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The EU Green Industrial Policy for Hydrogen Economy Development

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Abstract: This article examines the significance of green industrial policy in advancing the hydrogen economy within the European Union, and explores how hydrogen, as a versatile energy carrier, offers a solution for decarbonising sectors where emission reduction is both urgent and challenging. The evolution of the hydrogen economy, from its initial concept linked to nuclear power to its current association with renewable energy sources, is outlined, emphasising its potential to reduce carbon emissions and its growing significance in the EU's energy mix. First, the author discusses the strategic planning in economic policy and then delves into the concept of green industrial policy, its theoretical underpinnings, and empirical evidence from the EU. The focus then shifts to the EU's hydrogen strategy, including its objectives and critical actions for developing the hydrogen economy. The article discusses the role of hydrogen in the EU's green industrial policy, specifically in energy, transportation, and heavy industry sectors, and the efforts to increase the use of renewable hydrogen. The conclusion highlights the multifaceted functions of green industrial policy in addressing market failures, fostering new pathways, and disrupting the old ones, and how the EU's approach to developing a hydrogen economy exemplifies this policy. The research, confined to 2019-2023, provides insights into integrating environmental considerations in industrial policy, suggesting that the EU's strategy and policy serve as a model approach in this domain.

Keywords: hydrogen economy, green industrial policy, European Union

1. Introduction

(…) Hydrogen can be used as a feedstock, a fuel, or an energy carrier and storage, and has many possible applications across industry, transport, power, and building sectors. Most importantly, it does not emit CO2 and almost no air pollution when used. It thus offers a solution to decarbonise industrial processes and economic sectors where reducing carbon emissions is both urgent and hard to achieve. All this makes hydrogen essential to support the EU's commitment to reach carbon neutrality by 2050 and for the global effort to implement the Paris Agreement while working towards zero pollution.

The preamble to *A hydrogen strategy for a climate-neutral Europe* (European Commission, 2020)

Efforts to mitigate climate change and pursue sustainable development entail significant socio--economic shifts, particularly in the energy and transportation sectors. This involves a complex energy transition toward net-zero CO_2 emission solutions marked by changes in both the types and uses of primary and secondary energy sources. The transition is not just about energy consumption – it also represents a transformation in industrial structures, reflecting changes in the sourcing, processing, storing, and utilising of energy across various sectors. It can be perceived as a key to enhancing energy efficiency and achieving climate and sustainable development objectives simultaneously.

The hydrogen economy, conceptualised by Bockris and Appleby in 1972, was initially envisioned as an energy system primarily powered by nuclear-derived hydrogen (Bockris and Appleby, 1972). From that time, this concept has evolved significantly. Early ideas saw hydrogen akin to a natural gas system used in industry, transportation, and homes. Over the years, this vision has broadened, with scholars like Penner (2006), linking hydrogen to renewable energy sources and highlighting its role in reducing carbon emissions. The hydrogen economy now encompasses a comprehensive suite of processes and technologies, from production to energy conversion, as outlined by Chmielniak et al. (2017) and supported by policy frameworks like the *A hydrogen strategy for a climate-neutral Europe* (European Commission, 2020). Recently, the focus has been on using hydrogen, sourced from renewable or low-carbon methods, as a significant energy carrier and storage medium. This paradigm shift, analysed in later studies (Chapman et al., 2020; Odenweller et al., 2022), underscores hydrogen's potential role in the global energy mix and its importance in reducing carbon emissions across various sectors, particularly transportation through fuel cell technology. The progression towards a hydrogen economy is marked by opportunities across its value chain, offering a pathway towards a sustainable energy future and substantially reducing global carbon emissions.

