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Green Industrial Policy in Europe: Past, Present, and Prospects

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Abstract
This paper critically examines the concept of green industrial policy in the context of the European Union (EU) under the European Green Deal—an initiative aimed at achieving climate neutrality by 2050. While the European Green Deal emphasizes climate targets, it did not fully address the economic and social sustainability dimensions of the green transition. The EU, considering the growing concerns over the potential consequences of the United States Inflation Reduction Act (IRA) and China's assertiveness in the value chains of clean technologies, reassessed its green industrial policy approach in the Net Zero Industry Act proposal. Considering these developments, this study delves into the historical evolution of European industrial policy, evaluates the current proposals presented by the European Commission, and puts forth principles and recommendations for a green industrial policy that can effectively facilitate the green transition within the EU.

Keywords Green transition · Industrial policy · Innovation · EU Green Deal · IRA · NZIA

JEL Classification O38 · Q58

1 Introduction

The transition of economies from brown to green represents the major socio-economic transformation of our time, often referred to as an industrial revolution against a deadline. Never in history has the call for policy been so crucial to tackling a global common good.

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The goal is clear: to facilitate a comprehensive decarbonization process to avoid the most dramatic impacts of global warming.

With the European Green Deal, Europe has pledged to become the first climate-neutral continent by 2050. To get there, the European Union has committed to cut its greenhouse gas emissions by 55% by 2030 compared to 1990 and has also started to adopt the necessary legislation—the so-called "Fit for 55" package—to turn this objective into reality (Tagliapietra and Veugelers 2021).

But a strategy only based on climate targets and instruments would fall short if firms and citizens fail to adjust or reject the adjustment. The need to meet climate and environmental targets, while ensuring their economic and social sustainability, requires a smooth transformation that generates enough benefits to compensate the losers and allows for an efficient reallocation. This puts green industrial policy under the spotlight. Turning European Green Deal's promise to be the EU's new growth engine is quite challenging, especially given the heavy reliance of the European economy on carbon-intensive industries, such as the automotive industry, which will require significant restructuring in the coming years. As Europe lagged Asia and the USA in the global race for digital technologies, its position in the global race for clean technologies and industrial growth opportunities from the green transition is first order.

The COVID-19 outbreak dramatically exposed economies to their vulnerabilities, introducing a call for policy ensuring resilience and security of supply of strategically considered inputs. The war in Ukraine and the weaponization of Russian gas further exacerbated this security of supply concerns, particularly for energy and particularly for Europe. The EU launched in May 2022 its REPowerEU plan to transition faster to clean energy, diversify its energy supplies, and save energy to improve its "strategic autonomy" in energy.

The EU is not the sole actor in this respect. All major economies are designing climate and clean energy industrial policies with assuring security of energy supply and strategic autonomy in clean energy value chains. In a global environment of increasing geopolitical tension and in the absence of global policy coordination, this sets in motion a train of mutually reinforcing reactive pressures to further the "strategic autonomy" angle in countries' green industrial policies. The Inflation Reduction Act in the USA is a clear recent articulation of this, particularly its local content requirement stipulations, which outlined Europe's response in March 2023 with its Net Zero Industry Act. Reacting to the deepened geopolitical risks, the NZIA takes "strategic autonomy" in net-zero technologies a few steps further.

Countries are still figuring out how to reconcile the multi-dimensional objectives of a "green industrial policy with strategic autonomy" particularly when these objectives counteract each other. In the wake of COP28, the momentum for the European Union to spearhead the global green transition has never been stronger. The conference not only fostered a unified stance on moving beyond fossil fuels towards a net-zero future by 2050 but also set ambitious targets to triple renewable energy installations and double energy efficiency improvements by 2030. This alignment presents an unprecedented opportunity for the EU to assert its leadership globally by leading by example and implementing the EU Green Deal while preserving its socio-economic model.

This article aims to contribute to the discussion on green industrial policy through the example of the EU. It examines the EU's scope for a global leadership role in green industrial policy making, by shedding light on the historical evolution of European industrial policy, taking stock of the current proposals put forward by the European Commission, and suggesting recommendations on how to move forward. It is structured as follows: Section 2 traces the historical evolution of European industrial policy; Sections 3 and 4 discuss EU's green industrial policy and its recent developments; Section 5 outlines a set of principles for green industrial policy making and evaluates EU's green industry policy choices, while Sect. 6 provides policy recommendations for a more effective green industrial policy in Europe; Section 7 concludes.

2 A Brief History of Europe's Industrial Policy

Industrial policy and economic security are not new entrants into the discussions of European policy circles. The debate has traditionally focused on the role of the state in the economy and driven by questions asking why, to what extent, and how governments should intervene in steering market mechanisms. Europe's answers to these questions of industrial policy have evolved depending on different political and policy cycles. A critical evaluation of its past success, particularly in achieving industry development, is essential to understand its impact and derive lessons for future policymaking.

After the Second World War, when the process of European reconstruction began, the focus was notably on the strategic industries of coal, steel, electricity, and railways. Between the early 1950s and the mid 1970s, referred to as the heyday of industrial policy (Owen 2012), most European countries were concerned with closing the income gap and reducing their dependence on the USA. Countries proactively pursued interventionist winners-picking sectoral policies, also defined as *vertical industrial policies*, targeting industries thought to be strategic for future growth. For example, France launched a program to promote its national computer industry—the "Plan Calcul"—and engaged in "Grands Projets."

At the European level, the European Coal and Steel Community (ECSC), set up in 1952 was a notable success in modernizing coal production and reducing overcapacity by enhancing coordination between states. The European Economic Community (EEC), established after the ECSC, progressively reduced tariffs in European markets. A notable milestone in this era was the Davignon Plan, adopted in 1977, under which European-wide solutions were sought for the so-called "sunset" industries, while wielding national control of "sunrise" industries, such as computers. It was in this context that the Airbus consortium was established as a European industrial alliance to produce aircraft. The first technology policy initiative at European Community level was PREST (Politique de Recherche Scientifique et Technologique), aimed at facilitating common European research projects. The motivation for this initiative was fear of European technology lagging behind the USA.

Later, in the 1980s, emerged a new phase of liberalization with market-oriented industrial policies, limited to setting the right framework within which economic processes could take place: *horizontal industrial policy*. Countries liberalized markets, trying to avoid the government failures of the typically vertical industrial policy and winner-picking initiatives of the past. At European level, the inefficiencies of uncoordinated national industrial policies became clear, leading to the development of two important instruments at EU level: the internal market and competition policy, including state aid. The Single European Act (1986) also laid the legal basis for affirmative action of the state in research and development. During this period, different initiatives were undertaken at European Community level to promote cooperation on research and innovation. One example was ESPRIT (European Strategic Programme for Research and Information Technology), a 5-year program focused on collaborative research with the aim of "bringing together companies, universities and research institutes across Europe" with a specific focus on information technology (Owen 2012). ESPRIT was born as an attempt to respond to the government-led initiatives that the Japanese Ministry for International Trade and Industry undertook, initiatives that successfully enabled Japan to catch-up quickly with the USA as a technological and economic leader, particularly in the field of semiconductors. ESPRIT, starting in 1984, is typically considered the precursor of the European Commission's framework programs, through which the Commission conducts science, technology, and innovation policy and

collaborative research initiatives. While successful in fostering cooperation, it faced challenges in significantly altering Europe's technological lag.

