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The Emerging Geopolitics of Hydrogen Value and Supply Chains: A Focus on EU's Future Relations with the Eurasian Supercontinent✢

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|ABSTRACT|

Hydrogen is gaining momentum as countries prioritize decarbonization of hard-to-abate sectors. However, hydrogen production entails technological and resource-intensive processes, resulting in intricate value chains and complex dependencies along them. Apart from that, hydrogen trade and market dynamics have the potential to alter not only economic but also power relations between countries and the geopolitical landscape. Eurasia, often overlooked in the context of Europe's hydrogen plans, emerges as a pivotal macro-region due to the concentration of technology and abundant resources (fossil fuels, renewable energy and critical minerals) along important transit routes as well as evolving intra-continental trade ties beyond Europe and the geographic West. Thus, the present paper will explore Eurasia's anticipated role within hydrogen value and supply chains and delve into how the European Union's (EU) hydrogen initiatives may reshape Europe's energy and geopolitical relationships with countries spanning the supercontinent. It underscores the importance of considering agency, priorities, interests, and motivations of potential hydrogen partners in effectively managing the arising dependencies. The findings highlight the need for a comprehensive understanding of the evolving hydrogen landscape, which promises to reshape energy relations and geopolitics across the Eurasian supercontinent.

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Ⅰ. Introduction

Hydrogen is increasingly seen as a crucial tool to rapidly reduce greenhouse gas emissions. Its versatile applications allow for "sector coupling", connecting energy-consuming sectors like buildings, transport, and industry with power production in the transition to a carbon-free energy system.[1] However, a market for low-carbon hydrogen is currently lacking and may not emerge before the early 2030s. Demand and supply are uncertain and final investment decisions are yet to be taken. While hydrogen is not necessarily "the future of energy", several advanced countries prioritize the development of a hydrogen economy to decarbonize energy-intensive industries, the transport or even heating sector, to stabilize their electricity grid, but also to retain or gain technological leadership and to increase supply security. Meanwhile, industrializing and developing countries in the global south are also keen to become part of the future's hydrogen economy to nurture economic and industrial development and maximize geopolitical dividends.

Hydrogen has thus the potential to redraw the geography of trade and to shift the strategic significance of countries and regions. It will presumably have its own, specific geopolitics.[2] Resource concentration, technological change, and power dynamics have traditionally shaped the geopolitics of fossil energy. Control over concentrated resources, prices, flows and infrastructure as well as over new technologies has long defined relations between producers and consumers and shifted paths of power. For their part, the nature of these relations in any given moment

1) Hydrogen Council, "Hydrogen For Net Zero," November 2021, https://hydrogencouncil.com/en/hydrogen-for-net-zero/ (Accessed October 10, 2023), p. 15.

2) Thijs Van de Graaf et al., "The new oil? The geopolitics and international governance of hydrogen," *Energy Research and Social Science*, Vol. 70 (2020); Nicola De Blasio, and Fridolin Pflugmann, "The Geopolitics of Renewable Hydrogen in Low-Carbon Energy Markets," *Geopolitics, History, and International Relations*, Vol. 12, No. 1 (2020), pp. 9–44.

–along with the current shape of the world order and its governance– have impacted energy markets and market relations, allowing for their weaponization. Hydrogen production is more technology and industry-driven than fossil energy, but nevertheless no less raw-material based. This will lead to intricate value chains with interconnected downstream, midstream, and upstream sectors and to no less asymmetrical dependence than in the fossil world. Meanwhile, with first bilateral hydrogen relations and value and supply chains expected to develop in the coming years,[3] existing power relations and the (geo-)political preferences of potential market actors will decisively influence political decisions needed to set up trade and scale up the market for hydrogen. Eventually, both factors will redesign the strategic role of regions and countries.

Particularly, Germany and the EU – along with advanced economies in East Asia like South Korea and Japan, and big "prosumers" like the United States (US) and China – place significant emphasis on hydrogen in their climate and energy policy plans. Other than the US and China, both Europe and East Asia will however also remain largely dependent on imports, which increases the international and thus geopolitical relevance of hydrogen for them.

For Europe's hydrogen plans, especially the Eurasian "supercontinent",[4] is a crucial yet under-discussed macro-region: taken as a single strategic and interconnecting "chessboard" rather than a geographic or geopolitical unity, from the point of view of energy and trade relations it not only

3) Hydrogen Council, "Hydrogen Insights 2022," September 2022a, https://hydrogencouncil.com/en/hydrogen-insights-2022/ (Accessed October 10, 2023), pp. 5-7.

4) This paper refers to broader Eurasia as the supercontinent including the post-soviet space, China and the belt of countries stretching from the Gulf and the Middle East to India, South and East Asia along the maritime rim. For a more specific definition and conceptualisation on the interacting dynamics of the supercontinent see: Kent E. Calder, *Super Continent: The Logic of Eurasian Integration* (Redwood City, CA: Stanford University Press, 2019); Jacopo M. Pepe, *Beyond Energy: Trade and Transport in a Reconnecting Eurasia* (Berlin: Springer, 2018).

harbors major emerging economic powers and demand centers like China or India, but also advanced technology leaders and net importers like Japan and South Korea, fossil and renewable energy-and mineral-rich countries like Central Asia, Russia or the Gulf countries, and major emitters, all already or potentially connected along important transit countries or sea trade lines. In the past two decades, countries and sub-regions in this vast space–from Russia and Central Asia to the Gulf and from China, East Asia to South East Asia and India–though diverse and remote, have come to interact even more closely and to increase their energy, industrial and infrastructural ties beyond Europe and the geographic west. Yet, especially since the Ukraine war, the region–at least in the narrow sense of the Post-Soviet space and eastern Europe–is largely ignored in European discourse, while trade interactions taking place in this vast space are scarcely outlined in favor of analysis privileging traditional geographic sub-groupings (Europe, Middle East and Northern Africa, Asia Pacific, Post-Soviet space).

