The Emerging Geopolitics of Hydrogen: Navigating Uncertainty and Industrial Legacies Within the Net-Zero Transition

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Abstract This final chapter provides an overview of how hydrogen policies are taking shape in the major economies covered in this volume and discusses their implications. The chapter begins with a review of domestic hydrogen policies, highlighting key features and their similarities and differences across the countries. We discuss the different approaches to production technologies, priority uses of hydrogen, the focus and design of support schemes, and the role of industrial policy. We conclude this part of the chapter with a brief reflection on the changing geopolitical environment and how this has affected domestic hydrogen policies and politics. We then move on to contrast the main features of international hydrogen policy engagement, linking it to domestic strategies and interests. The chapter closes with a reflection on how hydrogen policy developments in the major economies that are presented in this book are likely to affect global decarbonization efforts and the related geopolitics.

1 Introduction

The contributions in this volume illustrate the important variation across countries in their pursuit of hydrogen as a new energy carrier. Each of the major economies covered in this volume is seeking to build a unique position within a future net-zero economy where the envisioned role of hydrogen differs based on the resources and assets that the country controls. Combined with the particular institutional legacies and the configuration of stakeholder interests, these variables are driving differing strategies for exploiting hydrogen as an energy carrier within a net-zero economy.

In this final chapter, we provide an overview of how hydrogen policies are taking shape in the major economies covered in this volume and discuss their implications. The chapter begins with a review of domestic hydrogen policies, highlighting key

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features and their similarities and differences across the countries. We discuss the different approaches to production technologies, priority uses of hydrogen, the focus and design of support schemes, and the role of industrial policy. We conclude this part of the chapter with a brief reflection on the changing geopolitical environment and how this has affected domestic hydrogen policy and politics. We then move on to contrast the main features of international hydrogen policy engagement, linking it to domestic strategies and interests. The chapter closes with a reflection on how hydrogen policy developments in the major economies that are presented in this book are likely to affect global decarbonization efforts and the related geopolitics.

2 Hydrogen Policies in the Major Economies: Key Features and Their Domestic Underpinnings

2.1 Technology Pathways

One common theme emerging from the individual case studies is the diversity in the choice of hydrogen production pathways. Existing research in the geopolitics of the energy transition has focused primarily on the role and implications of future trade in renewable (or "green") hydrogen, which, unlike oil and gas, can be produced in many renewables-rich locations around the globe (van de Graaf et al, 2020; IRENA, 2022). Yet, a closer look at the hydrogen strategies and policies of key economies reveals a much wider range of preferences for possible hydrogen production pathways—albeit paired with persistent uncertainty about the future prospects of each particular pathway.

In line with its ambitious climate policy and its self-positioning as an international climate leader, the EU has put the strongest emphasis on promoting green - or renewable as it is referred to in EU legislation - hydrogen. It has introduced a stringent definition and binding mandates for green hydrogen use in industry and transport (including aviation and maritime shipping) from 2030 onwards. Production subsidies introduced in 2023 as part of the European Hydrogen Bank also target green hydrogen and its derivatives. That said, the clear priority given to green hydrogen at the EU-level has also seen challenges at the member state level. France and other countries with an important share of nuclear power have successfully pushed for exemptions in the strict EU policy framework for hydrogen produced with low-carbon nuclear power (Quitzow & Zabanova, 2024).

Similarly, blue hydrogen, produced from natural gas with carbon capture and storage (CCS), was not initially considered an important option for meeting EU hydrogen demand. Rather, green hydrogen has been framed as an important option for reducing dependency on Russian natural gas imports (Zabanova, 2024). By this logic, imported blue hydrogen was not viewed as a reasonable alternative. However, as green hydrogen projects have been slower to emerge than originally expected, blue hydrogen is now increasingly considered a viable transitional solution. Germany, the

bloc's biggest proponent of a rapid ramp-up of green hydrogen, has grown increasingly open to the idea of importing blue and other types of low-carbon hydrogen. A definition of low-carbon hydrogen (including blue hydrogen and other types) is expected to be finalized in 2025, which would create the needed EU-policy framework. Nevertheless, investor confidence in the prospects of blue hydrogen remains mixed, and the scale of blue hydrogen use in the EU is difficult to predict.

The rest of the global frontrunners have largely chosen a technology agnostic approach from the outset. However, policy and regulatory choices reveal how the configuration of national interests permeates hydrogen strategy-making. Brazil, for instance, supports all pathways and has proposed one of the more lenient definitions of low-carbon hydrogen, with an emissions threshold of 7 kg of CO_2 equivalent/kg of hydrogen, more than double the EU's threshold of 3.38 kg. This is meant to enable the production of hydrogen from biomass, reflecting the country's bioenergy legacy.

Countries with a significant fossil-fuel industry, like the US, UK, and Australia, have also promoted technology-open approaches, despite criticism from national NGOs that have highlighted the risk of reinforcing fossil-fuel lock-ins. In the UK, the government has adopted a twin-track approach, as well as a stringent definition of low-carbon hydrogen. While the UK's key subsidy, the Hydrogen Allocation Round, targets electrolytic hydrogen, in October 2024 the government announced it would provide 22 billion GBP in funding over 25 years to develop two large-scale carbon capture clusters, which are expected to give a significant boost to blue hydrogen production (Collins, 2024a). In the US in particular—whether by design or by accident—the policy regime has initially strongly favored investment in blue hydrogen. The "45 V" hydrogen tax credit introduced in the Inflation Reduction Act (2022) links the amount of subsidy—up to the 3 USD/kg cap—to the total reduction in GHG emissions provided by clean hydrogen, irrespective of the production pathway. In addition, a separate tax credit for CCS, "45Q", rewards the amount of CO_2 that is captured and sequestered. Blue hydrogen projects may thus choose to apply for either tax credit. As of mid-2024, blue hydrogen projects have seen much greater progress in the US compared to green hydrogen ones, representing some 85 percent of total committed clean hydrogen production capacity (Hydrogen Council and McKinsey, 2024, p. 19). Trump's re-election in the US in 2024 and his combative stance vis-à-vis the Biden Administration's clean energy policies, however, cast uncertainty on the future of the US hydrogen tax credits.

