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Building partnerships for an international hydrogen economy

Entry-points for European policy action

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EXECUTIVE SUMMARY

This paper discusses the key questions and challenges for promoting international cooperation between the EU and potential international partners within an emerging hydrogen economy. On this basis, it identifies entry-points for related policy action. Specifically, it outlines six policy dimensions (see Figure 1) that European policymakers should consider when engaging in the development of international partnerships within the emerging hydrogen economy: climate mitigation, green industrial development in Europe, just transitions in partner countries, geopolitics, security of supply, and economic feasibility. Taking these six dimensions as its starting point, the paper presents nine policy messages for the development of an international hydrogen economy within the context of broader decarbonisation efforts in the EU.

MESSAGE 1
PREFERENCE SHOULD BE GIVEN TO RENEWABLE HYDROGEN CAPACITY DEVELOPMENT IN THE EUROPEAN UNION AND ITS IMMEDIATE VICINITY

The development of hydrogen production capacities in the European Union (EU) and in its immediate vicinity has clear advantages that should not be underestimated. First, hydrogen supply within the EU and its immediate vicinity has important advantages from a security of supply perspective. While this goes without saying for countries within the EU, also those in the immediate vicinity of the EU are less likely to abandon the EU market for other buyers. This should not lead to an unbalanced dependence on single suppliers or transport routes. However, a base of regional suppliers can build a robust core, to be supplemented with suppliers from farther afield.

MESSAGE 2
THE EU NEEDS A HYDROGEN PIPELINE INFRASTRUCTURE, INCLUDING INTERCONNECTIONS BETWEEN SPAIN AND FRANCE, FOR TRADE AMONG MEMBER STATES AND WITH THE EUROPEAN NEIGHBOURHOOD, AS WELL AS SHIPPING TERMINALS TO DIVERSIFY IMPORTS

A European hydrogen pipeline infrastructure will be essential not only for Member States with large renewable energy potential to supply demand centres in other parts of the EU (IRENA 2022a). It is also important for enabling the supply of hydrogen from the EU's northern, southern and eastern neighbourhood. To support diversification, it will also be important to equip major European ports to be able to handle hydrogen and hydrogen-based synthetic fuels.

MESSAGE 3
REGIONAL TRADE IN HYDROGEN SHOULD NOT REPLACE AMBITIONS TO INCREASE ELECTRICITY TRADE WITH COUNTRIES IN THE EUROPEAN NEIGHBOURHOOD, BUT SHOULD COMPLEMENT IT

Current discussions on an emerging hydrogen economy and related policy developments appear to have sidelined previous discussions on increased integration of electricity systems both within the EU and between the EU and its neighbours. While renewable electricity production has steadily increased in the EU over recent years, interconnection capacity has not (Pepermans 2018). Increased interconnections within the EU and with neighbouring countries provide the basis for increased electricity imports with benefits for balancing variable renewable energy sources. Electricity grids also have an often neglected geopolitical dimension. They can function as a distinct realm of integration and may be used as channels of influence (Westphal, Pastukhova and Pepe 2022).

MESSAGE 4
PARTNERSHIPS FOR THE PROMOTION OF HYDROGEN TRADE NEED TO BE EMBEDDED IN BROADER GREEN INDUSTRIAL DEVELOPMENT PARTNERSHIPS AIMED AT SUPPORTING SOCIO-ECONOMIC DEVELOPMENT AND DECARBONISATION OF THE PARTNER ECONOMY

Partnerships for promoting hydrogen trade between potential producer countries and the EU will be successful only if embedded in broader green industrial partnerships aimed at supporting decarbonisation and socio-economic development in both the EU and partner countries. Indeed, some of the most tangible efforts at promoting investment in renewable hydrogen projects are linked to strategies for increasing domestic value-creation in the sector. The development of future economic relations will have to take these industrial development ambitions into account.

MESSAGE 5
SUSTAINABILITY CERTIFICATION SCHEMES ARE NEEDED TO ENABLE THE RAMP-UP OF RENEWABLE HYDROGEN PRODUCTION AND SHOULD PROMOTE INCREASINGLY SUSTAINABLE PRODUCTION PRACTICES OVER TIME

Robust sustainability-certification schemes are needed to ensure that hydrogen production in partner countries makes a positive contribution to both climate protection and local sustainable development. It is also likely to represent a precondition for sustained public acceptance of policies in support of hydrogen-based decarbonisation schemes (ILF and LBST 2021). The example of international biofuel trade – and the import of biofuels based on palm oil in particular – has shown how a lack of credible sustainability standards may lead to the erosion of public acceptance and reduced policy support over time (Oosterveer 2020). At the same time, there are concerns that adherence to sustainability standards will slow down the needed ramp-up of renewable hydrogen production. This dilemma cannot be resolved entirely. However, a phased approach to the implementation of sustainability certification schemes could offer an entry-point for enabling the needed scale-up of investment, while ensuring that sustainable production practices are established over time (Climate Bonds 2022).

MESSAGE 6
THE EU NEEDS TO DEVELOP JOINT PRINCIPLES FOR ITS HYDROGEN FOREIGN POLICY

Without common principles for hydrogen foreign policy in the EU, different Member States may send contradictory signals to respective partner countries. This weakens the EU's attractiveness as a partner and hence its ability to influence global standards for hydrogen trade. While overcoming such differences may not be easy, this should be an important goal of EU-level hydrogen policy. In the absence of such an agreement, a second-best option would be a common approach among a group of like-minded countries.

MESSAGE 7
THE EU SHOULD SEEK TO ALIGN ITS PROMOTION OF A GLOBAL HYDROGEN ECONOMY WITH THE UNITED STATES AND OTHER G7 COUNTRIES

While the EU wields significant market power that it can deploy to promote international standards, a joint approach across G7 economies would significantly augment the weight of related standards. In this vein, the various G7 initiatives, such as the G7 Industrial Decarbonisation Initiative, the G7 Hydrogen Action Pact and the Climate Club initiative represent important steps in this direction that should receive strong support from the EU and the European G7 countries (G7 Germany 2022). Of course, this also implies compromise with G7 partners. It is, however, in the EU's interest to find an accommodation within the G7 on these issues to retain its influence on global developments in this sphere.

MESSAGE 8
IN PURSUIT OF THEIR HYDROGEN PARTNERSHIPS, EUROPE AND GERMANY NEED TO ACTIVELY TACKLE THE CHALLENGING QUESTIONS RELATED TO "BLUE HYDROGEN" AND, IN THIS CONTEXT, ALSO CARBON CAPTURE

Emerging hydrogen partnerships, such as Germany's partnerships with the UAE and Norway, have acknowledged that blue hydrogen is expected to play a major role in planned hydrogen imports from these countries (BMWK 2022a; BMWK 2022b). Against this background, it is essential that Germany and the EU clarify the conditions under which blue hydrogen, and hence CCS, should in fact be part of their pathways towards climate neutrality. In addition, imports of blue hydrogen require engagement with partner countries to ensure the capture and large-scale, safe geological storage of CO2, as well as the highest possible standards for natural gas production and transport to avoid methane leaks (Tovar and Azadegan 2022; Filiou et al. 2003; Floristean and Brahy 2019). This should be a precondition for any imports of blue hydrogen.

