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The geopolitical implications of the German hydrogen sector development and its imports strategy

Abstract: Germany has a long history of making bold choices in its foreign policy, and the Hydrogen Strategy (NHS), along with the Import Strategy for Hydrogen and Hydrogen Derivatives (ISHHD), is another instance of its strategic gambling. In the past years, Germany's federal government has proven its ambitious approach to energy transformation by systematically expanding its focus on renewable energy via the Energiewende strategy. Today, low-carbon hydrogen, identified by the German government and the European Union as a key element of the future net zero economy, plays a central role in Germany's energy transformation. The scale of these ambitions is immense: the strategy projects that by 2030, Germany will need 95–130 TWh of hydrogen, and by 2045, this demand could rise to as much as 500 TWh. Under every plausible scenario, the vast majority of this demand would need to be covered with imports. The materialization of such imports is therefore the "but for" condition for the success of the German hydrogen strategy. Accordingly, the ISHHD includes extensive investment plans and envisages to the creation of new economic and political structures. Germany views hydrogen as a pathway to reducing its reliance on traditional fossil fuels and decarbonising its economy, while simultaneously taking on risks associated with new uncertainties of technological and market developments. The implementation of the ISHHD, if successful, will entail structure-altering changes to the international energy landscape. This article

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examines the geopolitical implications that such successful implementation would likely entail for Germany and beyond. It begins with an overview of the policy and market developments, followed by a geopolitical analysis of Germany's strategy and its implementation measures.

Keywords: Germany, European Union, hydrogen, geopolitics, energy transition

Introduction: the German hydrogen ambition vs. technical, environmental and economic challenges

According to the adopted strategic papers, hydrogen is meant to become a cornerstone of decarbonization strategy both in Germany (KSG 2019, 2021; EnWG 2021; BEHG 2021) and the EU (EGD 2019; EU HS 2020; Ff55P 2021). Whether these EU-wide plans become reality depends largely on the success of the hydrogen plans of the EU's largest economy. Nationale Wasserstoffstrategie, i.e. the National Hydrogen Strategy (hereinafter: NHS), adopted in June 2020 (NHS 2020) and updated in 2023 (NHS 2023), is a critical component of Germany's strategic outlook. The Import Strategy for Hydrogen and Hydrogen Derivatives (hereinafter: ISHHD), presented in July 2023 (ISHHD 2023), is an integral part of the updated NHS.

The NHS is intended to advance Germany's interests on two issues that the Federal Government has identified as vital: energy security and decarbonization. The first of these essentially pertains to the goal of reducing the reliance of German heavy industries on natural gas, previously imported from Russia, and currently from several other countries, largely in the form of LNG (Moll et al. 2023). The latter concerns Germany's commitment to reduce carbon emissions and attain climate neutrality by 2045 (KSG 2021), i.e. five years earlier than the date previously set (KSG 2019). The NHS focuses on green hydrogen, i.e. its type that is produced with energy harvested from renewable sources like wind and solar, and thus promising near-zero emissions. The strategy has set ambitious goals for domestic production and infrastructure development, while the ISHHD laid out plans for international partnerships needed to secure hydrogen derivative imports, which will be indispensable if the strategy's targets are ever to be achieved. The Federal Government forecasts a significant increase in hydrogen demand by 2030: its current estimate puts the volumes at between 95 and 130 TWh, with 50–70% of which would be secured via imports (NHS 2020). By 2045, it expects the demand to rise to 360–500 TWh, of which 200 TWh would come from imported hydrogen derivatives. The main sources of demand are expected to be the steel, chemical, and petrochemical sectors first. Eventually, additional demand may also stem from transportation, maritime shipping, heavy-duty logistics and heating (NHS 2020).

Given Germany's limited capacity for producing green hydrogen domestically, international cooperation is essential for realising its hydrogen ambitions. As discussed below, Germany has signaled that it strategically prioritizes partnerships with states that exhibit the potential to produce abundant and cheap renewable energy that could be used to produce green hydrogen cost-effectively. If effectively executed, these partnerships, tying Germany with miscellaneous governments from all continents, could stimulate the emergence of robust global hydrogen supply chains. Ultimately, the optimal market structure of green hydrogen will require not only that it becomes a globally traded commodity, but also international market competition to further incentivize driving down costs.

This plan, however, faces significant challenges of various sorts. First, large-scale green hydrogen production requires huge electrolysis capacity, which uses electricity from renewable sources to split water into hydrogen and oxygen. Such capacity in Germany is and will remain limited: the present trajectory for production is off the track for the 5 GW target that the NHS had set to generate by 2030, and which its 2023 update doubled to 10 GW. Massive investments in technology and renewable energy capacity are therefore required in Germany alone. Crucially, electrolysis consumes vast amounts of pure, deionised water, with approximately 9 liters needed to produce 1 kg of hydrogen (IEA 2024). Production methods from seawater are being studied but remain technologically challenging and currently unavailable (Feng et al. 2024). As the scale of production increases, the environmental impact of clean water usage, especially in regions with limited freshwater supplies, is expected to pose sustainability concerns (Henriksen et al. 2024). This is all the more important in the context of planned production in places with abundant renewable energy, but with limited technological and financial resources, and where water stress is becoming an increasingly severe issue under the strain of climate change.