In the Asia–Pacific, Australia, which is rich in renewable energy but is also a major coal and gas producer, has declared openness to various pathways, including, in one region, hydrogen made from coal. Nevertheless, Australia has started to shift toward a preference for green hydrogen, especially following the election of a new government in 2022, which introduced more stringent climate targets - a trend that is expected to continue under the Labor government elected in 2025. In China, the government targets primarily green hydrogen, which is consistent with the massive development of renewable energy nationally. However, at the sub-national level, a wide range of pathways are supported, with the tacit approval by the national government. A number of provincial governments have chosen to focus first on deploying new hydrogen technologies, regardless of the carbon footprint, and postponing the decarbonization

of hydrogen production to a later stage. Finally, Japan, as a country planning to import most of its clean hydrogen and ammonia, is more preoccupied with developing robust and diversified international supply chains for these new energy carriers. It has established large demonstration projects focused on testing different transportation routes and modalities, regardless of the production route employed. Indeed, CO_2 emissions from imported hydrogen will not affect Japan's domestic GHG accounting, so that policymakers have chosen to largely ignore the emission profile of its hydrogen supply for now.

2.2 Priority Uses

Industrial legacies and domestic interests also play a key role in what hydrogen uses are prioritized. The EU, guided by its climate neutrality targets and eager to safeguard its energy-intensive industry within a net-zero future, was the first to strongly prioritize industrial decarbonization, especially in the steel and chemical sector. Yet, due to high costs of green hydrogen, investment in hydrogen-based industrial decarbonization has been sluggish at best. It is European refineries that are currently emerging as early adopters of green hydrogen, partly because of their ability to act simultaneously as producers and off-takers. Industrial end uses are beginning to attract attention outside of the EU as well. This includes large steel-producing countries like China, Japan, and the US but also Australia, where policymakers have shown increasing interest in developing a net-zero steel industry building on the combination of abundant renewable resources and domestic iron ore reserves.

Outside industry, transport is a prominent priority area for Asian economies such as Japan and China. Both have long legacies in the support of fuel-cell electric vehicles (FCEVs) (Gong et al, 2024; Haslam et al, 2012; Li et al, 2023; Trencher et al, 2020). In Japan, incumbent automakers like Toyota have made important investments in the technology, while the Chinese government has pursued FCEVs—alongside battery-electric vehicles—as an industrial policy strategy. Following the success of the battery-electric vehicle in the passenger car segment, support for FCEVs now primarily targets buses and heavy-duty commercial vehicles. Similarly in the US, the government continues to support the manufacturing and development of FCEVs alongside battery-electric vehicles with a focus on heavy-duty, commercial vehicles.

In the EU, there is a controversial debate on what role hydrogen may play in decarbonizing passenger mobility. While there is an emerging consensus that hydrogen-based e-fuels will likely play an important role in decarbonizing aviation and maritime shipping—despite limited progress to date—there is significant skepticism about the future of hydrogen in road transport. Nevertheless, the EU has adopted a target for e-fuel use in road transport and is promoting the development of refueling infrastructure in large urban centers. Brazil, with its developed expertise in biofuels (Rodrigues, 2021), is strongly targeting the e-fuel sector. Among other things, it is planning to produce hydrogen from ethanol.

As for power generation, Japan is the country with the strongest focus in this area. This has to do with the unique characteristics of Japan's power sector, where coal still plays an important role and where, in the wake of the 2011 earthquake, major nuclear power plants were shut down, eliminating the bulk of the country's low-emission generation. This has significantly deepened Japan's electricity sector's reliance on fossil fuels. While Japan has experienced a strong growth in renewable generation in recent years, the spatial constraints mean that renewables alone cannot fully decarbonize the power sector. In an effort to confront these challenges while protecting its legacy assets, Japan's industry has strongly promoted ammonia co-firing at thermal power plants. Bowing to these interests, the government has adopted this as a central approach for reducing its domestic carbon footprint in the short- to medium-term. Moreover, it is investing in R&D for related technologies and is supporting its industrial firms in promoting the technologies in other Asian countries. In China, the global leader in absolute volumes of renewable energy deployment, hydrogen is also viewed as an important element of its future electricity system, but for its storage and grid balancing functions and for reducing curtailment rates.

The UK stands out as one of the few countries that has also emphasized hydrogen as a major contribution to the decarbonization of residential heating, despite criticism from civil society and the country's Climate Change Committee. Overall, the UK government has taken a broad approach to hydrogen use and discussions are underway on the merits of introducing a separate support model for hydrogen use in the power sector.

2.3 Support Mechanisms

The countries featured in this volume have all developed schemes and support instruments for hydrogen development. Investment in R&D is the most established instrument, with each country targeting the technologies of particular interest to them. For instance, while the EU's Innovation Fund supports a wide range of clean technologies that have not yet reached market maturity, the US emphasizes large-scale domestic cleantech manufacturing of already market-ready technologies. China and Japan, in turn, have traditionally put an emphasis on developing FCEVs. Given its unique focus on ammonia co-firing, Japan has also supported technology development in this field. Brazil with its legacy in biofuels has a strong emphasis on the fuels sector.