MESSAGE 9
THE USE OF HYDROGEN-BASED SYNTHETIC FUELS WILL REQUIRE INTERNATIONAL COOPERATION AND DIALOGUE FOR THE SUSTAINABLE DEPLOYMENT OF TECHNOLOGIES FOR CARBON CAPTURE AND TRANSPORT

If increased hydrogen imports are to unfold their mitigation potential in hard-to-electrify segments of the transport sector (such as aviation) an infrastructure for synthetic fuels will have to be developed. Synthetic fuels are produced in an energy-intensive process on the basis of hydrogen and carbon dioxide (CO2) (Ferrari et al. 2014). This means that emerging hydrogen partnerships targeting synthetic fuels will also have to support the establishment of an infrastructure for CO2 capture and transport (Billig et al. 2019). This should build on an informed public debate and the creation of related standards and regulations to ensure the compatibility of these CO2-related technologies and their deployment in partner countries with climate-neutrality targets (Chauvy and De Weireld 2020). ←

1
INTRODUCTION

An increasing number of national governments, regional authorities, cities, companies and private businesses have formulated climate-neutrality targets and are striving to achieve climate neutrality by the middle of this century. Hydrogen-related technologies will play a key role in this endeavour, particularly for decarbonising hard-to-electrify industrial processes, such as steel production, and long-distance transport, including aviation and maritime shipping. Additionally, hydrogen can be used as a potential storage medium for renewable electricity to stabilise future electricity systems that will be dominated by variable renewable energy (IEA 2019). Moreover, these areas of application are not only key to achieving climate neutrality, they are also linked to prospects for new industrial value creation and related employment opportunities.

The deployment of hydrogen must go hand in hand with a rapid expansion of renewable energy, however. Hydrogen demand in the EU and Germany is projected to exceed domestic production capacities. In 2050, Germany is likely to consume an estimated 400 to 800 TWh of hydrogen and synthesis products (Wietschel et al. 2021). This amounts to two to four times the current renewable energy generation in Germany, which stood at 234 TWh in 2021 (BMWK, 2022c). After 2040, imports from both EU and non-EU countries are therefore expected to become the leading source of hydrogen supply for hydrogen in Germany (BMWK 2020; Wietschel et al. 2021). Simultaneously, the EU's REPower Plan targets the production of 10 million tonnes of domestic hydrogen production and an equivalent amount of imports by 2030 (EC 2022c).

To realise these goals, both the European and the German hydrogen strategies envisage strategic technology and energy partnerships with other regions that offer favourable conditions for the production of renewable hydrogen (BMWK 2020; EC 2020). However, the development of such partnerships faces important challenges and has implications that extend far beyond the hydrogen sector. The development of an international hydrogen economy will reshape the global energy landscape and affect broader economic relations and related spheres of geopolitical influence (IRENA 2022b). Moreover, these developments are taking place against the background of major geopolitical realignments, caused by the increasing geoeconomic competition with China and the Russian invasion of Ukraine. Indeed, the latter has led the EU to announce a major increase in its hydrogen ambitions as part of its strategy to reduce its dependence on Russian natural gas (EC 2022c). This in turn raises questions regarding the development of new dependencies and vulnerabilities within an emerging hydrogen economy.

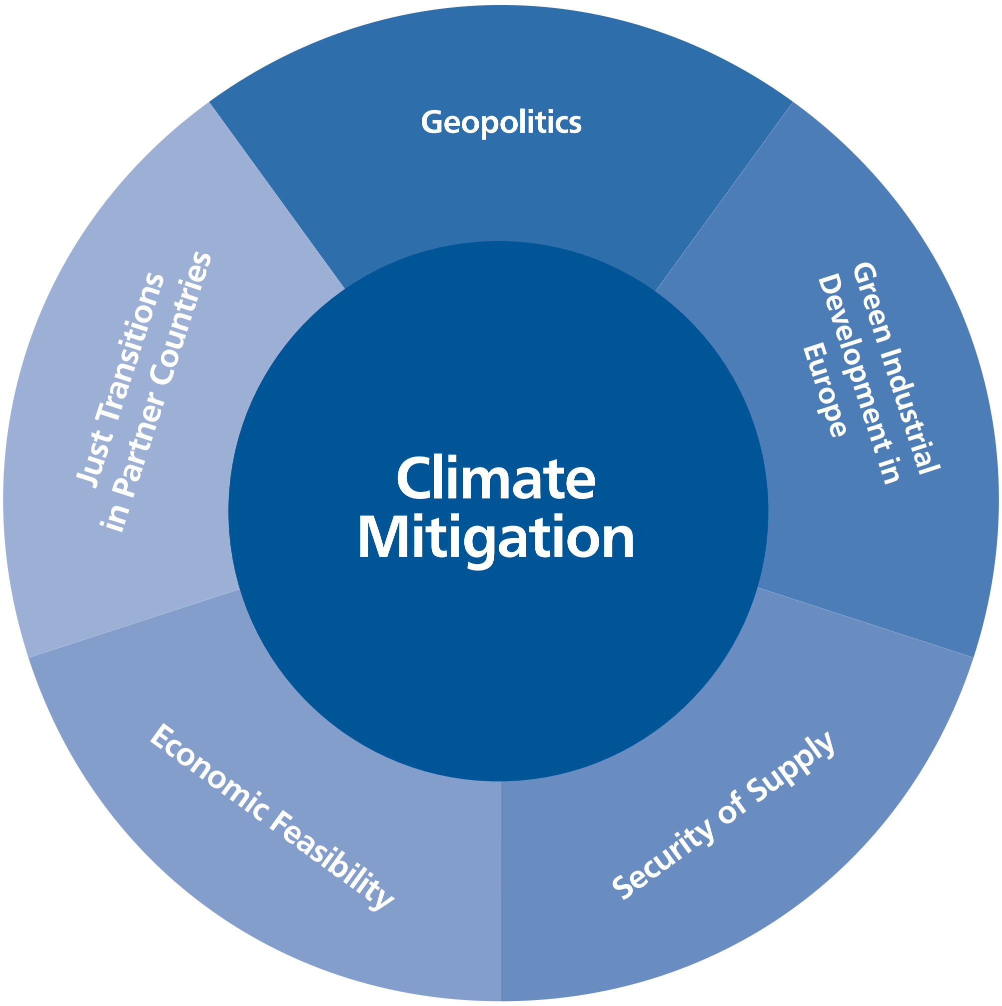
Against this background, this paper discusses the most important questions and challenges for the promotion of international cooperation between the EU and potential international partners within an emerging hydrogen economy. On this basis, it identifies entry-points for related policy action. Specifically, the paper proposes a framework consisting of six policy dimensions that European policymakers should consider when developing and supporting international partnership development. Taking these six dimensions as its starting point, the paper presents a set of nine policy messages for developing an international hydrogen economy within the context of broader decarbonisation efforts in the EU. ←

2
INTERNATIONAL COOPERATION IN AN EMERGING HYDROGEN ECONOMY: KEY DIMENSIONS FOR POLICY DEVELOPMENT

In the following, we outline six basic policy dimensions (see Figure 1) that in our view European policymakers should consider when engaging in the development of international partnerships within the emerging hydrogen economy: climate mitigation, green industrial development in Europe, just transitions in partner countries, geopolitics, security of supply, and economic feasibility. These six dimensions and related policy objectives may be mutually reinforcing, but, depending on the context, they may also conflict. Hence, the development of international cooperation involves the challenging task of considering the trade-offs between these dimensions. Each of the six policy dimensions and their relevance for international cooperation in the field of hydrogen are outlined briefly below.

