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Risky Business? Evaluating Hydrogen Partnerships Established by Germany, The Netherlands, and Belgium

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Abstract: Following the introduction of the EU's Hydrogen Strategy in 2020 as part of the European Green Deal, some EU member states have deployed a very active hydrogen diplomacy. Germany, The Netherlands, and Belgium have been the most active ones, establishing no less than 40 bilateral hydrogen trade partnerships with 30 potential export countries in the last three years. However, concerns have been voiced about whether such hydrogen trade relationships can be economically feasible, geopolitically wise, environmentally sustainable, and socially just. This article therefore evaluates these partnerships considering three risk dimensions: economic, political, and sustainability (covering both environmental and justice) risks. The analysis reveals that the selection of partner countries entails significant trade-offs. Four groups of partner countries can be identified based on their respective risk profile: "Last Resorts", "Volatile Ventures", "Strategic Gambits", and "Trusted Friends". Strikingly, less than one-third of the agreements are concluded with countries that fall within the "Trusted Friends" category, which have the lowest overall risk profile. These findings show the need for policy makers to think much more strategically about which partnerships to pursue and to confront tough choices about which risks and trade-offs they are willing to accept.

Keywords: energy diplomacy; hydrogen diplomacy; hydrogen partnerships; energy security; import dependence; energy security risks

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1. Introduction

The European Union (EU) envisions renewable hydrogen (this article focuses on renewable hydrogen, which means hydrogen produced via electrolysis of water and renewable electricity) to play a pivotal role in its goal of becoming carbon neutral by 2050 [1]. To achieve this goal, EU member states, such as Germany, The Netherlands and Belgium, explore hydrogen imports to meet the expected domestic hydrogen demand. To facilitate these imports, the EU has articulated an External Energy Strategy, designed to create partnerships with what it terms "*reliable partner countries*" while taking into account the "*social, economic and environmental needs of the export countries*" [2].

At the same time, the changing geopolitical landscape has instilled a heightened sense of caution among countries when it comes to engaging in transnational trade relations and dependencies. In this context, more and more countries show a preference for engaging in partnerships with trusted or friendly countries, a phenomenon dubbed "friend-shoring". Nevertheless, the current landscape of hydrogen partnerships reveals a more nuanced reality, showcasing a spectrum of agreements that have been concluded, with both "friendly" and potentially less "friendly" countries. All of this raises concerns in terms energy security related to these partnerships.

Despite the growing body of literature on hydrogen trade relations and hydrogen diplomacy, existing studies often focus on identifying potential hydrogen trade partners, based on a set of mostly economic and technological criteria. They hardly address the already established partnerships and possible energy security risks. This article aims to fill this gap by evaluating the 40 partnerships concluded between Germany, The Netherlands, and Belgium on the one hand, and 30 prospective hydrogen trade partners, on the other. The assessment covers a comprehensive set of criteria, encompassing economic and technological criteria, but also political and sustainability factors. The central question guiding this analysis is: what are the economic, political, and sustainability risks related to these hydrogen partnerships?

The remainder of this article is structured as follows: Section 2 provides a conceptual framework for hydrogen diplomacy, as well as energy diplomacy more broadly, in order to gain a deeper understanding of the scope, nature, and tools of hydrogen diplomacy. Section 3 employs a content analysis to identify the indicators relevant to establishing secure hydrogen partnerships. Using a multi-criteria analysis, the existing partnerships are then evaluated against these indicators. In Section 4, partner countries are classified based on their performance in the various indicators. Finally, in Section 5, the article assesses the overall energy security implications of the hydrogen partnerships.

2. Hydrogen Diplomacy: A New Form of Energy Diplomacy?

Diplomatic efforts to secure energy resources are not new. Therefore, before diving deeper into hydrogen diplomacy, it is necessary to provide a broader conceptualization of energy diplomacy to understand the overlaps and differences between the two.

2.1. Conceptualizing Energy Diplomacy

While the term "energy diplomacy" is widely used in various academic and non-academic contexts, there is no universally accepted definition of the concept. Instead, scholars have used different terms such as "oil diplomacy" [3,4], "petropolitics" [5], "pipeline politics" [6], or "petroleum geopolitics" [7] to describe diplomatic efforts related to obtaining energy resources. In an attempt to obtain a general definition of energy diplomacy, Goldthau defines energy diplomacy as "*the use of foreign policy to secure access to energy supplies abroad and to promote (mostly bilateral, that is, government to government) cooperation in the energy sector*". In this definition, he considers states as the primary actors of pursuing energy diplomacy and puts forward national security as the main goal [8]. Chaban and Knodt expand the definition by including non-state actors such as international organizations or the EU. Furthermore, they argue that energy diplomacy should consider development and sustainability criteria, in addition to securing access to energy [9]. Barra and Svec provide further insight by differentiating between two forms of energy diplomacy: bilateral energy diplomacy and multilateral energy diplomacy; the latter involves collective diplomacy through international organizations like the International Energy Agency (IEA) or the International Renewable Energy Agency (IRENA) [10].

