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[EWI-Study]

H_2-Geopolitics

Geopolitical risks in global hydrogen trade

On behalf of Gesellschaft zur Förderung des Energiewirtschaftlichen Instituts an der Universität zu Köln e. V.

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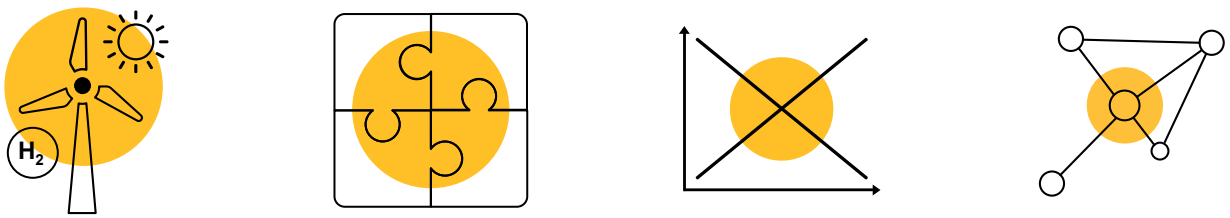

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Executive Summary

Due to the current energy crisis, the issue of energy security has suddenly come into focus. The diversification of the energy supply, especially of energy import structures, is - in addition to decarbonisation - the central challenge for the German energy system in the short, medium and long term.

Hydrogen plays an important role as a raw material and, in the future, as a green energy carrier. However, since renewable energy (RE) potentials in Germany will be used to electrify many end-use sectors to a large extent, the potential to produce green hydrogen domestically is very limited. Hydrogen imports will be necessary to meet the German demand for green hydrogen. If large quantities of green hydrogen are imported, consideration should be given to what this means for Germany's security of supply and what potential risks exist (Ariadne, 2021; Fraunhofer ISI, 2020). In addition to potential supply costs, political-economic and social factors should be considered when establishing hydrogen supply chains to ensure investment security and hydrogen supply security.

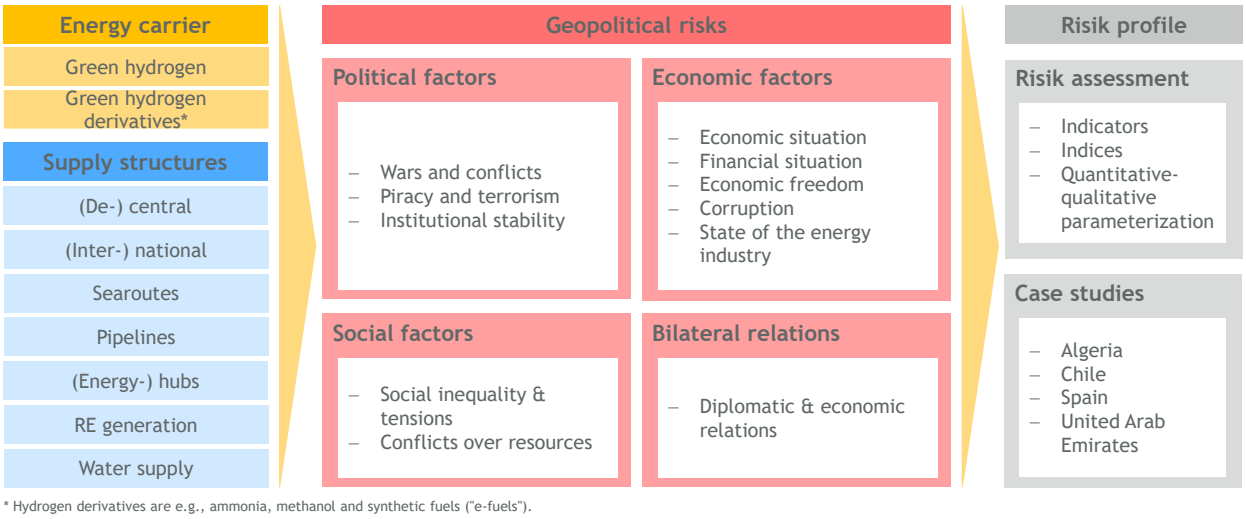


Figure 1: Graphical Abstract

Source: Own illustration

This study analyses potential geopolitical hydrogen import risks for Germany - from the renewable energy production in the country of origin to the hydrogen delivery to Germany. Geopolitical risks that could pose a threat to the security of the hydrogen supply or could do so if tensions increase are studied. Four geopolitical risk dimensions of the hydrogen supply chain were identified and discussed (see Figure 1).

An assessment of the reliability of export countries, transport routes and investment security is complicated since countries' risk potentials are not directly measurable. Therefore, country risks

are captured by assigning measurable variables (quantitative-qualitative parameterisation). Various indicators are used as an indication of the identified risk factors. To discuss the geopolitical risks in global hydrogen trade, four possible exporters - Spain, Algeria, Chile and the United Arab Emirates (UAE) - were selected, and their risk potential was examined comparatively.

Security of supply and geopolitics

An uninterrupted energy supply is central to every modern economy and society. Due to low domestic resources import security is of great importance for Germany and plays a central role in the discussion about national energy security. In the energy sector, high dependence on energy imports is an inherent risk because dependencies and potential vulnerabilities can accompany imports.

Geopolitics and energy are closely intertwined. The emergence of a global hydrogen market and the energy transition have geopolitical implications. By 2050, one-third of the green hydrogen used could be traded across borders. The geopolitical consequences of a hydrogen market have not yet been analysed in depth. The trade flows of hydrogen and hydrogen derivatives will differ from today's fossil supply corridors. New interdependencies will emerge due to new hydrogen trade flows.

Geopolitical risks in the global hydrogen trade

Global supply chains and energy imports are confronted with various potential risks. In addition to natural disasters and technical or human failure, various geopolitical risks threaten supply security. Geopolitical risks are defined as the endangerment, realisation and escalation of conflicts and tensions between states or political actors.

Geopolitical energy risks pose a threat to securing the supply of hydrogen consumers in Germany. Investment risks threaten German companies and make the establishment of hydrogen supply chains more expensive or delay them. The risk potential of hydrogen trade is determined, particularly by the structure of hydrogen supply chains. As the relevance of hydrogen increases, so does the risk that hydrogen supplies will be used as political leverage.

Geopolitical risks are closely related to a country's political, economic and social risks and challenges. In addition, the bilateral (political and economic) relations between countries interacting directly in the hydrogen trade are another risk dimension.

- **Political factors** in production or transit countries can influence the stability and political situation of a country or region and, thus, the reliability of hydrogen supplies. Political instability, as well as domestic, regional or international conflicts, pose a risk to import security. Political risk factors include wars and conflicts, terrorism and piracy, and institutional stability. Various indices, such as the Global Peace Index, Global Terrorism Index or the Fragile State Index can be used to capture political risks.
- In addition to political factors, numerous **economic factors** influence the risk potential of countries of origin. The economic situation in a country impacts political and social stability, and the development of the hydrogen market and companies. A country's economic factors can be closely interwoven with global economic developments. Economic factors include economic stability, financial situation, economic freedom,

corruption and parameters on the state of the energy system. Indicators that can be used to assess economic stability include the Economic Diversification Index, Weighted Average Capital Costs (WACC), Economic Freedom Index, Corruption Perceptions Index and Value of Lost Load.

- **Social factors** of geopolitical energy risks are closely linked to the other factors and can, in particular, be secondary risks of economic factors and cause political risks. Social inequality, tensions, and resource conflicts can lead to instability and pose a risk to a stable and reliable hydrogen market. Social country risks are captured, for example, by the Gini Index, youth unemployment or access to electricity and clean drinking water.
- **Bilateral relations** between the actors involved in the supply chain also play a central role in the security of supply. Close economic, diplomatic and cultural relations can reduce the risk of disruption or restriction of value chains. Indicators for the classification of bilateral relations can be trade agreements, trade volumes, and investment flows.