During the 1990s and early 2000s, liberalization programs continued in Europe, driven by consensus at EU level on the preference for a more holistic, integrated, and "horizontal" approach to industrial policy. The role of the EU was to ensure the right framework conditions, focusing on the use of internal market and competition instruments and stimulating R&D and innovation. This cumulated in the 2000 Lisbon Strategy: a program "to transform the EU into the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion" (European Council 2000). Its goal was to implement a comprehensive strategy of structural reforms by boosting innovation and investment in R&D and creating a more integrated and competitive internal market.

The Great Recession of 2008 marked the start of a new era across Europe, characterized by an industrial policy revival with more vertical characteristics. In 2012, the European Commission published a new industrial policy communication, "A Stronger European Industry for Growth and Economic Recovery" (European Commission 2012), which started from the premise that "Europe needs industry" and set out a roadmap for reindustrializing Europe, with the aim of "raising the share of industry in GDP to 20% in 2020." Although the Commission stressed the need for a comprehensive vision "mobilising all the levers available at EU level, notably the single market, trade policy, SME policy, competition policy, environmental and research policy in favor of European companies' competitiveness," the communication included a more targeted approach, identifying six priority action lines, including key enabling technologies, clean vehicles, and smart grids. The communication was followed by action plans for specific sectors, such as steel (European Commission 2013). Around the same time, national initiatives like the German Energiewende were announced marking the initiative-taking approach of Member States in this regard (Box 1).

Box 1: Overview of the German Energiewende

The German Energiewende represents a comprehensive and multifaceted approach to transitioning the country's energy system from fossil fuels and nuclear power towards renewable energy sources to reduce greenhouse gas emissions and ensure reliable and affordable energy. It aims to have at least 65% of electricity generated from renewable sources by 2030 and a reduction of emissions compared to 1990 levels by 55% by 2030.

Supported by the Renewable Energy Sources Act (EEG), it promotes the expansion of wind, solar, biomass, and hydroelectric power offering incentives for renewable projects. It involves upgrading and expanding the transmission infrastructure to integrate renewable energy effectively, guided by the Grid Expansion Acceleration Act (NABEG), and it encompasses standards for building insulation and heating systems to reduce overall energy consumption, as mandated by the Energy Efficiency Act (EnEG). Finally, it aims for market liberalization, competition, and consumer protection under the Energy Industry Act (EnWG).

In the decade that followed its launch, the Energiewende has faced challenges. The transition has led to an increase in electricity prices for consumers, partly due to the costs associated with integrating renewable energy into the grid. Furthermore, despite progress in reducing emissions, Germany has struggled to meet its near-term targets, particularly in sectors like transport and heating. To address these challenges, Germany has implemented reforms and measures, including the Climate Action Programme 2030, which introduces a phased carbon pricing system for sectors not covered by the EU Emissions Trading System (ETS), incentives for energy-efficient building renovations, subsidies for electric vehicles, and investments in public transport.

Source: Agora Energiewende (n.d.), The German Energiewende; IEA (2020), Germany 2020, IEA, Paris https://www.iea.org/reports/germany-2020.

Europe's industrial policy history presents a complex tapestry of successes and failures. While initiatives like the ECSC and the internal market were successful in achieving certain objectives, others fell short, particularly in fostering a robust, innovation-driven, and sustainable industrial ecosystem.

3 Europe's Green Industrial Policy

The increasing pressure to put Europe on a trajectory towards climate neutrality added to the significance of the revival of a more targeted industrial policy development. Before embarking into the detailed exploration of Europe's green industrial policy, it is crucial to first understand the foundational principles that (should) guide a green industrial policy approach. The concept of green industrial policy emerges from the intersection of environmental sustainability and economic growth, underpinned by the imperative to transition towards carbon neutrality. This policy framework is not merely an extension of traditional industrial strategies; rather, it represents a transformative agenda that integrates ecological considerations into the heath of industrial planning and decision-making. The adoption in 2019 of the European Green Deal serves as a cornerstone of this policy approach, symbolizing a change in thinking towards sustainable growth. The principles of green industrial policy, as discussed in Section 3.1, extend beyond the economic metrics encompassing broader societal goals such as environmental preservation, social equity, and long-term resilience. Section 3.2 delves into how these principles are operationalized in the European policy context, distinguishing green industrial policy from industrial policy more generally, to be the "new growth strategy" of Europe.

3.1 Green Industrial Policy Specifics

Very much like standard industrial policy, the selection of tools and projects for green industrial policy should be based on where private and public returns of clean markets diverge the most. Yet, green industrial policy tackles the larger societal challenges that stem from climate change and thus has much broader objectives than the competitiveness of industries and companies, like standard industrial policy. This also sets it apart from climate change policy, which usually has more limited objectives of reducing emissions. Specifics for green industrial policy include the following:

- A green industrial policy mix should be developed in coordination with the policy instruments used by climate policy and industrial policy instruments more generally. Carbon pricing is an important complement for the green industrial policy mix, leveraging its other instruments, such as subsidies or taxes, targets, regulations, standards.
- An obvious but worth remarking feature of the climate crisis is the absolute need and urgency of an effort to mitigate the climate crisis. This makes the uncertainty of green technologies, particularly at early stages like prototyping and before scale-up, a significant challenge. This is why, for green industrial policy, more than for other areas of industrial policy, the lack of risk-taking can be particularly problematic in the long run, as running in scenarios of doing too little too late is extremely worrisome. However, this uncertainty need not be a stumbling block, nor should it be resolved solely through institutional choices. This makes experimentation a key principle for green industrial policy.