The present paper will analyze the emerging geopolitics of hydrogen's value and supply chains by looking specifically at the (new) interdependence which might emerge between the EU and single countries and regions across the broader Eurasian space, should the EU plans for a hydrogen economy be realized and the stalemate in the Russia-Ukraine war further dominate the EU relations toward the continental regions of Eurasia. While similar analysis might apply to other advanced economies in East Asia, this paper will take the European Union and its evolving relations with the broader Eurasian space as a case study. It will ask one major question: how may the EU's hydrogen plans reshape Europe's energy and geopolitical interdependencies with selected key countries and regions across the supercontinent? Secondary research questions functional to address the main will revolve around the theoretical nexus between hydrogen and geopolitics as well as the role, interests and

preferences of single countries and region in greater Eurasia in shaping the geopolitics of hydrogen. While the paper will not delve into potential hydrogen interactions among single Eurasian subregions, it assumes a certain level of interaction fostered by potentially cross-regional hydrogen value and supply chains.

The core assumption is that, first, as hydrogen will redraw the geography of energy trade on the basis of more complex supply and value chains, it will have its own geopolitics. Second, the EU hydrogen plans will impact its relations with broader Eurasia such that the more Europe bets big on hydrogen, the more complex dependencies and competition will be created through new emerging trade configurations. Third, since a hydrogen economy will impact future geopolitical settings, and is also simultaneously impacted by the current geopolitical environment, agency, priorities, interests and motivation of potential hydrogen partners and competitors need to be considered to manage these dependencies.

The paper is structured as follows: the first part briefly sketches up the theoretical nexus between geopolitics and energy, before delving into the peculiar characteristics of hydrogen and its expected geopolitics. The second part maps out the hydrogen landscape in the broader Eurasian region and identifies major expected players along the hydrogen value and supply chains. The third section focuses on the European Union's hydrogen push and its implications for its relations with selected Eurasian subregions. The reality check section discusses the challenges of precarious leadership and multiple import dependencies, leading to implications for EU relations with Eurasian countries. The paper concludes by summarizing key findings and insights.

Ⅱ. Geopolitics and Hydrogen

1. Geopolitics of Energy – Resources, Technology, and Power

Geopolitics and energy have been highly interwoven since the industrial revolution. Historically, the interaction between resource location, geographic distribution of demand and supply centers, and technological change, has contributed to the emergence of a new geography of energy trade and to power shifts, defining the essence of the geopolitics of energy.[5] The control over concentrated fossil energy resources in different geographic locations, their transport, and trade has historically helped shape patterns of power and wealth over time.[6]

While the concentration of fossil resources is paramount to define paths of power and influence, the emergence of new technologies and forms of energy can re-define and redistribute power among supply and demand centers. The rise of Arabia from being an irrelevant backwater of world politics to a key region due to the discovery of oil in the 1930s illustrates this process. More recently, the emergence of the United States as a major oil and gas producer following the shale oil and gas revolution has turned the US in an energy superpower and altered its dependence on the Gulf. However, the nexus between resources, technology, and power is not unidirectional: technology and resources are not per se geopolitical.[7] Interdependences can be weaponized[8] if existing power relations are conducive to it.

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5) See amongst others Michael Bradshaw, "The Geopolitics of Global Energy Security," *Geography Compass*, Vol. 3, No. 5 (2009), pp. 1920-1921.

6) Thijs Van de Graaf, and Benjamin K. Sovacool, *Global Energy Politics* (Cambridge: Polity, 2020).

7) Otto Maull, *Politische Geographie* (Berlin: Safari-Verlag, 1956), p. 30.

8) Albert O. Hirschman, *National Power and the Structure of Foreign Trade* (Berkeley, CA: University of California Press, 1945).

A multilateral world order with well-functioning global institutions and global governance mechanisms is more conducive to the unimpeded flow of energy, open and liberalized markets, and fair competition than an environment with weak global governance institutions, competing powers, and a lack of cooperation among states as we currently witness. For instance, the gradual liberalization of energy markets and the pursuit of global energy governance (with the Energy Charter Treaty of 1991) occurred in a period of growing acceptance of a liberal, multilateral world order largely shaped by the West at the end of the Cold War. Conversely, since the financial crisis of 2008/2009 shattered the belief in unfettered globalization, systemic competition and great power rivalries, including military confrontation, have shaken the fundaments of the liberal world order, and globalization has grown indeed more regionalized. The Arab Spring, the subsequent upheaval in the Middle East and the first Russia-Ukraine war in 2014 have contributed to an increasing fragmentation of energy and good markets. The forceful systemic competition between China, and the US and between the West and Russia, as well as the emergence of self-confident powers in Asia, Middle East and South America with own agency and stakes in the international system has led to the revival of paradigms of power competition, military rivalry and economic-industrial self-reliance. As a result, especially in the energy sector, political attention is increasingly given to greater energy independence, supply chains resilience, industrial re- and near-shoring, and technological-regulatory competition, leading to energy market distortions and new state interventionism.

2. Hydrogen: A Technology and Raw Material- Intensive Energy Carrier

The bidirectional nexus between resources, technology, and power is at the core of the geopolitics of hydrogen as well, though with some

significative peculiarities. Its production might be less dependent on concentrated resources like in the fossil world. However, hydrogen production is both technologically and raw material-intensive, resulting in a complex and diverse value and supply chain, dependent on technology pathways and end-use.[9)]

Based on the chosen technology and product, the potential for hydrogen production and leadership in industrial applications are distributed unequally on a global scale. This potential depends largely on production costs, resource distribution, infrastructure, know-how, policy, regulatory measures, and climate goals. However, industrial and (geo-)political priorities are often overlooked motivations behind the push for hydrogen.

On the demand side, research identifies potential centers of hydrogen demand in China, India, Japan, South Korea, the US and the EU.[10)] The future situation in countries like China or India depends on policy choices and the given geopolitical priorities and environment of single countries and regions. Conversely, the EU, Japan, or South Korea remain industrialized net energy importers with limited maneuvering space. In their case, a successful (green) hydrogen market ramp-up is not only conducive to net-zero ambitions but could help mitigate asymmetrical dependencies and limit the possibility of using energy resources as power tools. Nevertheless, these countries are forced to enter bilateral, state-to-state, or state-backed relations to align their demand with the interests of the suppliers under growing competitive geopolitical and

9) Julian Grinschgl, Jacopo M. Pepe, and Kirsten Westphal, "A New Hydrogen World: Geotechnological, Economic, and Political Implications for Europe," *Stiftung Wissenschaft und Politik,* 2021, https://www.swp-berlin.org/10.18449/2021C58/ (Accessed October 10, 2023), pp. 3-4.