The technology challenge concerns not only electrolyser efficiency but also hydrogen storage and transport. The density of hydrogen is higher by weight (c. 120–142 MJ/kg) and lower by volume (c. 5.6 MJ/L when compressed to 700 bar and up to 8.5 10.1 MJ/L in liquid form at –253°C). As a result, when compared to traditional fuels, hydrogen requires more sophisticated and specialised infrastructure. Moreover, while hydrogen is in itself non-toxic, its leakage into the atmosphere can arguably exacerbate climate change indirectly if its molecules interact with other gases in the atmosphere, thus increasing the atmospheric lifetime of methane, a potent greenhouse gas (Bertagni et al. 2022). Preventing leakages and moving hydrogen smoothly, therefore, requires careful infrastructure development and monitoring. Some existing natural gas pipelines can arguably be retrofitted to transport hydrogen, but extensive investment is needed to build an efficient hydrogen transport network. Liquefying hydrogen or converting it into ammonia for easier transport, which is indispensable for the planned long-range shipping from far-flung destinations, adds complexity and costs.

Germany's ambitions seemingly echo the broader narrative around hydrogen that is being promoted by the Global North. The sixth Hydrogen Energy Ministerial in Japan in 2023 announced a target of 150 million tons of hydrogen demand by 2030, with 90 million tons being renewable or low-carbon hydrogen. This ambitious target has drawn criticism for being unrealistic. Achieving it would require nearly half of the current fossil-fuel-based hydrogen production to be replaced or retrofitted, 60 times more clean hydrogen production capacity that today would need to be funded, and 50 million tons of new demand from sectors not currently using hydrogen would have to be created (Liebreich 2023). Currently, only about 700 megawatts of electrolysers are operational globally, producing just 110,000 tons of green hydrogen annually. No blue hydrogen (i.e. one that is produced from natural gas with captured carbon) facilities are functional as of yet. Although electrolyser manufacturing capacity has expanded rapidly worldwide, orders in 2023 barely reached 2 gigawatts, and the share prices of key manufacturers like Plug Power have dropped by up to 95% from their 2021 peaks (Liebreich 2023). There are plans for 170 million tons of hydrogen production, but as of October 2024 just about 1.5 million tons have reached final investment decisions, while clean hydrogen offtake agreements only cover 7.9 million tons, with just 1 million tons under binding contracts (Liebreich 2023).

The greatest challenge of all, however, remains the question of the competitiveness of green hydrogen as a fuel. Current production costs are prohibitively high, making it less attractive compared not only to fossil fuels but also to every other available method of hydrogen production presently in use. Green hydrogen currently costs approximately USD 3–6/kg, while the price tag for hydrogen produced from natural gas (gray hydrogen) is about USD 1–2/kg. Despite projections of falling costs to some EUR 4.4/kg, in 2030, and to EUR 2.7/kg in 2050 (Frieden and Leker 2024), and targets of USD 1/kg in the U.S. and USD 2.20/kg in Japan by 2030 (Liebreich 2023), estimates suggest that the actual cost might be higher even in regions with abundant renewable resources like the U.S., Saudi Arabia, and Australia, notably due to the needed capital expenditures currently projected to exceed USD 20tn by 2050 (Palladino 2023). The price trajectory of hydrogen imported to Germany is challenging to estimate and its actual impact on the energy system is difficult to assess (Schmitz et al. 2024). Inflation and higher interest rates have likewise made blue hydrogen projects costly and subject to similar challenges.

Hydrogen imports are no less problematic: shipping liquefied hydrogen or ammonia would increase costs significantly, with estimates for hydrogen moved by ship ranging between USD 3 and USD 8/kg. Pipeline transport, while in principle less complex and more cost-effective, is similarly a challenge, as purpose-built infrastructure will be required, with costs estimated at USD 0.40 to USD 0.80/kg. Achieving the 90-million-ton clean hydrogen target by 2030 might require USD 230 billion annually in subsidies, totaling USD 2.3 trillion over the next decade (Liebreich 2023). To bring down costs, significant technological breakthroughs are therefore needed in key areas. These include the development of high-efficiency electrolysers, advancements in storage and transportation technologies, and the creation of more efficient fuel cells. Making electrolysis more efficient arguably remains the most critical challenge, where improvements in catalysts and membrane materials could greatly reduce energy consumption during the hydrogen production process. These market and economic factors are crucial to the study of the assessment of the geopolitical effects of the ISHHD.

With the above introduction providing the necessary context, a geopolitical analysis may now follow. It is primarily guided by a set of research questions. The first one considers how Germany's increasing reliance on hydrogen imports would impact its energy security and foreign policy, particularly given its shifting energy dependencies. The second question ponders how these imports are likely to influence global energy relations, including aspects such as supply chain security and the competition for technological leadership in the green hydrogen sector. A third question examines the risks and opportunities Germany faces as it pursues a low-carbon hydrogen economy, focusing on economic dependencies and the formation of new geopolitical alliances. Finally, the fourth question revolves around how Germany's growing hydrogen demand will shape its geopolitical relations with the future expected hydrogen exporters, such as Chile and Australia.

The above questions have guided this article to posit several research hypotheses. First, it is hypothesised that Germany's hydrogen strategy – if successfully implemented – will enhance its geopolitical influence within the EU. It will also increase Germany's standing as a leader in a sophisticated, high-margin and possibly increasingly important energy sector. Second, the research substantiates the hypothesis that Germany's dependence on hydrogen imports will introduce new geopolitical risks, particularly due to economic and political vulnerabilities in its relationships with hydrogen-exporting countries. A third hypothesis suggests that the Import Strategy for Hydrogen and Hydrogen Derivatives (ISHHD) will significantly alter global energy trade patterns, with Germany emerging as a central player in the hydrogen market and fostering new economic relationships. The fourth hypothesis posits that the growing demand for hydrogen will place Germany at the center of technological competition and alliances, particularly with major players such as the US and China, both of which are heavily investing in green hydrogen technologies. Finally, it is hypothesised that Germany's hydrogen strategy will strengthen its geopolitical ties with key hydrogen-exporting nations in Africa, the Middle East, and Australia, thereby influencing regional power dynamics and shifting traditional energy relationships.