The concept of energy diplomacy is often used interchangeably with energy governance or energy statecraft. However, there is an important distinction between these concepts in the scholarly literature [9,11–13]. Energy diplomacy is the practice of securing energy resources with foreign policy. In this context, energy dependence is viewed as a political challenge that requires addressing to safeguard national interests [12]. On the other hand, energy governance is closely linked to the energy market [9,12]. It is based on a market-oriented approach, which assumes that energy security can be attained through the market and a well-regulated system with producing countries [12]. Finally, energy statecraft is the use of energy policy tools as instruments of country's foreign policy, this includes, for example, manipulating energy prices or infrastructure for geopolitical reasons [13].

In summary, energy diplomacy is closely intertwined with geopolitics and national security concerns and is, therefore, frequently linked with a nation's foreign or security policies [3]. Bovan et al. see this securitization of energy policy [14,15] as a result of the growing energy demand and (over)dependence of modern consumers on energy resources [16].

2.2. The Energy Diplomacy Toolbox

The toolbox of energy diplomacy is extensive and can be pursued at different levels [10]. Bilateral intergovernmental agreements and large infrastructure projects are often seen as essential instruments of energy diplomacy [12]. Additionally, energy diplomacy is closely connected to development policy, linking energy-related policies to development aid [8,17].

Over the past few decades, various forms of energy diplomacy have been employed by both energy importers and exporters. Following the oil crisis of 1973, Japan, a major oil importer, faced difficulties in securing affordable oil supplies for its industries. In response, the Japanese government sent special envoys to oil-producing nations like Syria, Egypt, Sudan, and Persian Gulf countries to enhance its political relations with them. In exchange for economic and technical assistance, Japan was able to ensure a stable oil supply [18]. Another example is China's energy diplomacy. As a significant energy importer, China has established partnerships with oil-producing African countries such as Nigeria and Angola to satisfy its domestic oil demands [19].

Energy diplomacy is not limited to countries that rely on energy imports. Russia, a significant exporter of fossil fuels, has also employed energy diplomacy to secure market share for its national energy company, Gazprom. Another example of energy diplomacy pursued by exporting countries is Brazil's biofuel diplomacy. The Brazilian government utilizes its knowledge and expertise in producing and trading biofuels as a foundation for creating partnerships for biofuel infrastructure projects with countries such as Nigeria, Angola, and Mozambique [20,21].

The transition from fossil fuels to renewable energy has set in motion a shift in power relations. The emergence of new strategic technologies and value chains, such as clean hydrogen or critical raw materials, along with rising geo-economic competition, has compelled countries to rethink their traditional energy diplomacy [22]. As the low-carbon energy transition continues to gain traction, countries are forming new partnerships based on technology cooperation and negotiating fresh bilateral agreements concerning the import of hydrogen and its derivatives.

2.3. Hydrogen Diplomacy

Recently, hydrogen diplomacy has gained prominence as an essential aspect of energy diplomacy. Though it involves some new approaches, hydrogen diplomacy resembles other forms of energy diplomacy. Numerous countries and other players such as ports are engaging in dialogues or signing memorandums of understanding with potential import or export partners. For instance, similar to Japan's approach during the 1970s, The Netherlands has dispatched special envoys to potential hydrogen-producing countries to discuss future trade agreements [23]. Additionally, the German government has launched the "H_2-Diplo" initiative, which has created "hydrogen diplomacy offices" in potential export countries like Angola, Nigeria, Ukraine, and Kazakhstan to foster hydrogen cooperation [24].

Currently, existing accounts of hydrogen diplomacy focus primarily on establishing bilateral hydrogen partnerships [23]. Prospective importers such as Germany, The Netherlands, and Belgium are actively engaging in establishing hydrogen partnerships in the form of technological cooperation with other import countries such as Japan or by establishing prospective trade agreements with potential export countries such as Morocco, Namibia, or Oman [25].

The research and practice around potential hydrogen partnerships has been dominated by a technical approach. Countries with a high level of renewable energy and water resources are considered suitable partner countries for renewable-based hydrogen [26–29]. Pflugmann and de Blasio have identified five groups of countries based on their resource potential, including categories like export champions, import countries, and self-sufficient hydrogen consumer countries [28]. Eicke and De Blasio have built on this research by adding "economic relatedness" and "the size of the current hydrogen and/or its derivates market" to examine potential changes in geopolitical relations related to establishing a hydrogen value chain [30].