This article presents a review of how the EU, through the lens of the adopted strategies, plans to support the development of a hydrogen economy. The article is theoretically conceptualised around the assumptions of green industrial policy, which essentially demonstrates the integration of environmental considerations within the conceptual framework of industrial policy, becoming a new paradigm in this domain. The structure is as follows: section 2 presents the significance of strategic planning in broadly understood economic policy, especially regarding guiding the structural shifts in the industrial sector. The subsequent section demonstrates the concept of green industrial policy from a theoretical perspective, presenting empirical evidence from the EU. The fourth section delves into the assumptions of two strategies: *A hydrogen strategy for a climate-neutral Europe* and *The Green Deal Industrial Plan*, which set the example of incorporating a green industrial policy approach in industrial policymaking in a narrow scope targeting the development of the hydrogen economy. The conclusions and summary are placed at the end of the article. This research was limited to 2019-2023, as 2019 was marked by the recognition of the need to guide the shift toward the hydrogen economy, and 2023 defined the availability of data.

2. The Significance of the Strategic Planning Process in Economic Policy

Strategy is a planned course of action to achieve specific objectives under given constraints and circumstances. This can involve various decision-making processes and plans used by individuals, enterprises, state authorities, or international organizations to optimise outcomes in different economic and political contexts, as well as different time and spatial dimensions. According to Mintzberg, "strategy is generally defined, whether in game, military, or management theory, as a deliberate, conscious set of guidelines developed in advance of the specific decisions they apply. In common terminology, a strategy is a plan (…)" (Mintzberg, 1977, p. 28). He conceptualised strategy by encapsulating its five dimensions (Mintzberg, 1987): *Plan, Ploy, Pattern, Position,* and *Perspective*. As a *plan*, a strategy is a consciously designed course of action or set of guidelines prepared in advance to achieve specific objectives. This perspective on strategy emphasises intentionality, forethought, and purpose in actions. A strategy represents specific tactics designed to outwit competitors or opponents

in its dimension as a *ploy*. Here, strategy operates as a tool for advantage in competitive scenarios, and as a *pattern* represents consistency in action, either deliberate or emergent; the focus is on the actual behaviour resulting from or leading to strategy. Deliberate strategies are those where pre-existing intentions are realised, while emergent strategies arise from patterns that developed without or despite initial intentions. Furthermore, when viewed as a *position*, the strategy involves the placement of an organization within its environment, mediating between internal organizational factors and external determinants. This perspective highlights the strategic alignment between an organization and its surrounding landscape. Lastly, as a *perspective*, strategy embodies a shared and ingrained way of perceiving the world within an organization. Analogous to personality for an individual, it signifies a collective mind shaped by common thinking and behaviour. This perspective underscores strategy's cultural and cognitive aspects that unify organizational or institutional members. Porter distinguished strategy from operational effectiveness by adding a new dimension to deliberations of what strategy is. He postulated that "strategy is making trade-offs in competing. In other words, the essence of strategy is choosing what not to do – without trade-offs, there would be no need for choice and thus no need for strategy" (Porter, 1996).

As a comprehensive process, strategy typically unfolds in two principal phases: *formulation* and *implementation. The formulation* as an initial phase involves environmental scanning and analysis, diagnosing the issues and opportunities within this context, and subsequently crafting guiding policies. Strategic formulation activities encompass strategic planning – where specific, long-term objectives are determined and approaches to achieve them are decided – as well as strategic thinking, which involves continuous consideration and synthesis of insights from the environment to shape the organization's vision, direction and competitive advantage. To structure this initial phase, Pettigrew (1977, pp. 79--80) proposed the following sequence of six steps: (1) identification of the set of dilemmas faced by an organization over time; (2) analysis of the dilemmas that become a focus for organizational interest and of those that are suppressed; (3) specification of the individuals or subgroupings that seek to define alternative dilemmas as worthy of organizational attention; (4) study of the demand by those individuals and subgroupings that certain dilemmas be discussed, and of the attempts to mobilise power in support of those demands; (5) specification of the outcomes of these processes demand-generation and power-mobilisation and their implementation as the patterns of thinking about, evaluating, and acting upon the world, i.e. strategy; (6) consideration of the relationship between strategy formulation and strategy implementation and of the impact of the implementation of strategy on the formulation of future strategy.