1. German ambitions vs. geopolitics constraints

An analysis of the geopolitical dimensions of the NHS and the ISHHD must account for the broader context of a future where hydrogen is presumed to play a major role in the global energy landscape. The shift towards a low-carbon economy that is based to a significant extent on hydrogen would necessarily engender new dependencies of a political and economic nature, most of which differ from those characterising the supply chains of traditional energy resources. While fossil fuels like oil and natural gas are geographically concentrated in specific regions, green hydrogen is produced from renewable energy sources, and therefore as a commodity its availability will be more distributed. Nonetheless, large-scale hydrogen production still depends on access to critical raw materials, such as nickel and platinum, which are essential for processes like electrolysis. These materials are geographically concentrated and are more complex and harder to monitor compared to those for hydrocarbon energy resources. Even nations that do not import hydrogen directly will find themselves reliant on technologies and components sourced from other countries. For instance, despite Europe's ambition to lead in hydrogen production, it will remain dependent on critical materials like platinum and iridium, which are vital to produce advanced electrolysers and are heavily concentrated in countries such as South Africa and Russia (Kiemel et al. 2021).

The rise of hydrogen in the global energy realm would inevitably trigger structure-altering geopolitical shifts at both international and sectoral levels. Germany views the hydrogen economy as a crucial component of new global dynamics, one that is only emerging, and therefore remains particularly susceptible to its influence. Indeed, a new layer of the global energy landscape may emerge as hydrogen value chains and supply networks develop, and the geopolitical landscape grows more complex. If the development of the hydrogen market reaches the threshold of viability, states that lead in hydrogen production, technology, and the components required for its processing will hold a competitive edge. Germany appears to have recognised the vast potential of this new value chain, and despite tangible risks and uncertainties hindering its development has visibly decided to pursue what could be seen as a strategic gamble. Its success, therefore, depends largely on supply diversification, scientific progress, and risk management, which is why Germany is investing in the development of domestic infrastructure for hydrogen production, transport, and storage (NHS 2023; ISHHD 2023), all the while forging global partnerships to avoid over-reliance on any single supplier.

2. Rationale and objectives of the ISHHD

At the heart of the ISHHD is a determination to seize the moment and influence the global energy landscape, steering it toward green hydrogen. While hydrogen is unlikely to ever surpass electricity in terms of scale, it represents an emerging field that necessitates clear policy and economic direction. The thinking laid out in the NHS and ISHHD reveals that Germany aims to establish itself as a leader in this area, positioning its economy to reap the rewards associated with being at the forefront of hydrogen technology and infrastructure development. This strategy reflects Germany's dual focus: not only decarbonising its industrial base but also enhancing energy security resilience in an era of increasing geopolitical uncertainties. The import strategy recognizes that hydrogen is essential for maintaining the competitiveness of energy-intensive German sectors such as steel, chemicals, and automotive manufacturing which are the core of the country's export-driven economy. Reaching this goal will not only require substantial investments but also a willingness to pay a premium for the resilience stemming from the steadiness of supply, given that it is expected to remain largely uncompetitive economically as a fuel due to constraints on its cost long-term reduction. Although mass production would likely substantially reduce the costs of both alkaline and PEM manufacturing (Subramani et al. 2023), the demand would need to be consistently rising over the years. A substantial reduction in the cost of renewable electricity alone is unlikely to make green hydrogen highly competitive because the less flexible costs associated with electrolysers such as the infrastructure needed for hydrogen storage and transport are expected to remain and need to be tackled with innovative solutions (IRENA 2020). This, in turn, raises the question about the cost of energy security and the long-term economic implications of greater usage of hydrogen in energy systems.

Germany's ISHHD also emphasizes the importance of establishing a comprehensive regulatory framework that incentivizes hydrogen production and fosters competitive market conditions. Such a framework is crucial for addressing the high costs associated with green hydrogen production and substantiating the hope that it becomes an attractive option for industrial sectors. To this aim, the Federal Government has envisaged a robust hydrogen import infrastructure, interconnected via pipelines and ships which the plans identify as the primary means of transport (NHS 2023). Existing pipelines that heretofore have moved natural gas are meant to be repurposed for hydrogen imports, particularly in neighboring European states. The ISHHD proposes a trans-European hydrogen network that connects production, import, and usage centers across the EU, all leading to Germany as the central hub. The scale of this plan is overwhelming but also constitutes a means of strategic market signaling. The infrastructure development laid out in the NHS and the ISHHD is aimed at enhancing planning security for stakeholders and solidifying connections with neighboring states and ports, thus stimulating the emergence of a stable and reliable market for hydrogen. In October 2024, the German Federal Network Agency approved a 9,040-kilometer hydrogen core network, of which 60% will be pipelines converted from natural gas and 40% newly built. The works are to be carried out by a consortium of 15 transmission system operators, which is meant to become operational by 2032 and has an initial price tag of EUR 18.9 billion (Bundesnetzagentur 2024).

In targeting the creation of a stable hydrogen market, the ISHHD aims to engage a diverse range of stakeholders, including producers, project developers, traders, buyers, and financial institutions. Germany seeks to provide market leadership to its hydrogen technology companies through research, innovation, and promotion of foreign trade (Nunez and Rainer 2024) to compete effectively with other powers invested in the hydrogen realm (Eicke and de Blasio 2022). The ISHHD also points out the need to support smaller EU Member States in ramping up their hydrogen markets. It thus recognizes that the diversification of the planned import routes in such states and securing necessary infrastructure will require Germany's involvement. This echoes what the Federal Government has inscribed in its Climate Foreign Policy, which explicitly calls on building international hydrogen markets and import relationships to maintain Germany's industrial leadership (KAP 2023).