Geopolitical risks of selected supply corridors

The analysis of the geopolitical risk potential of Spain, Algeria, the United Arab Emirates and Chile has shown that each country has individual opportunities and risks.

Spain as a member of the European Union (EU) and a stable democracy, is characterised by low geopolitical risks for German hydrogen imports. The European single market, the joint energy sector and the possibility of pipeline transport offer numerous advantages for companies, investors and Germany's supply security.

Algeria is well placed to be a potential exporter of hydrogen thanks to its large RE potential, its geographical proximity to the EU and the plans for the EU supply corridor across the southern Mediterranean. However, the country faces numerous domestic - political, economic, and social - challenges. The disruptions and conflicts in the MENA region (*Middle East and North Africa*), such as the conflict between Algeria and Morocco, pose a risk to Germany's supply security. However, hydrogen production could make an important contribution for Algeria to reduce its dependence on fossil energy exports and diversify its economy.

The **UAE** is characterised by a good economic situation and political stability. However, the UAE is located in an unstable and conflict-ridden region. This also leads to transport risks for hydrogen imports due to three critical straits on the shipping route from the UAE to Germany. Even if the diversification of the economy in the UAE is being strongly promoted, it remains to be seen to what extent the energy transition poses a risk to the economic, social and political stability of the UAE - and the region.

Chile offers strong economic freedom and therefore developed into a country that is especially attractive for investors and companies. However, social discontent and tensions caused political and economic stability to falter. The current uncertainty about the development of the Chilean constitution and, thus, the orientation of the political-economic system pose risks for hydrogen projects.

1 Background on security of supply and geopolitics

This chapter first discusses the conceptual framework for analysing geopolitical risk factors in global hydrogen trade. This includes the topic of energy supply security as well as the concept of geopolitics.

1.1 Security of supply

The discussion of energy security is based on the assumption that an uninterrupted supply of energy is central to the functioning of any modern economy and society (Kruyt et al., 2009; Sovacool & Mukherjee, 2011)

Security of supply refers to uninterrupted access to energy sources or access that is guaranteed without unplanned disruptions. Security of energy supply is primarily associated with oil imports and increasingly also with gas imports.[1]

The concept of security of supply goes beyond a purely physical definition of the geographical availability of energy sources. Since resources such as oil and gas can be traded globally and scarcity affects the price of commodities on the world market, security of supply also has an economic dimension. In addition, the political stability of energy producers and transit countries and external shocks, e.g. extreme weather events, are crucial as these impact reliable supply.

From an economic perspective, trade - and thus imports - can generally be seen as positive. As early as 1776, Adam Smith described trade as a "positive-sum game" in *The Wealth of Nations* and emphasised that all trading partners can benefit from trade in specialised goods. David Ricardo also confirmed the positive effects of trade in his book 1817 *On the Principles of Political Economy and Taxation* in his thesis on comparative advantage.

From a geopolitical perspective, however, trade can also entail risks. In the energy sector, a strong dependence on energy imports is assessed as an inherent risk because dependencies and vulnerabilities can accompany imports. Import security is of great importance for Germany due to its low domestic resources and plays a central role in the discussion on Germany's energy security. Although during the energy transition, import security remains a major concern (Ariadne, 2021; Fraunhofer ISI, 2020).

[1] Another area of focus is security of supply in electricity generation to ensure a reliable and stable power supply on a permanent basis. The energy transition poses an enormous challenge for electricity generation and electricity transport. Security of supply in electricity generation is therefore a central task domestically and intra-European, but not the subject of this analysis.

The triangle of energy policy goals (see Figure 2) constitutes the compass of German energy policy. In addition to environmental compatibility and economic efficiency and affordability, security of supply is a central goal. The principle for the security of supply is "to efficiently meet energy demand in Germany at all times" (BMWK, 2021a). An energy supply must be created that can withstand external shocks.

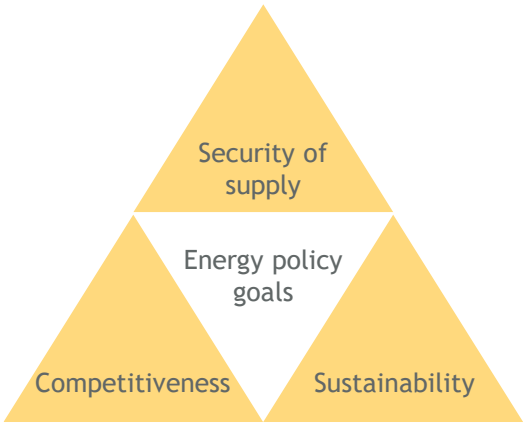


Figure 2: Energy policy triangle

Source: Own illustration

Measures to ensure energy supply security include diversification of supply sources so as not to be tied to individual geographical regions or countries. Diversifying the energy source, the energy carrier, and the transport routes increases the security of supply, as does sufficient domestic production. In addition to diversification, stable relationships with exporters and transit countries and a reliable supply infrastructure also contribute to the security of supply (BMWi, 2020; Chester, 2010)

Many energy system analyses show that hydrogen will be used not only as a raw material in the future but also as an energy carrier. As the use of hydrogen increases, so does the need to establish a secure and resilient hydrogen supply. Hydrogen supply security describes the state of a secure, reliable and affordable (and sustainable) supply of hydrogen imports for Germany (Ariadne, 2021).

1.2 The geopolitical dimension of hydrogen

Energy plays a significant role in numerous crises and conflicts. Geopolitics and energy are closely intertwined. The emergence of a global hydrogen market and the energy transition have geopolitical implications. The geopolitical dimension of the energy transition and hydrogen is explained below.

Geopolitics of the energy transition

Geopolitics is generally understood in public debate as the interplay between geography and international politics. The term geopolitics is used today to refer to the role of geographical factors, such as natural resources, on the relationship between states, the influence of states in the international system and the advancement of national strategic interests.

Due to the geographical, geological, and physical characteristics of energy resources and the central importance of energy for society and the economy, the topics of energy and geopolitics are closely interlinked (Månberger & Johansson, 2019; Scholten & Bosman, 2013). Access to and supply of oil and natural gas have strongly shaped relations between states and global politics in the last century. The geographical concentration of fossil energy reserves, the import dependence of large industrialised countries and strategic supply routes to centres of demand

have, on the one hand, promoted conflicts and, on the other hand, led to cooperation and alliance building.

The transformation of energy systems worldwide has far-reaching geopolitical implications. The new geopolitical reality of decarbonised energy systems will be very different from the geopolitical landscape of fossil energies. Increasingly, renewable energies are leading to cooperation between states. However, renewable energies can also foster competition and new conflicts (IRENA, 2019; Overland, 2019; Scholten et al., 2020)

The energy transition offers geopolitical opportunities but, at the same time, also poses (new) risks. Countries that import large quantities of fossil energies can initially reduce their dependence on fossil energies and, thus, on major fossil powers and transit routes during the energy transition. With the growing importance of secondary energy sources such as electricity, hydrogen and hydrogen derivatives, and other valuable resources such as (precious) metals, and rare earth elements, dependencies and vulnerability will increase (IRENA, 2019, 2022).

(UBA, 2022) shows that in 2020, Germany imported almost 100 % of its conventional energy sources hard coal, uranium, mineral oil and natural gas. These energy sources accounted for around 74 % of Germany's primary energy consumption and 40 % of gross electricity generation in the same year. Renewable energies (RE) had a share of around 17 % of primary energy consumption and about 44 % of gross electricity generation in 2020. Even if the share of RE in gross electricity generation can be significantly increased through the expansion of renewable energies, the RE potentials are insufficient to substitute the primary energy consumption of conventional energy sources. Even in a decarbonised German energy system, energy imports will be necessary, which will continue to be confronted with security and transit risks (Adelphi & Wilson Center, 2021).

