond the EU-level initiatives, member states' policy agendas, including in Austria, are not short of initiatives, funds and programmes for the green transition (see, for example, BMBWF, BMK and BMAW, 2023). Many of these initiatives, however, seem focused on technology adoption, rather than the production and innovation of new green technologies.

Second, it is high time to do 'whatever it takes' for Europe to be a leader in green technologies. The stakes at play and the challenges are, in some cases, so large that the EU cannot afford to remain marginal in this competition. It is not just about competitiveness, economic growth, and jobs. In an era marked by geopolitical turmoil, over-reliance on a single external source poses risks in terms of long-term energy security and the resilience of EU supply chains.[17] The US has already shifted gears: the Inflation Reduction Act (IRA) has provided timely subsidies and ad hoc incentives for various green companies, including European ones.[18] According to some estimates, IRA could unlock USD 11 trillion in investments by 2032.[19] Moreover, the IRA is just one component of the US industrial policy, which also includes the CHIPS and Science Act and the Bipartisan Infrastructure Law. These incentives are coupled with trade policies, for example, in the form of import tariffs on solar PVs from China.[20] The US is also raising tariffs on its imports of Chinese batteries and EVs amid concerns of excessive dependence on China.[21] Amid this

16 https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6462

17 https://foreignpolicy.com/2024/03/22/europes-solar-industry-panels-energy-strategy/

18 https://www.reuters.com/business/autos-transportation/audi-ceo-planning-electric-car-factory-us-due-ira-2023-02-24/ ; https://www.reuters.com/technology/northvolt-says-believes-germany-battery-plant-talks-ongoing-2023-01-18/

19 https://www.goldmansachs.com/intelligence/pages/the-us-is-poised-for-an-energy-revolution.html

20 https://foreignpolicy.com/2024/03/22/europes-solar-industry-panels-energy-strategy/

21 https://www.bruegel.org/first-glance/us-tariffs-chinese-imports-managed-trade-back

scenario, the EU strategy cannot just be a defensive strategy, or a fund to be spent. Greater proactivity and vision are needed, together with the ambition and courage to aspire for more (Findeisen and Mack, 2023). Beyond the efforts to fight foreign subsidies non-compliant with international trade rules and to address unsustainable and inhumane business practices within supply chains (through the Due Diligence Directive), the EU must put in place a coherent industrial policy with appropriate funding to tackle all aspects of the green transition (Findeisen and Mack, 2023; Redeker, 2024).

Third, such investments will aim to increase manufacturing capacity but also (and foremost) to spur innovation of new green technologies. To stay ahead of the game and accelerate the roll-out of green technologies, Europe crucially needs to **invest more in R&D and innovation** for the green transition. The companies that will come up with the next technological breakthroughs will profit the most from their diffusion. It is important, therefore, that EU companies can play a role in the global innovation landscape of green technologies.[22] The two Important Projects of Common European Interest (IPCEIs) on batteries[23] are examples of the type of initiatives that are required to foster innovation and increase the chances that the next green breakthrough technologies are 'created and made in the EU'. Austrian companies are part of several IPCEIs, including for batteries and hydrogen and the Austrian government contributes to these initiatives via the funds of the Recovery and Resilience Facility (BMBWF, BMK, and BMAW, 2023). To truly make a difference, innovation policies should be courageous in **supporting early-stage projects with potentially great potential but also high risks in terms of market success**. This means that such a policy should accept risks and **failures**, acknowledging that innovation is (and will always be) a trial-and-error process.

To advance in this area, research will be undertaken to answer the following questions. Are all the initiatives by the EU and member states together adequate for the challenges ahead, and are they comparable in size to the incentives provided by other global superpowers? Is the current fragmentation of funds and initiatives spreading funds too thinly and preventing the creation of 'critical masses'? Do current policies, funds and initiatives pay equal attention to the adoption, production and innovation of green technologies?