In recent years, many jurisdictions have been experimenting with supply-side subsidies such as production premiums, contracts for difference, or tax credits. The specific choice often reflects existing policy legacies, institutional capacities, and political constraints. In the EU, the European Hydrogen Bank awards premiums for green hydrogen production as part of a competitive bidding process, aimed at ensuring a cost-effective allocation of subsidies. The level of subsidy requested by and awarded to the winning projects in the first round of auctions in 2024 ranged from 0.37 EUR to 0.48 EUR per kg, far below the 4.5 EUR/kg cap. In parallel, a growing number of EU member states are developing their national production subsidies as

well. In the UK, on the other hand, production subsidies in the framework of the "Hydrogen Production Business Model" are designed as contracts for difference, mirroring its subsidy scheme in the renewable energy sector (Bunn & Yusupov, 2015). They provide revenue support to hydrogen producers by compensating the gap between the production costs of green hydrogen versus natural gas via 15-year contracts. The first Hydrogen Allocation Round held in 2023 resulted in probably the highest level of subsidy worldwide: in December 2023, the average strike price for the eleven winning green hydrogen projects stood at £9.49 ($12.44) per kilogram of hydrogen. However, even at this high level of subsidy, not all projects are likely to reach the crucial final investment decision stage (Martin, 2024).

Japan and Australia, despite being early to adopt hydrogen strategies, have lagged behind in developing more substantive financing schemes for domestic deployment. They have sought to close this gap by launching major funding schemes in 2024. The Japanese government passed the Hydrogen Society Promotion Act, which includes a contract-for-difference scheme that compensates the buyers of low-carbon hydrogen or its derivatives for the price gap to conventional fuels (Nishimura & Asahi, 2024). In Australia, the 2 billion AUD Headstart Programme provides ten-year production support contracts to large-scale hydrogen producers, seeking to compensate for the difference between the market price and the high costs of producing hydrogen.

A separate instrument in Australia—as well as in the US—are tax credits per kg of hydrogen produced in accordance with previously defined carbon thresholds. The US approach not only mirrors its long legacy of renewable energy support, via the so-called production tax credits (Barradale, 2010), but it is also considered the only politically feasible option in the context of a divided political system (McGlynn & Sparks, 2024). In Australia, there is a flat tax credit of 2 AUD per kg, while in the US the amount of tax credit is linked to the total carbon footprint of hydrogen and is capped at 3.5 USD/kg (and in addition, there is a separate tax credit for projects using carbon capture and sequestration). Brazil is planning to use tax incentives as well. The law adopted in September 2024 earmarked 18.3bn Brazilian reals ($3.36bn) in funding for companies producing or consuming "low-carbon" hydrogen in 2028–32, to be selected competitively, with projects featuring lower GHG emissions prioritized; other selection criteria are still to be determined (Argus Media, 2024).

Another prominent focus of support policies in leading jurisdictions are regional hydrogen hubs (also called clusters, or valleys). These are geographic areas where local hydrogen value chains are developed by bringing together hydrogen producers and consumers (and sometimes exporters) and bundling a variety of hydrogen uses in one place. Common examples include seaports such as Rotterdam, where hydrogen can both be produced on site from wind and solar power and imported by sea, and then distributed via a pipeline network to industries located nearby. Hubs can play a crucial role in jumpstarting a hydrogen economy, especially where little or no long-distance hydrogen transport infrastructure exists yet. The EU has been instrumental in promoting the idea of hydrogen valleys in Europe and globally, spearheading this work area in the framework of the global initiative by Mission Innovation.

The idea has been picked up by other global frontrunners as well. The US has dedicated a 7 billion USD budget line for funding regional hydrogen hubs through the Bipartisan Infrastructure Law (2021). The winners were selected in a competitive process and include seven regional hubs to be awarded federal funding, ranging between 750 million and 1.2 billion USD, with the first tranches disbursed in 2024. Trump's re-election, however, has cast uncertainty on the future of further funding, especially in the case of renewable and nuclear-based hydrogen hubs (Colman et al, 2025). Australia has allocated over 500 million AUD in federal funding, to be supplemented with a similar amount of funding from the subnational level, to support regional hub development, with five regions given the priority status. In China, so-called pilot cities have been launched for the development and deployment of FCEVs and the related infrastructure (Gong et al., 2024).

While hydrogen production has enjoyed large amounts of support around the globe, policies to promote the uptake of clean hydrogen in key demand sectors have been less commonplace. This reflects the general state of affairs in the hydrogen economy, where there is an abundance of investment in hydrogen production and supply yet sizable investment gaps exist when it comes to hydrogen end uses and infrastructure (Hydrogen Council and McKinsey, 2024). In the EU, Germany has led the way by launching a 50 billion EUR carbon contracts for difference (*Klimaschutzverträge*) scheme for industrial decarbonization. The scheme incentivizes the use of green production methods in industrial sectors (including renewable hydrogen) by compensating for the price differential between conventional and climate-friendly technologies. The EU in turn has launched targets and mandates for minimum shares of green hydrogen and green hydrogen derivatives in the industry and transport sectors, which will be binding from 2030 onward. However, reflecting the constraints on the EU as an industrial policy actor, they lack EU-level funding to ensure their implementation. Rather, responsibility largely rests with EU member states, despite highly diverging capacities and willingness to support the needed investments. The result may be a highly uneven investment landscape in the EU, further exacerbated by moves to relax the EU's restrictions on state aid. In the wake of the energy crisis, the European Commission has allowed member states additional leeway in providing subsidies to national industries, raising questions about the integrity of the European single market.