- A strategy inspired by models like the US DARPA, coupled with the introduction of venture capital funds for early-stage green technology investments, can create a competitive environment that effectively mitigates uncertainty. This approach, adopting a portfolio perspective as discussed later in the paper, accepts the likelihood of numerous failures but recognizes that few successes will significantly compensate for these. The implementation of such a policy not only accelerates the pace of technological innovation but also ensures that a diverse array of potential solutions is explored.
- Green technologies are risky and uncertain. Nevertheless, they have witnessed significant advancements in the last two decades, considerably dispelling earlier uncertainties. With investments flowing into the sector, renewable energy technologies (especially solar) are becoming more cost-effective and competitive with traditional energy sources for power generation, like coal power plants, reaching a point where installing solar panels and decommissioning existing coal power plants is more cost-effective than continuing their operation.
- This goes to show that in a dynamic perspective, with evolving future costs and risks, climate change policies should emphasize learning and information sharing, and self-discovery on the market, and industry-research-policy collaborations to share risks, costs, and information, driving down the cost curves of green technologies as fast as possible.
- Green technologies are not only characterized by high risk and uncertainty, but also have higher externalities (see Martin et al. 2022). This calls for a more directed approach in supporting investments in green technologies. In addition, an investment push directed to green technologies is necessary to counter the locking-in of fossil fuel-based technologies and their path-dependencies. The difficulty in profiting from green technologies and in developing new low-carbon technologies lies in the hidden support to fossil fuel products given in different forms—starting from the absence of a sensible carbon price to explicit fossil fuel subsidies. These mechanisms can skew the market, not only in terms of production and technology adoption, but also in terms of innovation (Aghion et al. 2011, 2016, 2019). The case for subsidizing green technologies, in this sense, is broader and stronger than the general case. Environment-directed technology policy cannot be neutral. It must choose for "clean" to address the higher knowledge externalities and lock-in problems discussed supra. This still leaves the issue of whether and how to choose among "clean" technologies, picking winners (e.g. focusing on individual clean technologies such as batteries or hydrogen). When choosing among clean technologies, this should be guided by the same principle of divergence between expected social and private returns and highest scope for reducing clean market failures, while being able to address the government failure challenges sufficiently. Choosing within green technologies should also consider the "externalities" of any choice on other non-selected green technologies, calling for a good mix between vertical and horizontal instruments, limiting in time support and the importance of ensuring competition as a level playing field (Aghion et al. 2011).
- By addressing larger societal concerns, green industrial policy requires the involvement of a variety of stakeholders. Public-private partnerships will be central in green innovation policy, much more so than in climate policy and classic industrial policy, covering a larger set of private sector areas. And with climate change a big transformative change, it will also require the involvement and support of civil society more than in other areas of industrial policy. To implement a new green indus-

trial policy approach, it is important for the government to work collaboratively with the private sector and civil society to identify constraints and opportunities, leveraging their knowledge and capacities to generate solutions, while at the same time addressing issues such as rent-seeking and political capture. Incentivizing resources and information sharing while discouraging rent-seeking requires accountability and a balanced set of incentives and penalties, with measurable targets that enable effective monitoring and evaluation of policy. These targets should be clear, transparent, and openly communicated.

- Finally, coordination among the many diverse types of stakeholders, policy governance areas, instruments, and projects will require a strong operational governance for a successful green industrial policy.

3.2 Europe's Green Industrial Policy Making

Today, Europe is still far from having a full-fledged green industrial policy with the principles set out in Section 3.1. Table 1 offers an overview of Europe's green industrial policy landscape. The various initiatives are based on a mix of a horizontal approach of creating general framework conditions for green industrial developments and a vertical approach allowing for a more specific targeting of certain green technologies (for instance with targeted innovation funding or with targeted subsidies for deployment).

It is rather a multitude of green industrial policy initiatives that are generally not coordinated—if not even conflicting. There is the issue of geographic coordination, as green industrial policy involves various levels of governance: regional, national, and EU. In addition, there is the issue of coordination among different policy competences.

Focusing on the EU level, the EU sets the framework for green industrial policies through competition policy, trade policy, EU single market rules, energy, and climate policy. research and innovation policy, a macro-economic framework for member states public expenditures, and regional development policy. It has in place a wide range of specific green policy tools ranging from clean energy standards, and most notably with its Emission Trading System (ETS) scheme a carbon price (Tagliapietra and Veugelers 2023).

Most of the public funding for R&D in the EU runs through Member States. Yet, the EU level is important, primarily through its Directorate-General for Competition (DG COMP). This department controls the state aid provided by Member States, ensuring that subsidies are effective, efficient, and proportional to the market failure they are intended to address and do not disturb the single market. It also checks compatibility with WTO rules (local content requirements). And second, its own R&D funding programs, although only representing a small share of all public R&D spending in the EU, are important complements and leverage for member states funding. The European Commission funds projects under its Framework Programs. These programs typically cover only research and development, not going beyond early-stage prototyping and demonstration. The current 2021–2027 Framework Program, Horizon Europe, has a budget of EUR 95.5 billion of which around EUR 15.1 billion is earmarked for climate, energy, and mobility projects (Tagliapietra and Veugelers 2023). Relatively new components of EU's framework program are its Knowledge and Innovation Communities (KICs)s and its Missions, turning into practice the innovation policy's vision of more need for an institutionalized process of collaboration between the public sector and the private sector and civil society.

Table 1 Main green industrial policy tools in Europe

	Innovation	Deployment	Framework conditions
EU level	Horizon Europe European Research Council European Innovation Council European Institute of Innovation and Technology	Industrial Alliances IPCEIs EU Innovation Fund European Investment Bank EU Cohesion Funds NextGenerationEU EIB	Competition policy Environmental standards Energy policy Climate policy (e.g. carbon price, renewable and energy efficiency targets, clean standards) Trade and investment policy Development policy
National level	R&D programmes	Government investments programs, incentives, subsidies, public procurement, NDBs	Energy policy Environmental standards Environmental taxation Public procurement rules Clean energy standards
Regional level	Regional PPPs	"Smart" specialization strategies Regional investment budgets Implementation of EU Cohesion policies	Regional regulations

Source: Bruegel

- Its *European Institute of Innovation and Technology* (EIT), running pan-European partnerships among companies, research labs, and universities, has several of its current KICs strongly relevant to green industrial policy, such as EIT Climate-KIC; EIT InnoEnergy.
- A truly directed part of Horizon Europe is its new partnership instruments, *Horizon Europe Missions*. Four out of its five currently running Missions have a climate change/environment angle.

Other EU instruments go beyond the Framework Program and beyond R&D. The *Innovation Fund*, financed from its ETS revenues, leverages private financing for large deployment projects covering an entire supply chain as well as small-scale projects focusing on emerging greenhouse gas (GHG) reduction technologies through grants in multiple rounds.

A relatively new EU instrument to establish European public private partnerships are the *European Alliances*. European Alliances aim at creating European integrated, cross-border, value chains in technologies that are considered as central for the future of the energy transition. In practice, these Alliances constitute a network of key industrial and innovation players (including SMEs), regional authorities, national authorities, the EC, and the EIB. Importantly, projects developed in this Alliance context and beyond as *Important Projects of Common European Interest* (IPCEI) are allowed to receive State aid from member states and are therefore an instrument through which the EU level can support and coordinate national or regional green innovation policies.

> The *European Battery Alliance* was the first Alliance, launched in 2017. It focuses on supporting the development of highly innovative and sustainable technologies for lithium-ion batteries that last longer, have shorter charging times, are safer and more environmentally friendly than those currently available. The *European Clean Hydrogen Alliance* was launched in 2020, aimed at fostering the deployment of hydrogen technologies by 2030, bringing together renewable and low-carbon hydrogen production and distribution with users in industry, mobility, and other sectors.