On the domestic plane, the economic implications of the ISHHD would unfold across different sectors in Germany, albeit unevenly, depending on sectoral needs and technical specifics. Manufacturing sectors, which account for nearly 20% of its GDP (World Bank 2023), would be particularly affected, especially since steel production would arguably be the most. Major German steel producers, such as Thyssenkrupp and Salzgitter, are exploring hydrogen-based methods for producing green steel. Hydrogen's potential to transform the chemical industry is another significant target of the ISHHD (Seithümmer et al. 2024). Leading German chemical companies such as BASF and Covestro are actively investigating how to best employ hydrogen in their respective value chains, notably via ammonia and methanol. The chemical sector is responsible for a substantial share of Germany's CO_2 emissions (McKinsey 2023), and effective utilization of hydrogen could significantly mitigate them, thus possibly trailblasing a template for chemical production in other countries in the future low-carbon economy. The automotive industry is likewise poised to benefit from the hydrogen transition. Although battery-electric vehicles should in all likelihood dominate the push for low-emission transportation, German manufacturers are exploring options for hydrogen fuel cell vehicles, especially for heavy-duty transport, as well as in shipping and aviation. Companies like Daimler and BMW are investing significant amounts in hydrogen technology.

For Germany, the premise of developing an international hydrogen market offers opportunities that extend far beyond industrial applications. The plans that the imports strategy sets for large-scale hydrogen production, storage, and distribution networks are intended to create jobs, spur innovation, and stimulate investment in innovative technologies (ISHHD 2023). Major German engineering and energy companies, for instance, Siemens Energy and Linde, are well-positioned to capitalize on these developments, both domestically and internationally. Development of the hydrogen sector is also seen by the German government as a possible source of stimuli for job creation, not least in regions where traditional industries are in decline, such as the Rhineland and Ruhr Valley. These areas are undergoing structural but risky economic transformation at a time when Germany is gradually phasing out coal. The hydrogen industry offers them a promise to revitalize local economies by generating new jobs in hydrogen production, research, and infrastructure development (ISHHD 2023).

3. Implementation measures of the ISHHD

Germany's hydrogen imports policy is being built upon both the existing and robust network of long-standing energy partnerships with key global economies, as well as the newly deepened ties with selected states of the Global South. Germany's effort in this regard contrasts with the partnerships of the United States, China, France, and Japan, whose energy alliances have been significantly more focused on fossil fuels (Quitzow and Nunez 2024). During its G7 presidency in 2022, Germany launched the G7 Hydrogen Action Pact and co-founded the Green Hydrogen Catalogue, an initiative from the UN High-level Dialogue on Energy aimed at promoting green hydrogen commitments. In May of that year, Germany signed the Esbjerg Declaration with Belgium, Denmark, and the Netherlands, with which it committed to the development of 65 GW of offshore wind and 20 GW of green hydrogen production in the North Sea by 2030. During its presidency of the EU in 2020, Germany initiated support for Important Projects of Common European Interest (IPCEI) on hydrogen technologies and developed a Strategic Research and Innovation Agenda (SRIA) for green hydrogen.

Domestically, Germany is developing the aforementioned hydrogen core network "to connect what are expected to be Germany's major hydrogen consumption and generation regions – central locations such as large industrial centers, storage facilities, power plants, and import corridors – with each other" (Bundesnetzagentur 2024). The network is intended to become operational by 2032 and will be privately financed through grid fees, with grid fee caps implemented to encourage market ramp-up. The Federal Government also intends to integrate the core network with emerging European hydrogen networks through interconnectors and trans-European import corridors, supported by the IPCEI Hydrogen program, which has approved ten German pipeline projects. Further legal frameworks for dedicated hydrogen networks were set by the EU hydrogen and gas decarbonization package, which came into effect in May 2024 (European Commission 2024).

Within Europe, the primary effort that Germany is pushing for is the development of the so-called European Hydrogen Backbone – a pan-European network of pipelines meant to move hydrogen across the continent (EHB 2024). It is a vast project that aims to connect production hubs in regions rich in renewable energy with high-demand areas, such as Germany's industrial centers. The hydrogen import corridors are being pursued from regions such as the North Sea, Baltic Sea, South-West Europe, and Southern Europe, supported by Projects of Common Interest (PCIs) and Projects of Mutual Interest (PMIs), which receive backing from the European Commission through the Connecting Europe Facility (CEF). The Federal Government is also collaborating with Baltic Sea countries on pipelines like the Baltic Hydrogen Collector and the Nordic-Baltic Hydrogen Corridor. The South-West corridor will link Germany to Spain, Portugal, and potentially Morocco through the H2Med pipeline project, while pipelines from Algeria, Tunisia, and Italy will bring hydrogen to Germany, with the SoutH2 project already having PCI status. Cross-border hydrogen pipelines are planned between Germany and countries like Denmark and Norway. Interestingly, the pipeline to Denmark was initially expected to become operational by 2028, with a final investment decision (FID) planned for 2025, but its inauguration was postponed until 2031 due to Denmark's environmental concerns. Germany has also joined the Benelux states, France, Austria, and Switzerland in the Pentalateral Energy Forum declaration to accelerate hydrogen development across these regions (PEF 2023).

Beyond European borders, the ISHHD focuses primarily on building durable relationships with states from various regions exhibiting real potential to produce ample and cheap renewable energy. The strategy catches up with the diplomatic and political developments in this area, notably in Latin America and the Middle East. For instance, Germany's discussions with Chile, a potential major supplier, have already resulted in a memorandum signed in 2022, predicting future imports of Chilean hydrogen via the port in Hamburg. In North Africa, cooperation is being developed with Morocco and Tunisia, and the Federal Government has already initiated pilot projects, including a significant agreement with Morocco to establish one of the world's first industrial green hydrogen plants. These efforts are aligned with broader EU initiatives to integrate North Africa into Europe's hydrogen economy via the Africa-Europe Green Energy Initiative.