The US has also faced a lack of offtake contracts despite existing subsidies for hydrogen production, resulting in discussions on subsidies for users purchasing clean hydrogen from government-funded regional hydrogen hubs. With 1 billion USD in funding, the details of the scheme are expected to be disclosed by early 2025 and are likely to follow the contracts-for-difference logic as well (Collins, 2024b). In China, support for hydrogen end uses has largely taken the shape of consumer subsidies for the purchase of FCEVs.

2.4 Industrial Policy

Linking hydrogen development to green industrial policy has been a strong trend across all the countries. In particular, China's rise as a cleantech global superpower has been a major concern first and foremost for the US, but also increasingly for the EU. In the US, promoting local supply chains for clean energy has been an essential precondition for securing bipartisan support for major green investments, as outlined in the Inflation Reduction Act (2022). This is true for hydrogen as well. While the US does not mandate local content requirements for electrolyzers per se, it does incentivize the use of locally manufactured solar, wind, and battery technologies as well as the domestic sourcing of iron and steel and critical raw materials. In addition to promoting the "made in the USA" principle, the US explicitly excludes facilities relying on Chinese-made batteries and critical raw materials from receiving hydrogen subsidies. The newly elected Trump Administration has adopted a starkly protectionist stance in trade policy, further increasing tariffs on Chinese goods. Affected product categories include such key technologies as EVs, solar panels, and semiconductors (Abrahams, 2025).

In turn, the EU, which is home to many of the world's leading innovative electrolyzer manufacturers, has been highly apprehensive about losing technology competition to China, as was already the case with solar PV panels in the past. Although the EU has stopped short of mandating a certain percentage of local content in hydrogen projects, following lobbying by the electrolyzer industry, it has introduced a "resilience criterion" for European Hydrogen Bank auctions. The criterion requires bidders to ensure they source no more than 25% of electrolyzer stacks from China (Directorate-General for Climate Action, 2024). In addition, while the EU has traditionally focused on investing in technologies that have not yet reached market maturity, it is now increasingly beginning to promote EU-based manufacturing of clean technologies, through a combination of EU- and national-level funding.

China, for its own part, has a longstanding industrial policy aimed at promoting FCEV manufacturing, not only in China but also along the Belt and Road Initiative (BRI). The government encourages producers of FCEVs to export products, services, technologies, and standards by investing in foreign markets and supports the development of overseas automotive industrial parks. Typically, lead state-owned enterprises (SOEs) cooperate with other privately owned suppliers in spearheading such efforts. Another longstanding goal of Chinese industrial policy is the promotion of technology and innovation and the acquisition of foreign know-how to overcome remaining technology bottlenecks in China to ensure its strategic autonomy. Most recently, China has stepped up its efforts in promoting innovation in the hydrogen sector with the launch of the Central Enterprises Green Hydrogen Production, Storage, and Transportation Innovation Joint Venture. Initiated by SASAC and jointly led by CNPC and Sinopec, the initiative brings together major SOEs, technology providers, and academia in an effort to promote innovation and technology development in various areas of the hydrogen economy.

Japan has been strongly driven by industrial policy considerations as well. Japanese companies lead globally as patent holders for a number of hydrogen technologies along the value chain. This includes fuel cells, hydrogen and ammonia used in co-combustion in coal power plants, hydrogen use in steel, chemicals, and shipping as well as e-methane and e-fuels. The power sector and the transport sector are the two most important priority areas for Japanese industrial policy. In addition to planning hydrogen and ammonia imports, Japan is intent on promoting Japanese hydrogen know-how abroad and sees a major business opportunity in supplying co-combustion technologies to help decarbonize coal power plants in Southeast Asia. The government is also funding R&D for developing a 10+ MW hydrogen-ready turbine by Mitsubishi. The government's numerical targets are strongly linked to the automotive industry, with a target number of FCEVs on the road and hydrogen refueling stations, as well as to the electrolyzer industry, with a 15 GW target in global electrolyzer capacity operated by Japanese companies globally.

Other countries, especially potential hydrogen exporters, are increasingly considering the necessity to develop higher value-added industrial activities in the hydrogen sector. Guided by its policy priority of neo-industrialization, Brazil aims to create a domestic green fertilizer industry and plans the introduction of local content requirements. Australia, an established commodity exporter, envisions a leading role as a future hydrogen exporter but is also planning to promote domestic use of clean hydrogen, including a green steelmaking industry. The UK, by contrast, despite the ambition to become a "green energy superpower", has lacked strategic focus in its green industrial strategy. Partly, this is a reflection of the fractious domestic debate on the future role of hydrogen in the domestic economy. Although the government supports a wide range of uses, this also means resources are spread thinly and may be insufficient to make a substantive impact in any single area of application.

2.5 Domestic Hydrogen Politics in a Shifting Geopolitical Landscape

Over time, the hydrogen economy has picked up momentum, with an increasing number of countries jumping on the hydrogen bandwagon. At the same time, geopolitical developments—and their economic consequences—have begun to take their toll on the sector, calling into question some of the more ambitious goals, in particular in Europe. Rising energy prices and inflation have not only hampered the investment climate and slowed down—or even reversed—urgently needed price reductions. They have also translated into increasing skepticism toward the green transition among the public in the US and Europe. Moreover, increasing calls for resilience and national sovereignty have introduced new challenges for the design of green industrial policy measures. Finally, the election of Donald Trump in the US has introduced further uncertainty into the sector. That said, there are also countervailing trends with China, Japan, Australia, and Brazil all stepping up their hydrogen action. In Brazil and

Australia, this follows significant electoral shifts with left-wing forces taking over power from conservative parties.