10) Hydrogen Council, "Global Hydrogen Flows: Hydrogen Trade As A Key Enabler For Efficient Decarbonization," October 2022b, https://hydrogencouncil.com/en/global-hydrogen-flows/ (Accessed October 10, 2023), p. 12.

techno-political competition.

On the supply side, countries like Russia, Australia, Algeria, Qatar, Saudi Arabia, Canada, and the US, but also Morocco have (on paper) the chance to produce more hydrogen than needed, enabling them to turn into net-exporters.[11] Consequently, new power dynamics might emerge, or existing ones might be reinforced. For instance, a new class of exporters can additionally emerge along new green hydrogen value chains, with structures and dependencies more diffuse than in the case of fossil fuels, but not less complex to manage. Meanwhile, the power positions of natural gas producers like the Gulf countries or the post-Soviet space can be stabilized by continuing to export gas along established trade relationships, if Carbon Capture and Storage (CCS) technologies develop to produce "decarbonized" blue hydrogen.

As for critical components, risks and uncertainties related to nickel supplies from Russia add to attempts by countries like Indonesia or the Philippines to prevent the export of unrefined nickel.[12] Furthermore, the monopolistic role of South Africa for platinum and iridium, the role of China and Russia in the South African mining sector, and South Africa's own ambiguous geopolitical loyalties render diversifying these supply chains a particular challenge.[13]

Finally, for both blue or green technologies, the logistic chain and transport type play a crucial role. Hydrogen transport creates dependencies and power relations. Thus, the choice of transport type (shipping or pipelines) not only influences the necessary infrastructure but, ultimately, also the market structure and the type of trading relationships.

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11) Ibid.

12) Dawud Ansari, Julian Grinschgl, and Jacopo M. Pepe, "Electrolysers for the Hydrogen Revolution: Challenges, dependencies, and solutions," *Stiftung Wissenschaft und Politik,* 2022, https://www.swp-berlin.org/10.18449/2022C57/ (Accessed October 10, 2023).

13) Ibid.

Ⅲ. The Eurasian "Supercontinent": Mapping the Future Hydrogen Landscape

The broader Eurasian space, as the vast landmass, spanning from Europe to China overland, and its maritime shores extending from the eastern Mediterranean and the Black Sea to the Arabian Sea and across the Indian Ocean to the Asia-Pacific intersection, encapsulates in a nutshell crucial defining factors, potential key players, and geopolitical dynamics within the emerging hydrogen market as presented above. The significance of the supercontinent in the context of the global and European energy transition is therefore paramount.

The concept of Eurasia is widely used yet hard to grasp since the borders of this space shift along with cultural, ideological and political borders. For the sake of this paper, we will consider the broader Eurasian space in the definition of Kent E. Calder (Eurasia as a "Supercontinent", i.e. as a growing political economic interaction among distinct parts of a broader system, between globalization and regionalization)[14] as opposed to a narrow definition of post-Soviet continental Eurasia. To be sure, this space is certainly largely inhomogeneous and geopolitically fragmented, hard to grasp as an analytical unicum. Yet, for the past twenty years, specific geopolitical and economic regional realities have been increasingly tied-up by geographic contiguity, the emergence of energy and industrial demand and production centers unleashed by major critical junctures like the end of the Soviet Union, the rise of China, India and Iran, the growing integration with Asian booming economies as well as energy and logistics corridors across both the maritime and continental belt of the continent.[15]

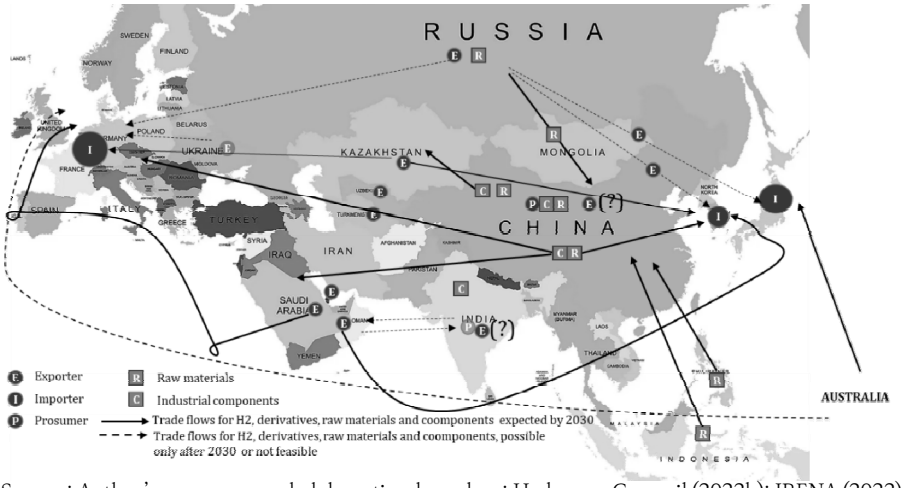
14) Kent E. Calder (2019), p. 9.
15) Ibid.; Pepe (2018).

Against this backdrop, not only does a substantial portion of global emissions originate here, but a significant part of the global energy transition is also anticipated to unfold within this vast space. It inhabits the majority of emerging economic powers such as China and India, and major carbon dioxide (CO_2) emitters, including China, India, and Russia. In the same space, the majority of fossil energy exporters, namely the Gulf region, Russia, and Central Asia, are located while countries like Japan and South Korea have long-standing energy, industrial and trade relations with them. Thus, interactions within this space are of the uttermost relevance also for Europe's hydrogen plans.

Thus, considering the broader Eurasian space as an interacting, though not fully integrated unity, helps map future intricated value and supply chains emerging across different subregions before assessing their potential role for Europe. Meanwhile, hydrogen strategies, motives, and priorities in the region certainly vary based on resource availability, future position along the value chains, technological maturity, and the role hydrogen plays in the energy, climate, and industrial strategies of these countries, as well as within the geopolitical environment. This necessitates a brief exploration of production potential, expected roles in the market, distinctive industrial, climate, energy, and geopolitical incentives and challenges.