FIGURE 1

Key policy dimensions for developing international partnerships within the emerging hydrogen economy



Source: Authors.

CLIMATE MITIGATION

Climate mitigation is the central motivation and driver for the development of a hydrogen economy. Thus, it is intentionally placed at the centre of Figure 1. The central aim of international cooperation on hydrogen should be to reduce global greenhouse gas emissions. Related investments in hydrogen production and trade should offer a tangible contribution to achieving the Paris Agreement. In this vein, it is important to acknowledge that the direct use of renewable energy in the power sector offers significantly higher reductions of greenhouse gases (GHG) than when converted into renewable hydrogen and deployed for the decarbonisation of end-use sectors in transport, heating or industry (Ueckerdt et al. 2021). From a short-term perspective and in the absence of a fully decarbonised power sector, the direct use of renewable power represents a more effective climate mitigation option.

Nonetheless, there is a rationale for investments in renewable hydrogen production today, despite the fact that the power supply in most countries still relies heavily on fossil-based electricity generation. Renewable electricity cannot be employed directly for the decarbonisation of a number of end-use sectors. Particularly in a number of energy-intensive industries, hydrogen is therefore essential for achieving climate neutrality in the long-term (Committee on Climate Change 2018). This in turn requires a long-term process of innovation and industrial development to enable the production of renewable hydrogen at the required scale and cost, and to develop the necessary market and transport infrastructure for trading it internationally (IAP UNIDO 2022).

In addition, even if overall renewable shares are still woefully insufficient overall, there may be regions with high shares of renewable power that enjoy a surplus of electricity during times of high resource availability. Because of lags in the development of sufficient grid infrastructure, this may mean that extra capacity could be utilised for hydrogen production without affecting power sector decarbonisation (Kalpin et al. 2021). In certain instances, hydrogen production could even function as a storage medium to balance volatile renewable resources (IRENA 2019). Furthermore, in countries or regions with only incipient renewable power development, foreign-supported investments in renewable hydrogen production may indeed provide added impetus for the deployment of renewables (ESMAP 2020). It may catalyse initial investments and support capacity-building and institutional development, with positive spillovers for the sector.

In conclusion, climate mitigation provides the core rationale for investment in renewable hydrogen production. Hence, investments in renewable power for this purpose should not undermine climate mitigation efforts. Whether this is the case depends on local infrastructure conditions, as well as the broader development of the sector and its institutional environment. It is essential that international efforts take these different aspects into consideration when designing and implementing support schemes in an emerging hydrogen economy.

GREEN INDUSTRIAL DEVELOPMENT IN EUROPE

European green industrial policy objectives represent another critical dimension in the pursuit of global hydrogen partnerships. This includes the ambition to build a competitive electrolyser industry, as well as securing European value creation in future climate-neutral industrial sectors. The former involves the promotion of European technology suppliers, both domestically and in those countries and regions with high potential for investment in renewable hydrogen. Increasingly, this hinges on the question of financing (Tagliapietra and Veugelers 2020). Not only Chinese firms but also firms from the United States, the Middle East and other Asian economies have been strongly supported by favourable export financing arrangements to facilitate investment and exports in both the traditional and the clean energy sectors. The EU and its Member States have yet to develop similarly favourable financing approaches, putting European suppliers at a disadvantage in this regard (ExFiLab 2021).

At the same time, securing value creation in future, climate-friendly industrial sectors is strongly linked to securing access to climate-friendly hydrogen, as well as renewable electricity at competitive prices (EPRS 2021). Given the relative scarcity of land for the deployment of renewables in Europe, this means building supply partnerships for these energy resources. It could, however, also involve the development of new relationships for the supply of other intermediate products, such as renewable naphtha as the basis for future chemical production or so-called direct-reduced iron for climate-friendly steel production (Quitzow et al. 2022).

JUST TRANSITIONS IN PARTNER COUNTRIES

The European green industrial policy ambitions stand side by side with corresponding objectives in potential partner countries. This raises questions regarding the distribution of costs and benefits between producers and users of renewable hydrogen. While the production of renewable hydrogen may offer substantial export revenues, it also comes with a substantial environmental impact (Ullman and Kittner 2022). This in turn raises questions of global economic and environmental justice and potentially exploitative relationships of economic exchange (Quitzow et al. 2022). Related to this, potential hydrogen suppliers may be less interested in the export of hydrogen as a primary good than in the development of more sophisticated hydrogen-based supply chains. These questions of global justice and local socio-economic development goals are being addressed within the framework of a "just transition" (Newell and Mulvaney 2013). Like the transition to climate neutrality more broadly, investments in hydrogen production and the export of hydrogen and hydrogen-based products will be contingent on realising credible just-transition processes in partner countries (Kalt and Tunn 2022).

SECURITY OF SUPPLY

The invasion of Ukraine and the escalating conflict between Russia and the West have demonstrated with great force that stable supply relationships and liberalised energy markets based on economic competition cannot be taken for granted (Quitzow et al. 2022). The tense relations with Morocco, one of Europe's closest partners in the sphere of clean energy development, resulting from the conflict in the Western Sahara further illustrate this point (Reyes 2022). Clearly, this cannot be ignored in the development of new energy relationships for a future climate-neutral economy and specifically hydrogen trade. It implies the need for diversification of supply relationships and transport routes to support the security of future hydrogen supply (Wietschel et al. 2022).

GEOPOLITICS

Russia's invasion of Ukraine has also highlighted the close relationship between energy security and geopolitics. However, geopolitics goes beyond questions of energy security. The development of partnerships in the hydrogen sector will not only reshape the global energy landscape, but will affect broader economic relations and related spheres of geopolitical influence and levers in the long term. Moreover, the transition to climate neutrality will create disruptive changes that may cause turbulence and conflicts in the affected countries and regions (Bazilian et al. 2019). Both require consideration in an effort to ensure geopolitical stability and maintain and strengthen Europe's global influence in support of its values and interests. For instance, production of hydrogen and its derivatives may represent an entry-point for maintaining stability in fossil-fuel exporting countries, offering possible avenues for economic diversification (IRENA 2022b). More generally, hydrogen diplomacy may offer opportunities for strengthening relationships with strategic and like-minded partners in an effort to promote European values and interests abroad.

On the other hand, hydrogen production based on renewable electricity requires land in order to install renewable energy systems, as well as water for electrolysis. In many water-stressed, rural economies, hydrogen production has the potential to increase the conflict around land and water (Herold et al. 2021). Finally, the race for leadership in climate-friendly technologies is likely to intensify in the coming years, leading to heightened competition over technological know-how, as well as critical resources for the development of hydrogen-based supply chains (IRENA 2022b). As Europe, the United States and China compete for leadership in this field, this will involve building strategic partnerships with resource-rich countries, while promoting a favourable climate for innovation and industrial development.