Another pillar of the strategy concerns the scientific effort, with Germany having already acknowledged the importance of international research and innovation in hydrogen technology. Collaborations with industry leaders in Europe and selected non-EU states, particularly in Australia, are underway. Notable initiatives include HySupply and HyGate, particularly focusing on advancing hydrogen supply chains and infrastructure. Within the EU, Germany has initiated joint calls for proposals with the Netherlands and under the EUREKA network. Beyond the EU, it has launched hydrogen research partnerships with Ukraine, Central Asia, Canada, New Zealand, South Korea, Japan, Chile, Oman and Namibia. Germany has set up several domestic initiatives open to international researchers to spearhead the science and technology of hydrogen. These include programs such as the International Future Labs and the Redefine H2 Economy project. German firms are also accumulating hands-on experience, all the while building valuable relationships, with involvement in significant R&D initiatives abroad. These include Thyssen-Krupp's electrolyser project in Saudi Arabia and the liquid-organic hydrogen carrier (LOHC) project that is being implemented in partnership with Uniper, ADNOC, and Japan's Jera.

Germany's commitment to the field of research and knowledge building encompasses capacity and skill development in developing and emerging economies. Energy-focused cooperation initiated by Germany includes Tunisia, Morocco, Brazil, and South Africa. Initiatives from the Federal Ministry of Economic Affairs and Climate Protection (BMWK) through the International PtX Hub, a training center for Power-to-X technologies, are active in 13 countries. No less noteworthy are the initiatives aimed at Africa, where the chances of developing hydrogen infrastructure seem presently less conceivable due to political instability in concerned regions. Germany's Ministry of Education and Research has committed EUR 8 million in the years 2021––2025 for capacity-building in Africa, which includes a Master's program on green hydrogen technologies in collaboration with the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) and the H2 Atlas Africa, an initiative assessing hydrogen production potentials across the continent.

Germany's international partnerships in climate, energy, and hydrogen with developing and emerging economies are being set up primarily as Just Energy Transition Partnerships (JETPs). These relationship formats promote and advance socially just energy transition that aligns with Agenda 2030 goals, such as SDG7 (Affordable and Clean Energy). Another highly relevant undertaking of the German government is the H2-Diplo initiative, under which Hydrogen Diplomacy Offices have been set up in key export and transit countries, such as Saudi Arabia, Angola, Nigeria, Kazakhstan, and Ukraine. Yet another important initiative is the Green Hydrogen Business Alliance, created in 2019 by the Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the German Development Agency (GIZ). Currently composed of around 150 companies from Germany and the EU, it "aims at contributing to a socio-ecological transformation in cooperation with the private sector" (H2BA 2024).

To facilitate these developments, the H2 Global initiative features an auction mechanism providing subsidies for hydrogen and its derivatives. Through a competitive tendering process, the Hydrogen Intermediary Network Company (HINT.CO) awards long-term, 10-year contracts for purchasing hydrogen and short-term, 2-year contracts for sales to users. Both measures operate under a Contracts for Difference (CfD) scheme funded by the Federal Government to cover price gaps. The endeavor is intended to result in supply contracts for delivering hydrogen to ports in the Netherlands, Belgium, or Germany. H2 Global aims to target the first hydrogen supply outside the EU with EUR 900 million in funding, and an additional €3.5 billion will be allocated for future auctions (H2G 2024). Germany's National Strategy for Sea and Inland Ports, in turn, aims to expand port infrastructure to accommodate hydrogen derivatives (NPS 2024), while legal frameworks are being adapted to streamline plant approvals. Moreover, the EU regulation on alternative fuels infrastructure (AFIR) sets standards for upgrading infrastructure, notably for hydrogen.

Germany also recognizes the importance of establishing international hydrogen standards and certification schemes to ensure that imported hydrogen meets stringent environmental criteria. This includes developing a certification system that differentiates between green and blue hydrogen. Such standards are crucial to ensuring that imports align with Germany's environmental goals, particularly in avoiding reliance on hydrogen derived from fossil fuels. Germany advocates for harmonization to prevent market fragmentation and ensure mutual recognition of hydrogen certifications internationally, notably via agreements reached at COP28 (EHO 2023). The Federal Government is indeed highly active in multilateral forums such as the G7, G20, Clean Energy Ministerial (CEM), Mission Innovation (MI), and International Hydrogen Trade Forum (IHTF) where it promotes its hydrogen narrative. Collaborations with organizations like the IEA, IRENA, UNIDO, and ISO are seemingly driven by the will to facilitate the establishment of technical and sustainability standards, which are indispensable for the global hydrogen rollout.

4. The geopolitical and geoeconomic implications of the ISHHD

Germany's plan to introduce green hydrogen as a large-scale substitute for natural gas to power up its industries signifies trading one set of dependencies for another. Its implications for the geopolitical positioning of Germany and all other concerned stakeholders would – or will – be far-reaching and multilayered. The analysis of the ISHHD offers valuable insights into political economy, not least because Germany's approach to developing the hydrogen economy is deeply rooted in its ordoliberal tradition, traditionally centered around the premise of the state assuming the double function of creator and guarantor of the framework for a functional market economy.