In this regard, a **taxonomy of all policy initiatives** that directly and indirectly affect the green transition is necessary for a stocktake of what policy gaps and synergies exist at the EU level in terms of policy instruments, goals and sectors. Such a taxonomy will be complemented by a **data-intensive empirical analysis** of the specific technologies where the EU and its member states could credibly (and ambitiously) build a leading position in innovation and production. To this end, such an analytical study will unpack the components of each critical technology and study their value chains and production patterns in Europe vis-à-vis the rest of the world.

22 https://foreignpolicy.com/2024/03/22/europes-solar-industry-panels-energy-strategy/

23 https://competition-policy.ec.europa.eu/state-aid/ipcei/approved-ipceis/batteries-value-chain_en

REFERENCES

Arjona, R., W. Connell and C. Herghelegiu (2023), 'An enhanced methodology to monitor the EU's strategic dependencies and vulnerabilities', Single Market Economics Papers WP2023/14, Publications Office of the European Union.

BMBWF, BMK and BMAW (2023), 'Austrian Research and Technology Report', BMBWF, BMK, and BMAW, Vienna.

Carvalho, M., A. Dechezleprêtre and M. Glachant (2017), 'Understanding the dynamics of global value chains for solar photovoltaic technologies', WIPO Economic Research Working Paper No. 40, World Intellectual Property Organisation, Geneva.

Delanote, J., M. Ferrazzi, M. Ghodsi, D. Hanzl-Weiss, A. Kolev, A. Locci, S. Petti, D. Rückert, J. Schanz, T. Slacík, M. Stanimirovic, R. Stehrer, C. Weiss and M. Wuggenig (2022), 'Recharging the batteries: how the electric vehicle revolution is affecting Central, Eastern and South-Eastern Europe', ECONOMICS - THEMATIC STUDIES, European Investment Bank (EIB), 89th East Jour Fixe of the Oesterreichische Nationalbank, March 2022.

European Commission (2021), 'Strategic dependencies and capacities', Staff Working Document SWD(2021) 352 final, Brussels.

European Commission (2022), 'EU strategic dependencies and capacities: second stage of in-depth reviews', Staff Working Document SWD(2022) 41 final, Brussels.

European Commission (2023), 'Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity', Staff Working Document SWD(2023) 68 final, Brussels.

European Commission (2024), 'State aid scoreboard 2023', European Commission, Brussels.

European Investment Bank (2024), 'Investment Report 2023/2024: Transforming for competitiveness', European Investment Bank, Luxembourg.

Findeisen, F. and S. Mack (2023), 'Do more with more: How the EU can improve funding for the European Green Deal', Policy Brief, Jacques Delors Centre Hertie School, Berlin.

Ghodsi, M. and Z. Mousavi (2023), 'Patents as green technology barometers: trends and disparities', in: V. Astrov (ed.), wiiw Monthly Report, No. 10/2023, The Vienna Institute for international Economic Studies (wiiw), Vienna, October, pp. 11-19.

Goers, S., F. Schneider, H. Steinmüller and R. Tichler, R. (2020), 'Wirtschaftswachstum und Beschäftigung durch Investitionen in Erneuerbare Energien', Energieinstitut an der Johannes Kepler Universität Linz.

Guadagno, F. and R. Stehrer (2024), 'Assessing the international interlinkages and dependencies of the EU27 "energy-renewables" ecosystem', wiiw Research Report No. 473, The Vienna Institute for International Economic Studies (wiiw), Vienna, May.

International Energy Agency (2024a), 'Global EV Outlook 2024', International Energy Agency, Paris.

International Energy Agency (2024b), 'Batteries and secure energy transitions', World Energy Outlook Special Report, International Energy Agency, Paris.

Leonard, M., J. Pisani-Ferry, J. Shapiro, S. Tagliapietra and G. Wolff (2021), 'The geopolitics of the European Green Deal', Policy Contribution 04/2021, Bruegel.