In the subsequent paragraphs, we will delve into the motives and future positions of some post-Soviet continental Eurasian countries, along with key regions and countries across maritime Eurasia. Subsequently, we will explore Europe's priorities and potential interactions with this vast continent, identifying key expected interaction paths.

<Figure 1> Eurasia's Potential Hydrogen Map:
Expected Importer, Exporter, Raw Materials, Industrial Components and Trade Routes



Source: Author's own map and elaboration based on: Hydrogen Council (2022b); IRENA (2022); Ansari, Grinschgl, and Pepe (2022).

1. Continental Post-Soviet Eurasia: A More Marginal Role

In terms of hydrogen production, continental Eurasia seems to offer significant opportunities for blue hydrogen and, to a lesser extent, green hydrogen production and export.[16] However, it also holds a major potential for critical raw materials needed for manufacturing electrolyzers.[17] Russia, Ukraine, and Central Asia, in particular, have growing chances and strategies in place, although their motives vary based on their geopolitical situation. Proximity to the European and Asian markets would make the region a natural swing producer on paper, but geopolitics alters this equation.

Before the Ukraine war, Russia[18] and Ukraine had major aspirations

16) See map and Hydrogen Council (2022b).

17) Ansari, Grinschgl, and Pepe (2022).

18) Government of the Russian Federation, "Pravitel'stvo Rossiyskoy Federacii," 2021, http://static.government.ru/media/files/5JFns1CDAKqYKzZ0mnRADAw2NqcVsexl.p

to tap into the potential of the European hydrogen market, while Central Asia remained largely marginal. Russia was working on a roadmap for natural gas-based hydrogen development for 2021-2024 to preserve the country's leading role as a global energy exporter.[19] The end goal of 50 million tons (Mt) per year by 2050[20] would be equivalent to the entire amount of gas Russia sold to Europe before the war. Given the current situation, the implementation of these plans largely depends on Russia's fiscal capabilities, but also on the changed geopolitical environment.

The break-up with Europe leaves Russia with East Asian hydrogen markets as the only option. Japan, which has frozen cooperation with Russia in several sectors, might resume plans to work with Russia on hydrogen and ammonia, as well as CCS in the future. Moreover, Russia is a major producer of nickel, both raw and refined, making it a potential key player in the hydrogen upstream sector and critical minerals supply chains.

As for Ukraine, the hydrogen strategy draft[21] aimed at renewable hydrogen exports, building on existing pipeline infrastructure, vast storage capabilities, and mainly targeting the European market. However, uncertainties about the outcome of the war and the presence of Russian occupation troops in the renewable energy-rich east and southeast mean that Ukraine might re-enter the hydrogen equation only in the second half of the 2030s.

In the aftermath of the war, Central Asia is emerging as a promising

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df (Accessed October 11, 2023).

19) Tatiana Mitrova et al., "The hydrogen economy – a path towards low carbon development," *Moscow School of Management,* 2019, https://energy.skolkovo.ru/downloads/documents/SEneC/Research/SKOLKOVO_EneC_Hydrogen-economy_Eng.pdf (Accessed October 11, 2023), pp. 50-51.

20) Government of the Russian Federation (2021).

21) Stanislav Dubko, "Draft Roadmap for production and use of hydrogen in Ukraine," 2021, https://unece.org/sites/default/files/2021-03/Hydrogen%20Roadmap%20Draft%20Report_ENG%20March%202021.pdf (Accessed October 15, 2023).

additional production center for hydrogen. National strategies for hydrogen in Uzbekistan and Kazakhstan have been approved or are set to be approved soon, focusing on green and low-carbon hydrogen. Solar potential (and to a lesser extent wind) is high, and the countries have significant experience with and know-how on raw material exports and some potential for natural gas based production. The countries' priorities and motives are primarily of an industrial policy and geopolitical nature: increasing the resilience of their carbon-intensive economies, diversifying their industrial base, and integrating into green value chains of all the important players in order to preserve their space of maneuver and their multivectoral foreign policy approach.[22] Besides the hydrogen production and use itself, the whole region bears a significant yet overlooked potential when it comes to critical minerals, especially regarding nickel and aluminum.[23] However, it remains questionable, whether they represent an alternative to other minerals suppliers like Russia or Indonesia.

Moreover, infrastructure bottlenecks are large in the Western direction, with Russia's role as a major transit territory for pipelines to Europe leaving Central Asia largely dependent on complex logistics to reach other countries outside the region.[24] Thus, an upgrade of transport infrastructure across the Caspian Sea-Black Sea route is quintessential. The construction of an investment-intensive and geopolitically sensible

22) Yana Zabanova, "Towards a Geoeconomics of Energy Transition in Central Asia's Hydrocarbon-Producing Countries," in Rahat Sabyrbekov et al. (eds.), *Climate Change in Central Asia* (Cham: Springer International Publishing, 2023), p. 106.

23) Roman Vakulchuk, and Indra Overland, "Central Asia is a missing link in analyses of critical materials for the global clean energy transition," *One Earth*, Vol. 4 (2021), p. 1682.

24) Saule Zholdayakova et al., "Toward Hydrogen Economy In Kazakhstan," *Asian Development Bank Institute*, 2022, https://www.adb.org/publications/toward-a-hydrogen-economy-in-kazakhstan (Accessed October 11, 2023); Joanna Lillis, "Kazakhstan: Oil-rich west to become green hydrogen hub," *Eurasianet*, October 2, 2023, https://eurasianet.org/kazakhstan-oil-rich-west-to-become-green-hydrogen-hub (Accessed October 11, 2023).

transcaspian-trans-black sea hydrogen pipeline system is required. Alternatively, shipping and re-conversion of hydrogen carriers like ammonia or methanol along an intermodal route would come along with both high energy losses and increased transaction costs. Lastly, the region faces water constraints and lacks a strong refining and processing industry.

All in all, in the future hydrogen economy, continental Eurasia might still be relevant, but the combined effect of geopolitical, infrastructure, technological, and financial constraints make the region more marginal than in the fossil world.