Following *formulation*, the strategy is operationalised through the phase of *implementation*. This entails devising and executing action plans consistent with the guiding policies set during formulation to attain the established objectives. It involves coordinating and mobilising resources, aligning organizational structures and systems with strategic objectives, monitoring progress, and making the necessary adjustments to realise strategic objectives effectively. As such, strategy formulation and implementation are sequential yet interrelated processes, each providing critical input to the other and forming a continual loop of strategic planning and execution (Lampel et al., 2013).

Various entities can formulate and implement a strategy depending on the dimension of consideration, including microeconomic and macroeconomic dimensions. For individuals and enterprises within the *microeconomic* dimension, a strategy could involve decisions about consumption, savings, investment, pricing, production, or market entry, often in response to market conditions, competition, regulatory environments, or changes in consumer behaviour. These strategies are typically aimed at maximising profit, market share, or utility, subject to budget, resource, and technological constraints. The primary function of strategic management in a *microeconomic* dimension is to design a process for managing the development of enterprises that will significantly increase their chances of success in a designated market or markets identified based on geographical and commodity constraints. An adequately designed strategic management process requires, namely the allocation of roles among the assorted stakeholders, the implementation of a procedural chronology, and the establishment of an unbroken

continuity of activities and control measures. Enterprises of varying sizes necessitate customised strategic management processes, considering a company's size, operational complexity, market dynamics, competitive landscape, and regulatory environment (Kaleta, 2014; Kaleta and Wojnicka, 2014).

In the *macroeconomic* dimension, a strategy often refers to the decisions made by political actors (such as politicians, parties, or governments on different administrative levels) or other societal actors (like interest groups) in pursuit of their designated objectives. This can include policy decisions, negotiation tactics, alliance formation, lobbying efforts, or public communication strategies. These strategies are designed to navigate the complex intersection of economics and politics, balancing considerations of economic efficiency, distributional equity, political feasibility, public opinion, and institutional constraints.

Formulating a strategy (or, in other words, strategic planning) based on a state's economic policy assumptions follows a comparable sequence of actions. It does so in the case of any other types of strategies: (1) investigation of circumstances in areas anticipated to be impacted by the proposed initiative, ascertainment of prevalent inadequacies, and creation of a diagnostic analysis; (2) establishment of the objective (or objectives) of the strategy, i.e. the envisioned state that is to be realised within a given area during a predetermined temporal window; (3) acknowledgment of the present and prospective conditions influencing the strategy's execution; (4) formulation of the so-called imperative (obligatory) component of the strategy, specifically the delineation of action-oriented resources, the methods of their temporal and spatial deployment, the ordering of discrete operations, and the assignment of executing institutions. The quality of strategy implementation is determined by the adequacy of diagnosis, results of prognosis, and selection of the measures and resource allocation. It is noteworthy that implementing strategies in the macroeconomic dimension can influence the formulation and implementation of strategies in the microeconomic dimension by shaping the political and legal (regulatory) environment. Moreover, strategic planning performs three distinctive functions. Firstly, in the macroeconomic dimension it can shape the socio-economic development and structural changes within an economy following the economic policy framework, focusing on the entire economy or individual sectors or industries. An example of this function is a presentation of a structured short and long-term development strategy in the form of plans. Secondly, strategic planning in the macroeconomic dimension is a way to influence the functioning of the economic system and its mechanisms to stabilise an economy and sustain the efficiency of the processes within it. Lastly, strategic planning and management processes in the macroeconomic dimension allow for the influence of the diverse entities within the public sector and institutions that constitute the political system (Winiarski et al., 2012). In addition, strategic planning in the macroeconomic dimension can also consider spatial differentiation by introducing diverse objectives concerning different administrative levels and geographical regions within an economy. As an action of climate change mitigation and a pursuit of sustainable development, individual states and economic organizations, such as the EU, are formulating and implementing detailed strategies, in the form of industrial policies, to guide the net-zero energy transition to achieve climate neutrality.