ECONOMIC FEASIBILITY

Last but not least, the question of economic feasibility and efficiency remains a fundamental criterion for investments in hydrogen-related infrastructure. However, this criterion is also very difficult to assess because market development is in its early stages and there is a high level of uncertainty (Odenweller et al. 2022). The two largest cost components in renewable hydrogen production are renewable electricity and electrolysis facilities (IRENA 2020). Costs for renewable electricity have seen steep declines over recent decades. The cost of electrolysis and related equipment are in the early stages of industrial development and face much greater uncertainty. While experts agree that cost reductions will be forthcoming as manufacturing capacity is expanded, timescales remain uncertain (Christensen 2020). Among other things, it is unclear at what pace the needed scaling-up of production capacity will occur. Added to this are other cost factors beyond electricity and equipment, including transport, system integration of renewable hydrogen, the broader regulatory framework of the power sector, as well as the cost of capital (Odenweller et al. 2022). Finally, cost estimates provide a somewhat artificial picture of developments in a market environment, where both supply and demand variables remain uncertain (Dos Reis 2021). This is already playing out in the current gas crisis. Increasing gas prices have also driven up the cost of producing so-called blue hydrogen based on natural gas with carbon capture and storage (CCS) technologies (Tillier 2021). This has fundamentally altered the calculus for investments in blue hydrogen, especially in Europe. As markets start to take shape, developing insights into market prices will be essential. ←

3 KEY POLICY MESSAGES FOR THE DEVELOPMENT OF INTERNATIONAL HYDROGEN COOPERATION

Based on the six dimensions outlined above, the remainder of this paper proposes a series of more specific implications for the development of hydrogen partnerships between the European Union and international partners. These are captured in the form of nine messages.

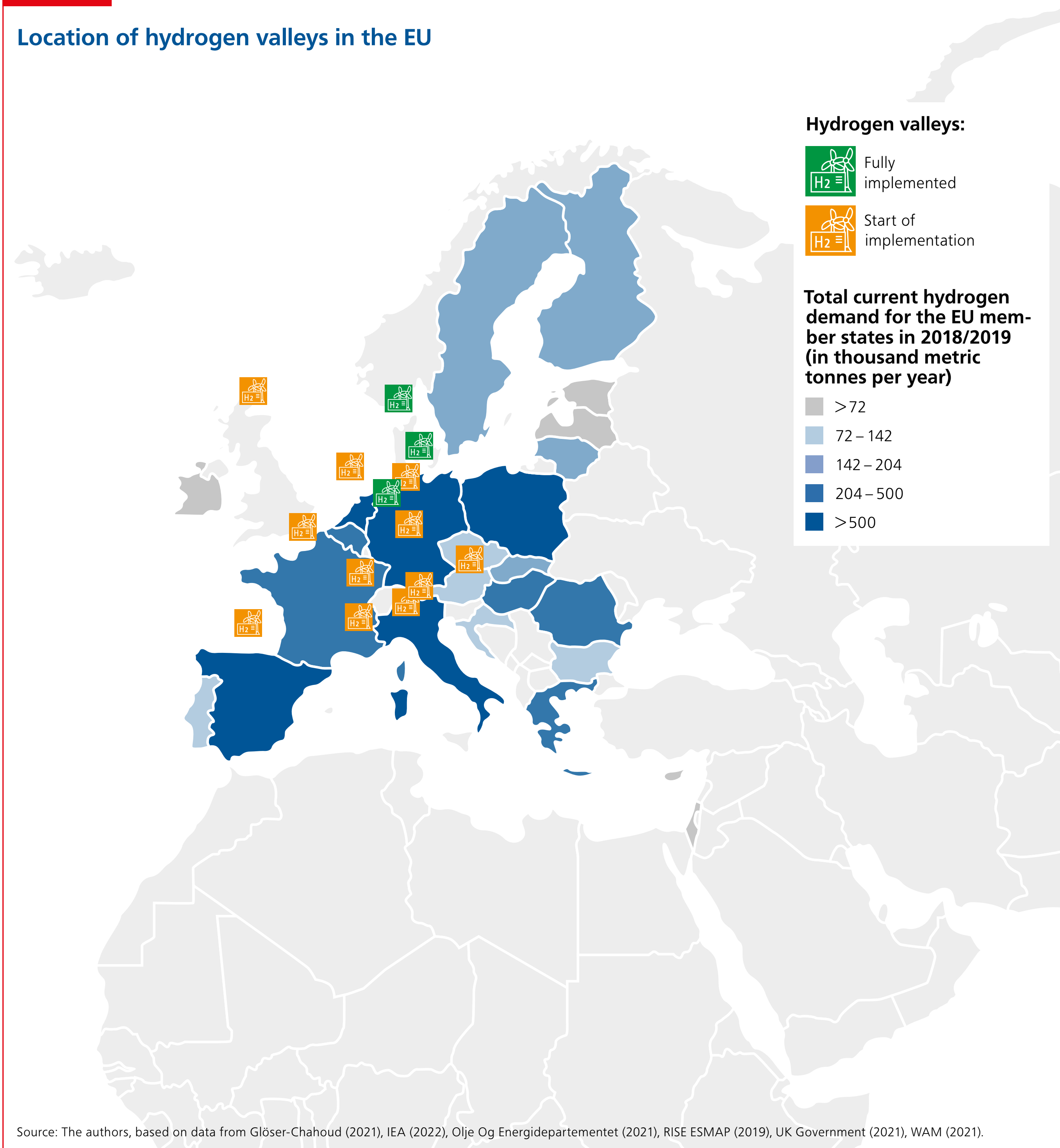
MESSAGE 1
PREFERENCE SHOULD BE GIVEN TO RENEWABLE HYDROGEN CAPACITY DEVELOPMENT IN THE EUROPEAN UNION AND ITS IMMEDIATE VICINITY

The development of hydrogen production capacities in the European Union and in its immediate vicinity has clear advantages that should not be underestimated. First, hydrogen supply within the European Union and its immediate vicinity has important advantages from a security of supply perspective. While this goes without saying for countries within the EU, also those in its immediate vicinity are less likely to abandon the EU market for other buyers. This should not lead to an unbalanced dependence on single suppliers or transport routes. However, a base of regional suppliers can build a robust core, to be supplemented with suppliers from farther afield.

Moreover, partners from the European neighbourhood should be integrated into regional hydrogen production clusters. This will act as an incentive for industrial actors to invest in a new generation of climate-neutral industrial processes (Witecka et al. 2021). The idea of hydrogen valleys, or clusters, is to identify areas with a high renewable energy potential that are also attractive locations for an industry pursuing decarbonisation. This would reduce the cost of renewable hydrogen by ensuring a high load factor for electrolysers and match hydrogen supply with the demand generated by the industrial off-takers located onsite (Petrollese et al. 2022). If the EU can develop such hydrogen valleys in high potential areas within the EU, these can become the nuclei for partnerships with nearby suppliers. The region around the North and Baltic Sea stands out as such a region in Northern Europe, where EU countries along with Norway, the United Kingdom and Iceland could emerge as such an industrial zone (Simonyi and Svendstorp 2022). Similarly, the Iberian Peninsula with its existing electricity trade with Morocco could be the starting point for such a development (Nuñez-Jimenez and De Blasio 2022).

FIGURE 2

Location of hydrogen valleys in the EU



Source: The authors, based on data from Glöser-Chahoud (2021), IEA (2022), Olje Og Energidepartementet (2021), RISE ESMAP (2019), UK Government (2021), WAM (2021).