Korpar, N., M. Larch and R. Stöllinger (2022), 'Comparing scenarios for a European carbon border adjustment mechanism: trade, FDI and welfare effects with a focus on the Austrian economy', wiiw Research Report No. 460, The Vienna Institute for International Economic Studies (wiiw), Vienna, July.

McWilliams, B., S. Tagliapietra and C. Trasi (2024), 'Smarter European Union industrial policy for solar panels', Policy Brief 02/2024, Bruegel.

Noailly, J. (2022), 'Directing innovation towards a low-carbon future', WIPO Economic Research Working Paper No. 72, World Intellectual Property Organisation, Geneva.

Pindyuk, O. (2023), 'Implications of China's growing geo-economic influence for the EU: addressing critical dependencies in the green transition', wiiw Policy Notes and Reports No. 67, The Vienna Institute for International Economic Studies (wiiw), Vienna, March.

Pisani-Ferry, J., S. Tagliapietra and G. Zachmann (2023), 'A new governance framework to safeguard the European Green Deal', Policy Brief 18/2023, Bruegel.

Redeker, N. (2024), 'Chasing Shadows: What the Net Zero Industry Act Teaches Us About EU Industrial Policy', Policy Brief, Jacques Delors Centre Hertie School, Berlin.

Reiter, O. and R. Stehrer (2021), 'Learning from tumultuous times: an analysis of vulnerable sectors in international trade in the context of the corona health crisis', wiiw Research Report No. 454, The Vienna Institute for International Economic Studies (wiiw), Vienna, July.

Reiter, O. and R. Stehrer (2023), 'Assessing the importance of risky products in international trade and global value chains', *Empirica*, Vol. 50(1), pp. 7-33.

Strategic Perspectives (2023a), 'Competing in the new zero-carbon industrial era: assessing the performance of five major economies on key decarbonisation technologies', Strategic Perspectives, Brussels.

Strategic Perspectives (2023b), 'Turning the European Green Deal into reality'. Strategic Perspectives, Brussels.

Widuto, A. (2024), 'Wind energy in the EU', European Parliamentary Research Service.

WTO, ITC and UNCTAD (2019), 'Special topic: aligning trade and tariff policies with sustainable development', in: WTO, ITC, and UNCTAD, *World Tariff Profiles 2019*, pp. 218-241. World Trade Organisation, Geneva.