Recently, experts are increasingly pointing out the need to assess non-technical criteria when studying future hydrogen partnerships [31–34]. For instance, Hanusch and Schad [32] call for a social science research agenda on setting up hydrogen partnerships, while Kalt and

Tunn [31] similarly argue that research from social and sustainability perspectives is crucial to avoid a technocratic hydrogen transition, as they may eventually lead to path dependencies or social inequalities. In a study on hydrogen partnerships, Quitzow et al. [35] argue that there are six dimensions that should be considered by policy makers when engaging in hydrogen partnerships: climate mitigation, green industrial development, just transition in partner countries, geopolitics, security of supply, and economic feasibility. According to their findings, these dimensions may reinforce each other, yet they may conflict as well. Such conflicts may then trigger trade-offs between the different dimensions.

Only a few studies have integrated such parameters in their assessment of hydrogen partnerships. The H_2Atlas, developed by the German Federal Ministry of Education and Research and African partners in the Sub-Saharan region, assesses the political environment of hydrogen partner countries by looking at socio-economic criteria such as the ease of doing business, the world governance indicator and current energy policies [36]. Brauer et al. have incorporated as well what they call "soft factors", such as political stability, ease of doing business, and a country's R&D spending per capita, when discussing prospective hydrogen partnerships. Based on their assessment, countries such as Norway, Algeria, and the UK are considered suitable trading partners for importing hydrogen in Europe. Moreover, according to their analysis, countries like Saudi Arabia, Oman, and Jordan perform well in terms of producing low-cost hydrogen, but they score low on their soft-factor criteria [34]. Similarly, in a study by Frontier Economics, technical criteria like renewable energy potential and infrastructure are juxtaposed with socio-economic criteria [33]. Nevertheless, in these studies, these criteria are labelled as "soft factors", implying the technical criteria are still considered as more important (the "hard factors").

Furthermore, there is an increasing body of literature that addresses another blind spot, namely the implications of hydrogen trade for the hydrogen export countries. These studies start from the objective of energy justice and have taken a more critical perspective towards hydrogen partnerships [37–40]. Müller et al. point out that hydrogen partnerships with countries such as Morocco or Namibia risk exacerbating existing inequities rather than leading to a just transition [38]. Lindner draws a similar conclusion, having evaluated 21 countries from the Global South that are considered for potential hydrogen partnerships. He concludes that many of those partnerships lack an energy justice perspective, resulting not only in inequalities in terms of energy justice, but also damaging the overall long-term stability of these partnerships [37]. The inclusion of an energy justice lens to studying hydrogen partnerships highlights that these parameters have repercussions in terms of energy security in both the short term and the long term for import as well as for export countries. Such implications are not assessed when solely relying on the technical potential of export countries.

In summary, the literature on hydrogen diplomacy and related partnerships focuses mostly on defining the technical potential of potential partner countries and much less on studying agreements that are actually already in place. The majority of studies scrutinize, thus, which countries the EU and its member states *should* partner with, in terms of their technical potential. This article takes a different approach. Instead of applying *a priori*-defined criteria to select potential import countries, it conducts a *post hoc* evaluative review of current agreements. The aim is to evaluate whether these partnerships and the agreements are posing any economic, political, or sustainability risks. Simply put, the assessment wants to determine whether Germany, The Netherlands, and Belgium are succeeding in securing hydrogen imports in a secure and sustainable way.

3. Methods

To assess the prospective hydrogen partnerships, this article employs a mixed method approach, which consists of three steps: (1) the identification of prospective hydrogen partnerships and related indicators in terms of risks, (2) the classification and analysis of the indicators mentioned in the literature, and (3) the multi-criteria analysis of the prospective hydrogen partnerships based on the indicators. In terms of data collection and analysis, a database of hydrogen partnerships and a literature review is conducted to identify partnerships and indicators related to prospective hydrogen partnerships. To identify the dominant indicators for sustainable hydrogen partnerships, a content analysis is performed on the literature on indicators related to hydrogen partnerships and related risks. Lastly, the hydrogen partner countries are analyzed using a multi-criteria analysis. A more detailed discussion of each step can be found below.

3.1. Data Collection

Firstly, a database of potential hydrogen partnerships is established using government announcements and media reports published prior to August 2023. The database includes 40 future trade partnerships between, on the one hand, prospective importers, Germany, Belgium, or The Netherlands, and 30 unique prospective hydrogen exporters, on the other. The database covers a range of cooperation agreement types related to hydrogen, including memorandums of understanding, bilateral cooperation agreements, letters of intent, and dialogues. Partnerships centered on technological collaboration with other potential import countries (for example with Japan or South Korea) are not included in the database as the focus of this article is on hydrogen imports. There are other European countries, such as Hungary, Italy, or Austria, that concluded a hydrogen trade partnership with future export countries. However, these partnerships are not included in the database as these agreements are rather ad hoc and less of an example of hydrogen diplomacy. A complete overview of all the partnerships can be found in Supplementary S1, Table S1.