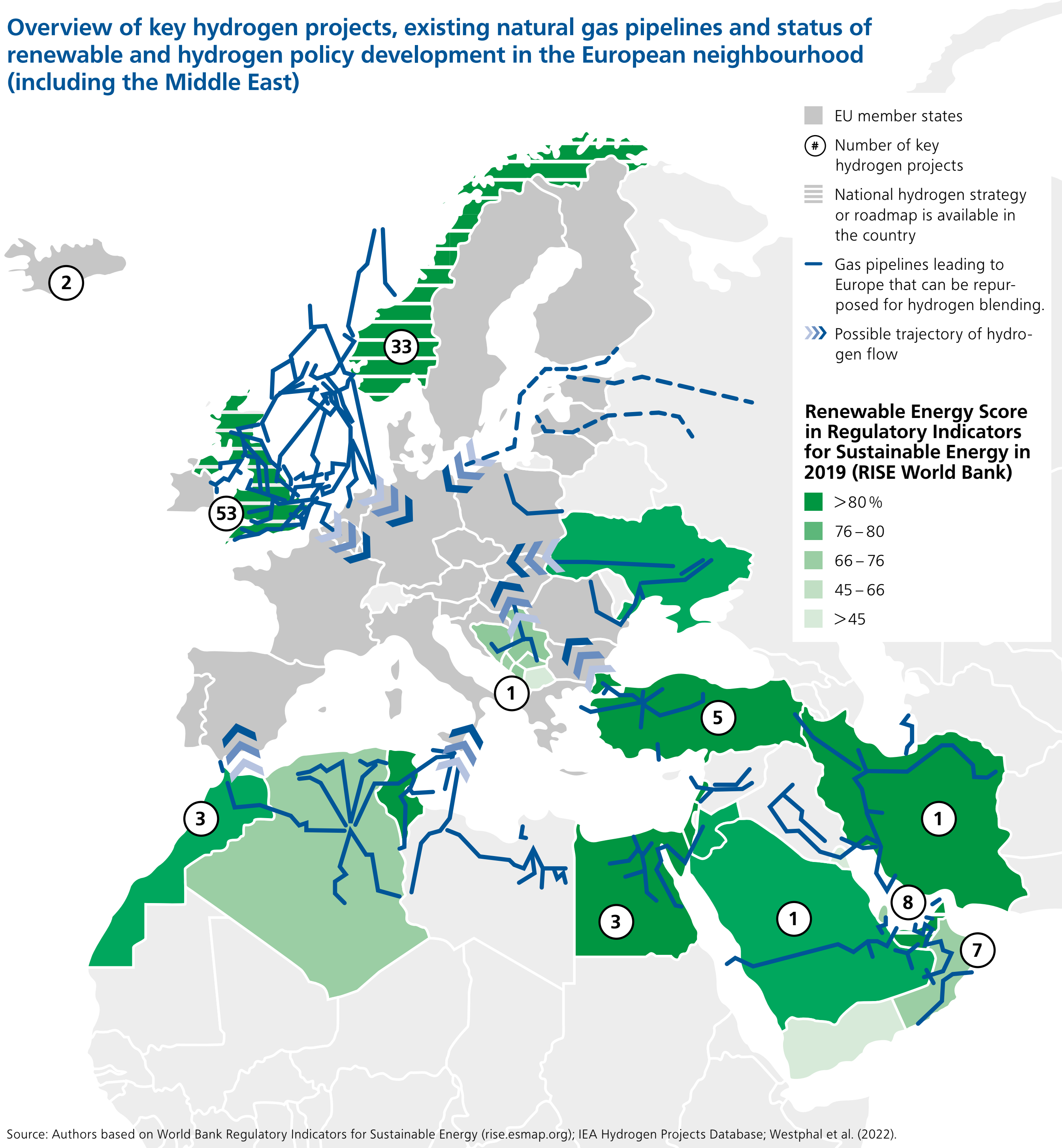
MESSAGE 2
THE EU NEEDS A HYDROGEN PIPELINE INFRASTRUCTURE, INCLUDING INTERCONNECTIONS BETWEEN SPAIN AND FRANCE, FOR TRADE AMONG MEMBER STATES AND WITH THE EUROPEAN NEIGHBOURHOOD, AS WELL AS SHIPPING TERMINALS TO DIVERSIFY IMPORTS

A European hydrogen pipeline infrastructure will be essential not only for Member States with large renewable energy potential to supply demand centres in other parts of the EU (IRENA 2022a). It is also important for enabling the supply of hydrogen from the EU's northern, southern and eastern neighbourhood. During the first stage of development, the focus should be on supplying areas with high industrial demand, such as refineries, as well as the steel, ammonia and chemical industries, which can serve as reliable, large-scale off-takers (Agora 2021). In this context, it will also be important to develop interconnections between the Iberian Peninsula and France. This will be important, not only for providing an export route for supplying demand centres in Central and Western Europe with hydrogen from Spain and Portugal, but for enabling cost-effective imports from Europe's southern neighbourhood (see Figure 3).

A regional pipeline network will be one important avenue for supplying European demand centres with low-cost hydrogen from within the EU and its immediate neighbourhood. Infrastructure for imports via shipping routes from more distant locations, such as North America or Africa, will offer additional security of supply (HBS 2022). As the current gas crisis has shown, the availability of alternate supply routes can become critical in the case of disruptions in regional supply. They also weaken suppliers' political leverage by reducing asymmetric dependencies (IEC 2022c). To support diversification, it will be essential to equip major European ports for handling hydrogen and hydrogen-based synthetic fuels. This would involve investing in hydrogen conversion and reconversion plants and storage facilities and the development of partnerships and demonstration projects similar to those pursued by the Port of Rotterdam in its ambition to become a major European hydrogen hub (Port of Rotterdam 2022).

FIGURE 3

Overview of key hydrogen projects, existing natural gas pipelines and status of renewable and hydrogen policy development in the European neighbourhood (including the Middle East)



Source: Authors based on World Bank Regulatory Indicators for Sustainable Energy (rise.esmap.org); IEA Hydrogen Projects Database; Westphal et al. (2022).

MESSAGE 3
REGIONAL TRADE IN HYDROGEN SHOULD NOT REPLACE AMBITIONS TO INCREASE ELECTRICITY TRADE WITH COUNTRIES IN THE EUROPEAN NEIGHBOURHOOD BUT SHOULD COMPLEMENT IT