In the EU, other priorities—such as the need to ensure access to low-cost energy to increase the competitiveness of European industry as well as hard security issues—have been competing for attention with the green transition. The EU's parliamentary elections in 2024 resulted in a clear shift to the right. Enthusiasm for hydrogen development has been weakening, discouraged by the slow progress and high costs and the resulting cancelation of a spate of hydrogen projects. The green backlash in many Member States as citizens and businesses grapple with the costs of the transition, compounded by the ongoing economic impact of the war in Ukraine and the loss of competitiveness of European companies, has presented a challenge to the Commission's green course. Forging a common path among Member States with very different starting points in their energy mixes as well as highly divergent attitudes to green industrial policy is a particular challenge (Quitzow & Zabanova, 2024).

In the US, President Biden's landmark Inflation Reduction Act (2022), complete with generous tax credits for hydrogen and investment incentives, catapulted the US to the position of the green tech frontrunner, sparking serious concern in the EU. Yet, Trump's re-election in November 2024 creates uncertainty for investors—not only for US firms but also for European companies that have considered moving their production facilities across the Atlantic in response to the IRA. At the same time, Republican-dominated US states have been some of the key beneficiaries of US hydrogen funding, making them interested in upholding this legislation.

Though the US and Europe remain central to an emerging international hydrogen economy, these challenges are not mirrored in the same way elsewhere. China saw important advances in 2024 with the passing of its Energy Law, which officially classifies hydrogen as an energy source rather than a hazardous chemical, as well as the launch of the Central Enterprises Green Hydrogen Production, Storage, and Transportation Innovation Joint Venture as a major new vehicle to promote innovation in the sector. Japan in turn passed the Hydrogen Society Promotion Act in May 2024, which introduces a major new subsidy scheme for hydrogen supply. Brazil, with its historical insistence on reducing hydrocarbon dependencies dating back to the oil crisis of the 1970s, has also seen hydrogen plans accepted across party lines. Lula's re-election as president in 2023 has further solidified the country's commitment to the sector and strengthened the link to decarbonization and green industrial development. The passing of the Hydrogen Act and the launch of the Low Carbon Hydrogen Development Program in 2024 represent critical steps forward in this regard and signal the country's ambition to assume a more active leadership role. In Australia, the commonwealth government elected in 2022 has pursued a more ambitious climate policy, including a stronger focus on promoting renewable hydrogen and developing domestic end-use sectors, a trend likely to continue under the new Labor government.

3 International Hydrogen Politics and Policies

As outlined in the preceding sections, hydrogen policies cannot be separated from domestic resources and assets and the pre-existing industrial legacies and stakeholder interests. Along with prevailing institutional legacies, these are shaping preferences regarding production pathways and preferred end-use sectors and are defining policy priorities across the countries considered in this volume. These domestic approaches and their political and economic underpinnings also translate into unique strategies for international engagement and cooperation (Quitzow et al, 2024). Each country is not only seeking to position itself within an emerging hydrogen policy landscape but also to influence and shape this landscape to match its priorities and needs.

3.1 The Question of Hydrogen Trade: Importers, Exporters and Prosumers

The European Union—led by its largest member state Germany—and Japan stand out in the international hydrogen landscape as the most important proponents of international hydrogen trade. With large industrialized economies and only limited renewable energy potential, both are strongly reliant on imported hydrogen to decarbonize their economies. Also, both the EU and Japan only have limited scope to scale-up nuclear energy. Although there has been growing openness to nuclear energy in the EU, and member states like France or Sweden remain committed to nuclear energy for domestic use, the future role of this technology in EU-level decarbonization efforts remains contested due to the high costs and continued political opposition in a number of member states, including Germany. In Japan, political establishment has remained open to nuclear energy, but its nuclear sector has not fully recovered from the Fukushima disaster, and its potential to play a major role in its net-zero future is highly uncertain. Hence, Japan, Germany, and the EU more broadly see their futures tied to an international hydrogen economy able to supply them with imports.

However, despite these similar starting points, their approaches to international engagement have differed markedly, reflecting the domestic political economy of hydrogen and their broader institutional legacies. As an international climate policy leader, the EU and Germany have focused strongly on the development of an international hydrogen market with a strong focus on green hydrogen. Both the German government and the European Commission are pursuing engagements around the world to promote green hydrogen as the energy carrier of the future and to support a favorable climate for hydrogen investment (Quitzow et al, 2024; Zabanova, 2024). While the prospect of hydrogen imports plays a major role in this regard, engagements from these two players have been characterized by their broad geographical scope and broad-based support for hydrogen policy development. Their international

strategies are creating the political and institutional underpinnings of an international hydrogen market.

While the development of physical infrastructure and import corridors is a part of these efforts, it has not been the most prominent feature of their strategy. Partly, this is a result of internal EU politics (Quitzow & Zabanova, 2024). Not only has France been reluctant to assume its role as a potential transit country for hydrogen trade between Germany and the Iberian peninsula (Bouacida, 2024), but also Spain, with hydrogen export ambitions of its own, has been slow to support the continuation of a potential pipeline route to Morocco (Urbasos & Escribano, 2024). With the war in Ukraine precluding development of an Eastern route, a Southern corridor through Italy and a pipeline interconnection with Norway have emerged as the most tangible options for pipeline development. The latter, however, has seen setbacks, due to the uncertainty regarding the long-term viability of blue hydrogen within the EU regulatory framework. Shipping-based solutions are being pursued in parallel, though efforts are relatively hands-off. Germany's H2 Global, the most prominent initiative, takes a market-based approach, where supply chain development is clearly placed in the hands of private sector actors.