Secondly, a literature review is undertaken to gather insights on the criteria or indicators that could be taken into account when establishing hydrogen partnerships. This review covers the academic literature, including peer-reviewed journals, working papers, and books, as well as grey literature such as blog posts, reports, websites, and newspaper articles on the topic of hydrogen partnerships. The complete overview of the literature review can be found in Supplementary S1, Table S2.

3.2. Data Analysis

3.2.1. Hydrogen Partnership Indicators

In order to identify the indicators that could be considered to establish secure hydrogen partnerships, a content analysis is conducted on 15 studies related to the establishment of hydrogen partnerships. The analysis includes each indicator that was mentioned in three or more studies referring to indicators to chose hydrogen partners and minimize economic, political, or sustainability risks. Factors related to the technological potential to produce hydrogen, such as solar irradiation and wind speed, are not directly included in the set of indicators, but they are covered indirectly by the economic dimension. The resulting eight indicators are grouped into three dimensions of energy security risks, as shown in Table 1.

Economic risks are associated with the costs of hydrogen. They include (1) hydrogen production costs, which means the cost of hydrogen production and (2) the delivery ex ship (DES) costs, which are the supply costs from the export country to the import country [27,29,34].

Political risks are related to the investment climate within a potential partner country. They include socio-political indicators such as the (3) corruption perception index, (4) fragile state index, and (5) ease of doing business [33,34,37,41].

Sustainability risks include the risks related to a clean and just transition. Firstly, they address the availability of clean energy within the partner country. This includes (6) local access to electricity, to align with distributional justice effects of access to green electricity and (7) the share of renewables in a country's electricity mix, to ensure local development of green energy. These dimensions aligns with the 'local first' approach [37–42]. Secondly, they address risks related to water scarcity which is measured by (8) the water stress index, considering that the production of green hydrogen requires large volumes of water.

Table 1. Dominant risk categories in the literature and related indicators.

Risk Category	Indicator	Mentioned in
Economic risks	Hydrogen costs: 1. Production cost 2. DES cost	Brauer, Truby and Villavicencio [34], Ikonnikova et al. [29], Moritz, Schönfisch and Schulte [27]
Political risk	3. Corruption perception index	Lindner [37], Perner and Brothe [33], Breitschopf et al. [41], Heinemann and Mendelevitch [40]
	4. Fragile state index	Lindner [37], Perner and Brothe [33], Breitschopf et al. [41]
	5. Ease of doing business index	Lindner [37], Brauer, Truby and Villavicencio [34], Perner and Brothe [33]
Sustainability risk	Domestic energy demand: 6. Access to electricity, 7. Share of renewables in electricity	Breitschopf et al. [41], Heinemann and Mendelevitch [40], Bouacida and Berghmans [42], Bouacida [39]
	8. Water availability	Breitschopf et al. [41], Heinemann and Mendelevitch [40], Lindner [37] Bouacida [39]

3.2.2. Multi-Criteria Analysis of Prospective Hydrogen Trade Partnerships

Finally, the eight above-mentioned indicators are applied to the 30 unique countries according to a multi-criteria analysis. Each country is first evaluated based on the eight different indicators; subsequently, their performance on the eight indicators is dichotomized. In this article, I chose a binary approach to ensure consistency in the analysis as there is variation between the different databases of the eight individual indicators. The thresholds for the dichotomization are either theory based or based on global averages. Below, I discuss the indicators and their respective coding.

(1) *Green hydrogen production costs*: The data of production costs of green hydrogen are retrieved from a study by Moritz et al. [27]. They assess the cost of green hydrogen produced by renewables by 2025. Their modeling is based on a baseline scenario with present technology levels, and with an import volume of 100 TWh. A country that has a higher cost than the average production cost of USD 113/MWh is coded “zero”; a country that has a lower cost is coded “one”.

(2) *Green hydrogen Delivery Ex Ship (DES) costs*: The data on DES costs are retrieved from a study by Moritz et al. [27] and are calculated based on exports to Germany. As Germany has already concluded more than half of the partnerships that are being discussed in this article, and other prospective import countries are also situated in Northwestern Europe, these costs are considered representative. The study assesses the cost of green hydrogen produced by renewables by 2025. Their modeling is based on a baseline scenario with present technology levels and with an import volume of 100 TWh. A country that has a higher cost than the average DES cost of USD 189/MWh is coded “zero”; a country that has a lower cost is coded “one”.

(3) *Corruption perceptions index (CPI)*: The CPI, published by an organization called Transparency International, calculates the corruption level of states [43]. A country that performs above 50/100 is coded “one”; a country that scores below 50 is coded “zero”.

(4) *Fragile State Index*: This index, initiated by the Fund for Peace, assesses a state’s vulnerability to conflict or collapse [44]. When a country’s score is categorized as “warning” or worse, it is coded “zero”; while countries that are categorized as “stable” or better are coded as “one”.