The energy transition's geopolitical consequences differ from fossil energy's geopolitics. As there will continue to be cross-border energy and resource trade in the future, the geopolitics of the energy transition is still concerned with the issues of resource supply, strategic infrastructure, supply and trade routes, and the risk of supply disruptions (Overland, 2019).

Geopolitical dimension of the hydrogen trade

It seems increasingly realistic that hydrogen and its downstream products will develop into internationally traded resources and that a global hydrogen market will emerge. Figure 3 provides an overview of global scenarios for hydrogen demand in 2050. Across scenarios, the overview shows that global hydrogen demand could multiply by a factor of 3 to 6 by 2050. In this context, about one-third of the green hydrogen used in 2050 could be traded across borders (IRENA, 2022). The development of a global hydrogen and hydrogen derivatives market and the increasing investments in hydrogen technologies lead to geopolitical and geo-economic changes (IRENA, 2022).

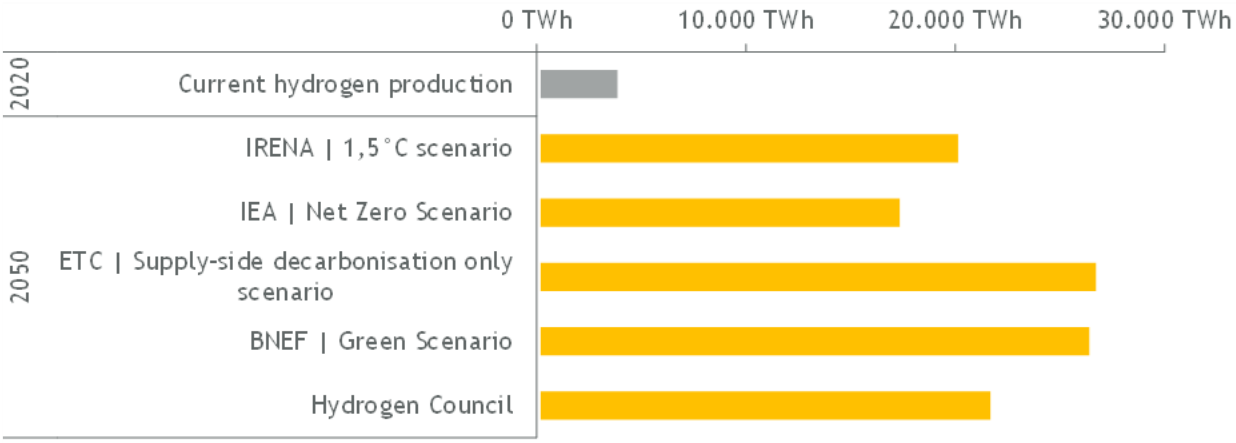


Figure 3: Estimations for the global hydrogen demand 2050

Source: Own illustration based on IRENA (2022)

It is still unclear how the hydrogen supply structures necessary for global trade will develop. A centralised system could evolve, as in the case of today's oil and natural gas exporters, or a decentralised supply system, as in the case of renewable energies (de Blasio & Pflugmann, 2021). A middle path of the two options seems most likely, whereby international hydrogen trade could develop similarly to the natural gas market. In this case, international hydrogen would primarily be traded regionally via pipeline, supplemented by a global dimension of hydrogen trade via ship transport.

Since green hydrogen could be produced in any country, it seems likely that less asymmetric market structures will develop than in the case of the global oil and gas market. This is mainly because many countries can produce green hydrogen cheaply (see EWI PtX Cost Tool, 2022) and hydrogen can also be transported over long distances.

A country's potential to produce green hydrogen competitively depends primarily on the RE potential and the availability of water sources. However, numerous other factors influence a country's hydrogen export potential (see Infobox 1).

Infobox 1: Factors influencing the hydrogen production potential

The decisive factor for a country's hydrogen export potential is the domestic demand for hydrogen and downstream products, as well as the status quo of the national energy supply.

The cost of capital plays an important role in the development of RE. Today, the cost of capital differs for countries worldwide. Therefore, countries with low weighted average capital costs (WACC)[2] have great potential to produce RE particularly cheaply. These countries are, e.g. Australia and Chile. A decrease in the WACC leads to a change in capital cost, favouring RE and green hydrogen production. (IEA, 2021, 2022; IRENA, 2022).

In addition to capital costs and financing options, it is crucial for the planning and implementation of hydrogen projects that human capital is available. Sufficient skilled labour and know-how in dealing with hydrogen and energy exports are prerequisites for building a hydrogen economy.

In addition to production potential and production costs, transport costs are important for estimating a country's export potential. A country's geographic location is crucial for its export potential, especially its proximity to potential importers and, if applicable, its direct access to the sea.

On the one hand, a country's infrastructure potential is determined by the condition and quality of its infrastructure, the potential for repurposing existing gas infrastructure and its experience in energy trading. Countries with a significant RE potential, sufficient water resources and good infrastructure potential could position themselves as significant exporters. Other countries with limited RE potential and, at the same time, high demand for hydrogen will have to import significant amounts of hydrogen to meet their demand in addition to producing their hydrogen.

Trade flows of hydrogen and downstream products will differ from today's fossil supply corridors. However, in the case of large hydrogen importers, old dependencies could be replaced by new dependencies. This could particularly affect the demand centres of Europe and Southeast Asia. Nevertheless, the role and importance of individual exporters will change. While North African states could gain importance in the global energy market as potential hydrogen exporters, Middle Eastern countries could lose geopolitical relevance (de Blasio & Pflugmann, 2021; Van de Graaf et al., 2020). New interdependencies and dependencies are also emerging due to new hydrogen trade flows (IRENA, 2019, 2022).

[2] WACC is a component of the cost of capital. The WACC of countries worldwide differs significantly. This is a cost of capital component whose development is uncertain (IRENA, 2022). For example, the WACC can be 20-50% of the Levelized Cost of Electricity of large photovoltaic projects. Low financing costs are important for the economic viability of the energy transition and the hydrogen market ramp-up (IEA, 2021, 2022).

Infobox 2: Geopolitical opportunities of hydrogen

While the energy transition and a global hydrogen market entail various risks, numerous geopolitical opportunities are also emerging.

In contrast to the oil and gas market, a hydrogen economy will have less asymmetric structures. The global trade in fossil energies is primarily shaped by the availability of large fossil reserves and the demand of large (industrial) states. In contrast, countries worldwide have RE potentials and could theoretically meet at least part of their hydrogen demand through their own production. Numerous countries could become "prosumers" by consuming hydrogen and producing it themselves (Van de Graaf et al., 2020).

New trade flows could potentially reduce the risk associated with particularly relevant gas and oil supply routes in the long term, e.g. the Strait of Hormuz (Van de Graaf et al., 2020).

The production and export of climate-neutral hydrogen can offer resource-rich petrostates an economic perspective. The energy transition directly affects fossil energy-producing countries, which must diversify their economies away from fossil energy exports. Stranded assets represent a major risk for fossil energy exporters. Hydrogen allows these states to diversify their economies. Such diversification also offers these countries the opportunity to achieve their own climate goals (IRENA, 2022; Van de Graaf et al., 2020).

In addition to production and transport, a hydrogen economy also includes great potential for technology providers. By producing hydrogen technologies such as electrolysers, water treatment plants and other technical equipment, individual countries could establish themselves as technology suppliers.

In general, green hydrogen is expected to make a key contribution to climate protection efforts. In addition to usage as feedstock, hydrogen could cover between 12 and 22 % of final energy consumption in 2050 (IRENA, 2022). Green hydrogen, in particular, has the potential to make an important contribution to slowing down climate change by substituting fossil fuels. This has the potential to mitigate or even prevent numerous negative geopolitical effects, such as migration movements and climate catastrophes that lead to instability.

The European Commission and European Union (EU) member states are among the frontrunners and early adopters in the global hydrogen market ramp-up. In the EU, numerous projects are being implemented, and large amounts of funding are being used for the market ramp-up. The EU thus plays an important role in the development of the hydrogen economy and, as a major demand centre, could help shape the development of the global hydrogen economy according to its own interests.