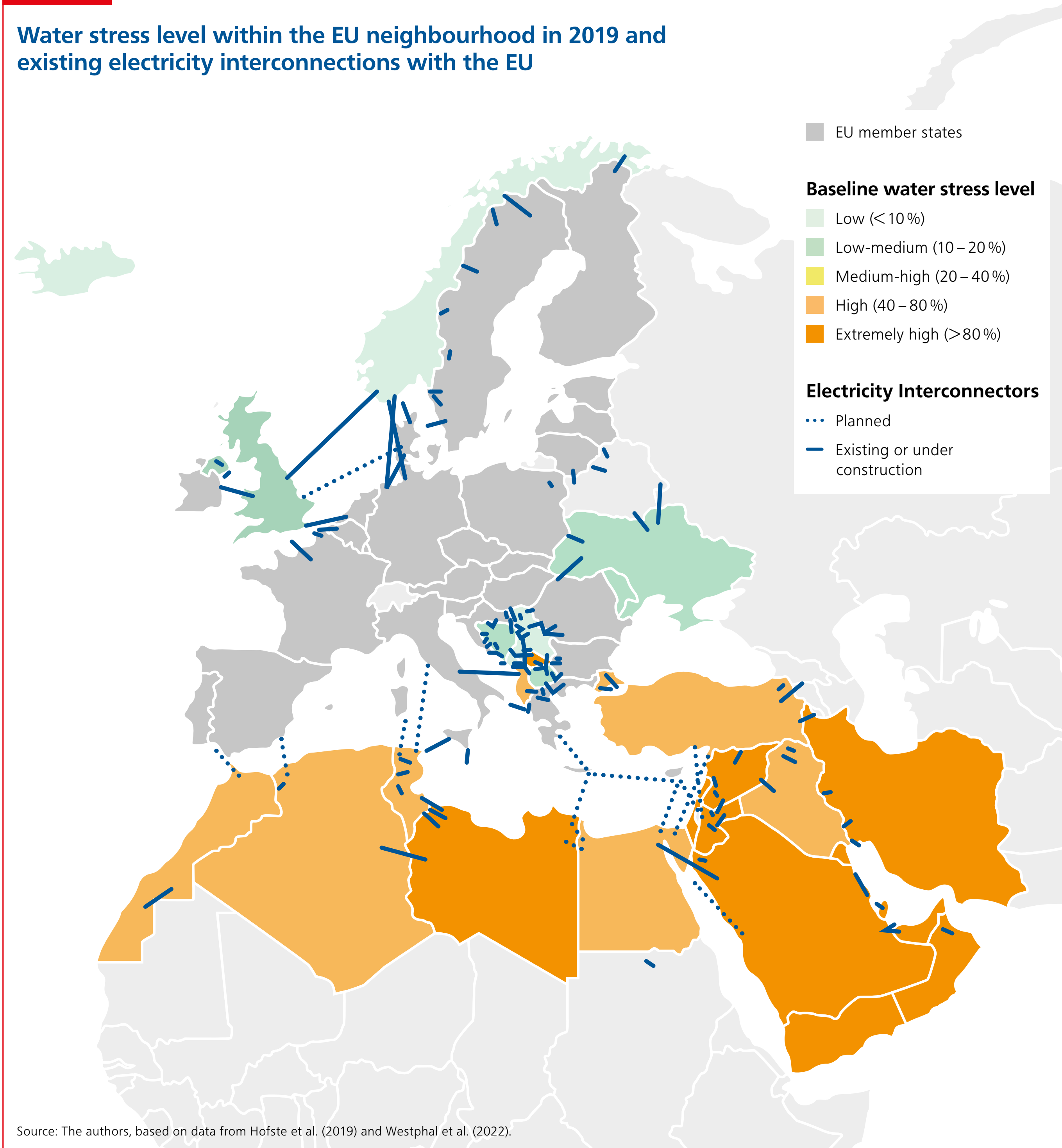
Current discussions on an emerging hydrogen economy and related policy developments appear to have sidelined previous discussions on increased integration of electricity systems both within the EU and between the EU and its neighbours. While renewable electricity production has steadily increased in the EU over recent years, interconnection capacity has not (Pepermans 2018). The EU has set a goal of achieving a 15 per cent interconnection rate by 2030, meaning that each Member State should have the infrastructure in place to allow at least 15 per cent of the electricity produced on its territory to be transported across its borders to neighbouring countries (EC 2022b). Increased interconnections within the EU and with neighbouring countries provide the basis for increased electricity imports with benefits for balancing variable renewable energy sources. This in turn would reduce overall energy system cost in Europe, with positive effects for the cost of domestic hydrogen production. Electricity imports could also benefit security of supply, which is increasingly affected by climate change. Severe heat waves may decrease electricity production from hydropower plants or reduce the availability of water for cooling nuclear reactors, as is currently the case in France (Linnerud et al. 2011; Pechan and Eisenack 2014). Lastly, the water requirements for electrolysis may act as a constraint on renewable hydrogen production in water-stressed regions, such as parts of North Africa. This may make electricity trade an attractive supplementary export route in some cases (see Figure 4).

Electricity grids also have an oft-neglected geopolitical dimension. They can function as a distinct realm of integration and may be used as channels of influence (Westphal, Pastukhova and Pepe 2022). Ukraine is a case in point: for years, it had been preparing to disconnect from the Russian-operated electricity network in favour of the European grid. Shortly after the invasion in February 2022, in which Ukraine's energy infrastructure was directly targeted, Ukraine fully disconnected from the Russian grid. In a matter of weeks, the Ukrainian power system was synchronised with the European grid, and in June 2022, Ukraine began exporting electricity to the EU (Blaustein 2022).

In other words, the potential for regional trade in electricity should not be neglected politically. Rather, efforts should be renewed in parallel or possibly even integrated with those aimed at the hydrogen sector. An integrated approach would offer the additional benefit of realising potential synergies (Seck et al. 2022).

FIGURE 4

Water stress level within the EU neighbourhood in 2019 and existing electricity interconnections with the EU



Source: The authors, based on data from Hofste et al. (2019) and Westphal et al. (2022).

MESSAGE 4
PARTNERSHIPS FOR THE PROMOTION OF HYDROGEN TRADE NEED TO BE EMBEDDED IN BROADER GREEN INDUSTRIAL DEVELOPMENT PARTNERSHIPS AIMED AT SUPPORTING SOCIO-ECONOMIC DEVELOPMENT AND DECARBONISATION OF THE PARTNER ECONOMY