(5) *Ease of doing business index*: This index by the World Bank evaluates the business regulation environment of countries [45]. A country that performs better than the global average is coded “one”; a country that scores below average is coded “zero”.

(6) *Access to electricity*: This indicator is measured based on the percentage of the population with access to electricity [46]. Electrification data are collected from the World

Bank. If in a country 100% of the population has access to electricity, the country is coded "one", otherwise it is coded as "zero". This 100% threshold is based on the "local first" approach that proposes that local energy needs should be met first, before hydrogen is used for export purposes [47].

(7) *Share of renewables in the electricity mix:* This UN indicator measures the share of renewable energy in a country's electricity mix, which is part of the SDG goal 7 [48]. Such indicator would avoid that renewable electricity is used for hydrogen production instead of decarbonizing local energy consumption. A country that has more than 28% of renewables in their electricity mix, which is the global average, is coded "one", while a country that scores below 28% is coded "zero" [49].

(8) *Water availability*: This is measured by the water stress index (WSI). This UN index calculates the ratio of renewable water supply compared to the water withdrawals in a country [50]. According to the UN, a country that has a WSI percentage greater than or equal to 25 is considered to be water stressed [51], and the country is coded "zero". Any other percentage is coded "one".

A complete overview of the coding of the countries for each indicator can be found in Supplementary S1, Table S3.

The next step involves calculating an aggregated score for each risk category, based on the individual indicator scores. A country that scores "one" in all indicators within a distinct risk category is considered to have a "low" risk for that category. A country that scores "zero" in only one indicator within a risk category is given a "medium" risk for that category. If a country scores a "zero" in two or more indicators within a dimension, the score for that dimension is labelled as "high" risk. An overall overview of the risk performance can be found in Supplementary S1, Table S4.

Lastly, the countries are divided into four categories based on their risk profile for the different categories (see Table 2). While, in theory, more than four categories are possible, our analysis reveals that these four categories effectively capture the overall trends and performance of the potential partner countries in this study:

- Last Resorts: countries that contain "high" economic risks.
- Volatile Ventures: countries that score "low" or "medium" on the economic risk but are considered to be "high" risk in political risks.
- Strategic Gambits: countries that have "low" risks for the economic and political dimension but impose "high" risks in terms of sustainability
- Trusted Friends: countries that are "low" risk on every dimension.

Table 2. Categorization of countries based on their performance on the three dimensions.

Economic Risks	**Political Risks**		**Sustainability Risks**	**Country Category**
High				Last Resorts
Low	High			Volatile Ventures
Low	Low	Medium	High	Strategic Gambits
Low	Low		Low	Trusted Friends

To check the robustness of the proposed categorization, I have conducted several robustness tests, employing alternative thresholds across all indicators for the 30 countries in the dataset. The results of the robustness checks are available in Supplementary S2. In general, the results of this robustness test affirm the categorization outlined in the article. When different threshold values are applied to each indicator, the overall categorization remains largely consistent. However, there are a four noteworthy exceptions where alternative thresholds would result in different country categorizations. Firstly, altering the thresholds for indicators (3), (4), and (5) would reclassify Namibia from the "Volatile Ventures" category to the "Strategic Gambits" category. Secondly, by employing a lower production cost threshold (1), Nigeria would transfer from a "Last Resort" to a "Volatile

Venture" country. In contrast, when employing a higher production cost threshold (1), Brazil would transfer from a "Volatile Venture" country to a "Last Resort" Country. Finally, an alternative threshold for the Corruption Perception Index (3) would transfer Saudi Arabia from a "Strategic Gambit" country to a "Volatile Venture" country. Nevertheless, these adjustments represent minor changes, and the categorization proposed in the article maintains its overall robustness.

4. Results: Seeking Risk-Free Partnerships

Starting in 2020, a total of 40 hydrogen partnerships were concluded between Germany, The Netherlands, and Belgium, 30 of which were with unique countries. The bulk of these partnerships was concluded by the German and Dutch governments, with 22 and 13 partnerships, respectively. Belgium entered into 5 partnerships. Of all 30 unique prospective export countries, about a quarter are considered to be "low risk", meaning that there are also partnerships that entail economic, political, or sustainability risks. The following section discusses the four different categories of partner countries as shown in Table 3, and the related risks.

Table 3. Categorization of partner countries.