2 Geopolitical risks in the global hydrogen market

Energy carriers, especially commodities such as coal, oil, natural gas, biomass or hydrogen, can be traded globally on the energy market. Global energy trade covers the supply chain from the energy exporter to the consumer. In the future global supply chains can be expected to develop for hydrogen. Chapter 3 discusses the risks of global supply chains, with a focus on geopolitical risks in the global hydrogen market.

Risks in energy trade

Global supply chains and energy imports are confronted with various potential risks. In addition to natural disasters and technical or human failure, various geopolitical risks threaten supply security. Security of supply is ensured by preventing or minimising these risks (Ariadne, 2021). The assessment of a country's energy supply security should therefore consider aspects such as the stability of energy producers and transport and transit risks, in addition to the share of energy imports in the energy supply and the substitutability of individual energy exporters (Fraunhofer ISI, 2020).

Definition of geopolitical risks and the object of study

The term geopolitical risk builds on the broad understanding in the public discourse of geopolitics. Geopolitical risks are defined as the threat, realisation and escalation of conflicts and tensions between states or political actors (Caldara & Iacoviello, 2022). In this analysis, geopolitical risks consider a wide range of geopolitical events, existing conflicts and those structures that pose a threat and could lead to further tensions.

The focus of the analysis are geopolitical hydrogen import risks. This means that environmental disasters, technical and human failures are not part of this analysis. Geopolitical risks are understood as risks related to energy imports and thus as external risks - geographically outside the importer's borders (B. Muñoz et al., 2015). The hydrogen supply chain includes input production, hydrogen production, cross-border transport and export infrastructure up to the point of reaching Germany's external borders. All geopolitical risks are considered that pose a threat to the security of hydrogen supply or could do so if tensions increase.

Geopolitical risks in hydrogen trade

International hydrogen supply chains can pose security of supply risks. Even if the global hydrogen trade will potentially not reach the same volume as today's oil and natural gas trade, risks can still arise which make affected countries or sectors vulnerable (IRENA, 2022).

Due to Germany's potentially high hydrogen import demand, hydrogen import security is essential. On the one hand, geopolitical energy risks threaten the security of supply for hydrogen consumers in Germany. On the other hand, investment risks pose a threat to German companies and make the establishment of hydrogen supply chains more expensive or slow down the ramp-up of the hydrogen market.

The risk potential of hydrogen trade is determined in particular by the structure of the hydrogen supply chains, i.e. from the hydrogen producer to the consumer. In addition to RE generation, water resources and the production of hydrogen, concentrating structures can emerge in transport, such as

- non-fixed transport routes (e.g. shipping routes),
- supraregional pipelines,
- pipelines to pipeline nodes and
- infrastructure nodes (e.g. liquefaction plants, ports of loading or large-scale storage facilities) (Adelphi & Wuppertal Institut, 2007).

Interdependencies allow political actors, domestic actors in exporting countries, international groups or actors in third countries to use energy supply as leverage to pursue political interests. Irrespective of developments in the global energy market, supply disruptions pose a risk to energy importers (B. Muñoz et al., 2015). Energy exports are repeatedly used as political leverage. In this context, energy is also referred to as a weapon (European Parlament, 2018).[3] Even the threat to withhold energy exports for political reasons can lead to severe insecurities with effects on energy prices (Fattouh, 2007).

As the relevance of hydrogen increases, so does the risk that hydrogen supplies are used as political leverage. Geopolitical risks in hydrogen trade can be classified into four dimensions:

- political factors
- economic factors
- social factors
- bilateral relations

Geopolitical risks are closely related to a country's **political, economic** and **social risks** and challenges. In addition, **bilateral relations** (political and economic) between the countries directly interacting in hydrogen trade are another risk dimension. The individual risk dimensions assess the geopolitical security of hydrogen producers and transit countries and routes (B. Muñoz et al., 2015).

Methodology

In the following, the four geopolitical risk dimensions of the hydrogen supply chain are discussed and divided into further risk factors. It is important for the analysis results that the entire range of risks is covered. Some geopolitical aspects cannot always be explicitly assigned to one risk dimension. The classification chosen here serves as a thematic orientation.

It is difficult to assess the reliability of export countries, transport routes and investment security, as the risk potential is not directly measurable. Nevertheless, country risks can be captured and compared by assigning measurable variables (quantitative-qualitative parameterisation) (Adelphi

[3] Energy is instrumentalised by states and political actors and used as a (political) weapon. Energy is utilised both as an offensive and defensive instrument of foreign policy. In the 2022 energy crisis, Russia was repeatedly accused of using energy as a weapon against the EU (BMWK, 2022). This accusation against Russia of using its energy resources as political leverage is not new; e.g., in 2006, 2009 and 2015 Russia cut off gas supplies to Ukraine; in 2006 and 2007 Russia stopped oil supplies to the two Baltic states Lithuania and Estonia. But other petrostates also use energy as leverage, e.g. the Organisation of Petroleum Exporting Countries (OPEC) in the 1973 oil embargo or Saudi Arabia from 2014 to 2015 to weaken Iran and Venezuela. Energy is also used as a defensive policy tool. E.g., Azerbaijan established gas relations with the EU to maintain its political independence after the fall of the Soviet Union (European Parlament, 2018; Newnham, 2011).

& Wuppertal Institut, 2007; B. Muñoz et al., 2015). Various indicators can be used as an indication of the identified risk factors. A non-exhaustive list of possible indicators is given for all risk factors.

2.1 Political factors

Various political factors in production or transit countries can influence the stability and political situation of a country or region and, thus, the reliability of hydrogen supplies. Political instability, domestic, regional or international conflicts and wars pose a significant risk to import security. This instability can harm every step of the hydrogen value chain. Three areas of political risks are divided and discussed below: **wars and conflicts**, **terrorism and piracy,** and **institutional stability**.

Wars and conflicts

A major risk is that producers or transit states are affected by intra- and interstate wars or international conflicts (Fattouh, 2007). Wars, conflicts and violence put a strain on global trade. Conflicts can negatively affect power generation, hydrogen production and transport, leading to supply disruptions (B. Muñoz et al., 2015). But price shocks, sanctions or embargoes as a consequence of or reaction to a conflict can also have far-reaching implications for supply security. These consequences are particularly evident, for example, in the case of the current energy crisis due to the Russian attack on Ukraine or the oil embargo that followed the war against Israel in 1973.

Relevant indicators

Global Peace Index | HIIK Conflict Barometer | Uppsala Conflict Data Program

Terrorism and piracy

Organised crime, terrorist groups and piracy also threaten supply chains. Energy infrastructure is an attractive target for terrorist attacks because the potential economic damage is great (Iskandarov et al., 2020). Attacks and the threat of attacks create uncertainty for producers and consumers and can initiate price increases. In the worst case, an attack hits a strategic supply route.

Both energy installations, pipelines and tankers are targets of attacks. In the last 50 years, oil and gas pipelines have regularly been the target of terrorist attacks or sabotage, e.g. in Syria, Iraq, Egypt, Algeria, Libya or Nigeria (Fattouh, 2007; Giroux, 2009; Lee, 2022; B. Muñoz et al., 2015). E.g., most recently, a gas pipeline in Egypt was targeted by the terrorist group Islamic State (IS) in April 2022.

In addition to pipelines, terrorist attacks are carried out on electricity infrastructure, tankers and other infrastructure. Such attacks can also pose a risk to hydrogen trade. Added to this is the

increasing threat of cyber attacks, which can massively disrupt power supply and pipeline operations (Lee, 2022).

In addition to terrorist attacks, piracy poses a risk to hydrogen transport via tankers, affecting for example, the coast of West Africa (Hakirevic Prevljak, 2020).