2. Maritime Eurasia: A New Center of Gravity

1) China's Paramount Role: A Prosumer Dominating Technology and Value Chain

A more variegated and complex picture emerges when looking at the hydrogen map of maritime Eurasia. Here, the major concentration of demand centers, potential producers, components and raw material manufacturers, and future logistic corridors can be found, as map 1 shows. Different actor preferences and energy policy orientations come together to create a conundrum, strongly impacted by regional and global geopolitical tension, particularly between China and the USA.

Particularly, China is expected to play several key roles along the future hydrogen value and supply. As a consumer, China is assumed to become the third major demand source worldwide but also to turn into the biggest of the "prosumers" who both consume and produce hydrogen.[25] Currently, it is the biggest consumer and producer of grey hydrogen. However, plans for green hydrogen utilization remain limited to the

25) Hydrogen Council (2022b); IRENA (2022).

transport sector, and hard-to-abate sectors might emerge as major off-takers only after 2035.[26] Because of the current gap between its overall demand for hydrogen and low-carbon production capacity, it is unlikely that China will become a major exporter of green hydrogen, nor is this planned in its national policy. However, this situation may change in the longer term if China shows capable of mass-producing green hydrogen. Nor will however China turn into a major importer of hydrogen, leaving the country in a rather autarchic position.

Consequently, the hydrogen plans build rather on China's dominance as industrial and technology provider. Through targeted industrial policy decisions,[27] China builds up on its market dominance in solar panels, (to a lesser extent) wind turbines production, and especially electrolyzer production. The country already accounts for a third of global electrolyzer manufacturing capacity and will become more competitive as it scales up production and further reduces costs.[28]

Furthermore, China's dominance extends to raw materials refining, particularly for nickel and Platinum Group Metals (PGMs), with the country already heavily involved in third countries' mining sector (for instance, China has already a strong presence in the Indonesian nickel refining and smelting industry) while striving for technological and industrial supremacy in fuel cell vehicles.[29] China might be tempted to use market dominance, especially in the upstream sector, more geopolitically to strengthen asymmetric dependencies, exert coercive power or gain market shares in hydrogen-producing countries. The latter might prominently apply for relations with the Gulf and to a lesser

26) Gong et al. (2023).

27) Brown, and Grünberg (2022); Gong et al. (2023), p. 58.

28) Brown, and Grünberg (2022), p. 8; Chinese Alkaline Electrolysers are already cheaper than European/Western; International Energy Agency (2022), "Global Hydrogen Review 2022," p. 82.

29) Ibid; Ansari, Grinschgl, and Pepe (2022), pp. 3-4.

extent Central Asia, Russia, or even India. Geography also gives China a competitive advantage: located at the geographic critical juncture between continental post-Soviet Eurasia and the Asia-Indo-Pacific space, it can profit from its central role in both continental and maritime value and supply chains for hydrogen-related industrial components and critical raw materials. Particularly, while Russia and Central Asia might serve as providers of raw minerals and limited production basis for renewable energy industrial components, bidirectional trade avenues with the Gulf might grow even stronger, as the Gulf might still provide fossil fuels while importing industrial components and refined minerals for green hydrogen production.

Ultimately, China's geopolitical environment and domestic development will dictate its future position on the hydrogen market along the entire value chain: amid growing tensions with the US, the race for technology and market leadership, and decoupling attempts from the West, China aims at minimizing external dependencies while increasing foreign dependencies on its own technologies and exports. Hydrogen holds the possibility of creating a market with innovation and standards that will be crucial for the future to dominate, without exposing the country to dangerous vulnerabilities.[30]

2) East Asian Net-Importer: Technology Supremacy and Supply (In)Security

Conversely, Japan and South Korea, located at the north-easternmost edge of maritime Eurasia, are the biggest future net-importers in the region and potential technology leaders, but lack both fossil and

30) Alexander Brown, and Nis Grünberg, "China's nascent green hydrogen sector: How policy, research and business are forging a new industry," *Mercator Institute for China Studies*, 2022, https://merics.org/en/report/chinas-nascent-green-hydrogen-sector-how-policy-research-and-business-are-forging-new (Accessed October 4, 2023).

significant renewable resources. Both have national strategies in place to reach net zero by 2050 while their hydrogen efforts are centered around the decarbonization of the economy and, above all, the development of a competitive industry and as in Japan's case the control of its value chains. Technological supremacy looms large in the hydrogen strategies of both countries, leading to technology-agnosticism.[31] For instance, South Korea targets a mix of grey, blue, and green hydrogen toward 2030, with demand (roughly 3 Mt) still entirely covered by imports in 2030. By 2050, South Korea will still be largely reliant on hydrogen imports (12 Mt imports versus only 7 Mt produced domestically).[32]

Due to limited natural resources and land capacity, both countries focus on importing hydrogen from resource-rich countries such as Australia, but also the Gulf in particular, and in this context see CCS as an essential part of the development of a cost-efficient hydrogen infrastructure as opposed to green hydrogen. Dependence on China would be relevant in the green hydrogen value chains for both alkaline electrolyzers and minerals (nickel). In fact, Japan's openness to technology is primarily due to the tense security and geopolitical environment, in which territorial disputes with China increase the risk of interruptions in energy supplies. Previously, cooperation with Russia in the field of hydrogen was also planned, but the war in Ukraine also led to a reassessment of relations and, as a result, to increased efforts

31) Ministry of Economy, Trade and Industry, "Revision of Basic Hydrogen Strategy," 2023, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/20230606_report.html (Accessed October 11, 2023); Ministry of Trade, Industry and Energy, "Government announces new policies to boost hydrogen industry," 2023, http://english.motie.go.kr/en/pc/pressreleases/bbs/bbsView.do?bbs_cd_n=2&bbs_seq_n=1120 (Accessed October 11, 2023).

32) Pilseok Kwon et al., "Climate Neutrality Roadmap for Korea K-Map Scenario - Implementing an ambitious decarbonization pathway for the benefit of future generations and the Korean economy," *Agora Energiewende,* 2022, https://www.agora-energiewende.de/en/publications/2050-climate-neutrality-roadmap-for-korea-k-map-scenario/ (Accessed October 11, 2023), p. 15.

to move away from Russia. This has reinforced the need to shape hydrogen ties and design new supply chains with traditional partners in the Gulf[33] and potentially Australia[34] (see below).