Last Resorts	Volatile Ventures	Strategic Gambits	Trusted Friends
Angola	Algeria	Oman	Australia
DR Congo	Brazil	Qatar	Canada
Egypt	India	Saudi Arabia	Chile
Nigeria	Kenya	United Arabic Emirates	Denmark
Russia	Mexico		Iceland
Ukraine	Morocco		Norway
Uruguay	Namibia		Portugal
Kazakhstan	South-Africa		Spain
	Tunisia		
	Turkey		

4.1. Last Resorts

According to the index, seven countries are identified as "Last Resorts". These countries display, in the first place, high risks in the economic dimensions, meaning that both the production and the supply of hydrogen from these countries would be very costly. Notably, most of these countries also pose a high risk in other dimensions; this is the case for Angola, the Democratic Republic of Congo, Egypt, Nigeria, Kazakhstan, Russia, and Ukraine. Only Uruguay poses high economic risks but medium and low risks in terms of, respectively, politics and sustainability.

An example that showcases an overall high risk is the Democratic Republic of Congo (DRC), which as well as high hydrogen production costs, also poses high investment and decarbonization risks. The hydrogen project that is being studied between Germany and the DRC necessitates further construction of the hydroelectric facility at the Inga dams, of which the progress has been stymied because of market and investment risks. The building of the dams would displace thousands of individuals and lead to detrimental environmental consequences, including a reduction in biodiversity and an increase in waterborne diseases [52]. Furthermore, certain regions of the DRC have experienced prolonged conflict, which raises concerns about the country's political stability. Overall, despite possessing significant potential for accomplishing the energy transition, including valuable mineral resources and renewable energy sources, the Congolese population has not yet reaped the benefits of the country's resource wealth.

The DRC is not the only country that has not yet profited from its resource wealth. A similar case can be made for both Angola and Nigeria, both rich in fossil fuel reserves and renewable energy potential, whose scores are also considered to be high risk in all dimensions. There is a concern that the production and exports of hydrogen from these regions to Europe may reproduce or even exacerbate the so-called "resource curse" which those countries are experiencing already today from fossil fuels [53].

Egypt poses another example that is considered to be a high-risk investment overall. Egypt has the ambition to develop into a hydrogen exporter. However, the country faces significant criticism from human rights organizations due to its human rights abuses, and these societal issues adversely impact its political stability [54]. Moreover, Egypt grapples with severe water scarcity as a result of climate change and its extensive water-dependent economy [55].

Furthermore, both Russia and Ukraine demonstrate high risks. Prior to Russia's invasion of Ukraine, Germany had established agreements with both countries. Russia, in particular, was regarded as a potential partner for exporting hydrogen derived from natural gas through carbon capture and storage [56]. However, given the current strained relations between Europe and Russia, the future trade of any energy source, including both fossil fuels and hydrogen, is highly uncertain. Similarly, hydrogen exports from Ukraine face considerable uncertainty, and their feasibility is contingent upon the outcome of the ongoing conflict. Nevertheless, Ukraine is still considered a potential export partner in the EU's hydrogen strategy and the REPowerEU plan due to its infrastructure and renewable energy potential. However, considering the prevailing political tensions and its geostrategic location, it remains to be seen how Ukraine could fulfill this role effectively.

Finally, for Uruguay, the case is slightly different compared to other countries in this category. Uruguay presents a lower level of risk in terms of political and sustainability risks compared to its counterparts in this category. This Latin-American country is renowned for its commitment to social equality and political stability and boasts a significant proportion of renewable energy sources within its power generation. However, engaging in hydrogen trade collaboration with Uruguay may involve higher costs. This situation creates a trade-off between the potentially elevated costs of hydrogen trade and the overall low risks associated with political and sustainability dimensions [57].

4.2. Volatile Ventures

The second category involves countries that pose low economic risks but high political risks. This category is called the "Volatile Ventures". Countries that are part of this category are Algeria, Brazil, India, Kenya, Mexico, Morocco, Namibia, South-Africa, Tunisia, and Turkey. Partnering with these countries is perceived to involve political risks that could potentially lead to an unstable supply of hydrogen molecules, despite their capability for cost-effective hydrogen production. This necessitates caution among investors when forming partnerships with countries falling within this category.

For example, Tunisia has experienced internal political instability since the Arabic Spring in 2011. In 2021, the president Kais Saied suspended the parliament [58] and consolidated his power through a new constitution. This has led to public protests and a deteriorating socio-economic situation in the country. South Africa too, is considered to be a high risk in political terms. The most industrialized country of the African continent is confronted with daily electricity black outs that have become a source of social unrest [59]. Similarly, Mexico knows a high level of corruption, and the role of the military in its economy is increasing. This situation undermines the ability to govern the country [60].

Friction between an import and an export country may also be a source of an unstable hydrogen supply. For example, when tensions arose around the sovereignty of the Western Sahara in 2021, Berlin showed support for the contested region. Morocco, who had concluded a hydrogen agreement with Germany already in 2020, suspended the hydrogen cooperation with Germany in 2021 [61]. Another example is the relation between European countries and Turkey which has been spiraling down following the coup attempt in 2016 and the erosion of democratic freedom in Turkey. These relations may even worsen with the recent re-election of president Recep Tayyip Erdogan [62].