Relevant indicators

Global Terrorism Index | International Maritime Bureau Piracy Map

Institutional stability

In addition to conflicts and acts of violence, other political factors can risk supply security. These include significant changes in the political system or regulatory framework and weak state institutions and governance structures in the exporting or transit country.

Political unrest, revolution or regime change pose risks to a country's stability and bilateral relations and can lead to domestic and international conflicts.

Weak state institutions lead to political and economic insecurity and can lead to fragile statehood or even state collapse. Fragile statehood fosters wars, violence, crime, radicalisation and terrorism. Institutional and political instability, as well as regulatory uncertainty, discourage private investors (Leonard et al., 2022).

Relevant indicators

Governance Effectiveness Index | Regulatory Quality Index |Fragile States Index

2.2 Economic factors

In addition to political factors, numerous economic factors also influence the geopolitical risk potential of exporters and transit countries. The economic situation in a country impacts the political and social stability, the development of the hydrogen market and companies. Various economic factors can play a role, but these can also be closely interwoven with global economic developments. Economic risks are divided into **economic stability**, **financial situation, economic freedom**, **corruption** and **energy industry parameters**.

Economic stability

Economic instability and a poor economic situation in exporting countries can negatively affect the domestic and global energy markets. Economic instability refers to macroeconomic fluctuations, e.g. the gross domestic product and the inflation rate. Macroeconomic factors are closely intertwined and can result in further negative developments.

Economic instability in a country can, among other things, lead to lower investments in the energy sector and reduced investments in constructing or maintaining energy infrastructures. In addition,

a poor economic situation increases other social and political risks (B. Muñoz et al., 2015). In contrast, economic prosperity can have a beneficial effect on the political, economic and social stability of a country.

The economic structures are also important for the economic stability of a country. Suppose a state has a poorly diversified economy and heavily depends on one or a few sources of income. In that case, the country is particularly vulnerable to price shocks and the collapse of individual markets. This is visible in the case of the resource-rich petro-states.

The energy transition leads to fundamental social and economic changes that may have far-reaching consequences. While decarbonisation brings numerous environmental and macroeconomic benefits, it also brings new potential conflicts with geopolitical consequences. A destabilisation of petrostates could have far-reaching consequences. In addition, climate change and resulting food and water shortages can foster political instability and conflicts. (IRENA, 2019).

Relevant indicators

Gross Domestic Product (GDP) per capita | Inflation rate | Economic Diversification Index (EDI) | Human Development Index (HDI)

Financial situation

Various factors influence the financial situation of a country. A stable financial environment is important for secure and stable trade. A poor financial situation, such as high public debt, can have far-reaching consequences. Sufficient financial resources are essential to give the state leeway.

A poor fiscal situation increases the risk of dependence on external influences, but also the risk of government instability. For example, high public debt can reduce government investment, which can have a negative impact on the education sector, the level of social services and public infrastructure.

In particular, factors such as an unstable currency, strong exchange rate fluctuations or non-transparent credit conditions restrain investors and pose a risk for energy projects.

Relevant indicators

Proportion of non-performing loans | WACC | Exchange rate fluctuation | Credit rating

Economic freedom

Economic freedom is of great importance for energy companies and the security of supply. Central aspects of economic freedom are

- the rule of law,
- contract security,
- the role or intervention of a state in the economy, and
- the regulations and the openness of the markets.

Market openness is defined as freedom of trade, investment and finance. Free competition reduces the disadvantage of foreign companies and favours the best possible supply.

Relevant indicators

Economic Freedom Index

Corruption

Corruption is a risk within the economic risk factors, but it is also linked to the political situation, especially the governance structures of a country, and could, therefore, also be classified as a political factor. Corruption is classified here as an economic risk since it can result in additional costs that have to be priced into projects. The investment costs of hydrogen projects can increase due to corruption, which can also increase the costs of hydrogen. Corruption can thus deter investors (Debnath & Mourshed, 2018).

Particularly in the case of state-owned enterprises (SOEs), which exist in the energy sector in many countries worldwide, there is concern that their activities are affected by corruption.

Relevant indicators

Corruption Perceptions Index (CPI) | Global Corruption Index (GCI)

Energy industry

Another indicator of the economic risk factor is the energy economy, or rather the energy demand of an economy. With high energy intensity and high energy demand, the probability increases that domestic demand and energy exports will be weighed against each other. Especially for countries with high population growth, the question arises of how much energy will be available for exports in the future. Egypt, for example, has changed from a net oil and gas exporter to an importer.

A secure energy supply, a stable and reliable energy infrastructure and sufficient investment in the energy system are important prerequisites for reliable energy exports. Problems in the energy supply of the exporting or transit country can pose supply risks and result in political and social reactions, such as unrest or political market intervention.

Relevant indicators

Energy intensity | Loss of value due to power outages

2.3 Social factors

Social factors of geopolitical energy risks are closely linked to other factors and can, in particular, be secondary risks of economic factors and cause political risks. **Social inequality, tensions, and conflicts over resources** can lead to instability.

Social inequality and tensions

Social inequality in a country can lead to conflicts that pose a risk to the security of supply (B. Muñoz et al., 2015). Social inequality manifests itself, for example, in wealth and income inequality.

The gap between rich and poor, unequal wealth and land ownership distribution, and a lack of perspectives can foster social unrest and lead to economic instability. Low-income earners may invest little in education, harming a country's innovation potential and economic growth.

High unemployment among the population and young people, in particular, can bring a sense of futurelessness and pose a significant risk to a country's social stability. Hunger and poverty, which can lead to migratory movements, are also key risk factors for national security.

Social tensions in the form of unrest and a lack of social acceptance pose another risk to global supply chains. The population's satisfaction is an essential factor in the stability of a country. The general satisfaction of the population reduces the risk of tensions and conflicts. Blockades within a country, which lead to disruptions in infrastructure, or strikes by the workforce, can threaten supply security.

Ethnic-religious tensions within a country have an inherent potential for conflict. Acceptance of renewable energy and water export projects and local participation reduces the risk of social tensions. Social tensions are difficult to measure, but indicators can provide some insight.

Relevant indicators

Gini Index (income inequality) | Poverty | Unemployment | Youth unemployment | World Happiness Report

Conflicts over resources

Conflicts or competition over possibly scarce local resources pose a risk. Especially in countries with strong population growth, conflicts over the distribution of resources such as food, water, energy, and fertile land may increase.

The production of green hydrogen consumes about 15 kg of water per kg of hydrogen produced (Woods et al., 2022). At the same time, regions with a lot of RE potential are often regions where freshwater availability is becoming increasingly critical. Hydrogen, therefore, also plays a role in the energy-water nexus. Water desalination plants can only solve this problem to a limited extent, as enormous desalination capacities would be necessary (Woods et al., 2022).

Especially in places where water is already scarce or where not the entire population has access to sufficient clean water, hydrogen production could cause tensions. Climate change is expected

to increase the water problem in many countries. This could have acceptance-promoting effects if the local population is granted access to these new energies and water resources. If this is not the case, the potential for conflict will increase.

In addition to hydrogen, downstream products such as ammonia can also be exported. In the destination country, this green ammonia can either be processed into fertiliser, split into hydrogen via crackers or used as a fuel (EWI, 2021). Green ammonia is easier and cheaper to transport than pure hydrogen, and there is great potential for international trade in the medium term. Conventional ammonia is already traded internationally today. (EWI, 2021; Odenweller et al., 2022).

Ammonia is an important precursor to fertiliser production and, thus, a key input for agriculture. Overall, ammonia today contributes to about 50 % of global food production. Expanded worldwide trade and increased competition for ammonia could lead to price increases for fertilisers and, thus, for food. An increase in local consumer prices poses an inherent risk of social tensions. (IRENA & AEA, 2022).