In contrast to this, the Japanese government has engaged in a number of large-scale, bilateral demonstration projects to pilot specific supply routes and transport technologies, while showing only limited concern for the mode of hydrogen production. Prominent examples include the Hydrogen Energy Supply Chain (HESC) project, in partnership with the state of Victoria in Australia, and a project to import hydrogen from Brunei. The former aims to advance technology for shipping liquid hydrogen, including its regasification in Japan. It involves the production of hydrogen via coal gasification, initially without CCS, though the consortium has signaled that this would change once production is scaled up. The partnership with Brunei involves the export of hydrogen produced from natural gas using a liquid-organic hydrogen carrier (LOHC). Complementing these larger-scale projects, Japan supports a number of smaller pilot projects via its Green Innovation Fund.

Australia as well as Brazil represent important counterparts to these activities launched by Japan, Germany, and the EU. Australia in particular has positioned itself as a major future exporter of hydrogen. Its legacy as a large fossil-fuel exporter, including coal and natural gas, predisposes it to this approach, with major incumbent firms as strong proponents. It has had little inclination to position itself strongly in favor of any particular production pathway, given its large endowments not only in renewable but also in fossil resources. However, following a change of government in 2022, it has shifted its emphasis more strongly to renewable hydrogen, proclaiming Australia a future hydrogen and renewable energy "superpower". It is now also exploring exports of downstream products, like hydrogen-based green iron, steel, and alumina.

Brazil has been slower to position itself in an international hydrogen economy. The national government has been supporting hydrogen as a complement to its strong

biofuels sector, but did not feature among the frontrunners of hydrogen strategy development. Nevertheless, it aims to become "the most competitive producer of hydrogen" by 2030 (RadarH2, 2024). Moreover, subnational governments have formulated their own export ambitions. A number of regions in the northeast of Brazil have identified their strong renewable energy potential and relative proximity to European export markets as an asset in a future hydrogen market. At the national level, hydrogen received an important boost with the Lula government, where it now features as an important ingredient for industrial decarbonization and for safeguarding and further developing Brazil's position on European markets against the background of the EU's carbon border adjustment mechanism (CBAM). These developments exhibit important parallels to developments in the UK. While the national government has taken a more inward-looking approach overall, the Scottish government has pursued an export-oriented hydrogen policy, in line with its strong renewable energy potential and its pro-European outlook.

Neither the US nor China have a strong motivation to articulate a nuanced position on hydrogen trade. While they both represent important centers of future hydrogen demand, they also have the renewable potential to supply these needs. This is also clearly reflected in their international engagement, which does not include a strong component for the development of hydrogen trade. Similar to Brazil or the UK, this does not preclude subnational governments or firms from pursuing export opportunities. The ambition of the local government in Shanghai to position itself as a regional trading hub for hydrogen is a case in point. Similarly, developments along the Texas Gulf Coast indicate export-oriented ambitions.

3.2 Bilateral Hydrogen and Energy Diplomacy

As outlined in the previous section, securing hydrogen imports is a major driver behind the strong international engagement and leadership of Japan, Germany, and the European Union. This engagement is underpinned by broader climate, energy, and industrial policy goals as well as efforts to promote cooperation and knowledge exchange on hydrogen technologies and solutions. In the case of Japan, engagement on hydrogen supply is complemented by broader dialogue to facilitate investment and technology cooperation in the field of hydrogen and ammonia production as well as ammonia co-firing, bolstered by private sector interests in exporting related technologies.

EU-level activities are generally embedded in broader energy and climate policy initiatives and, in some cases, its Global Gateway strategy to support investments in infrastructure and connectivity. As such hydrogen is viewed as a promising field for cooperation, not only to supply the EU with hydrogen but also as an opportunity for investment and economic development in partner countries. Similarly, large member states, including Germany, France, and Italy, have added hydrogen to their broader cooperation on climate and energy. In both Germany and France, this offers important opportunities for supporting their domestic firms and technologies. In Italy, large

state-owned energy firms, i.e., ENI and SNAM, have started integrating hydrogen into their existing energy relations in North Africa (Prontera, 2024). Germany in particular has seized on hydrogen as an important entry-point for engaging oil and gas-exporting countries in a dialogue on the opportunities of decarbonization, as emphasized in its H_2diplo initiative (Quitzow et al., 2024).

The UK has also begun addressing hydrogen-related issues within its existing energy cooperation initiatives, with a primary focus on the US and its European neighbors. It has incorporated hydrogen in its strategic energy dialogue with the US, and it is increasing its engagement on hydrogen with a number of European countries. In particular, it engages with Norway and other North Sea countries on cross-border energy projects, including hydrogen. Technology cooperation has not featured as an explicit priority so far.

The Australian government has launched cooperation with a series of partner countries to promote technology cooperation and supply chain development. Complementing the cooperation between the state of Victoria and Japan on hydrogen trade, it has launched the Japan-Australia Partnership on Decarbonization through Technology to facilitate collaboration on a number of decarbonization technologies, including clean hydrogen and ammonia. Similar agreements exist with Germany, South Korea, and Singapore. The Brazilian government has engaged primarily with the EU and Germany so far, successfully securing financial support to promote its domestic hydrogen sector. This includes USD 2 billion in funding, which is being channeled through the EU's Global Gateway initiative to finance hydrogen-related infrastructure. It has also launched the Brazil-UK Hydrogen Hub to support investment in the hydrogen sector.