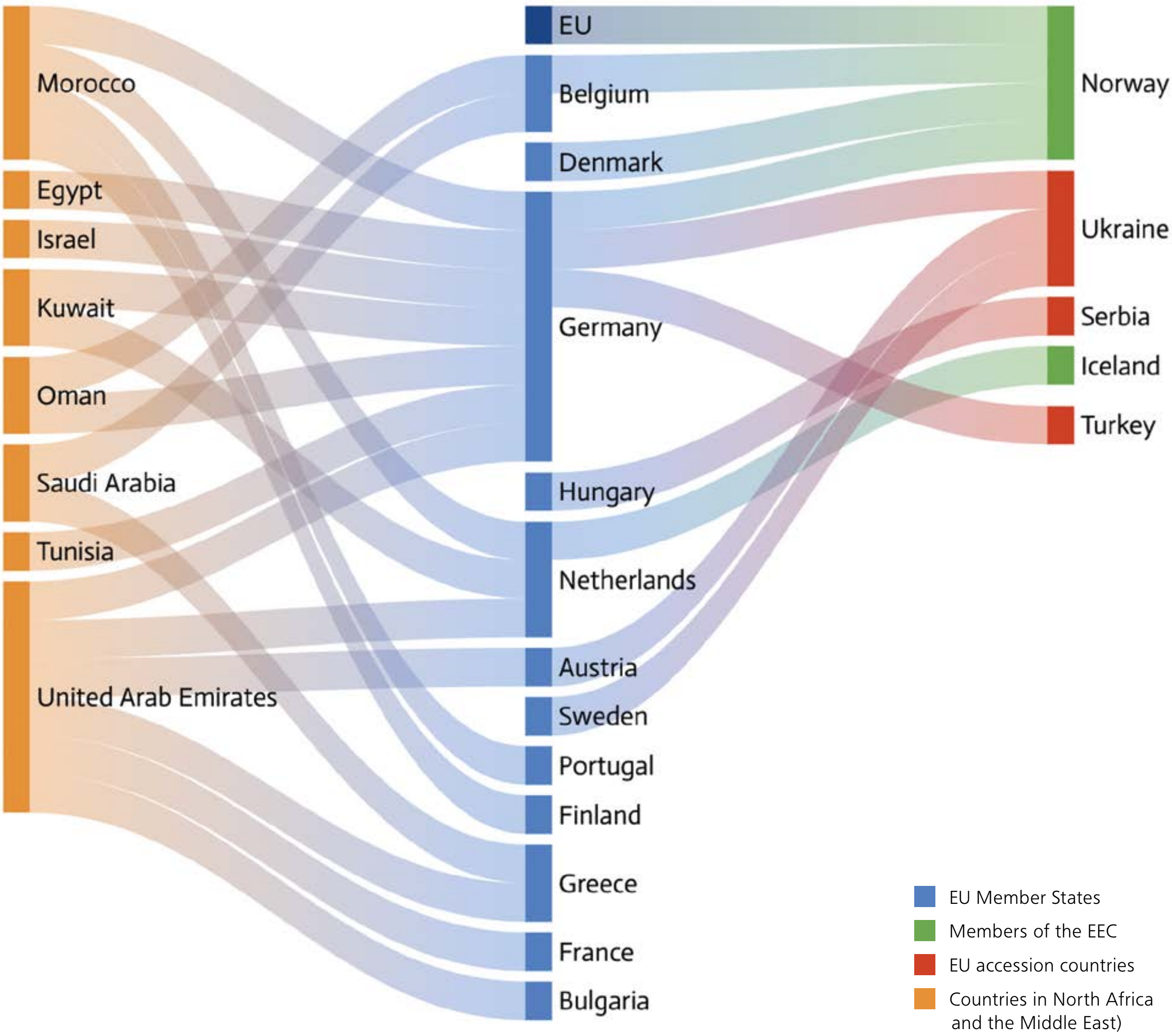
Partnerships for promoting hydrogen trade between potential producer countries and the EU will be successful only if embedded in broader green industrial partnerships aimed at supporting decarbonisation and socio-economic development in both the EU and partner countries (see Figure 5 for an overview of emerging hydrogen partnerships in the European neighbourhood). To begin with, it is uncertain whether African and Middle Eastern countries are interested in developing partnerships focused primarily on the supply of renewable hydrogen and other raw materials for the decarbonisation of the European industrial system. Rather, it appears that the most tangible efforts at promoting investment in renewable hydrogen projects have been launched with domestic value-creation in mind. Countries such as Morocco and Egypt, for instance, have supported investments in renewable hydrogen supply as the basis for the production of green ammonia, seeking to position these countries as producers and potential exporters of climate-friendly fertilisers (Nweke-Eze and Quitzow et al. 2022). Similarly, zero-carbon direct reduced iron (DRI) could be produced with renewable hydrogen directly at electrolysis sites and become a globally traded commodity (Gielen et al. 2020; Trollip et al. 2022). Namibia is considering this among a number of options to utilise its large potential for renewable hydrogen production to support local industrial development (Creamer 2022).

The development of future economic relations will have to take these industrial development ambitions into account. Indeed, such efforts should be welcomed as important stepping stones towards the development of progressively more ambitious climate targets. Experience has shown that the formation of green industrial alliances represents a crucial ingredient in the process of ramping up domestic climate action over time, as foreseen by the Paris Agreement's ambition mechanism (Meckling 2021).

Finally, such broad-based green industrial development partnerships may also be important for strengthening European geopolitical influence in partner countries, while securing the competitiveness of European industry in a future climate-neutral economy. Indeed, it may mean that the import of competitively priced intermediate goods may be the key to supporting the competitiveness of European industrial value chains in the future (Tagliapietra and Veugelers 2021). A narrower focus on hydrogen partnerships may squander opportunities for building mutually beneficial and stable trade relationships.

FIGURE 5

Emerging bilateral hydrogen partnerships between EU Member States and countries in the European neighbourhood



Sources: Official reports, websites and media sources. For details, see endnotes.

MESSAGE 5
SUSTAINABILITY CERTIFICATION SCHEMES ARE NEEDED TO ENABLE THE RAMP-UP OF RENEWABLE HYDROGEN PRODUCTION AND SHOULD PROMOTE INCREASINGLY SUSTAINABLE PRODUCTION PRACTICES OVER TIME

As outlined above, renewable power that is allocated to the production of hydrogen via electrolysis is less effective at mitigating climate change than its allocation to the power sector. Hence, arguably, renewable hydrogen production that slows down decarbonisation of the power sector in producer countries will also slow down overall reduction of GHG emissions. Moreover, the production of renewable hydrogen has local environmental impacts, most notably by increasing pressure on local land and water resources. If not managed appropriately, these local environmental impacts may translate into significant negative impacts on local populations (Herold et al. 2021).

For these reasons, there is widespread consensus that international hydrogen trade requires robust sustainability certification schemes. Indeed, they are likely to represent a precondition for the public acceptance of policies in support of hydrogen-based decarbonisation schemes (ILF and LBST 2021). The examples of international biofuel trade and the import of biofuels based on palm oil in particular have shown how the lack of credible sustainability standards may lead to the erosion of public acceptance and reduced policy support over time (Oosterveer 2020). At the same time, there are concerns that adherence to sustainability standards will slow down the needed ramp-up of renewable hydrogen production. This dilemma cannot be resolved entirely. However, a phased approach to the implementation of sustainability certification schemes could offer an entry-point for enabling the needed scale-up of investment, while ensuring that sustainable production practices are established over time (Climate Bonds 2022). This would involve the gradual ramping up of sustainability criteria, while supporting learning and innovation among value chain stakeholders. This is a common approach in voluntary sustainability certification schemes that could be adapted for a regulated hydrogen market (ISEAL 2014).

MESSAGE 6
THE EU NEEDS TO DEVELOP JOINT PRINCIPLES FOR ITS HYDROGEN FOREIGN POLICY

The development of international trade in hydrogen requires major investments in infrastructure for the production and transport of hydrogen. This in turn depends on clear and credible policy signals to provide the needed certainty for investment (Vijayakumar et al. 2022). Moreover, in early phases of market development, public financing will be needed to crowd-in private investors. Partnerships between potential importers and exporters of hydrogen and related products will have to be established for the creation of the needed policy framework and financing. Ideally, such partnerships should be embedded in a common EU foreign policy for climate and energy, including hydrogen. While partnerships may be driven by individual Member States, they should build on common principles and seek to actively coordinate their approach within the EU (EEAS 2022).

In the absence of such an EU approach, different Member States may send contradictory signals to respective partner countries. Indeed, differing economic stakes in the hydrogen economy across EU Member States have already begun to undermine the development of such a common approach to promoting an international hydrogen economy. Notably, France has pursued a strategy that prioritises domestic hydrogen production based on renewables and nuclear energy, while Germany has prioritised a combination of domestic and foreign renewable hydrogen supply, though it has also agreed to import blue hydrogen (produced from natural gas in combination with CCS technologies, see message 9 for more details). This weakens the attractiveness of the EU market and hence its ability to influence global standards for hydrogen trade. While overcoming such differences may not be easy, this should be an important goal of EU-level hydrogen policy. In the absence of such an agreement, a second-best option would be a common approach among a group of like-minded countries.