Finally, both Namibia and Kenya are also considered to be risky in terms of socio-political stability. Nonetheless, both Namibia and Kenya are considered emerging economies, with an enormous resource potential both for hydrogen and critical raw materials. The development of a hydrogen economy in these countries could, regardless of the higher investment risks, foster an avenue for the development of renewable energy and green industrialization within these countries.

4.3. Strategic Gambits

The third category, identified as “Strategic Gambits”, comprises countries capable of producing affordable hydrogen with low political risks. From a purely geostrategic and economic standpoint, establishing partnerships with these countries seems evident. However, such collaborations come with sustainability and energy justice risks. The focus on hydrogen production for export purposes might interfere with greening the local energy mix. This situation arises for example when green electricity used for hydrogen production competes with locally needed green electricity [47].

It is noteworthy that all the countries within this category, namely Oman, Qatar, Saudi-Arabia, and the UAE, are located in the Middle East and all of them are facing high water stress levels [50]. Therefore, the production of renewable hydrogen jeopardizes local water use in agriculture or other water-intensive industries. However, some studies suggest that the water stress level of hydrogen-producing countries should not be a showstopper for hydrogen production projects [63]. Compared to other industries, hydrogen’s water demand is relatively low. In addition, sea water could be desalinated to serve as freshwater for hydrogen production. This would boost the desalinization industry and could result in positive spillover effects for other industries as well [23,64]. Nevertheless, if the toxic brine, the waste from the desalinization process, is not properly treated before being disposed in the sea, it could harm maritime ecosystems. All of these factors make the production of hydrogen in these countries more challenging than in other countries that do not face high water stress levels.

Furthermore, considering that these countries are all rich in fossil fuels, hydrogen offers a potential avenue to diversify their economies and move from fossil fuel exports towards hydrogen exports [23]. However, when hydrogen is used solely for export purposes and the deployment of renewable energy for hydrogen production does not go hand in hand with greening the local energy mix, hydrogen trade with these countries hampers global decarbonization efforts and slows down the transition towards net zero. As a result, there is a trade-off between importing cheap hydrogen and the environmental, justice, and decarbonization challenges that such imports may cause.

4.4. Trusted Friends

Finally, eight partner countries score “low” in all dimensions. These countries are labeled “Trusted Friends” and include Australia, Canada, Chile, Denmark, Iceland, Norway, Portugal, and Spain. All of these countries are part of the OECD, and five of them are located in Europe. Canada, Australia, and Norway are currently net exporters of energy sources, mostly fossil fuels. Their experience with trading energy sources could prove beneficial for trading hydrogen. Considering geographic distance, European countries may face competition from North East Asia, specifically Japan and South Korea, when it comes to securing volumes from Australia. It would be, therefore, more suitable to secure volumes that are closer to home. In the case of Norway, the existing natural gas infrastructure may serve as a good basis for setting up trade with European countries [23].

Denmark, currently a net importer of energy, sees hydrogen as an opportunity to harness its wind potential and become an exporter of both electricity and hydrogen [65]. Partnerships with Portugal, Spain, and Iceland have emerged from feasibility studies as part of the larger national hydrogen strategy of the Dutch government [66]. These countries are located in the vicinity of hydrogen demand clusters in Europe and have the potential to produce hydrogen at a low cost using either solar PV in Portugal and Spain [67,68] or hydropower in Iceland [69].

5. Discussion: Energy Security Implications of Hydrogen Trade Partnerships

Energy diplomacy discussions still often focus on a narrow subset of issues: how to secure access to sufficient and available fossil fuels from abroad. As the world's energy system is on the cusp of a major overhaul, new energy trading relations may emerge, including for hydrogen. The emerging practice of hydrogen diplomacy thus offers an opportunity to reinvent energy trading relations and to move beyond narrow interpretations of energy security as security of supply. This analysis has, therefore, analyzed 40 hydrogen trade partnerships, not just in terms of the new dependencies and supply risks that they entail, but also in terms of other risks and trade-offs that they may trigger. The results imply that these concluded partnerships are not the result of a clear strategy, but rather seem to be an example of ad hoc cooperation between hydrogen import and export countries. Moreover, there is little to no cooperation between different import countries despite the available tools such as the Energy Platform announced by the EU or the H_2-Diplo initiative [70]. Policy makers in future hydrogen import countries thus face dilemmas as they seek to develop future trade relations.

Firstly, the countries that are deemed to be "low risk" are mostly western democracies, with the exception, perhaps, of Chile, yet the country is also part of the OECD. These prospective partnerships with predominantly "friendly" countries endorse the growing trend of friend-shoring, which involves moving crucial parts of the value chain of strategic sectors, such as energy, to "trusted" countries and allies. However, a country's trustworthiness might change over time, and a country that is currently deemed to be "low risk" may not necessarily score similarly in the future [71]. Moreover, such an approach could result in only a few like-minded partners left to partner with, therefore limiting diversification options.