Though China and the US have not made hydrogen a priority of their energy diplomacy, it is being integrated into existing initiatives. The US engages with partners for the promotion of the hydrogen sector within the context of established formats for international collaboration and finance in the energy sector, like the Strategic Clean Energy Partnership with India or the Partnership for Accelerating Clean Energy with the United Arab Emirates. Similarly, China has integrated hydrogen within existing energy cooperation with strategic partners like Pakistan, Egypt, Saudi Arabia, or Brazil, aiming to position China as a supplier of hydrogen technologies in these countries and around the world. Moreover, the government has supported overseas investment in FCEV manufacturing along the BRI as part of its industrial policy for the automotive sector. Finally, an important element of international cooperation is aimed at facilitating knowledge and technology transfer to China to close what are perceived as central technology bottlenecks in its domestic hydrogen sector (Gong et al., 2023).

3.3 Multilateral Cooperation

All the major economies highlighted in this volume have engaged in multilateral hydrogen cooperation. This cooperation includes knowledge exchange and technology cooperation as well as engagement in standard-setting. Multilateral hydrogen cooperation to date includes both hydrogen-specific initiatives, many of them focused on green hydrogen, as well as initiatives launched as part of existing institutions, like the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA) or UN bodies like United Nations Industrial Development Organization (UNIDO). The latter largely focuses on the broader hydrogen sector, with the notable exception of IRENA (Lentschig et al., 2024).

These multilateral initiatives generally focus on knowledge exchange on best practices, joint generation of research and analysis as well as the development and harmonization of standards and certifications. Prominent initiatives are the Clean Energy Ministerial's (CEM) Hydrogen Initiative, the Clean Hydrogen Mission under the auspices of Mission Innovation, the Hydrogen Breakthrough Agenda as well as the longstanding Hydrogen Technology Cooperation Program (TCP) of the IEA and the International Partnership on the Hydrogen Economy (IPHE). In addition, the G7 and the G20 have launched hydrogen-related initiatives to jointly advance the hydrogen economy. Except for Brazil, all the major economies presented in this volume are active in all the initiatives (with the exception of the G7 Hydrogen Action Pact, which is limited to G7 member countries). So far Brazil is only involved in the CEM initiative and the IPHE, signaling a lower level of engagement on hydrogen-related cooperation so far.

3.4 International Cooperation on Hydrogen Standards

Most of the countries assign particular importance to the development of standards and certifications as an enabler for hydrogen trade. This was underlined by a joint declaration signed at COP 28 on "Mutual Recognition of Certification Schemes for Renewable and Low-Carbon Hydrogen and Hydrogen Derivatives". Furthermore, the Hydrogen Breakthrough Agenda has initiated a report that outlines the main features of standardization and certification schemes as the basis for promoting mutual recognition and interoperability. The report was jointly developed with participation by the IEA TCP, IRENA, and IPHE, signaling the high level of importance attributed to it (Breakthrough Agenda et al., 2023). Another important activity has been the development of a methodology by the IPHE for determining the greenhouse gas emissions associated with the production of hydrogen. This was led by representatives of the EU and the US with participation of most of the other IPHE member countries. Notably, China and Brazil were not represented during the development process, however. So far China has focused most of its attention on the development of technical standards, notably in the sphere of fuel cells. Brazil has begun to

engage more actively in hydrogen-related standardization. However, the relatively high emissions threshold in its own *Brazilian System of Hydrogen Certification* is out of step with initiatives like CertifHy in the EU and may complicate efforts to harmonize its approach with other schemes. Brazil has also refrained from joining CertiLAC, a regional initiative to create a harmonized certification system.

The relatively strict standards in the EU for renewable hydrogen, referred to as renewable fuels of non-biological origin (RFNBOs), have been considered an important barrier to a more rapid ramp-up of hydrogen, not only in the Union but also in potential exporting countries. In the latter, electricity market rules that do not match those in the EU may complicate verification processes. Nevertheless, there are signs that EU regulatory power is shaping rulemaking in other jurisdictions. The US has proposed a similar set of rules for renewable hydrogen projects to benefit from the Hydrogen Production Tax Credits under the IRA.

4 The Emerging Geopolitics of Hydrogen and Decarbonization

The case studies in this book illustrate how the different political and economic conditions and legacies are shaping a wide variety of hydrogen strategies. The three dominant economic blocs—the EU, China, and the US—not only depart from very different starting points and different climate and energy regimes but their relative resource endowments and capacities also imply different types of challenges. Crucially, the renewable resource potential in the US and China will allow them to pursue a future green hydrogen economy without relying significantly on imports. The EU—like Japan—on the other hand will not have this luxury.

Nevertheless, the EU has emerged as a central champion of a hydrogen economy based on renewable power. It has built on its strength as a regulatory state (Bradford, 2019; Kennis & Liu, 2024) to develop a stringent set of rules aimed at ensuring a hydrogen ramp-up that is compliant with its net-zero goals. However, this approach has faced serious challenges, as the EU has seen itself confronted with a changing geopolitical and geoeconomic landscape (Prontera & Quitzow, 2021). The EU's regulatory model, centered on a combination of its emissions trading system and sector-based regulations, has to confront the fact that costly investments in decarbonization technologies, including hydrogen, may also harm short-term competitiveness. Specifically, hydrogen-based steel and chemical production could face serious challenges if exposed to competition from imported products from traditional producers. While the EU's carbon border adjustment mechanism (CBAM) seeks to address this challenge, it remains unclear whether this will suffice in protecting EU industries. This is further compounded by the energy price shock in the wake of the Ukraine war, which has driven up energy prices in the EU.