3. The Green Industrial Policy as a New Paradigm in Policymaking

The integration of environmental considerations into industrial policymaking is the essence of green industrial policy (Altenburg and Assmann, 2017, p. 11). The fundamental meaning of environmental-oriented objectives within the green industrial policy can be found in the definition by Hallegatte (2013), describing it as a specific industry sector-targeted policy that affects the economic production structure to generate environmental benefits. The green industrial policy also refers to any attempt in state intervention to hasten the development of low-carbon alternatives to fossil fuels (Karp and Stevenson, 2012). This definition could be expanded with the assumption that green industrial policy is designed to stimulate and facilitate the development of environmental technologies using various investments,

incentives, regulations, and other policy instruments (Allan et al., 2021, p. 3). Tagliapietra and Veugelers (2020, p. 20) suggest that green industrial policy necessitates applying specific instruments that exceed traditional industrial policy instruments which may not necessarily be new, but should be adapted to align with a green industrial policy. Any green industrial policy mix should be coordinated with the policy tools employed for climate and industrial policies, e.g. carbon pricing is critical to the green industrial policy mix. The green industrial policy must resort to secondary alternatives if the carbon price remains insufficient to stimulate low-carbon technology innovation across industry and other economic sectors.

Rodrik (2014) proposed two primary arguments for green industrial policy. Firstly, the emergence of new technologies, including low-carbon technologies, yields positive spillovers that exceed the initial investors' benefits, manifesting as cross-firm externalities, industry-wide learning, skill development, or agglomeration effects. The innovative nature, the highly experimental approach, and the significant risks faced by pioneering entrepreneurs suggest that low-carbon technologies might be exceptionally susceptible to these market failures. Secondly, low-carbon technologies warrant public subsidies due to the significant mispricing of carbon, a proxy for greenhouse gases (GHGs). This mispricing, rooted in fossil fuel subsidies and the absence of taxes or controls that would internalise climate change risks, reduces the user cost of carbon considerably below the sustainable level from a long-term societal standpoint. Consequently, the private return on low-carbon technologies falls significantly below the societal return, even when traditional R&D spillovers are not considered. Thus, the argument for subsidising low-carbon technologies aligns with the general case for mitigating R&D-related market failures and is fortified by the independent rationale stemming from carbon under-pricing, necessitating industrial policy intervention in this domain.

4. The Significance of Hydrogen Economy Development in the EU Green Industrial Policy

In July 2020, *A hydrogen strategy for a climate-neutral Europe* (European Commission, 2020) was adopted, demonstrating a clear path for the hydrogen economy's development. This document indicated several crucial actions that must be undertaken to guide and shape the hydrogen economy in the EU, especially in the context of expanding the essential role of low-carbon hydrogen production using the electrolysis process. Based on the adopted value-chain approach and targeting R&D as one of the fundamental actions for the hydrogen and fuel cell technologies to expand their application, the EU was planning to, among other objectives, install 40 GW of renewable hydrogen electrolysers by 2030, significantly changing the EU's energy mix. The strategy was founded on five objectives: (1) increasing the EU investment for hydrogen; (2) boosting demand for and scaling up hydrogen production; (3) designing an enabling and supportive legal and regulatory framework; (4) promoting research and innovation in hydrogen and fuel cell technologies; (5) developing international cooperation and alliances. Moreover, these five objectives were further conceptualised around a total of 20 detailed key actions that operationally guide achieving them. The EU's strategy to ramp up renewable hydrogen production foresees an increase in its contribution to the EU energy mix, rising from the present 2% to an anticipated 13-14% by 2050. This strategy aims not only to expand the EU's hydrogen economy but also to position the EU as a prospective global frontrunner in hydrogen and fuel cell technologies amid the ongoing shift towards net-zero industries. To facilitate this, the EU has earmarked an investment of 180-470 billion EUR by 2050 for technology development in this domain. Such high-scale and expensive ventures necessitate collaborative efforts across the community. Following the adoption of the *A hydrogen strategy for a climate-neutral Europe, the European Clean Hydrogen Alliance* (ECHA) was formed to foster investments in both renewable and low-carbon hydrogen production – the latter being derived from fossil fuels with carbon dioxide capture, utilisation, and storage (CCUS) in various applications. The *Strategic Forum for Important Projects of Common European Interest* (IPCEI) will oversee and coordinate these initiatives. Moreover, the *InvestEU* program, under the *NextGenerationEU*