3) The Gulf: Major Producer and Export Champion in spe?

Moving further south and west toward the Indian Ocean, the Arab Peninsula harbors the most favorable conditions for a rapid hydrogen production ramp-up, use, and export. In addition to abundant resources for hydrogen production, the states can rely on leading know-how in energy exports, the petrochemical industry, and CO_2 management as well as extensive financing capacities and a high level of agility through short decision-making processes.[35] The Gulf states' projects are entirely pragmatic in nature and aim to establish a sector that is complementary to the oil and gas business.[36] While early plans were only focused on exports, the production of goods such as "green steel" from renewable hydrogen is becoming increasingly popular. The major driver is the region's central effort to bring supply chains into the country and expand domestic value creation, especially to provide the rapidly growing,

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33) First actual hydrogen projects and high-level MoU for hydrogen supplies have been signed between Japan, as well as Korea and the Gulf Monarchies. See for example Takeo Kumagai, "Japan signs first hydrogen cooperation deal with UAE to consider supply chain," *S&P Global,* April 8, 2021, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/040821-japan-signs-first-hydrogen-cooperation-deal-with-uae-to-consider-supply-chain (Accessed October 11, 2023).

34) Australian Government, "Clean hydrogen collaboration with Japan," 2022, https://www.dfat.gov.au/about-us/publications/trade-investment/business-envoy/business-envoy-february-2022/clean-hydrogen-collaboration-japan (Accessed October 11, 2023).

35) Aisha Al-Sarihi, "Gulf States Hedge Against Global Energy Transition, Now With Hydrogen," *Arab Gulf States Institute in Washington,* 2022, https://agsiw.org/gulf-states-hedge-against-global-energy-transition-now-with-hydrogen/ (Accessed October 11, 2023).

36) Dawud Ansari, "The Hydrogen Ambitions of the Gulf States: Achieving Economic Diversification while Maintaining Power," *Stiftung Wissenschaft und Politik*, 2022, https://www.swp-berlin.org/10.18449/2022C44/ (Accessed October 11, 2023).

young population with (increasingly scarce) jobs.[37] The choice of technology is also pragmatic: mostly renewable hydrogen, but natural gas-based hydrogen is also on the agenda, especially given the region's CCS ambitions. The countries potential customers are Europe and the Asia-Pacific (particularly South Korea and Japan, see above), but the scale is increasingly tilted towards the Far East. Meanwhile China's first investment in the Gulf's emerging green hydrogen sector defines first hydrogen industrial value chains emerging between the two edges of maritime Eurasia.[38]

Ⅳ. EU's Hydrogen Push and Eurasia

1. EU Motivation and Goals

The EU plans to reach carbon-neutrality by 2050 and to reduce emissions by 55% by 2030. As the potentially largest demand center and for low-emission hydrogen worldwide,[39] the block strives to play a pioneering role in the development of a continental and global hydrogen market, giving priority to green hydrogen. Various instruments like the

37) Natalie Koch, "Gulf Hydrogen Horizons: Why are Gulf oil and gas producers so keen on hydrogen?" *Research Institute for Sustainability,* 2022, https://publications.iass-potsdam.de/pubman/faces/ViewItemOverviewPage.jsp?itemId=item_6002525 (Accessed October 11, 2023).

38) Middle East Monitor, "China and Saudi Arabia to power green hydrogen project with 2.2 GW of solar energy," August 11, 2023, https://www.middleeastmonitor.com/20230811-china-and-saudi-arabia-to-power-green-hydrogen-project-with-2-2-gw-of-solar-energy/ (Accessed November 17, 2023).

39) See for example European Commission (EC), "Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions," 2022a, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483 (Accessed October 11, 2023), pp. 7-10.

Repower EU Plan, the Green Deal, or the Clean Hydrogen Partnership[40] are intended to accelerate the hydrogen market ramp-up in the EU and its pioneering role through "technology push" and "demand pull".

With the Ukraine war, however, geopolitical considerations are becoming increasingly important in addition to climate policy aims. The need to diversify supply sources and suppliers and to increase the resilience of the EU's energy supply chains is one major reason.

Consequently, the EU aims at more than 120 GW installed electrolyzer capacity and 10 Mt domestic green hydrogen production by 2030.[41] In the long term, the EU will continue to prefer and promote green hydrogen produced from renewable energies over natural gas-based, blue or even nuclear-based pink hydrogen. However, blue hydrogen is increasingly considered a valid bridge towards a hydrogen future. CCS is therefore supported under the "Net Zero Industry Act", but only on a temporary basis.[42]

Furthermore, a renewed interest in traditional industrial policy to secure technological leadership and prevent the erosion of industrial capacities has emerged. For instance, an auction mechanism and a hydrogen bank are to guarantee demand while the Critical Raw Materials Act[43] is supposed to ensure a secure and sustainable supply of critical raw materials. This comes against the backdrop of the perceived

40) EC (2022a); EC, "Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions," 2020, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0301 (Accessed October 11, 2023); EC, "Clean Hydrogen Partnership," https://www.clean-hydrogen.europa.eu/index_en (Accessed October 11, 2023).

41) EC (2022a), p. 7 and Annex

42) EC, "Net Zero Industry Act: Accelerating the transition to climate neutrality," 2022b, https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en (Accessed October 11, 2023).

43) EC, "Critical Raw Materials: ensuring secure and sustainable supply chains for EU's green and digital future," 2023a, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661 (Accessed October 11, 2023).

technological-industrial onslaught by the US and China.

All in all, reducing dependencies from fossil fuels goes along with the ambition to shape a new post-fossil energy system where dependencies can be better managed, vulnerabilities minimized, and technological-industrial edge preserved.