It is worth noting that *Development Banks* (DBs) can facilitate industrial policies (Griffith-Jones 2018). Member States can leverage National Development Banks (NDBs) and the European level, the European Investment Bank (EIB). Their ability to provide long-term, stable finance and counteract the pro-cyclical behavior of private financing is particularly relevant for renewable energy projects that might face financial volatility. The role of DBs extends to fostering innovation and structural transformation as the capital offered by these banks is essential for supporting new sectors and cross-sectoral programs that are too uncertain for private finance to support initially. Tools like the shadow price of carbon, utilized by the EIB, underscore the innovative financial mechanisms that DBs can employ to align investment with environmental sustainability goals. The effectiveness of DBs, however, is contingent upon a broad context of well-functioning macroeconomic policies and financial sectors. A clear strategy, ideally linked to a modern industrial policy and clear, consistent policy mandates, is crucial for these banks to operate successfully. Germany's KfW bank exemplifies the importance of such stability, showing that with the right conditions, NDBs can be instrumental in advancing green industrial policies and sustainable development (Box 2).

Box 2: The role of KfW in advancing the German Energiewende

KfW, a German development bank, has played a key role in financing the country's energy transition by supporting SMEs to adopt renewables and energy efficiency measures. The bank has also facilitated communal infrastructure projects, enhancing environmental protection at a municipal level. Internationally, KfW collaborates with other development banks to promote green investments across Europe and in emerging economies, leveraging its strong position in the international money and capital markets for refinancing its activities.

A significant portion of KfW's success can be attributed to the strategic alignment with the German government's energy policies, such as the Renewable Energy Sources Act (EEG), which includes incentives like feed-in tariffs and reverse auctions. These policies have made renewable investments financially viable, with KfW funding a substantial share of these ventures. Notably, KfW was central to the initial surge in Solar PV investments between 2007 and 2009. KfW also ensures environmental standards are met by collaborating with independent consultants, contributing significantly to the design and implementation of Germany's green strategy.

Unlike other development banks that engage in direct project financing, KfW operates on the "Hausbankprinzip," reaching out to the mass market through financial intermediaries. This approach allows it to sometimes finance up to 100% of a project, distinguishing its role from institutions like the EIB, which typically caps its contribution at 50%.

KfW's programs are a product of government demand or the bank's market assessments and receive governmental endorsement, further solidifying its influence. The bank's AAA credit rating enables it to provide loans at favorable interest rates, mobilizing funds efficiently and supporting the government's targeted subsidies.

KfW's involvement in the energy transition in Germany could also serve as a blueprint for how national development banks can facilitate the transition to renewable energy and energy efficiency on a broader scale in other Member States as well.

4 Europe's Green Industrial Policy with Open Strategic Autonomy

In March 2020, the Commission presented a "New Industrial Strategy for Europe," built on the twin objectives of managing the green and digital transitions while avoiding external dependencies in a new geopolitical context, especially with China considered a "systemic rival" (European Commission 2019). Among the key policy goals in the strategy were beyond the stepping up of investment in green research, innovation, deployment, and up-to-date infrastructure, and creating lead markets in clean technologies, also securing the supply of clean technologies and critical raw materials.

On the day after the publication of the new strategy, the World Health Organization declared the COVID-19 outbreak a pandemic. That shock, with all the issues related to the emergency procurement of personal protective equipment and vaccines, triggered a substantial revision of the new industrial strategy, which came in May 2021. The updated strategy centered on the strengthening of the resilience of the single market. It did so by putting a strong focus on the need to improve Europe's "open strategic autonomy" in key areas including health, green, and digital technologies by monitoring strategic dependencies, developing Europe's strategic industrial capacities, and diversifying international partnerships (European Commission 2021a, b).

Since then, the issue of "open strategic autonomy," and particularly "strategic autonomy" avoiding the risks of supply disruption for critical items by relying on own strategic industrial capacity, has become more and more central to Europe's industrial policy debate, also because of the war in Ukraine, the subsequent energy crisis and the overall increase in international geopolitical tensions linked to the geopolitical decoupling of the USA and

China, and the strategic autonomy/local content requirement policy reactions to recent US legislation (Investment in Infrastructure and Jobs Act (IIJA), the CHIPS and Science Act (CHIPS), and the Inflation Reduction Act (IRA).

This change of paradigm first became evident with the European Chips Act proposed by the European Commission in February 2022 to address the shortage of chips during the COVID-19 crisis. The Act has the double objective of improving the resilience of the semiconductor ecosystem in the EU to minimize future supply chain disruptions and increasing Europe's domestic capacity for chip production. The Act seeks to attract foreign investment (European Commission 2022). Yet, it has also raised concerns about its emphasis on protectionism and its potential to create competition distortions (Poitiers and Weil 2022).

The Critical Raw Materials Act (CRMA), launched in March 2023, is another attempt to respond to the supply disruption risk in critical raw materials, by boosting their domestic production, refining, and recycling. The proposed Act identifies a list of strategic raw materials that are considered crucial for the manufacturing of green, digital, and defense technologies and sets precise domestic targets to be achieved by 2030. The CRMA aims to make the issuing of permits to relevant industrial projects subject to a common EU deadline. The proposed Act also includes provisions on supply chain monitoring, stockpiling, and improving the recyclability of CRMs. The CRMA acknowledges that, while important, domestic actions will never make the EU self-sufficient in critical raw materials. The Act thus also puts forward an international strategy to diversify the EU's imports of critical raw materials and strengthen its global partnerships with emerging markets and developing economies and to consider a "critical raw materials club" for like-minded countries.

While the CRMA is quite careful on how to implement "open strategic autonomy, assuring resilience," the Net Zero Industry Act (NZIA), also launched in March 2023, reacting to the Inflation Reduction Act in the USA, particularly its local content requirement stipulations, takes targeting and "strategic autonomy" through local manufacturing capacity in clean energy a few steps further:

> First, the NZIA lists net-zero technologies considered to be "strategic." These include solar photovoltaic and solar thermal, onshore wind and offshore renewables, batteries and storage, heat pumps and geothermal energy, electrolysers and fuel cells, sustainable biogas and biomethane, carbon capture and storage (CCS), and grid technologies.
> Second, it defines an overall benchmark target for EU domestic manufacturing in these technologies to meet at least 40% of the EU's annual deployment needs by 2030. The NZIA also proposes a target for an annual injection capacity in CO2 storage of fifty megatonnes (Mt) CO2 by 2030 to spur the development of CCS.
> Third, it outlines a governance system based on the identification of Net-Zero Strategic Projects (NZSPs) by member states, with a minimal check by the European Commission. NZSPs must contribute to CO2 reductions, competitiveness, and security of supply and should involve technologies close to commercialization.[1] This approach represents a break with what has been done so far in the EU: support focused on earlier stages of technology development, including research, early-stage development, and prototyping.
> Fourth, the NZIA outlines a set of policy instruments, mostly at national level, to support the selected NZIA projects:

[1] TRL (technology readiness level) classifies technologies by their stage of development. NZIA targets TRL 8 indicating technologies that have been tested and "flight qualified" and are ready for implementation into an existing technology.