framework for post-COVID-19 economic recovery, has seen a doubling of available funds, presenting an enhanced opportunity for financing projects aligned with the strategy. Member states will also receive additional support for these goals through the *European Regional Development Fund* and the *Cohesion Fund*.

After *A hydrogen strategy for a climate-neutral Europe* overview, it is worth reviewing the strategy that can be perceived as an essence of the green industrial policy approach, where the role of the hydrogen economy is emphasised. *A Green Deal Industrial Plan for the Net-Zero Age* (European Commission, 2023) adopted in January 2023 demonstrated a multidimensional response to contemporary crises the EU has faced recently. This strategy is founded on the following four pillars: (1) a predictable and simplified regulatory environment, (2) faster access to sufficient funding, (3) skills, (4) open trade for resilient supply chains. Regarding the first objective, it is worth noting that the EU is enhancing its regulatory framework to shape business conditions, employment quality, and environmental protection simultaneously. In 2023, the Commission added a *competitiveness check* to new regulations to assess their impact on competitiveness and minimise unnecessary burdens. Two critical proposals for industrial competitiveness are planned: *The Net-Zero Industry Act* to simplify the regulatory framework for manufacturing key net-zero technologies like batteries, windmills, and solar panels. It includes sector-specific goals, streamlined permitting processes, and support for cross-border supply chains and projects. *The Critical Raw Materials Act* focuses on securing the supply of critical raw materials for EU net-zero technologies. It highlights diversifying sources, recycling materials, and maintaining high environmental standards. In addition and as a response to energy challenges, the EU is focusing on reducing energy costs, increasing renewable energy production, and improving electricity market designs. Efforts include long-term price contracts for renewable power and infrastructure development for charging and refuelling networks. The EU also plans to foster innovation through regulatory sandboxes, boost demand for net-zero products through public procurement, and improve market transparency. In this domain, *The Green Deal Industrial Plan* relies on collaboration across sectors to achieve its goals.

The strategy recognised that the global net-zero industry, particularly in the EU, has seen significant growth with a 10% increase in low-carbon energy investments in 2022. As the foundation for this objective, the authors of the strategy acknowledge that the EU excels in industries like wind energy and heat pumps, despite high energy prices, but struggles in areas such as solar PV panels, where the EU industry faces competition and subsidy disparities, necessitating faster sector development and better funding access to transition to a net-zero economy. This is critical for the *Green Deal Industrial Plan* as defined in the second objective – *faster access to sufficient funding*. It is also acknowledged that both public and private funding play vital roles. The EU and national funding may increase innovation and infrastructure development significantly. An example is the already mentioned *NextGenerationEU* fund allocations for green industrial policy measures, with a simultaneous rise in *Horizon Europe* grants for R&D projects for low-carbon technologies. The EU has approved substantial aid for renewable energy and decarbonising industry. There are proposals to adjust state aid rules for greater flexibility and faster approvals, focusing on renewable energy, industrial decarbonisation, and strategic net-zero technologies. Various EU programmes, like *Cohesion policies* and the *Just Transition Fund*, provide substantial financial support, while *InvestEU* mobilises financing for net-zero investments, and the *Innovation Fund* allocates funds for net-zero technologies and solutions. Private funding is equally crucial for the net-zero energy transition, as recognised in the strategy. The EU aims to develop its *Capital Markets Union* to increase financing opportunities, particularly in net-zero technology industries. Sustainable green finance frameworks are also being strengthened to make green investments more attractive. Under the second objective, the EU is considering a *European Sovereignty Fund* to address investment needs and preserve technology leadership. This fund aims to safeguard cohesion and prevent market fragmentation due to unequal state aid availability.