2. Precarious Leadership and Multiple Import Dependencies

Market size, technological leadership in certain manufacturing processes and the regulatory power give the EU a comfortable first-mover advantage in shaping the future hydrogen market. However, areas within the EU with favorable climatic conditions for the production of fossil-free hydrogen are limited and cannot meet the needs of European actors. Thus, with 10 Mt of hydrogen by 2030, the EU is set to become the biggest hydrogen net-importer.[44] These volumes are only projected to increase in the time 2030-2050 along with significant growth in hydrogen demand under a best-case scenario.[45]

Particularly, electrolyzers and critical raw materials will present a bottleneck if demand is set to develop as forecasted. The electrolysis capacity currently installed in the EU will need to increase almost 900-fold within just eight years.[46] This leads to the dual challenge of ramping up electrolysis capacity while simultaneously securing the EU's market share in electrolyzer manufacturing vis-à-vis other electrolyzer producers. Finally, considering its own scarce mining capacities,[47] the

44) EC (2022a), pp. 7-8.

45) Christoph Peters, "How much green hydrogen will Europe's industry need in 2050?" *Fraunhofer ISI,* 2023, https://www.isi.fraunhofer.de/en/blog/2023/europa-energiesystem-2050-wasserstoff-industrie.html#:~:text=The%20demand%20for%20hydrogen%20could,production%20steps%20outside%20of%20Europe (Accessed October 11, 2023).

46) Ibid., p. 2.

47) Edoardo Righetti, and Vasileios Rizos, "The EU's Quest for Strategic Raw Materials: What

EU will need to import critical minerals whose supply faces shortages and risky market concentration.

Thus, technological and regulatory leadership alone will not suffice to shape the market and mitigate the biggest risks. Given the intensifying economic and geopolitical competition, a rapid expansion of electrolysis capacity can in fact become a decisive factor in determining the location of industrial activity. Similar applies to critical minerals. Finally, several geopolitically-related factors constrain the EU's choice of partners.

3. Implications for EU Relations with Selected Actors across Broader Eurasia

If the EU has to realize its ambitious hydrogen plans, it will need to develop strategic partnerships with selected producers and set up regulatory and governance mechanisms to kick start a market which is currently lacking.

From previous results, it is visible that a new geography of trade and power emerges particularly in the vast Eurasian supercontinent. From a European perspective, while the hydrogen production potential might be concentrated in only few subregions and countries across the vast space, and other continents (US, South America, Africa) might offer greater potential for diversification, it is the concentration and simultaneous presence of major hydrogen producers, alternative demand centers and net importers, manufacturers of raw minerals and industrial components as well as of transport and transit corridor, which foster the emergence of a hydrogen ecosystem indispensable for Europe's hydrogen plans, that highlights its geopolitical significance.

The Ukraine war has massively reduced or significantly changed the EU's strategic options in the future hydrogen economy. Even though

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Role for Mining and Recycling?" *Intereconomics*, Vol. 58, No. 2 (2023).

Ukraine still figures prominently in EU's hydrogen plans,[48] the realization of trade remains uncertain. For its part, Russia is out of the European hydrogen and energy equation for the time being. To this adds risks for nickel and aluminum supplies. The Ukraine-Russia conundrum alters dramatically EU relations both within continental Eurasia and with other relevant hydrogen actors across the continent. Central Asia certainly emerged as a partial alternative supplier in the long term. Besides its own domestic priorities and constraints (see Figure 1 above), the region has a geopolitical interest in serving as one of Europe's hydrogen partners. Yet, its potential for green hydrogen is particularly concentrated in Kazakhstan and comes along with beforementioned constraints.

1) EU-Gulf: Establishing New Dependencies for a Rapid Market Ramp-up

With Russia and Ukraine out of the equation, and Central Asia emerging only as a limited, long-term alternative, the EU is forced to look further south for hydrogen imports, but also further east for critical minerals and industrial components.

While North Africa holds significant promise as a key player in clean energy value chains, several challenges, including water scarcity, infrastructure limitations, and constraints in capital flows could impede a swift market ramp-up. In addition to cost considerations, the lack of hydrogen-related policy frameworks and geopolitical instability are crucial factors to be taken into account.

Conversely, as discussed, the Gulf countries emerge as the sole

48) EC, "Memorandum of understanding between the European Union and Ukraine on a Strategic Partnership on Biomethane, Hydrogen and other Synthetic Gases," 2023b, https://energy.ec.europa.eu/publications/memorandum-understanding-between-european-union-and-ukraine-strategic-partnership-biomethane_en (Accessed October 11, 2023).

realistic alternative for a rapid development of the hydrogen trade, even though current geopolitical instability in the interstitial space and crucial logistic gateway between the Arab Peninsula and the Eastern Mediterranean make this alternative hazardous. While the EU, driven by its ambitious clean energy objectives, may find common ground with these Gulf countries, discrepancies exist between their respective aspirations and priorities concerning climate and geopolitics. Furthermore, due to concerns about potential climate lock-in effects and political mistrust, the EU hesitates to deepen or establish new partnerships with selected regional players, cognizant of the risk of unidimensional dependencies from autocratic regimes.[49] Regarding the preferences of the Gulf countries, they are actively strengthening hydrogen collaborations with the Far East, particularly Japan and South Korea (see above). This trend extends beyond blue hydrogen to include green hydrogen, where the EU was long supposed to be a privileged market.

2) EU-China: Managing an Unavoidable Dependence

As in the case of the Gulf, the EU and China have mutual and complementary interest in collaborating on hydrogen technologies.[50] However, both have different stakes in the hydrogen value chains. The geopolitical environment and the growing technological-industrial competition complicate the relation even further.[51] From the EU's

49) Cinzia Bianco, "Renewable relations: A strategic approach to European energy cooperation with the Gulf states," *European Council on Foreign Relations,* 2023, https://ecfr.eu/publication/renewable-relations-a-strategic-approach-to-european-energy-cooperation-with-the-gulf-states/#:~:text=The%20EU%20has%20proposed%20comprehensive,sources%2C%20including%20the%20Gulf%20monarchies (Accessed October 11, 2023).

50) See for example Gniewomir Flis et al., "Green hydrogen clusters in Europe and China," *Agora Energiewende,* May 7, 2021, https://www.agora-energiewende.de/en/blog/green-hydrogen-clusters-in-europe-and-china/ (Accessed October 11, 2023).

51) Brown, and Grünberg (2022).

perspective, the aspiration to de-risk and de-couple from China collides openly with the EU's plans and its limited possibilities to rapidly secure autonomous mass-production of electrolyzers, renewable energy components and raw minerals processing. However, without importing Chinese electrolyzers, the EU can hardly realize its plans in scope and time, which makes decoupling and de-risking hard to achieve.