1. Acceleration of permitting and related administrative procedures, within time limits pre-set by the EU, including by identifying a one-stop-shop national authority in charge of these projects.
2. Coordination of private funding. The Commission estimates that meeting the headline 40% target by 2030 will require €92 billion in investment, with the bulk (around 80%) coming from the private sector, to be facilitated by a "Net-Zero Europe Platform fostering contacts and making use of existing industry alliances".
3. Limited public subsidies, at national level (see below). Support for NZSPs is to be prioritized in national and EU budgets. However, the NZIA proposal does not allocate new EU-level funding, and neither is such funding being allocated in parallel.[2]
4. Public procurement procedures and auctions that include "sustainability and resilience" criteria, which can be given a weight of up to 15–30%. At the same time, bids that include the use of equipment for more than 65% from a single non-EU country would be penalized.

No extra EU funds are included in the NZIA, deferring this to the to be set up European sovereignty fund. But the latter has now been downgraded to the Strategic Technologies European Platform (STEP), through which €10 billion will be added to existing programs.[3] EU countries are assigned the role of main provider of public funds for NZSPs. It is therefore important to read the NZIA in parallel with its modification to its Guidelines for State Aid by Member States, its *Temporary Crisis and Transition Framework* (TCTF), launched in March 2023 (European Commission 2023). The TCTF outlines conditions under which the Commission will approve "aid accelerated investments in sectors strategic for the transition towards a net-zero economy," defined as batteries, solar panels, wind turbines, heat pumps, electrolysers and carbon capture usage and storage, as well as the production and recycling of priority components and critical raw materials.[4] Specifically, EU countries are allowed to

1. Provide more support to cleantech production located in disadvantaged regions, capped at a certain percentage of the investment costs and nominal amounts, depending on the location of the investment and the size of the beneficiary.
2. Grant higher percentages of the investment costs if the aid is provided via tax advantages, loans, or guarantees. This implies that state aid is not limited to funding capital expenditures but that operating expenditures (OPEX) can also be covered, up to the identified funding gap. This approach is novel for Europe as it has been only rarely adopted previously, most notably in the case of cohesion regions.

[2] An EU-level "Sovereignty Fund," which might include clean-tech support, mentioned in speeches by Commission President Ursula von der Leyen in spring 2023, has not materialized. Instead, on 20 June, the Commission proposed a repackaging of existing EU funds under a so-called Strategic Technologies for Europe Platform (STEP), introducing a "sovereignty seal" as an "EU quality label for sovereignty projects" and a "sovereignty portal" for accessing funding opportunities under STEP. See European Commission press release of 20 June 2023, https://ec.europa.eu/commission/presscorner/detail/en/qanda_23_3347.

[3] Of the €10 billion STEP fund, €3 billion is going to invest EU, €500 million to Horizon Europe, €5 billion to the Innovation Fund, and €1.5 billion to the European Defence Fund. Announcing STEP, Commission President Ursula von der Leyen said it would "set the stage" to mobilize funding across various EU programs, to reach up to €160 billion in investments "in the coming years," as the "precursor to a fully-fledged Sovereignty Fund that would be created in the future."

[4] See "Support possibilities for schemes under Sect. 2.8 of the Temporary Crisis and Transition Framework: available at: https://competition-policy.ec.europa.eu/system/files/2023-03/overview_of_TCTF_section_2.8_schemes.pdf.

3. Provide matching aid, that is, the amount of support the beneficiary could receive for an equivalent investment in the alternative location or the amount needed to incentivize the company to locate the investment in the EU. This matching-aid option requires individual notification and must respect several safeguards: (i) investments must be in assisted areas, as defined in the applicable regional aid map; or (ii) cross-border investments involving projects located in at least three countries, with a significant part of the overall investment taking place in at least two assisted areas, one of which is an "a" area (outermost regions or regions where the GDP *per capita* is below or equal to 75% of the EU average). Furthermore, the beneficiary should use state-of-the-art production technology from an environmental emissions perspective. Finally, the aid cannot trigger relocation of investment between EU members.

The latter, matching-aid, part is the clearest revision of the state-aid guidelines as a reaction to the IRA. The final shape of the NZIA and CRMA will emerge from the EU co-legislation process, ongoing at the time of writing (Tagliapietra et al. 2023). However, both proposals are clearly underpinned by a more targeted, picking selected areas and projects for support, focusing on deployment, rather than the previous emphasis on early stage research and development, and focusing on local production as de-risking approach, an approach that has recently become an integral part of policy for both the EU (Von der Leyen 2023) and G7.

5 A Critical Assessment of the Trend in Europe's Green Industrial Policy

Europe remains far from having a full-fledged EU integrated green industrial policy, which considers the specifics such a green industrial policy should have, as exposed supra (see also Tagliapietra and Veugelers (2021). It has at best a multitude of green industrial policy initiatives at EU level, adding to the multitude of policy initiatives at Member State or regional level. These initiatives are generally not coordinated—if not even conflicting. This represents a major issue, because green industrial policies strongly differing across countries fragments the EU single market, failing to capitalize on the economies and synergies of an integrated EU scale and could undermine the level playing field across Europe. The recent developments with NZIA do little to try to address the fragmented state of clean energy industrial policy making in the EU, if not even adding further to the fragmentation.

Beyond the coordination of Member States policies, the proposal misses an overall systemic strategy for policy actions for clean tech manufacturing at EU level, neglecting to further strengthen its perhaps most potent policy instruments, its Single Market, its green regulation, and its EU ETS scheme (Kleimann et al. 2023).

Over the last years, the EU has tried to foster an industrial policy oriented at creating European ecosystems for the manufacturing of batteries and—more recently—electrolysers, via the European Alliances and related IPCEIs. While it is too early to assess ex post how effective they are, at least they are ex ante designed to take an EU scale perspective. The NZIA, by focusing almost exclusively on the promotion of individual national projects, seems to take a different tangential approach, unconnected to this EU-wide approach. Although the IPCEIs were also Member State financed, without an EU level budget, the projects involved at least cross-border EU ecosystem networks, and their formation and selection were coordinated by the EC and assessed by DG COMP to be compatible with

its State Aid Guidelines, ensuring level playing fields. While both approaches recognize national projects as fundamental also from an EU-wide perspective, diverting from an EU-coordinated approach is an important downside of the Act because only by exploiting a large, open, competitive home market at EU scale, and fostering synergies and collaborations within the EU, Europe can establish itself in the global clean tech manufacturing race with competitive and resilient net zero clean energy activities.