Under the third objective, the EU aims to actively address the workforce challenges of the net-zero energy transition, stressing the need for inclusive and equitable outcomes. Between 2000 and 2019,

jobs in net-zero industries in the EU increased from 3.2 million to 4.5 million, indicating a growing demand for new skills and large-scale workforce upskilling and reskilling. The battery industry alone forecasts a need for 800,000 additional workers by 2025. *The EU's Green Deal Industrial Plan* prioritises skills development, especially in net-zero and digital industries, focusing on inclusivity for women and young people. The EU faces significant labour shortages in sectors crucial for the net-zero energy transition, where technical skills are increasingly in demand. Net-zero industries exhibit higher productivity, making green skills vital for future prosperity. *The EU's European Skills Agenda*, aligned with the *European Education Area*, addresses these skill-related challenges. Initiatives like the *European Pact for Skills*, the *Clean Energy Industrial Forum*, and the *Digital Education Action Plan* are part of this agenda, aiming to upskill and reskill millions for a net-zero and digital economy. The EU is also focusing on attracting and retaining top talent, especially in STEM fields, and is establishing partnerships and academies to meet the specific skill needs of industries such as renewable energy, energy efficiency, and sustainable construction. Recognition of qualifications and labour mobility policies are being enhanced to better match skills with employer needs. Financially, the EU supports skills development through the *Multiannual Financial Framework*, *NextGenerationEU, European Social Fund+*, and the *Recovery and Resilience Facility*, allocating funds for net-zero-related skills and jobs.

Lastly, regarding the fourth objective, the EU strategy emphasizes the importance of fair competition and open trade in supporting net-zero energy transition. It highlights its strength as a trading powerhouse and an attractive investment destination while addressing challenges such as unfair practices and maintaining a level playing field. As defined in the strategy, the EU plans to finalise trade agreements with various countries and regions, including Australia, India, Indonesia, Chile, Mexico, New Zealand, and MERCOSUR, while exploring opportunities in the Indo-Pacific. The EU also focuses on developing partnerships beyond traditional trade agreements, collaborating with the US and India in technology, and addressing concerns through the *EU-US Task Force*. *The Sustainable Investment Facilitation Agreements* (SIFA), particularly with African partners, aim to attract investments with integrated environmental and labour rights commitments. Therefore, it can be stated that the EU supports developing countries in adapting to sustainability requirements and promotes cooperation in renewable hydrogen through policy dialogues. Considering the assumption of the discussed strategy, the EU plans to implement new initiatives, including forming a *Critical Raw Materials Club* for secure raw material supplies, developing *Clean Tech/Net-zero Industrial Partnerships*, and strategising export credits to align with net-zero emission goals. Hence, the EU is committed to addressing trade distortions caused by non-market economies and will use trade defence instruments to protect its market. It seeks to ensure reciprocity in public procurement and coordinates with allies to protect European assets and respond to economic intimidation, enhancing its foreign direct investment screening mechanism and advancing the *Anti-Coercion Instrument*.