This is even more true in the realm of raw materials sourcing, China's stranglehold on the production and processing of critical minerals and the manufacturing of electrolysis technology, designates it as a primary supplier to the EU. Concerns about potential market manipulation and China's strategic industrial policy underscore the vulnerabilities inherent in such a dependence, but leave the EU with a risk partnership to manage and limited diversification option, rather than with any significant decoupling option.

3) EU-Japan and EU-South Korea: Between Technological Cooperation and Latent Market Competition

The EU does not only share similar political values, geopolitical goals and challenges with Japan and South Korea, but also similar targets for achieving carbon neutrality and have thus a common interest in developing a hydrogen economy. As technological leaders, they are committed to setting common standards for hydrogen production, storage, and utilization. Collaborations in technology exchange and research initiatives are evident, with a focus on leveraging each other's expertise in fuel cells, electrolysis, and storage technologies.[52] The EU is working with both on aligning standards for the hydrogen sector and

52) European Commission and Ministry of Economy, Trade and Industry, "Memorandum of Cooperation on Hydrogen," 2023, https://energy.ec.europa.eu/system/files/2022-12/C_2022_8622_1_EN_annexe_acte_autonome_nlw_part1.pdf (Accessed October 11, 2023).

creating joint ventures and collaborative projects in technology development, reflecting a shared vision for a hydrogen-based future. Furthermore, the EU has signed a Green Partnership with South Korea which includes a major focus on low-carbon hydrogen.[53)]

However, both regions will need to address challenges such as cost reduction, scaling up production, and ensuring the sustainability of hydrogen production methods. Despite collaborative efforts, though, a subtle competition between the EU, Japan, and South Korea in the development and commercialization of cutting-edge hydrogen technologies might emerge. While each country is in fact vying for a leadership position in innovation, with potential implications for global market dominance, intensifying competition could crystalize.

This extends most notably to issues like securing hydrogen supplies and accessing alternative sources for critical materials. Here, a major region of competition is the Gulf and the emerging Gulf-Far East hydrogen corridor, but also the future relation with China as major electrolyzers and raw material providers. Taking a Eurasian perspective, while dependence on China for electrolyzers and critical raw material processing might create shared dependencies to manage, the Gulf might play a pivotal role in the future hydrogen economy. In addition, Europe (like South Korea and Japan) has scarcely other alternatives for rapidly kick-starting hydrogen imports, making the region a focal point for competition in securing reliable and cost-effective inputs. Thus, the EU will need to take in careful consideration both the Gulf and South Korean and Japanese priorities and actions across the maritime Eurasian belt.

53) EC, "European Green Deal: EU and Republic of Korea launch Green Partnership to deepen cooperation on climate action, clean energy and environmental protection," 2023c, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_2816 (Accessed October 11, 2023).

V. Conclusion

Hydrogen value and supply chains will be more interwoven and complex. In addition, the interplay of cost factors, technology, resources and geopolitical priorities will shape trade flows, while dependencies are expected to be more diffused and harder to manage. The Eurasian supercontinent might emerge as a focal point in shaping the trajectory of Europe's hydrogen plans, more than generally assumed, although the strategic role of single countries and regions might evolve as the double impact of geopolitical crisis (Russia-Ukraine war) and technological change (new value and supply chains) unfolds. Specifically, the combined effect of Europe's ambitious plans, contradictory expectations toward hydrogen and hydrogen partnerships, and major geopolitical dynamics confront the EU with major dilemmas.

For Europe, the intricate interplay of geopolitical, economic, and technological factors within this vast territory underscores the need for nuanced and collaborative approaches, but also robust and quick responses to rapidly ramp-up the hydrogen market and set up partnerships. Being cut-off from growing intra-regional dynamics might offset Europe's position as a hydrogen first-mover.

Strategic alliances and pragmatic partnerships within the broader Eurasian space thus offer avenues for the EU to diversify its hydrogen sourcing and enhance energy security.

In terms of hydrogen production, sourcing and trade, the synergies arising from cooperation with countries in the Middle East, and to a certain extent in Central Asia, might contribute to the creation of a more resilient and interconnected hydrogen landscape. However, interdependence might arise especially with the Gulf, as the region is more ready to rapidly kick-start hydrogen production. The potential of these partnerships might yet be limited by geopolitical factors and

conflicting priorities and emerging alternative demands in Asia. While Ukraine and Russia offer potential, due to political reasons, a partnership is currently not possible with either of them. Meanwhile, Russia and Central Asia will play an ancillary, yet key role as raw material supplier to China's hydrogen industry.

For its part, the EU's hydrogen cooperation with Japan and South Korea represents significant strides towards a sustainable and collaborative energy future. However, the underlying currents of technological competition and the latent race for Gulf hydrogen supplies underscore the complex dynamics shaping the global hydrogen landscape. As these partnerships evolve, careful navigation of these challenges will be essential to ensure a balanced and mutually beneficial hydrogen ecosystem, also against the backdrop of the common challenge of Chinese dominance in the green industrial and mining sector. Its growing investments in green technologies won't allow the EU for any rapid or complete decoupling. From a European perspective, balancing the benefits of collaboration with China against potential risks is essential to ensure a resilient and secure hydrogen future. Strategic policy decisions will play a crucial role in navigating this complex landscape and safeguarding the EU's position in the global hydrogen market.

All in all, the broader Eurasian space can emerge as a dynamic arena that significantly influences the future of Europe's hydrogen endeavors. The maritime nexus Gulf-China-East Asia and the interstitial spaces along the Caspian-Black Sea axis will gain even greater strategic relevance for Europe's hydrogen future. As the EU charts its course towards a sustainable and decarbonized energy future, it must navigate the complexities of this region, leveraging opportunities and addressing challenges collaboratively to ensure the success of its hydrogen plans. Challenges such as geopolitical tensions, varying policy frameworks, and the need for harmonized standards underscore the complexity of

the broader Eurasian context. Addressing these challenges requires diplomatic finesse, pragmatism, robust state-backed investments and strategic planning.

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