Another miss in the NZIA proposal, and related to the previous discussion, is the lack of an EU-level funding strategy to support clean energy technologies. The proposal does not take any action to simplify and streamline the existing EU funding instruments and better align national funding. And the EU Sovereignty Fund/STEP includes only marginal increases in funding for existing EU funding instruments. There are no new EU funding instruments programmed. As a result, key public incentives to spur the needed private investments in this space currently only come from national State aid, running the risk of single market fragmentation and flaring political tensions among Member States. It is important to stress that this risk might quickly materialize in case countries with more fiscal space decide to go for their own green industrial policy packages. For instance, the effect of Germany going for a large subsidy scheme to lower electricity costs in energy-intensive industries in general and clean tech manufacturers in particular[5] might revive across Europe economic—and political—fragmentation fears (Tagliapietra et al. 2022). The same goes for France adopting a "green industry bill" including generous tax credits for national clean tech manufacturers.[6]

Even more troubling is how the proposed NZIA prioritizes net-zero technology sovereignty and the pursuit of strategic autonomy over efficiency and the imperative of global decarbonization and goes "vertical" to establish this direction.

First, the NZIA adopts a top-down approach in which policy makers cherry-pick specific technologies and within these specific projects to be considered as "strategic" for the transition to net-zero and receiving favorable treatment. While the list of NZIA technologies contains most of the major technologies, currently in or sufficiently close to commercialization, it does preclude other potential options. For instance, while it does recognize "advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle, small modular reactors, and related best-in-class fuels" to be net-zero technologies, the Act does not include them in the list of strategic net-zero technologies, thus preventing them from becoming NZSPs. Another example is provided by recycling and reuse of clean technologies and their components such as batteries and solar PV panels: this is an emerging sector that will be key to enhance the carbon footprint of clean technologies in which Europe may hold strong cards for building world competitiveness, but also enhance Europe's strategic autonomy, namely when it comes to critical raw materials. These technologies are not included as "strategic," although they tick all boxes for NZIA, particularly for addressing security of supply for key materials that may become critical bottlenecks when demand expands. The same holds for technologies for improving energy efficiency. And then there are technology options that are still early stage, such as near zero materials (like cement, steel…), or Direct Air Capture (DAC), which are excluded in the NZIA, let alone the ideas, that are still at concept stage or still to be generated. They may not be able to reach the 2030 target, but there may be

[5] See press release, 5 May, 2023: https://www.bmwk.de/Redaktion/DE/Pressemitteilungen/2023/05/20230505-habeck-legt-arbeitspapier-zum-industriestrompreis-vor.html.

[6] See press release, 11 May, 2023: https://www.elysee.fr/emmanuel-macron/2023/05/11/accelerer-notre-reindustrialisation-le-president-presente-sa-strategie.

future breakthroughs to tackle the transition. Given the technological optionality required to meet the complex net-zero challenge, and the degree of uncertainty intrinsic to technological innovation, it would have been better to adopt a more technology neutral approach, including any project and technology that can contribute to the net-zero emission, competitiveness, and resilience targets, irrespective of its TRL. More generally, the NZIA seems too much as a turn towards a vertical top-down, picking winners type of industrial policy. The selection criteria for picking "winners" only refers to contributions being made to targets, not whether the winners are the most effective and efficient projects, compared to others, nor whether the "winners" need the support in view of which market failures, and with which proportionality, i.e., the classic criteria of the State Aid Guidelines. This matters as it may distort the level playing field for non-selected projects. The check of selection of NZIA projects at EU level is only minimal and does not involve a State Aid Guidelines check, even if this selection implies preferential treatment, even if not necessarily financial. Overall, the vertical picking winners' direction seems weakly designed to properly balance the risk of government failures with any market failures that one tries to address.

In terms of targets for reaching "strategic autonomy," the NZIA adopts as only headline benchmark, a 40% domestic manufacturing KPI. As such, this is conceptually highly problematic. It is unclear why this must be the key KPI for the NZIA to be achieved by 2030. Will it be the right level to achieve security of supply? At what cost for global competitive positions for the EU? And at what cost for decarbonization? Will it make it cheaper/faster or more expensive/slower to get to net-zero? And, even when buying the import substitution approach as the best and only pathway to reach "strategic autonomy," it is unclear why this benchmark should apply to all NZIA technologies to the same extent, given their different situations, e.g.,. in terms of current domestic manufacturing (see Tagliapietra et al. 2023).

6 The Way Forward for Europe's Green Industrial Policy

As Europe stands at a critical juncture in advancing its green industrial policy, this section aims to distil policy recommendations for the way forward. Despite the EU and Member States already deploying a variety of green industrial policy instruments over the course of the years, including carbon pricing, regulation, and public support for R&D and early deployment, there remains a significant gap between current practices and the realization of an effective EU green industrial policy. In fact, the EU green industrial policy strategy appears more as a patchwork of energy, climate, innovation, and social policy initiatives—than as a coherent green industrial policy framework. The recent developments, such as the NZIA as reaction to the US Inflation Reduction Act and the pursuit of resilience and autonomy, have introduced additional complexity and fragmentation, emphasizing the need for stronger coherence and better use of the EU's scale.

Drawing on the principles for an effective green industrial policy as outlined supra, this section provides recommendations to refine EU green industrial policy making, aiming to transform the green transition into an opportunity for clean, resilient growth. These recommendations encompass enhancing EU green industrial policy governance, revamping support for public-private clean tech ecosystems, introducing new EU-level support programs for green innovation, leveraging private investments, maximizing the potential of the single market, and focusing on skill development. Each of these aspects is explored in detail, offering a comprehensive roadmap for a more integrated and effective approach to EU's green industrial policy.

i. A strong EU green industrial policy governance

Given the inherent complexities of both green industrial policy and the EU as policy-making machinery, strong governance is a prerequisite for effective EU green industrial policy. Only a leadership that is competent, independent, and accountable to clear goals and milestones, and that encourages risk-taking, may coordinate the progress of different government groups who are each responsible for distinct parts of a green industrial policy.

A strong governance is needed to address the key challenge of coordinating different stakeholders, EU policy competences and instruments and monitoring and evaluating progress on targets. Another governance challenge has to do with the need for a long-time horizon for green policy making. A long-term vision and commitment are important to incentivize clean tech private investments, particularly those with long lead times. At the same time, the elevated level of risks and uncertainty underline the strong need for ensuring flexibility and resilience under different forward-looking settings.

The higher externalities from clean technologies and the lock-in of dirty and less clean technologies make the case for a more directed approach, supporting investments in clean technologies. A more directed approach runs the risk of making the wrong choices, particularly when risks and uncertainty are high. To avoid as much as possible such directionality failures, it requires a strong monitoring and evaluation capacity to assess which policy interventions work and which not, learn fast and shift fast to adapt policy making, if needed.