The Green Deal Industrial Plan recognises the significance of renewable hydrogen as a storage medium, fuel, and feedstock for the net-zero energy transition. First, it addressed the need to develop the necessary infrastructure, described as the *European Hydrogen Backbone*, which consists of gas system operators allowing the advanced existing gas network to transport this energy carrier. Moreover, the strategy assumes the required revision of the *TEN-E Regulation* to enhance cross-border gas infrastructure planning, financing, and deployment. Secondly, the EU plans to increase the share of renewable hydrogen in the energy mix and particular sectors, which was already defined in the RED III directive adopted in September 2023. For instance, these targets assume that renewable hydrogen will consist of 1% of fuels used in transportation by 2030. Interestingly, it also assumes that 42% of hydrogen will be sourced from renewable sources by 2030 in the EU industry sector. The strategy defines the funding source for the projects indicated in the IPCEI framework, including the allocations from the *InvestEU* programme and the *EU Innovation Fund.*

Additionally, the European Investment Bank must provide a joint venture for technology and product developments of hydrogen automotive propulsion technologies. Note that the European Commission assumed that the increase in renewable hydrogen production requires the introduction of the auction –

or competitive bid. As expressed in the strategy, the auction winners will be awarded a fixed premium for each kilogram of renewable hydrogen produced over the next decade. This auction and fixed premium, operated by the EU Hydrogen Bank, is believed to significantly increase hydrogen production to meet the *RED III* and *REPowerEU*. Lastly, regarding international cooperation, the EU plans to launch broad industrial cooperation with North African countries to secure future imports of renewable hydrogen from that region, stabilising and growing the hydrogen economy on both shores of the Mediterranean.

5. Conclusions

In the time of climate change mitigation and pursuit of sustainable development, the green industrial policy can perform four general functions, as postulated by Lütkenhorst and others (Lütkenhorst et al., 2014; Lütkenhorst & Pegels, 2014): *responding to pervasive market failures, addressing high uncertainty and long-time horizons, creating new pathways*, and, lastly, *disrupting old pathways*. It can be stated that the EU attempts to *respond to pervasive market failures*, such as imperfect competition, asymmetric information, externalities, coordination failures, and public goods. It recognises that while price correction using market-based instruments such as taxes and quotas is vital, the EU green industrial policy also tackles other facets, acknowledging that more than pricing instruments are required, including feed-in tariffs for renewable energy sources, fixed premium tariffs for hydrogen and emission trading systems in the form of EU ETS. Secondly, the EU *addresses high uncertainty and long--term horizons* by establishing far-reaching financial instruments and objectives that have been set for decades. Thirdly, the EU *creates new pathways* in the industrial sector by intensively subsidising R&D alongside the wide-scale demonstration and deployment of net-zero technologies, including hydrogen and fuel cell technologies. Interestingly, the EU offers space for international cooperation in this domain by establishing numerous trade and investment partnerships, spurring the growth of those newly established industries. Lastly, as expressed in the discussed strategies, the EU green industrial policy is disrupting old pathways and dismantling the industries with an adverse environmental impact while simultaneously transforming their structure and economic relations. This shift necessitates investment--discouraging incentives alongside investment-encouraging ones, with an acute focus on addressing the challenges of stranded assets and the pressing issue of limiting carbon emissions. In conclusion, the EU represents an approach that can be identified as a green industrial policy, which is continuously advancing based on the process of strategic planning with the formulation and implementation of subsequent, yet consistent and consequent strategies.

Based on the conducted deliberations, it can be stated that hydrogen and fuel cell technologies are expected to play a significant role in net-zero energy transition in the coming decades in the EU. However, it must be emphasised that hydrogen performs a fundamental function in the EU industry – from fertiliser production to oil refinement. The main challenge is to shift from fossil-fuel-based hydrogen to renewable hydrogen produced, i.e. using water-splitting electrolysis or biomass pyrolysis. Therefore, industry-wide decarbonisation can be achieved by replacing high-carbon hydrogen with low-carbon renewable hydrogen. The broad portfolio of hydrogen-focused green industrial policy instruments is characterised by a value-chain approach, thereby supporting hydrogen production, storage, transportation, and various end-use applications.