ANNEX

Table 1 / The products analysed in this study

HS 2017 codes	HS product description	Technology	ISIC Rev.4 2-digit code
850650	Cells and batteries; primary, lithium	Batteries	27
850680	Cells and batteries; primary, (other than manganese dioxide, mercuric oxide, silver oxide, lithium or air-zinc)	Batteries	27
850710	Electric accumulators; lead-acid, of a kind used for starting piston engines, including separators, whether or not rectangular (including square)	Batteries	27
850720	Electric accumulators; lead-acid, (other than for starting piston engines), including separators, whether or not rectangular (including square)	Batteries	27
850730	Electric accumulators; nickel-cadmium, including separators, whether or not rectangular (including square)	Batteries	27
850740	Electric accumulators; nickel-iron, including separators, whether or not rectangular (including square)	Batteries	27
850750	Electric accumulators; nickel-metal hydride, including separators, whether or not rectangular (including square)	Batteries	27
850760	Electric accumulators; lithium-ion, including separators, whether or not rectangular (including square)	Batteries	27
850780	Electric accumulators; other than lead-acid, nickel-cadmium, nickel-iron, nickel-metal hydride and lithium-ion, including separators, whether or not rectangular (including square)	Batteries	27
850790	Electric accumulators; parts n.e.c. in heading no. 8507	Batteries	27
870220	Vehicles; public transport type (carries 10 or more persons, including driver), with both compression-ignition internal combustion piston engine (diesel or semi-diesel) and electric motor for propulsion, new or used	EVs	29
870230	Vehicles; public transport type (carries 10 or more persons, including driver), with both spark-ignition internal combustion reciprocating piston engine (diesel or semi-diesel) and electric motor for propulsion, new or used	EVs	29
870240	Vehicles; public transport type (carries 10 or more persons, including driver), with only electric motor for propulsion, new or used	EVs	29
870340	Vehicles; with both spark-ignition internal combustion reciprocating piston engine and electric motor for propulsion, incapable of being charged by plugging to external source of electric power	EVs	29
870350	Vehicles; with both compression-ignition internal combustion piston engine (diesel or semi-diesel) and electric motor for propulsion, incapable of being charged by plugging to external source of electric power	EVs	29
870360	Vehicles; with both spark-ignition internal combustion reciprocating piston engine and electric motor for propulsion, capable of being charged by plugging to external source of electric power	EVs	29
870370	Vehicles; with both compression-ignition internal combustion piston engine (diesel or semi-diesel) and electric motor for propulsion, capable of being charged by plugging to external source of electric power	EVs	29
870380	Vehicles; with only electric motor for propulsion	EVs	29
871160	Vehicles; public transport type (carries 10 or more persons, including driver), with both compression-ignition internal combustion piston engine (diesel or semi-diesel) and electric motor for propulsion, new or used	EVs	30
850131	Electric motors and generators (excluding generating sets) – Other DC motors; DC generators: of an output not exceeding 750 W	Electric motors	27
850134	Electric motors and generators (excluding generating sets) – Other DC motors; DC generators: of an output exceeding 375 kW	Electric motors	27
850161	Electric motors and generators (excluding generating sets) – AC generators (alternators): of an output not exceeding 75 kVA	Electric motors	27
850162	Electric motors and generators (excluding generating sets) – AC generators (alternators): of an output exceeding 75 kVA but not exceeding 375 kVA	Electric motors	27

Contd.

Table 1 / Continued

HS 2017 codes	HS product description	Technology	ISIC Rev.4 2-digit code
850163	Electric motors and generators (excluding generating sets) – AC generators (alternators): of an output exceeding 375 kVA but not exceeding 750 kVA	Electric motors	27
850164	Electric motors and generators (excluding generating sets) – AC generators (alternators): of an output exceeding 750 kVA	Electric motors	27
850231	Electric generating sets and rotary converters – Other generating sets: wind- powered	Electric motors	27
280461	Hydrogen, rare gases and other non- metals – Silicon: containing by weight not less than 99.99% of silicon	PVs	20
381800	Chemical elements doped for use in electronics, in the form of discs, wafers or similar forms; chemical compounds doped for use in electronics.	PVs	20
392010	Other plates, sheets, film, foil and strip, of plastics, non- cellular and not reinforced, laminated, supported or similarly combined with other materials – Of polymers of ethylene	PVs	22
392091	Other plates, sheets, film, foil and strip, of plastics, non-cellular and not reinforced, laminated, supported or similarly combined with other materials – Of other plastics: of poly(vinyl butyral)	PVs	22
392190	Other plates, sheets, film, foil and strip, of plastics:	PVs	22
848610	Machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays; machines and apparatus specified in Note 9 (C) to this Chapter; parts and accessories – Machines and apparatus for the manufacture of boules or wafers	PVs	28
848620	Machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays; machines and apparatus specified in Note 9 (C) to this Chapter; parts and accessories – Machines and apparatus for the manufacture of semiconductor devices or of electronic integrated circuits	PVs	28
848690	Machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays; machines and apparatus specified in Note 9 (C) to this Chapter; parts and accessories – Parts and accessories	PVs	28
854140	Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes; mounted piezo-electric crystals – Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes	PVs	26
730820	Structures (excluding prefabricated buildings of heading 9406.00) and parts of structures (for example, bridges and bridge sections, lock gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel – Towers and lattice masts	WTs	25
730890	Structures (excluding prefabricated buildings of heading 9406.00) and parts of structures (for example, bridges and bridge sections, lock gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel – Other	WTs	25
841280	Other engines and motors – Other	WTs	28
841290	Other engines and motors – Parts	WTs	28
848210	Ball or roller bearings – Ball bearings	WTs	28
848230	Ball or roller bearings – Spherical roller bearings	WTs	28
848310	Transmission shafts (including cam shafts and crank shafts) and cranks; bearing housings and plain shaft bearings; gears and gearing; ball or roller screws; gear boxes and other speed changers, including torque converters; flywheels and pulleys, including pulley blocks; clutches and shaft couplings (including universal joints) – Gears and gearing, other than toothed wheels, chain sprockets and other transmission elements presented separately; ball or roller screws; gear boxes and other speed changers, including torque converters	WTs	28