Relevant indicators

Population size | Population growth | Access to electricity | Access to clean drinking water | Water stress

2.4 Bilateral relations

In addition to the numerous factors that influence stability in individual exporting states and transit countries, the relationship between the actors involved in the supply chain also plays a central role. Therefore, the nature of the relationship between states is another important dimension of geopolitical risks.

Close economic, diplomatic and cultural ties can reduce the risk of disruption or restriction of value chains. The degree of diplomatic and economic interdependence is a sign of mutual obligations and mutual trust. The greater the interdependence, the more stable bilateral relations appear, positively impacting supply security (B. Muñoz et al., 2015).

Political relations between states are characterised, for example, by formal diplomatic relations, the number of embassies and diplomatic representatives or the number of state visits. Partnership agreements, e.g. in the case of German energy partnerships or EU association agreements, can also indicate good relations. For example, Germany has hydrogen partnerships, among others, with Namibia, Canada, Australia and New Zealand, and energy partnerships, e.g., with Saudi Arabia, Qatar, and Morocco. However, the existence of an energy partnership agreement does not mean that import security is guaranteed. Germany also shared a strategic energy partnership with Russia until the beginning of 2022.

In addition to diplomatic relations, intensive trade and foreign direct investment (FDI) between states indicate the intensity of bilateral relations. In addition, the actors involved in trade and investment agreements can provide collateral.

On the other hand, political and trade tensions pose a risk to supply security. Tensions can result in trade and investment restrictions, such as quotas, FDI restrictions, tariffs, import restrictions, transit restrictions or export restrictions. Trade tensions can lead to significant economic and financial disruption.

Relevant indicators

Trade agreements | Import volume | Export volume | FDI inflow | FDI outflow

3 Discussion of the geopolitical risks of specific supply corridors

Germany will import significant quantities of hydrogen in the long term (EWI et al., 2022). Due to Germany's limited RE potential, only domestic green hydrogen production is insufficient. Therefore, global trade in hydrogen is necessary and makes economic sense since, despite high transport costs, importing green hydrogen is prospectively cheaper than domestic production. However, what a global hydrogen market will look like is not yet foreseeable. Numerous countries are striving to become hydrogen exporters, and other countries are counting on being able to cover their hydrogen needs through imports.

Four potential hydrogen exporting states were selected to discuss the global hydrogen trade's geopolitical risks. These countries are Spain, Algeria, Chile and the United Arab Emirates (UAE). The countries were chosen to represent a diverse picture. The potential hydrogen exporters differ in terms of their distance to Germany, the transport and transit route and the political system.

In the following, geopolitical risks are discussed as examples for the selected countries. For this purpose, some indicators were selected that reflect the dimensions of geopolitical risks. In the course of this, an overview was prepared for each country. Further information on these indicators is presented in Table 1.

Table 1: Explanation of country profile indicators

	Indicator	Unit	Comment	Year	Source
Basic data	Population		Population	2021	
	GDP per capita	$/Population	High values are favourable	2021	World Bank (2021b)
	Inflation rate	%	Low values are favourable; Consumer prices (annual %)	2021	World Bank (2021d)
	Trade agreement		Trade agreements with Germany or the European Union	2022	European Commission (2022b)
	Credit Rating	AAA-D	The more letters and the closer to A, the better	2022	S&P Global Ratings (2022)
Political factors	Global Peace Index	5-1	Low values are favourable	2022	Vision of Humanity. (2022)
	Global Terrorism Index	10-0	Low values are favourable	2022	Vision of Humanity (2021)
	Governance Effectiveness Index	-2.5-2.5	High values are favourable	2020	World Bank (2022c)
	Regulatory Quality	-2.5-2.5	High values are favourable	2020	World Bank (2020c)
Economic factors	Economic Freedom Index	0-100	High values are favourable	2022	The Heritage Foundation (2022a)
	Corruption Perception Index	0-100	High values are favourable	2021	Transparency International (2021)
	Energy intensity	MJ/$ GDP	Low values are favourable; primary energy consumption in relation to GDP (2017 PPP)	2019	World Bank (2019)
Bilateral relations	Import	Billion €	High values indicate a stronger economic relationship; imports from Germany	2021	Destatis 2022a
	Export	Billion €	High values indicate a stronger economic relationship; exports to Germany	2021	Destatis 2022a
	Outflow	Billion €	Direct investment abroad (negative = disinvestment)	2021	UNCTAD (2022)
	Inflow	Billion €	Foreign direct investment (negative = disinvestment)	2021	UNCTAD (2022)
Social inequality & tensions	Poverty	%	Low values are favourable; proportion of population below poverty line: $2.15 per day (2017 PPP)	2019	World Bank (2021e)
	Gini index (income inequality)	%	Low values are favourable; extent to which income distribution among individuals within an economy deviates from perfectly equal distribution	2020	World Bank (2021c)
	Unemployment rate	%	Low values are favourable; share of the total labor force	2021	World Bank (2021f)
	Youth unemployment rate	%	Low values are favourable; proportion of total labor force aged 15-24 years old	2021	World Bank (2021g)
	Water stress level	%	Low values are favourable; freshwater withdrawals relative to available freshwater resources	2019	World Bank (2022b)
	Access to electricity	%	High values are favourable; proportion of population with access to electricity	2020	World Bank (2020a)
	Access to clean drinking water	%	High values are favourable; proportion of population with access to safe drinking water	2020	World Bank (2020b)

Source: Own illustration

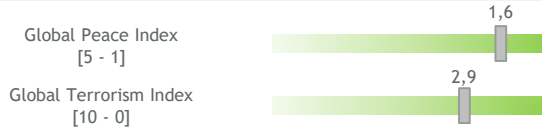
3.1 Spain

COUNTRY PROFILE SPAIN

Basic Data		Change
Population	47.326.687 (2021)	-0,08 % (2021)
GDP per capita	30.116 USD (2021)	5,13 %
Inflation rate	3,09 % (2021)	
Trade agreement	Eu internal market	
Credit rating	A (S&P, 2022)	

Political Factors

Wars & Conflicts (2022)



Institutional Stability (2020)

Economic Factors

Economic Freedom (2022)

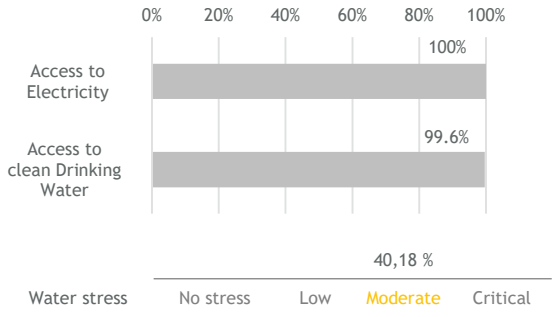
Corruption (2021)

Energy Economics - Energy Intensity

	MJ/$ BIP	
Spain	4,67	(2019)
EU	4,59	(2019)
Germany	5,31	(2019)

Social Factors

Conflicts Over Resources (2020)



Social Inequality & Tensions

Poverty rate	0,6 %	(2019)
Gini Index (income inequality)	34,7	(2019)
Unemployment rate	14,7 %	(2021)
Youth unemployment rate	36,9 %	(2021)

Bilateral Factors

Economic Relations (2021)

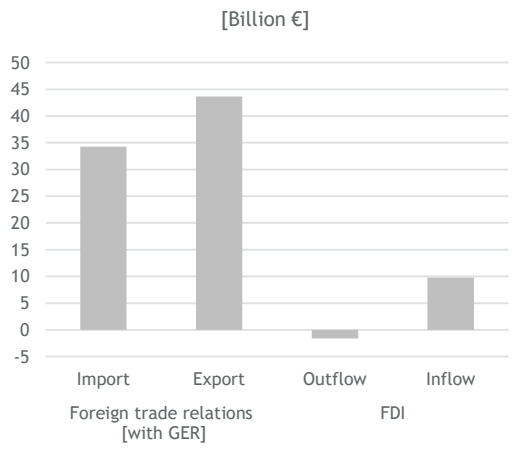


Figure 4: Overview of relevant information and indices for geopolitical risks - Spain

Source: Own illustration based on sources cited in Table 1

Possible transport route

Hydrogen could be transported from Spain via the announced pipeline from Barcelona to Marseille (Pinedo & Carreño, 2022) and from France to Germany. Alternatively, transport by ship to Germany would be possible.