The initiatives and endeavors discussed above testify to how the Federal Government embraces the classically German principle of the state as a market enabler. Its push for standardization and certification in hydrogen production and trade reflects the ordoliberal emphasis on clear, stable rules for market participants. The ISHHD is largely structured around the central premise of collaboration between state entities and private companies in a feedback loop of adjustments that should eventually yield a market optimum. If successful, this method could become a template for both other national regulatory frameworks, and the global economic governance structures for the emerging hydrogen economy. If the global hydrogen market develops, Germany's role in setting technical standards and regulatory frameworks for hydrogen production, transport, and certification could shape this new market to align with its interests, much like it did with the automotive sector in the past. This regulatory leadership would likely facilitate exerting influence on how the hydrogen value chain develops, and how hydrogen is traded globally.

From a realist standpoint, Germany's hydrogen import strategy can be interpreted as a manifestation of power politics in the energy sector. The pursuit of hydrogen technology and import networks aligns with realist emphasis on state survival and self-help in an anarchic international system. The double goal of diversifying its energy sources while at the same time positioning itself as a hydrogen hub aims to enhance Germany's relative power and reduce vulnerabilities associated with previous fossil fuel dependencies. The materialization of this strategy undoubtedly could alter the balance of power among the relevant stakeholders both in the EU and globally, with the extent of ensuing changes depending on how far the hydrogen economy proliferates. The power that such a scenario would grant Germany would arise primarily from its disproportionate control over supply chains and technology, coupled with the dependence on other states involved in exporting or transmitting hydrogen or its derivatives to Germany. As power in the international realm is a zero-sum game, and the rise of hydrogen would entail lesser dependence on fossil fuel exporters, new geopolitical alignments and rivalries are all but inevitable.

Seen through a liberal institutionalist lens, the ISHHD represents an attempt to foster international cooperation and create new institutions around hydrogen technology and trade. It reflects Germany's decades-long support for multilateralism and international governance structures. The network of hydrogen partnerships centered around Germany is meant to increase economic interdependence. The push for standardization and certification in hydrogen production and trade indicates an effort to establish new international regimes. A constructivist analysis, in turn, reveals how Germany's hydrogen strategy is shaping and being shaped by ideas, norms, and identities related to energy and sustainability. Germany is acting as a norm entrepreneur, promoting green hydrogen as a solution to climate change and energy security, thus reinforcing its identity as a leader in sustainable technology and environmental protection. Its emphasis on knowledge sharing and capacity building in hydrogen science reflects a constructivist understanding of how states learn and adapt, and the primary beneficiary of this knowledge growth is Germany itself. Whether its hydrogen partnerships eventually thrive will depend primarily on whether the very relationships they structure are balanced out. Such agreements may be used to advance other geopolitical objectives, linking energy cooperation to broader political and economic goals in an ever-evolving geoeconomic reality. In such a scenario, pushbacks via external alliances in the hydrogen space could be formalised with bilateral agreements. All in all, balancing national interests with multilateral commitments in hydrogen development will prove challenging for Germany, especially if the technology becomes more strategically important and alternative technological solutions become available.

5. A tentative conclusion

The ISHHD is an ambitious illustration of an instance of the shift in the geopolitical center of gravity from natural resource endowments to technological capabilities and expertise. This ever-accelerating shift is not unique to green hydrogen, though, but encompasses other renewables too. While China pursues its determined focus on PV and EV technologies, Germany has increasingly concentrated on hydrogen. The market-state feedback loops of decisions will only reveal in years, if not decades, whether green hydrogen delivers on the hopes that transpire from the NHS and the ISHHD. If it does, states with advanced hydrogen technologies should gain substantial leverage in the international realm. That influence, while different from the one wielded by hydrocarbon exporting nations that trade consumable commodities, will nonetheless appear structure-altering for the global energy landscape, and therefore for the balance of power either regionally or globally.

The insistence on research, development, and innovation in hydrogen technologies could eventually become one of the principal nutrients of a knowledge-based economy, currently driven by technologies in sectors other than energy. Intellectual property and technological expertise would then increasingly become sources of national power. Physical control over hydrogen infrastructure, including production facilities, transportation networks, and storage systems, would likewise become a new form of geopolitical leverage. It could empower Germany's partners, whose exports of hydrogen derivatives might alleviate the economic and political distress that various such states experience today. Such empowerment could be conditional, however, for their hydrogen-fueled prosperity would depend excessively on Germany's consistent demand unless a truly global market takes hold. In Europe, the development of the Hydrogen Backbone centered around Germany could in theory further boost the integration of European energy markets. As a hub, Germany would become the indispensable intermediary between hydrogen -producing states and European consumers, thus endowing it with substantial political and diplomatic leverage. Yet Germany's vital role in hydrogen infrastructure and dealmaking would undoubtedly and above all reinforce its own economic and political influence within the EU. This should be expected to prompt tensions with other EU Member States, already wary of Germany's huge clout in European affairs.

Yet the scale of risks and uncertainties of the implementation of the ISHHD seems unparalleled as the scale of the strategy itself. While reducing dependency on fossil fuels, Germany would create new vulnerabilities related to hydrogen imports and critical technologies, the practical consequences of which can only partially be foreseen and mitigated. Reliance on hydrogen imports from regions with political instability would expose the importer to supply disruptions. Indeed, the stability of green hydrogen supply chains will depend on the political stability of supplier countries, as well as their ability to build and maintain the necessary infrastructure. This creates a paradox: while Germany seeks to reduce its energy vulnerability, it may still find itself exposed to new geopolitical risks tied to its reliance on hydrogen-producing nations. Moreover, hydrogen transport and storage infrastructure remain in the early stages of development, and there are significant challenges in scaling this technology, making Germany's future energy security conditional on advances in both global supply chains and technological innovation.