All this requires a highly competent and empowered governance body, which is sufficiently politically independent—or detached from political pressures—yet accountable for its achievements with a set of clear realistic milestones and targets. The US experience can be inspiring in this regard. After the approval of the Inflation Reduction Act, President Biden appointed John Podesta as Senior Advisor to the President for Clean Energy Innovation and Implementation and Chair of the President's National Climate Task Force, with a mandate to oversee the implementation of the Inflation Reduction Act's clean energy and climate provisions. A similar move by the European Commission might make sense in the current governance setting to ensure top-level coordination and steering of the overall process—which is vital for the longer-term socio-economic and political sustainability of the European Green Deal and its core aim of being Europe's new "growth strategy."

ii. Revamping EU-level support for public-private clean-tech ecosystems at the EU scale

Key green industrial policy instruments are the EU Missions, KICs, IPCEIs, and Alliances to turn into practice an institutionalized process of iterative collaboration between public institutions, private sector, and civil society as the core principle of modern industrial policy (Rodrik 2014). In their current format, they tend to be bureaucratically heavy and end-up mostly supporting a few large incumbent players that have the ability and experience to propose and manage such projects, and as they typically take place in the EU countries that have sufficiently deep pockets to (co-) support them. While large firms can play anchor roles in such projects, it is important to ensure that smaller players and radically new clean ecosystems can find their place. Otherwise, such programs may fail to support "winning" clean ecosystems or particularly disruptive new green technology solutions, proposed by new young firms. The EU needs to be more ambitious to use these instruments more and better for its green industrial policy. For

this to happen, these instruments must have more clear targets, sticks and carrots, and intermediary milestones to allow more risk-taking, to be able to monitor progress and assure commitment and to avoid rent-seeking. When it comes to the selection of areas and projects, and the phases in which to support them, selection should be based on the NZIA targets of highest potential socio-economic, resilience, and climate returns that could not have been reached without public support. The aim is to take a portfolio approach of supported projects, covering a balanced set of projects which on the one hand, consolidate, upscale, and further accelerate existing scientific and industrial higher TRL technology capacity together with projects targeting early stage, to be further developed, lower TRL frontier technologies and markets. In any case, for each technology, the whole value chain from research, development, diffusion to manufacturing, distribution, and sales must be considered. Neglecting the scalability and commercialization steps, Europe may fail to deliver sustainable competitive clean tech ecosystems from any innovation advantage it may have nurtured. For example, the North Sea Wind Power Hub exemplifies a successful renewable energy cluster under the EU's green industrial policy. This project, a collaboration among energy companies, grid operators, and turbine manufacturers, aims to construct a massive wind farm in the North Sea. Its goal is to efficiently harness wind energy on a large scale, potentially powering millions of homes across Europe with renewable electricity. This initiative not only focuses on energy production but also integrates solutions for storage and grid stability, highlighting the effectiveness of collaborative, technology-driven approaches in achieving Europe's sustainable energy ambitions.

iii. New EU-level support programs for green innovation

The current portfolio of funding instruments is already sizable (Kleimann et al. 2023), yet there are still gaps in public funding at EU level to be filled. The green part of the EU Sovereignty Fund (NZIA-Fund) should be a cornerstone of a rebooted green industrial policy. To this end, it should be designed to (i) focus on supporting the development and scaling of pan-European public private ecosystems; (ii) support the whole innovation cycle of clean tech, from disruptive innovation to deployment at scale; (iii) prioritize areas where market, network, and transition failures are most likely and government selection failures least, ensuring additionality and leveraging other public and private funding; (iv) provide support in a relatively non-bureaucratic way to unleash high risk/high return ideas; (v) fit within a portfolio of funding instruments, which is well balanced between top down and bottom-up solicited projects; (vi) compatible with the subsidiarity principle, fit with member states initiatives. An EU-level approach is particularly justified for early-stage, high-risk projects, more vulnerable to market and ecosystem failures. An EU-level approach can provide more scope for synergies, integration of knowledge spillovers, and cost and risk sharing, rather than on national subsidies.

Following these principles, several areas of action come to mind for new initiatives. First is the creation of an EU version of the US Advanced Research Projects Agency—and this for Energy & Climate ("ARPA-EC"), aimed at fostering high-risk early-stage development projects for new (versions of) clean tech manufacturing technologies. [7]Such EU

[7] The Advanced Research Projects Agency–Energy (ARPA-E) program, established shortly before the 2007-2008 financial crisis, has around USD 350 million of annual funding and aims, like its DARPA sister, to nurture new strategic energy technologies to achieve rapid deployment of radical technologies with high market potential.

ARPA-EC could also issue competitive biddings for new technological alternatives to critical components, products, or services where there are supply concerns in existing green technologies, thus addressing the EU's demand for resilience and autonomy by soliciting EU's science and innovation capacity. Such an ARPA-EC should connect to other complementary funding schemes, both at national (e.g., German's SPRIND) and at EU level (such as ERC and EIC). ERC and EIC should keep their focus of supporting bottom-up ideas, thus balancing the top-down clean tech programs. It is important to stress that an ARPA-style approach requires more than just importing a label to ensure its unique character as risk-taking public funder for Energy & Climate. It requires sufficient funding to allow it to make multiple bets within a portfolio approach. Equally important is to design it properly, ensuring key success factors, most notably, its autonomy and organizational flexibility, especially flexibility to recruit and accommodate the venture capital entrepreneur type of policy programmers and officers. Calls must have clear quantifiable goals and trackable metrics so that policy officers can be given elevated levels of autonomy, together with clear mandates and accountability.

Second is the creation of a support scheme designed to top-up national and other EU funding in projects that demonstrate a pan-European collaboration, thus contributing to the creation of clean tech ecosystems at EU scale ("NZIA TOPUP"). This scheme can also be utilized to top-up national public procurement of innovative clean technologies, so to allow for a more strategic use of this tool in Europe and foster innovative clean technologies roll-out at EU scale.

Third is the funding of programs to stimulate the intra- and extra-EU mobility of clean tech skills via dedicated Erasmus and Marie Curie fellowships ("NZIA EMCs") or top-ups in Horizon projects for researcher mobility. This could be particularly targeted at fostering intra-EU mobility between upstream and downstream parts of European clean tech ecosystems.