The conducted research was limited to studying and presenting two EU strategies directly related to the issue of developing a hydrogen economy based on the usage of renewable hydrogen. The diversity and complexity of the EU policies and strategies offer a space for future studies to explore the integration and interplay of these policies within the broader EU economic and environmental framework. Future research could focus on the effectiveness of these strategies in achieving sustainable development goals and transitioning towards a net-zero economy. This would involve assessing the impact of green industrial policies on various sectors, including energy, transportation, and manufacturing. Additionally, investigating the role of public-private partnerships and the involvement of stakeholders at different levels, from local to international, could provide deeper insights into the policy implementation process.

Another promising direction for research could be the comparative analysis of the EU's approach with other global models, examining the successes, challenges, and lessons learned. This could help understand the scalability and adaptability of the EU's green industrial policy in different socio--economic and political contexts. Moreover, continuous monitoring and analysis of the policy outcomes are essential, taking into consideration the rapid technological advancements and the evolving nature of global environmental challenges. This will enable the identification of gaps and the development of more targeted and effective strategies, ensuring that the transition to a sustainable and resilient economy is inclusive, equitable, and aligned with global climate change mitigation efforts.

In summary, *A hydrogen strategy for a climate-neutral Europe* and the broader green industrial policy are pivotal in the net-zero energy transition. This approach is not only about transitioning to renewable hydrogen but encompasses a comprehensive plan addressing market failures, uncertainty, and the creation of new pathways while disrupting old ones. It highlights the significance of hydrogen and fuel cell technologies in diverse industrial applications, aiming for a shift from fossil-fuel-based to renewable hydrogen as part of the deep decarbonisation of the EU industry. The EU's green industrial policy approach is a dynamic and evolving strategy, which requires continuous monitoring to ensure its alignment with sustainable development objectives, disruptive economic events and climate change mitigation efforts, marking a significant step towards a sustainable and resilient economy.

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Zielona polityka przemysłowa Unii Europejskiej na rzecz rozwoju gospodarki wodorowej

Streszczenie: W artykule omówiono znaczenie zielonej polityki przemysłowej w rozwoju gospodarki wodorowej w Unii Europejskiej. Przedstawiono, w jaki sposób wodór, jako wszechstronny nośnik energii, może stanowić odpowiedź na potrzebę dekarbonizacji sektorów, w których redukcja emisji jest kwestią problematyczną i jednocześnie priorytetową. Przedstawiono ewolucję gospodarki wodorowej, od jej początkowej koncepcji związanej z energią jądrową do jej obecnego powiązania z odnawialnymi źródłami energii, podkreślając jej potencjał w redukcji emisji dwutlenku węgla i wpływ na zmiany w strukturze zużycia energii w UE. Struktura artykułu obejmuje omówienie planowania strategicznego w polityce ekonomicznej, a kolejno przedstawienie koncepcji zielonej polityki przemysłowej, jej podstaw teoretycznych i przykładów zastosowania w Unii Europejskiej. Następnie skoncentrowano się na unijnej strategii wodorowej, w tym na jej celach i kluczowych działaniach na rzecz rozwoju gospodarki wodorowej. Omówiono rolę wodoru w unijnej zielonej polityce przemysłowej, w szczególności w sektorach energii, transportu i przemysłu ciężkiego, a także przedstawiono wysiłki na rzecz zwiększenia produkcji i wykorzystania wodoru odnawialnego. W podsumowaniu podkreślono wieloaspektowe funkcje zielonej polityki przemysłowej w eliminowaniu niedoskonałości rynku, wspieraniu nowych i modyfikowaniu dotychczasowych kierunków rozwoju gospodarczego. Badanie, ograniczone do okresu 2019-2023, zapewnia wgląd w integrację zagadnień środowiskowych z polityką przemysłową, sugerując, że strategia i polityka UE mogą służyć jako modelowe podejście w tym obszarze rozważań.

Słowa kluczowe: gospodarka wodorowa, zielona polityka przemysłowa, Unia Europejska