With hydrogen technologies becoming more valuable, international disputes over intellectual property rights may intensify. The excessive costs of green hydrogen production may lead to international disputes over subsidies and fair competition: internationally under the WTO regime, within the EU under the EU rules, and geopolitically could result in tit-for-tat trade spats. Divergent standards and regulations for hydrogen production and trade could result in new trade conflicts. Yet without subsidies neither the green hydrogen market can emerge fully, nor can Western electrolyser producers compete with their Chinese counterparts.

Germany's hydrogen imports strategy represents a high-stakes gamble in the realm of energy geopolitics. Elements of realist power politics, liberal institutionalist cooperation, and constructivist norm-setting all transpire to varying degrees from the ISHHD, which also reflects distinctly German approaches to international relations, including multilateralism, ordoliberal economic thinking, and technological diplomacy. Ultimately, the insurmountable condition for the ISHHD to succeed is the emergence of a robust hydrogen market, with longstanding demand and supply within a complex interplay of technological innovation, international cooperation, and strategic competition. From a political science standpoint, Germany's hydrogen imports strategy is an example of geoeconomic statecraft, where economic tools are used to achieve geopolitical objectives. With hydrogen becoming the great theme of the energy transition, the consequences of Germany's successes or failures in this domain will extend beyond its geopolitical position on the global stage. They are inevitably meant to equally shape the broader dynamics of international relations in the 21st century.

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References

Bengtsson et al. – Bengtsson, W., Knapp, S., Crispeels, P., Somers, K., Weihe, U. and Weskamp, T. – McKinsey Report. *Decarbonizing the chemical industry*. [Online] https://www.mckinsey.com/industries/chemicals/our-insights/decarbonizing-the-chemical-industry [Accessed: 2024-10-24].

Bertagni et al. 2022 – Bertagni, M.B., Pacala, S.W., Paulot, F. and Porporato, A. 2022. Risk of the hydrogen economy for atmospheric methane. *Nature Communications* 13, DOI: 10.1038/s41467-022-35419-7.

Bundesnetzagentur. *Hydrogen core network.* [Online] https://www.bundesnetzagentur.de/EN/Areas/Energy/HydrogenCoreNetwork/start.html [Accessed: 2024-10-24].

Eicke, L. and De Blasio, N. 2022. Green hydrogen value chains in the industrial sector – Geopolitical and market implications. *Energy Research & Social Science* 93, DOI: 10.1016/j.erss.2022.102847.

European Commission. Hydrogen and decarbonised gas market (explainer). [Online] https://energy.ec.europa.eu/topics/markets-and-consumers/hydrogen-and-decarbonised-gas-market_en [Accessed: 2024-10-24].

European Hydrogen Backbone. [Online] https://www.ehb.eu/ [Accessed: 2024-10-24].

European Hydrogen Observatory (EHO). *New ISO standard on hydrogen unveiled at COP28*. 23 December 2023 [Online] https://observatory.clean-hydrogen.europa.eu/media/news/new-iso-standard-hydrogen-unveiled-cop28 [Accessed: 2024-10-24].

Feng et al. 2024 – Feng, Z., Zhang, M., Gu, C., Zhang, A. and Wang, L. 2024. Seawater Electrolysis: Challenges, Recent Advances, and Future Perspectives. *Advanced Sustainable Systems*, DOI: 10.1002/adsu.202400689.

Frieden, F. and Leker, J. 2024. Future costs of hydrogen: a quantitative review. *Sustainable Energy Fuels* 9, DOI: 10.1039/D4SE00137K.

GrInHy2.0: Green Hydrogen for Green Steel. Salzgitter AG. [Online] https://www.salzgitter-ag.com/en/newsroom/press-releases/details/grinhy20-green-hydrogen-for-green-steel-20194.html [Accessed: 2024-10-24].

H2 Business Alliance (H2BA). [Online] https://green-hydrogen-business-alliance.de/ [Accessed: 2024-10--24].

H2 Global (H2G). *H2Global – Idea, Instrument and Intentions*. Policy Brief. [Online] http://files.h2-global.de/H2Global-Stiftung-Policy-Brief-01_2022-EN.pdf [Accessed: 2024-10-24].

Henriksen et al. 2024 – Henriksen, M.S., Matthews, H.S., White, J., Walsh, L., Grol, E., Jamieson, M. and Skone, T.J. 2024. Tradeoffs in life cycle water use and greenhouse gas emissions of hydrogen production pathways. *International Journal of Hydrogen Energy* 49(C), pp. 1221–1234, DOI: 10.1016/j.ijhydene.2023.08.079.

HySupply. [Online] https://www.globh2e.org.au/hysupply [Accessed: 2024-10-24].

Instytut Energetyki (IEN). *Basic information on hydrogen*. [Online] https://ien.com.pl/images/struktura/pion-cieplny/CPE/FAQ_final_EN.pdf [Accessed: 2024-10-24].

IRENA 2020. *Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal*, International Renewable Energy Agency, Abu Dhabi.

Kiemel et al. 2021 – Kiemel, S., Smolinka, T., Lehner, F., Full, J., Sauer, A. and Miehe, R. 2021. Critical materials for water electrolysers at the example of the energy transition in Germany. *International Journal of Energy Research* 45, DOI: 10.1002/er.6487v.

Krishnan et al. 2023 – Krishnan, S., Koning, V., de Groot, M.T., de Groot, A., Granados Mendoza, P., Junginger, M. and Kramer, G.J. 2023. Present and future cost of alkaline and PEM electrolyser stacks. *International Journal of Hydrogen Energy* 48(83), pp. 32313–32330, DOI: 10.1016/j.ijhydene.2023.05.031.

Liebreich, M. 2023. *Clean Hydrogen's Missing Trillions.* [Online] https://about.bnef.com/blog/liebreich-clean-hydrogens-missing-trillions/ [Accessed: 2024-10-24].