While the EU should not copy the US IRA production subsidies, there may be a case for building or maintaining within the EU minimum levels of capacity in certain critical areas for the green transition to make the EU more resilient to natural or political shocks. The EU should design such subsidies without harming the single market's level playing field and while minimizing trade-offs on decarbonization and economic efficiency. The way forward to reach this balance is support for innovative technology solutions which solve or reduce EU's dependence. The EU should, for example, fund mission-oriented programs to develop innovations which can substitute for certain critical raw materials (NZIA-Resilience Missions).

iv. Leveraging private investments

The effectiveness and efficiency of public funding depends on how it can leverage private investments in clean-tech public-private partnerships. The European Commission estimates that about 80% of the needed investment in clean tech manufacturing capacity between 2023 and 2030 to reach the NZIA headline target is expected to come from the private sector. With the size of the multiplier depending on the framework conditions that shape the private incentives for clean-tech investment, policy should focus on efficiently leveraging private investments and in creating strong framework conditions able to shape the private incentives for clean-tech investment. Barriers faced by private firms when investing in clean tech not being addressed can jeopardize any policy intervention to reach its targets. These barriers include lack of access to finance, excessive regulatory burdens, lack of access to public and private markets, and lack of access to critical skills and components. A green EU subsidy policy should

thus be accompanied by monitoring of the barriers private firms face when investing in clean tech. A further complementary policy instrument is carbon pricing. The EU ETS remains the critical cornerstone of any net-zero industry strategy. Development banks could contribute to mobilize private finance by mitigating risks, engaging in blended finance, creating markets for green technologies at their initial stages of market adoption, and supporting the development of green project.

xxii. Leveraging the single market as critical EU policy tool

Only an open, globally linked EU market scale can leverage the necessary private investments in clean tech ecosystems which Europe needs to become a globally competitive, resilient, clean tech powerhouse. An integrated single market for goods, services, components, energy, capital, people, and ideas is the key framework condition to make any targeted policy action—like specific subsidy programs, a fast tracking of permits or preferential treatments in procurement—more effective and efficient.

Single market rules can accelerate the roll-out of clean technologies by avoiding regulatory costs associated with fragmentation, uncertainty, and bureaucracy. These include regulations that place time limits for decisions at each stage of permitting procedures, accelerating developments in areas vital to decarbonization, thus enlarging clean-tech markets more quickly. For example, in December 2022, EU countries agreed a temporary emergency regulation to fast-track permits for renewable energy infrastructure and grids.[8]

Another option are regulatory sandboxes—frameworks for experimentation—to push for quicker development of clean technologies and fast-tracking of the necessary certifications required for placing them on the market.[9]

EU wide coordinated use of procurement can provide a larger, more integrated lead market for clean technologies, particularly in sectors in which public purchasers make up a large share of the market, such as transport and construction (Joint Research Centre 2019). By introducing sustainability requirements for clean technologies (for instance, by rewarding in tenders the use of electric cars that are produced according to certain sustainability criteria, or based on certain innovation or environmental features), the EU could prioritize the deployment of clean technologies produced to European standards.[10]

The single market, to be a forceful lever for private clean tech manufacturing investments, should also be open and competitive. EU's trade policy cannot fall into a reciprocal protectionist trap and needs to remain open to provide the creative destruction playing field for competitive, resilient green EU ecosystems.

[8] See Council Regulation (EU) 2022/2577.

[9] Such schemes already exist in EU countries, notably in Germany. See dossier, September 2022: https://www.bmwk.de/Redaktion/EN/Dossier/regulatory-sandboxes.html. EU countries endorsed regulatory sandboxes in November 2020. See proceedings, 16 November 2020: https://www.consilium.europa.eu/media/46822/st13026-en20.pdf.

[10] Environmental criteria in public procurement should be handled carefully, as they might expose officials to lobbying and electioneering (for instance, in view of protecting local producers against competition; (Blanchard et al. 2022). But this risk could be mitigated by using precise and easy-to-verify award criteria (e.g., CO2 emissions of cars or carbon intensity of electricity) rather than imprecise and hard-to-verify criteria (e.g., environmental criteria related to the suppliers). This requires a clear categoriztion of green criteria, as well as adequate investment in the training of public authorities that must apply them (Sapir et al. 2022).

vi. Skills

The speed of the roll-out of clean technologies is correlated closely with the simultaneous development of a qualified workforce to implement clean projects. Ensuring enough skilled workers is of prime importance for Europe, to avoid shortages and to ensure a prominent level of productivity for its clean-tech industry. A just transition requires that part of the workforce currently employed in carbon-intensive sectors can be re-skilled and re-employed in green-energy projects (IEA 2022).

The EU has a European Skills Agenda (European Commission 2020a, b) intended to help individuals and businesses develop more and better skills in clean tech sectors. The establishment in February 2023 of a large-scale skills partnership for onshore renewable energy[11] was a welcome first step, but more needs to be done (European Commission (2023). For instance, as Europe seeks to develop pan-European clean-tech supply chains, it would be efficient to have continuous monitoring at EU level of the supply of and demand for green skills and jobs. The EU single market for clean skills could be promoted by developing a Europe-wide strategy for clean-tech higher qualifications and by easing intra-EU mobility of talent, linked also to Erasmus + funding.

7 Conclusions

The imperative to address climate change necessitates the advent of a green industrial revolution. In the context of the USA adopting a more protectionist stance and China's increasing dominance in the clean technology value chains, Europe faces a critical juncture that demands a re-evaluation of its green industrial policy approach. The historical discussion shows how such concerns are not completely new to Europe or the world. Old industrial policy questions are re-emerging, yet with a new level of complexity because of the urgent need to move forward with the green transition. A novel perspective on industrial policy is advocated for, one that encompasses broader multidimensional objectives, balancing decarbonization with economic growth and jobs and building world competitive clean tech value chains, and all this while assuring resilience and security of supply.

In the simultaneous pursuit of decarbonization, economic growth and jobs and resilience and autonomy, it becomes necessary to identify and support strategic technologies and projects that can deliver on these objectives. At the same time, it is important to minimize trade-offs, thus calling for promoting technological innovation to substitute critical inputs. An innovation approach can reduce the need for costly import substitutions and bolster the domestic capacity for sustainable production as a global competitiveness stronghold. Innovations can be the cornerstone of a successful transition that can reconcile decarbonization, competitive value creation and jobs, and strategic autonomy at global scale, provided the innovation machine is properly guided by policy.

Green industrial policy cannot be neutral. It needs to make an ex-ante choice for clean technologies and projects to support. Such a more targeted policymaking should be a collaborative process among the public sector, the private sector, and society, eschewing the conventional top-down fund allocation approach that favors only a select few beneficiaries, calling for a good mix between vertical and horizontal instruments, with a carbon price and

[11] Under the Pact for Skills. See press release, 10 February 2023: https://news.industriall-europe.eu/Article/860.

environmental regulations as strong horizontal instruments complementing targeted financial support. Moving away from a purely horizontal policy to a more targeted one should include robust competition policies, ensuring competition as a level playing field. The EU needs to preserve the power of its competition policy toolbox to avoid incumbency, protectionist, and rent-seeking traps, if it wants to have reasonable chances to leverage private investments in the EU to reach its green ambitions.

Europe has instruments in its green industrial policy toolbox to support the transition. However, strong governance that can ensure the consistency of green industrial policy is missing. This paper contends that Europe's way forward lies in adopting a revamped systemic green industrial policy that relies on the amalgamation of horizontal and vertical policy approaches and public and private knowledge and capabilities.

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