Political factors

Apart from the non-violent conflict with the United Kingdom over the territory of the Gibraltar Peninsula, Spain is not actively involved in any international conflict (HIIK, 2022). However, domestic conflicts continue to exist over the independence of two territories (HIIK, 2022). In particular, Catalonia's independence aspirations and related protests and arrests pose a political challenge to the national government.

Spain is a consolidated parliamentary democracy and a member of the EU. The country's political stability is well above the global average. Nevertheless, Spanish politics has become increasingly volatile in recent years, visible in the fragmentation of the parliament, the independence movements in Catalonia and several early parliamentary elections (Economist Intelligence Unit, 2021). The Governance Effectiveness Index fell from 1.2 in 2015 to 0.9 in 2020.

Economic factors

Spain's economic position has improved significantly in recent decades. Between 2000 and 2021, the GDP increased by 28 % (Destatis, 2022b). The Corona pandemic hit the Spanish economy hard. In 2021, the situation improved, and the GDP grew by 5.1 %. The economic strength of individual regions in Spain differs significantly. Catalonia, followed by Madrid, has the largest contribution to Spain's GDP (Shapiro, 2018). The inflation rate in 2021 was 3.09 %.

The budget deficit met the EU rule of below 3 % of GDP only once since 2012. Public debt rose from 109 % of GDP in 2019 to 141 % in 2020. Higher interest rates on new loans are a challenge for Spain. Reducing the budget deficit and public debt requires political unity, which is currently lacking. Spain receives extensive EU funding, e.g. from the Next Generation EU (NGEU) Fund. (Chislett, 2022). The European Economic Area and the Monetary Union offer significant economic opportunities and financial security.

Spain's economic freedom is above the global average but below the regional average; high government spending and poor fiscal performance weigh on Spain's ranking. The country performs well in the other categories of economic freedom, such as the rule of law, regulatory efficiency, and market openness (The Heritage Foundation, 2022d). The country has a diversified economy and hardly any country-specific economic risks for companies (Allianz Trade Economic Research, 2021a). Nevertheless, structural reforms to promote competitiveness, the labour market and the tax system are necessary (OECD, 2021).

Social factors

The current tense economic situation within the EU is leading to political polarisation in Spain (Nogueira Pinto, 2022). Spain stands out in the EU for its high unemployment rate. The unemployment rate of 14.73 % in 2021 was below the 10-year average of 19.38 %. At the same

time, there is a shortage of skilled workers, especially in the construction sector (Chislett, 2022). Youth unemployment is particularly high, even though it has fallen since 2012. It stood at 37 % in 2021. Overall, the potential for social conflict in Spain is nevertheless low.

Bilateral factors

Germany and Spain are linked by a friendly relationship and good economic ties (Die Bundesregierung, 2022). Intra-EU trade accounted for 61 % of Spanish exports in 2020. A total of 9.8 % of Spanish exports went to Germany in 2021. Germany is the most important destination for Spanish exports after France. Of Spain's total imports, 10.6 % came from Germany in 2021, making Germany the most important country of origin for Spanish imports (Destatis, 2022b; European Commission, 2022c). The European single market creates security, stability and reliability in economic relations.

3.2 Algeria

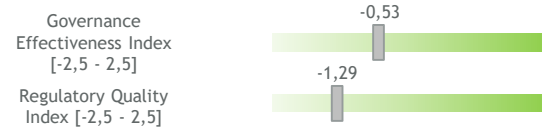
COUNTRY PROFILE ALGERIA

Basic Data		Change
Population	44.616.626 (2021)	1,73 % (2021)
GDP per capita	3.765 USD (2021)	3,85 %
Inflation rate	7,23 % (2021)	
Trade agreement	In place	
Credit rating	n/a (S&P, 2022)	

Political Factors

Wars & Conflicts (2022)

Institutional Stability (2020)



Economic Factors

Economic Freedom (2022)

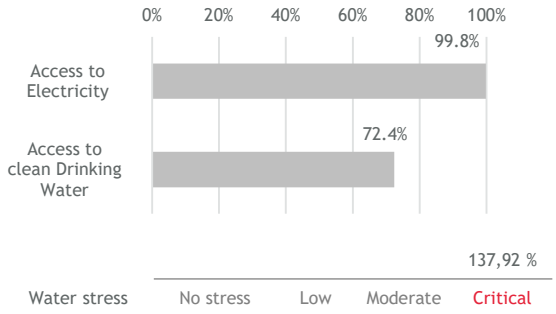
Corruption (2021)

Energy Economics - Energy Intensity

	MJ/$ BIP	
Algeria	5,04	(2019)
EU	4,59	(2019)
Germany	5,31	(2019)

Social Factors

Conflicts Over Resources (2020)



Social Inequality & Tensions

Poverty rate	0,2 %	(2019)
Gini Index (income inequality)	27,6	(2011)
Unemployment rate	12,7 %	(2021)
Youth unemployment rate	31,9 %	(2021)

Bilateral Factors

Economic Relations (2021)

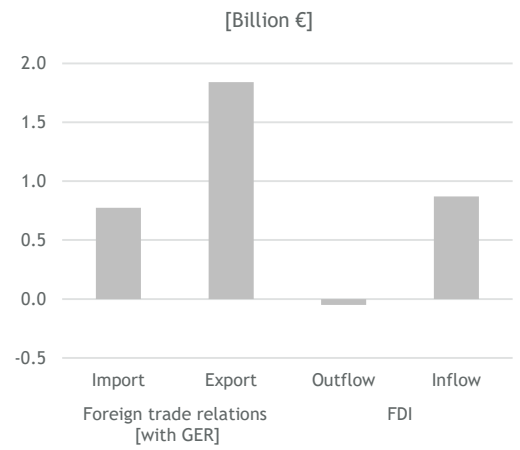


Figure 5: Overview of relevant information and indices for geopolitical risks - Algeria

Source: Own illustration based on sources cited in Table 1

Possible transport route

Algeria is part of the MENA region (*Middle East and North Africa*). Hydrogen from Algeria could be transported to Germany by pipeline and ship. Algeria is connected to Europe by pipeline via Spain. In addition, there are further pipeline connections to Europe via Tunisia and Morocco. According to the REPowerEU plan, the EU Commission envisages a hydrogen supply corridor via the Southern Mediterranean (European Commission, 2022a, 2022d). Alternatively, liquefied hydrogen can be transported by ship through the Strait of Gibraltar.

Political factors

The territorial division of the MENA region has repeatedly led to tensions and conflicts in the region in the past. Algeria's neighbours, Morocco, Libya, Niger, Tunisia and Mali, are all affected by intra- and inter-state conflicts. Morocco's violent crisis over the territory of Western Sahara is also intensifying the interstate conflict with Algeria that has been going on since 1963 (HIIK, 2022; Rachidi, 2022).

Domestically, Algeria also faces two conflicts. The Berber ethnic group continues to seek autonomy, and a conflict with the opposition remained intense in 2021 (HIIK, 2022).

Terrorism poses a threat to the region. In 2021, Algeria was hit by three terrorist attacks. Algeria's energy infrastructure has also been the target of terrorist attacks, e.g. attacks on gas infrastructure in 2013 and 2016 (Aljazeera, 2016; CTED, 2017; Giroux, 2009; Tichý, 2019).