Manufacturing, value added (*% of GDP*) – *Germany*. World Bank Group. [Online] https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=DE [Accessed: 2024-10-24].

MFA of Japan. *Sixth Hydrogen Energy Ministerial Meeting*. [Online] https://www.meti.go.jp/english/press/2023/0925_002.html [Accessed: 2024-10-24].

Moll et al. 2023 – Moll, B., Schularick, M. and Zachmann, G. 2023. The Power of Substitution: The Great German Gas Debate in Retrospect. *Brookings Papers on Economic Activity,* pp. 395–481, DOI: 10.1353/eca.2023.a935431.

Nunez, A. and Quitzow, R. 2024. Germany's Hydrogen Strategy: Securing Industrial Leadership in a Carbon–Neutral Economy. [In:] Quitzow, R., Zabanova, Y. (eds) *The Geopolitics of Hydrogen. Studies in Energy, Resource and Environmental Economics*, DOI: 10.1007/978-3-031-59515-8_3.

Palladino, C. 2023. *Lex in depth: the staggering cost of a green hydrogen economy.* [Online] https://www.ft.com/content/6e22930b-a007-4729-951f-78d6685a7514 [Accessed: 2024-10-24].

Production of green hydrogen: on the path to serial production. Thyssenkrupp. [Online] https://www.thyssenkrupp-steel.com/en/newsroom/highlights/hydrogen-production.html [Accessed: 2024-10-24].

Quitzow et al. 2024 – Quitzow, R., Nunez, A. and Marian, A. 2024. Positioning Germany in an international hydrogen economy: A policy review. *Energy Strategy Reviews* 53, DOI: 10.1016/j.esr.2024.101361.

Schmitz et al. 2024 – Schmitz, R., Brandes, J., Nolte, H., Kost, C., Lux, B., Haendel, M. and Held, A. 2024. Implications of hydrogen import prices for the German energy system in a model-comparison experiment. *International Journal of Hydrogen Energy* 63, pp. 566–579, DOI: 10.1016/j.ijhydene.2024.03.210.

Seithümmer et al. 2024 – Seithümmer, V., Lutz, J., Kaufmann, S., Chinnaraj, H., Rössner, P. and Birke, K. 2024. Powering the future: Germany's Wasserstoffstrategie in the transition to climate neutrality – case study on green hydrogen for the chemical industry. *Energy Advances*, DOI: 10.1039/D4YA00246F.

Legislative acts
Germany:
Federal Climate Protection Act (Klimaschutzgesetz – KSG, 2019, updated 2021).
Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG 2021).
Energy Industry Act (Energiewirtschaftsgesetz – EnWG, 2021 update).
Fuel Emissions Trading Act (Brennstoffemissionshandelsgesetz – BEHG, 2021 update).
Foregin Climate Policy (Strategie zur Klimaauswärtspolitik – KAP, 2023).
National Strategy for Sea and Inland Ports (NPS 2023).

European Union:
European Green Deal (EGD 2019).
EU Hydrogen Strategy (EU HS 2020).
Fit for 55 Package (Ff55P 2021).

Other official documents:
The Ejsberg Declaration, 2023.
G7 Hydrogen Action Pact, 2022.
Statement by Ministers of the Pentalateral Energy Forum (PEF 2023).

Maciej Filip Bukowski

Geopolityczne implikacje rozwoju niemieckiego sektora wodorowego i jego strategii importowej

Streszczenie

Niemcy mają długą historię dokonywania odważnych wyborów w swojej polityce zagranicznej, a Strategia Wodorowa (NHS), wraz ze Strategią Importu Wodoru i Pochodnych Wodoru (ISHHD), jest kolejnym przykładem ich strategicznego hazardu. W ostatnich latach rząd federalny Niemiec udowodnił swoje ambitne podejście do transformacji energetycznej, systematycznie zwiększając nacisk na energię odnawialną za pośrednictwem strategii *Energiewende*. Obecnie wodór niskoemisyjny, zidentyfikowany przez rząd niemiecki i Unię Europejską jako kluczowy element przyszłej gospodarki netto zerowej, odgrywa centralną rolę w transformacji energetycznej Niemiec. Skala tych ambicji jest ogromna: strategia przewiduje, że do 2030 r. Niemcy będą potrzebować 95–130 TWh wodoru, a do 2045 r. zapotrzebowanie to może wzrosnąć nawet do 500 TWh. W każdym prawdopodobnym scenariuszu zdecydowana większość tego zapotrzebowania musiałaby zostać pokryta importem. Materializacja takiego importu jest zatem warunkiem „ale nie" sukcesu niemieckiej strategii wodorowej. W związku z tym ISHHD obejmuje rozległe plany inwestycyjne i przewiduje stworzenie nowych struktur gospodarczych i politycznych. Niemcy postrzegają wodór jako drogę do zmniejszenia zależności od tradycyjnych paliw kopalnych i dekarbonizacji swojej gospodarki, jednocześnie podejmując ryzyko związane z nowymi niepewnościami dotyczącymi rozwoju technologicznego i rynkowego. Wdrożenie ISHHD, jeśli zakończy się sukcesem, pociągnie za sobą zmiany strukturalne w międzynarodowym krajobrazie energetycznym. W tym artykule zbadano geopolityczne implikacje, jakie taka udana implementacja prawdopodobnie pociągnie za sobą dla Niemiec i nie tylko. Rozpoczyna się od przeglądu polityki i rozwoju rynku, po czym następuje analiza geopolityczna strategii Niemiec i jej środków wdrożeniowych.

Słowa kluczowe: Niemcy, Unia Europejska, wodór, geopolityka, transformacja energetyczna