Another key question that emerges from the EU's focus on green hydrogen is how it will secure its green energy needs, and, closely related to this, how much of its

existing energy-intensive industry it will be able to retain in the future (Eicke & De Blasio, 2022). Led by Germany, its largest member state, it is pursuing ambitious import targets via an increasing number of hydrogen partnerships (Quitzow et al., 2024). While these efforts are driven by its vulnerability in the field of energy supply, it also places the EU at the forefront of an international hydrogen economy. It positions the EU as an important partner for countries seeking to reap the gains of their renewable energy assets in a future net-zero economy. It also places it at the center of political negotiation processes over the configuration of net-zero industries and supply chains (Quitzow & Zabanova, 2024).

At the same time, the EU needs to grapple with China's increasing dominance in the field of green technologies and its ability to rapidly scale up and reduce the costs in emerging green sectors (Lema et al., 2020). On the one hand, low-cost Chinese technologies could play a key role in accelerating hydrogen ramp-up. On the other hand, it raises fears of technological dependencies at a moment where the US has embarked on a path toward increasing decoupling from Chinese supply chains. Conversely, for China, this means that it may have to rely more strongly on domestic demand for hydrogen and hydrogen technologies if it wants to compete in the race for technological leadership in the hydrogen economy. For now, the national government has not yet taken a strong stance in support of green hydrogen deployment. Rather it is pursuing a strong policy to close perceived gaps in its domestic know-how, while relying on industrial ambitions in a number of provinces. These include provinces with strong chemical industries as well as abundant renewable resource endowments. This allows the Chinese government to experiment with different approaches and technologies, while developments take shape internationally. Clearly, its 2060 carbon-neutrality target—ten years later than the EU and the US—also plays in favor of this approach (Gong et al., 2024).

With the IRA, the US government under President Biden has arguably provided the strongest fiscal stimulus to the hydrogen economy so far, propelling the US into the spotlight of hydrogen investment. However, this comes against the backdrop of a deeply divided US political system. The election of the new Trump administration has introduced substantial uncertainty into the US policy landscape, weakening its role as a leader of a global net-zero economy. This raises the question to what extent state-level initiatives will fill an emerging gap in US policy support. Though driven by a different set of political framework conditions, the EU faces a similar dilemma. Due to limited fiscal capacities at the EU-level, it has to rely heavily on financing by its member states to support the hydrogen ramp-up. As it has moved toward loosening its strict competition rules to allow member states to fill a widening financing gap, this has raised important questions regarding the integrity of the EU's single market, a key geoeconomic asset in its own right.

Beyond the three leading economic blocs, the other case studies in this book also reveal how the interplay of political developments, resource endowments, and industrial legacies are shaping their positioning within an emerging hydrogen economy. While developments in Australia are influenced by its past as an exporter of carbon-intensive energy commodities, changes in the political leadership have marked a shift toward a strategy that emphasizes its renewable potential and its potential for

downstream value creation. Similarly, a new government in Brazil has not only increased the profile of its national hydrogen ambitions, but also emphasized its role within a new strategy for industrialization. Japan's resource constraints have placed it at the forefront of the global hydrogen economy, with a strategy strongly shaped by its traditionally close relationship between government and the national business community. In the UK, the hydrogen strategy epitomizes how the country's increasing shift toward a more active industrial policy in the hydrogen sector is complicated by its lack of clarity on priority applications and infrastructure.

These developments in the hydrogen sector are testimony to the growing confluence of geopolitics and markets in the context of global decarbonization processes. Efforts aimed at decarbonizing industries and stimulating new sectors are deeply intertwined with processes of policy development and the political negotiations underlying and shaping these. The choice and design of policy interventions have far-reaching implications for the competitiveness of technologies and economic actors and the resulting geographic configuration of a future net-zero economy (Quitzow and Zabanova 2025). The previously held belief in a liberal market governed by principles of efficiency and aimed at the optimal allocation of economic resources is giving way to a messy transition to a net-zero economy shaped in large part by regulatory choices and fiscal incentives (Goldthau, 2021).

It also reveals the intense challenges of developing the appropriate mix of policies that can help unlock the investment to unleash the needed economies of scale to bring down technology costs. Market uncertainties are compounded by regulatory, and underpinning this, political uncertainties. Compared to renewable electricity, hydrogen technologies suffer from a dual uncertainty. Not only is their uncertainty regarding the supply of hydrogen and the related costs, but future demand for hydrogen, i.e., the end-use sectors and technologies that will act as the hydrogen off-takers, is arguably even more uncertain (Lentschig et al., 2024).

Against this background, the central challenge of policymakers is to provide sufficient clarity and certainty to investors, while leaving options for adapting policy to international developments in market and technology. Historically, China has resolved this with strategic ambiguity and experimentation, combining this with the willingness to accept significant degrees of overcapacity. The US, with the IRA, has shown willingness to accept a degree of overinvestment and possibly stranded assets in its effort to catalyze new renewable and low-carbon technology pathways. The EU, on the other hand, remains committed to market-based incentives and mechanisms, including auctions and CO_2 pricing, while coupling this with a stringent regulatory landscape to avoid the misallocation of capital to unsustainable technologies. At the same time, with its Clean Industrial Strategy proposed in February 2025, the new European Commission formed in 2024 has pledged to focus on raising the competitiveness of European industry, closing the innovation gap with other major economies, and reducing strategic dependencies. This raises fundamental questions regarding the relationship between the EU, its member states, and the rules of its single market. It remains uncertain at this stage which approach will prove the most effective in the long run and how the green transition will affect geoeconomics more broadly. From a climate policy perspective, the central question is how the interplay of

these industrial policy approaches can enable the needed acceleration of investment to fuel a sustainable ramp-up of the hydrogen economy.

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