Secondly, many of the countries that can produce cheap hydrogen come with higher political risks. Therefore, this creates a dilemma between cost-efficient hydrogen and a safe investment climate. This can be exemplified by previous attempts to establish energy cooperation with resource-rich countries, for example, the Desertec project. In 2009, a consortium of European and North African companies proposed exporting electricity from the Sahara to Europe, with the aim of decarbonizing energy systems, improving Europe's energy security, and providing economic and social benefits to North African countries through job creation and income stability [72]. However, the project failed due to various reasons, such as economic risks, the destabilizing effects of the Arab Spring on North African countries, and concerns that the project would perpetuate colonial relations between the Global North and the Global South. Desertec was, therefore, deemed a "technology without a sociology" [73]. This underscores the imperative of a socio-political assessment of future hydrogen trade partnerships.

Thirdly, trade-offs emerge as well between sustainable hydrogen supplies and global energy justice. Countries from the Middle East often face high water stress levels and only have a low share of renewables in their local energy mix. This raises concerns that the production of hydrogen in these countries would interfere with renewable energy deployment for the local population or even increase fossil fuel production. Future hydrogen trade with these countries should, therefore, not occur at the expense of a local green transition in the export country.

6. Conclusions

In recent years, the EU and its member states have actively engaged in hydrogen diplomacy by establishing bilateral agreements pertaining to hydrogen imports into Europe. However, concerns have been raised regarding whether those partnerships are free of energy security risks. To shed light on this question, this article evaluated the 40 currently explored partnerships by Germany, Belgium, and The Netherlands. This article has identified four categories of partner countries based on the risks such partnership entails: "Last Resorts", "Volatile Ventures", "Strategic Gambits", and "Trusted Friends". Notably, less than one-third of the partnerships could be perceived as low risk. Consequently, there are still partnerships that pose economic, political, and sustainability risks. The choice of partnerships is therefore largely influenced by trade-offs.

Yet, the risks and trade-offs are not distributed equally over the three future import countries. There is a divergence between EU member states in terms of the energy security implications of their partnerships. Germany has concluded the most agreements, followed by The Netherlands and Belgium. The Netherlands has concluded 46% of its partnerships with "Trusted Friends" partner countries, while Germany and Belgium have, respectively, concluded 22% and 40% of their partnerships with "Trusted Friends" partner countries.

Furthermore, it should be noted that the risks associated with hydrogen partnerships are not only dependent on the partner countries. The diversification of supply countries, as well as the level of reliance on hydrogen in a country's energy mix, influences the risks related to import dependencies. In cases where countries are dependent on only a few suppliers and hydrogen is taking a prominent place in a country's energy mix, the choice of partner countries may be more important than in the case of a more diversified hydrogen supply in combination with a low share of hydrogen in a country's energy mix. Moreover, energy security risks are also determined by the volumes of hydrogen coming from each individual export country. Therefore, assessment of the partnerships should be performed on a case-by-case basis, taking into consideration their specific contexts.

This study has revealed how current partnerships may or may not contribute to the sustainable supply of hydrogen. However, due to methodological limitations, some parameters were not included in the dataset. For example, the various production methods for hydrogen were not factored in as a parameter for evaluating the partnerships, as the focus was on renewable hydrogen. In future research, a similar assessment could be conducted by adding the hydrogen production methods to explore how they influence a country's performance. In addition, the coding of the parameters as either "one" or "zero" reduces the granularity that is present in the different indicators. Future research could opt for a fuzzy-set approach when evaluating the countries. However, this may yield different results and a different categorization.

Moreover, this study has not taken into account the types of partnerships that are concluded between prospective hydrogen import countries and prospective hydrogen export countries. At present, most of these partnerships have taken the form of MOUs or Letters of Intent, which provide only little legal accountability. To further advance the field, future research could build on the results of this article by including the type of partnership as an indicator to assess the energy security risks. Such an exercise would generate new insights into the energy security risks related to the type of partnerships.

Finally, this study has only focused on the risks for future import countries, and not the risks that could emerge for future export countries. For example, based on currently announced hydrogen export projects, about 16 Mt of hydrogen could be traded across the globe by 2030. Yet, only three projects have reached the final investment decision, resulting in a lot of uncertainty for future export countries [74]. Future research could carry out a similar assessment from the perspective of future export countries and the risks they may encounter from current hydrogen trade partnerships.

In conclusion, this article has contributed to the existing body of literature by comprehensively scrutinizing the existing hydrogen partnerships and the economic, political, and sustainability risks they entail. By doing so, this article underscores the need for policy makers to think more strategically about which partnerships to pursue and confront future hydrogen import countries with tough choices about which risks and trade-offs they are willing to accept.

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