MESSAGE 7
THE EU SHOULD SEEK TO ALIGN ITS PROMOTION OF A GLOBAL HYDROGEN ECONOMY WITH THE UNITED STATES AND OTHER G7 COUNTRIES

Cooperation within the G7 is increasing in importance to confront a range of challenges posed by heightened geoeconomic rivalry with China and Russia. This also applies to activities aimed at promoting a global hydrogen economy and for developing related markets, infrastructure and industrial supply chains (Germanwatch 2022; Renseen 2020). While the EU wields significant market power that it can deploy to promote international standards, a joint approach across G7 economies would significantly augment the weight of these standards. In this vein, the various G7 initiatives, such as the G7 Industrial Decarbonisation Initiative, the G7 Hydrogen Action Pact and the Climate Club initiative, represent important steps in this direction that should receive strong support from the EU and the European G7 countries (G7 Germany 2022). Of course, this also implies compromise with G7 partners. In particular, questions related to the role of blue hydrogen (that is, the production of hydrogen from natural gas in combination with CCS) and technologies for carbon capture, use and storage (CCUS) more broadly may reveal divergent interests across G7 countries (IEA 2022).

It is, however, in the interest of the EU to find compromise within the G7 on these issues to retain its influence on global developments in this sphere. Given the strong interest of a range of potential hydrogen suppliers in CCUS technologies, this will constitute an important dimension of global climate policy, as well as a future climate-neutral economy (G7 Germany 2022).

MESSAGE 8
IN PURSUIT OF THEIR HYDROGEN PARTNERSHIPS, EUROPE AND GERMANY NEED TO ACTIVELY TACKLE THE CHALLENGING QUESTIONS RELATED TO "BLUE HYDROGEN" AND, IN THIS CONTEXT, ALSO CCS

Germany's Hydrogen Strategy emphasises imports of renewable hydrogen. As a transitional solution, however, it also mentions "CO2-neutral" hydrogen, which includes hydrogen production based on natural gas in combination with CCS (also known as "blue hydrogen"). CCS technologies, however, have yet to be deployed at industrial scale with levels of CO2 capture and storage that would be needed to meaningfully reduce GHG emissions (Brandl et al. 2021; Martin-Roberts et al. 2021). Nevertheless, emerging hydrogen partnerships, such as Germany's partnerships with the UAE and Norway, have acknowledged that blue hydrogen is expected to play a major role in planned hydrogen imports from these countries (BMWK 2022a; BMWK 2022b).

Against this background, it is essential that Germany and the EU clarify the conditions under which blue hydrogen and thus CCS should in fact be part of their pathways towards climate neutrality. First, this means establishing a benchmark for the maximum level of GHG emissions per unit of fossil-based hydrogen, along with a standardised approach for its measurement and verification. A certification system for assessing the greenhouse gas footprint of so-called "low-carbon hydrogen", which includes hydrogen from natural gas with CCS, was passed in December 2022 within the context of the EU's Hydrogen and Decarbonised Gas Market Package. It will be critical to create the conditions for its effective application both in the EU and in potential partner countries. This implies that EU Member States, including Germany, will have to (re)engage actively in discussions on CCS and its role as a climate mitigation technology. Indeed, the relevance of this debate goes beyond the hydrogen sector. For industries such as cement, CCS will be vital for mitigating residual CO2 emissions (Strunge et al. 2022; CEMBUREAU 2020).

In addition, imports of blue hydrogen require engagement with partner countries to ensure the capture and large-scale, safe geological storage of CO2, as well as the highest possible standards for natural gas production and transport to avoid methane leaks (Tovar and Azadegan 2022; Filiou et al. 2003; Floristean and Brahy 2019). This should be the precondition for any imports of blue hydrogen. Moreover, to be successful, this also means engaging actively in processes to shape related international standards. Finally, the EU will have to define how long it will use blue hydrogen as a bridge fuel before it switches exclusively to renewable hydrogen and, in consequence, a phase-out strategy for blue hydrogen on its pathway towards climate neutrality.

MESSAGE 9
THE USE OF HYDROGEN-BASED SYNTHETIC FUELS WILL REQUIRE INTERNATIONAL COOPERATION AND DIALOGUE FOR THE SUSTAINABLE DEPLOYMENT OF TECHNOLOGIES FOR CARBON CAPTURE AND TRANSPORT

If increased hydrogen imports are to unfold their mitigation potential in hard-to-electrify segments of the transport sector (such as aviation), an infrastructure for synthetic fuels will have to be developed. Synthetic fuels are a form of carbon capture and utilisation (CCU) with varying GHG mitigation potential, depending on how they are produced. In general, they are produced in an energy-intensive process on the basis of hydrogen and CO2 (Ferrari et al. 2014). Under the condition that only renewable energy is used in the entire production process and the CO2 used stems from Direct Air Capture (that is, CO2 captured directly from the atmosphere) or from biomass (Olfe-Kräutlein 2022), synthetic fuels can avoid the release of additional fossil-based CO2 emissions and contribute to climate neutrality. If residual CO2 emissions from industrial point sources (for example, the cement industry) are used to produce synthetic fuels, this form of CCU avoids additional CO2 emissions but is not compatible with climate-neutrality goals, unless compensated by negative emissions technologies elsewhere.

Synthetic fuels have the potential to start replacing jet fuels or diesel within the next decade (The Royal Society 2019). This will require the swift establishment of a CO2-related infrastructure for CO2-capture and transport (Billig et al. 2019). Similar to the case of blue hydrogen, this should build on an informed public debate to ensure the compatibility of these CO2-related technologies with climate-neutrality targets. Moreover, policies will need to support technological upscaling and commercialisation (Beck 2021). The process launched by the German federal government to develop a Carbon Capture, Utilisation and Storage (CCUS) strategy is an important step in this direction (Hanke, 2022). Both the strategy and emerging hydrogen partnerships will also have to address the challenges of deploying a CO2-related infrastructure along with corresponding standards and regulations for ensuring desired emission reductions in potential partner countries (Chauvy and De Weireld 2020). ←

LIST OF ABBREVIATIONS

BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
BMWK	Bundesministerium für Wirtschaft und Klimaschutz (Federal Ministry for Economic Affairs and Climate Action
CCS	Carbon capture and storage
CCUS	Carbon capture, use and storage
CCU	Carbon capture and utilisation
CHP	Clean Hydrogen Partnership
DRI	Direct reduced iron
ESMAP	Energy Sector Management Assistance Program
EEAS	European External Action Service
EPRS	European Parliamentary Research Service
FES	Friedrich Ebert Foundation
GHG	Greenhouse gases
HBS	Heinrich-Böll-Stiftung
IAS-UNIDO	Industrial Analytics Platform – United Nations Industrial Development Organization
IPCC	Intergovernmental Panel on Climate Change
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISEAL	International Social and Environmental Accreditation and Labelling
RISE	Regulatory Indicators for Sustainable Energy
TWh	Terawatt hour
RIFS	Research Institute for Sustainability – Helmholtz Centre Potsdam

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This paper discusses the key questions and challenges for promoting international cooperation between the EU and potential international partners within an emerging hydrogen economy. On this basis, it identifies entry-points for related policy action. Specifically, it outlines six policy dimensions that European policymakers should consider when developing international partnerships within the emerging hydrogen economy: climate mitigation, green industrial development in Europe, just transitions in partner countries, geopolitics, security of supply, and economic feasibility. Taking these six dimensions as its starting point, the paper presents nine policy messages for the development of an international hydrogen economy within the context of broader decarbonisation efforts in the EU.

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