Contd.

Table 1 / Continued

HS 2017 codes	HS product description	Technology	ISIC Rev.4 2-digit code
848340	Transmission shafts (including cam shafts and crank shafts) and cranks; bearing housings and plain shaft bearings; gears and gearing; ball or roller screws; gear boxes and other speed changers, including torque converters; flywheels and pulleys, including pulley blocks; clutches and shaft couplings (including universal joints) – Gears and gearing, other than toothed wheels, chain sprockets and other transmission elements presented separately; ball or roller screws; gear boxes and other speed changers, including torque converters	WTs	28
848360	Transmission shafts (including cam shafts and crank shafts) and cranks; bearing housings and plain shaft bearings; gears and gearing; ball or roller screws; gear boxes and other speed changers, including torque converters; flywheels and pulleys, including pulley blocks; clutches and shaft couplings (including universal joints) – Clutches and shaft couplings (including universal joints)	WTs	28
901580	Surveying (including photogram metrical surveying), hydrographic, oceanographic, hydrological, meteorological or geophysical instruments and appliances, excluding compasses; rangefinders – Other instruments and appliances	WTs	26

Source: Authors.

Table 2 / The industry classification used in this study

Code	Industry	ISIC Rev.4 2-digit codes
A01_02	Agriculture, hunting, forestry	01, 02
A03	Fishing and aquaculture	03
B05_06	Mining and quarrying, energy-producing products	05, 06
B07_08	Mining and quarrying, non-energy-producing products	07, 08
B09	Mining support service activities	09
C10T12	Food products, beverages and tobacco	10, 11, 12
C13T15	Textiles, textile products, leather and footwear	13, 14, 15
C16	Wood and products of wood and cork	16
C17_18	Paper products and printing	17, 18
C19	Coke and refined petroleum products	19
C20	Chemical and chemical products	20
C21	Pharmaceuticals, medicinal chemical and botanical products	21
C22	Rubber and plastics products	22
C23	Other non-metallic mineral products	23
C24	Basic metals	24
C25	Fabricated metal products	25
C26	Computer, electronic and optical equipment	26
C27	Electrical equipment	27
C28	Machinery and equipment, nec	28
C29	Motor vehicles, trailers and semi-trailers	29
C30	Other transport equipment	30
C31T33	Manufacturing nec; repair and installation of machinery and equipment	31, 32, 33
D	Electricity, gas, steam and air conditioning supply	35
E	Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39
F	Construction	41, 42, 43
G	Wholesale and retail trade; repair of motor vehicles	45, 46, 47
H49	Land transport and transport via pipelines	49
H50	Water transport	50
H51	Air transport	51
H52	Warehousing and support activities for transportation	52
H53	Postal and courier activities	53
I	Accommodation and food service activities	55, 56
J58T60	Publishing, audiovisual and broadcasting activities	58, 59, 60
J61	Telecommunications	61
J62_63	IT and other information services	62, 63
K	Financial and insurance activities	64, 65, 66
L	Real estate activities	68
M	Professional, scientific and technical activities	69 to 75
N	Administrative and support services	77 to 82
O	Public administration and defence; compulsory social security	84
P	Education	85
Q	Human health and social work activities	86, 87, 88
R	Arts, entertainment and recreation	90, 91, 92, 93
S	Other service activities	94,95, 96
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	97, 98

Source: Authors.

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