Algeria's population is dissatisfied with the country's weak economy and the political system. The country has moderate to weak institutional stability (see Governance Effectiveness Index). Algeria's politics are shaped by the quest for political change and the elites' goal of retaining power. In recent years, there have been repeated protests and, most recently, a political crisis (Bertelsmann Stiftung's Transformation Index (BTI), 2022a; Ottaway, 2021; Porter, 2019). This impacts the government's ability to implement policies and regulations that are important for the private sector and fundamentally necessary political reforms (see Regulatory Quality Index) (World Bank, 2022a).

Economic factors

The Corona pandemic and the crash in oil prices in 2020 hit the Algerian economy. In 2021, GDP nevertheless increased by 3.8 %. The fossil-based exporter's economic situation is recovering, mainly due to high energy prices (World Bank, 2021a). In 2021, the inflation rate of 7.23 % was clearly above the 10-year average of 4.77 %. The unemployment rate of 12.7% (2021) remained above the pre-Corona pandemic level.

Due to high energy export profits, the country's (external) financing needs have decreased significantly (World Bank, 2022a). Nevertheless, the country's financial stability is strained due to liquidity risks and banks' refinancing needs. Public debt continued to increase strongly, reaching almost 60 % of the GDP in 2021 (African Development Bank Group, 2022). The country's financial institutions also face recurrent liquidity problems, threatening income and pensions (BNR, 2021). The Corona pandemic has significantly impacted the exchange rate stability of some emerging markets, including Algeria (Economist Intelligence Unit, 2020; IMF, 2020).

In terms of economic freedom, Algeria is below the global and regional average of the MENA region; Algeria's economic freedom is assessed as repressive. Monetary freedom remains assured, but the rule of law is weak. Market access, foreign investment and access to credit are also restricted (The Heritage Foundation, 2022b).

Algeria's economy is mainly state-organised. In particular, the country's exports are poorly diversified. Almost 95 % of export revenues are attributable to the export of oil and gas (The Heritage Foundation, 2022b). This makes the country particularly vulnerable to external shocks.

Corruption continues to be a problem in the MENA region, including Algeria. Algeria is ranked 117 out of 190 countries worldwide, slightly below the global average.

The country's per capita energy consumption is high compared to other developing countries. Electricity consumption has increased rapidly over the last few years. Natural gas and oil consumption also increased significantly over the last thirty years.

Social factors

2019 was marked by protests due to political and economic discontent. Youth unemployment is particularly high in Algeria at 32 %. This poses a major risk to social stability. To avoid unrest, the government has announced a youth unemployment benefit.

Today, about 28 % of the population has no access to clean drinking water, and Algeria suffers from severe water scarcity. Due to population growth averaging 2 % over the last ten years, resource consumption of energy, land and water is expected to continue to increase. Effective political measures are needed to prevent social conflicts from arising.

Bilateral factors

Algeria is an important partner and gas supplier for Europe. The Federal Foreign Office classifies Algerian-German relations as good. Germany was the fourth biggest importer of Algerian goods in 2017 (WITS, 2017). The poor relations between Morocco and Algeria have recently impacted the relationship between the states and European countries. Morocco broke off all diplomatic relations with Germany and Spain at the beginning of this year. Even though relations with Germany and Spain have normalised, the conflict over the Western Sahara remains a risk.

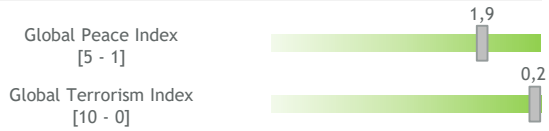
3.3 United Arab Emirates

COUNTRY PROFILE UNITED ARAB EMIRATES

Basic Data		Change
Population	9.991.083 (2020)	1,01 % (2020)
GDP per capita	36.285 USD (2020)	3,41 % (2019)
Inflation rate	-2,08 % (2020)	
Trade agreement	-	
Credit rating	AA (S&P, 2022)	

Political Factors

Wars & Conflicts (2022)



Institutional Stability (2020)

Economic Factors

Economic Freedom (2022)

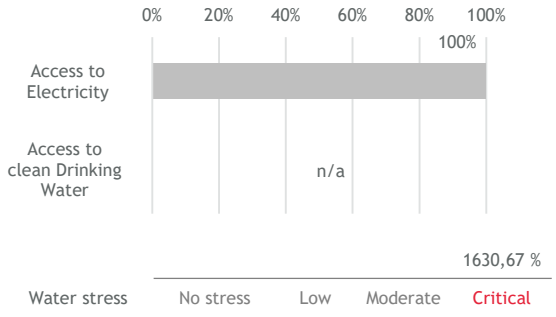
Corruption (2021)

Energy Economics - Energy Intensity

	MJ/$ BIP	
UAE	10,5	(2019)
EU	4,59	(2019)
Germany	5,31	(2019)

Social Factors

Conflicts Over Resources (2020)



Social Inequality & Tensions

Poverty rate	0,0 %	(2019)
Gini Index (income inequality)	26	(2018)
Unemployment rate	3,4 %	(2021)
Youth unemployment rate	10,7 %	(2021)

Bilateral Factors

Economic Relations (2021)

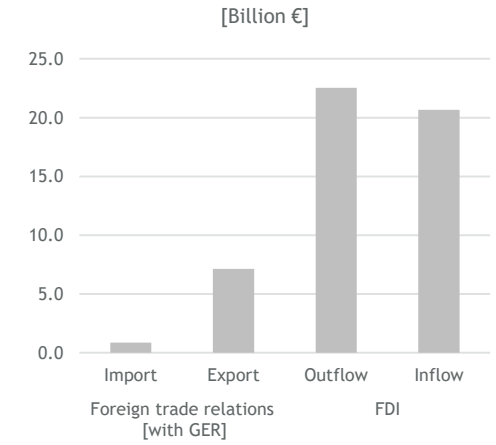


Figure 6: Overview of relevant information and indices for geopolitical risks - United Arab Emirates

Source: Own illustration based on sources cited in Table 1

Possible transport route

The shipping route from the UAE to Germany passes through four straits, the Strait of Hormuz, Bab al-Mandab, the Suez Canal and the Strait of Gibraltar. Each strait can pose a risk for various reasons, e.g. human or technical failure, natural disasters or political events. The economic and, thus, strategic importance of a sea route increases its vulnerability. The risk posed by these straits is closely related to the bordering countries' intra-state and inter-state conflicts and wars.

The Strait of Hormuz, between Oman and Iran, is the world's most important bottleneck in global oil trade. In 2018, around one-third of the global volume of oil traded by ship and a quarter of the LNG trade was transported through the Strait of Hormuz (EIA, 2019a). The UAE has an oil pipeline that bypasses the Strait of Hormuz and provides direct access to the Indian Ocean.

Located west of Yemen, the Bab al-Mandab chokepoint connects the Red Sea to the Gulf of Aden and is also a strategic strait in the global oil and LNG trade (EIA, 2019b). The war in Yemen directly threatens the maritime trade of the Bab al-Mandab strait, e.g. through the mining of the strait by Huthi rebels (Vaughan & Henderson, 2017).

Moreover, piracy and armed robbery remain a risk along the East African coastline (One Earth Future, 2020). The Suez Canal is also economically and strategically important. The vulnerabilities caused by a blockade of this shipping channel in Egypt became visible with the blockade in March 2021.

Political factors

The UAE is located in the world's most conflict-ridden region and is involved in various conflicts and disputes. The peace agreement with Israel in 2020 led to normalising bilateral relations, yet various other conflicts remain. The UAE perceives Iran as a threat to regional stability and security, and relations between Qatar and the UAE remain strained. The UAE was involved with troops in the Yemen war alongside Saudi Arabia. (HIIK, 2022). In early 2022, UAE oil tankers and infrastructure were targeted by Huthi rebels.

The UAE is a federation of seven monarchies and has been politically stable since its founding more than 50 years ago. Democratic reforms are not on the political agenda. The state's legitimacy continues to be accepted with almost no exceptions (Bertelsmann Stiftung's Transformation Index (BTI), 2022c).

Economic factors

GDP has grown by 99 % since 2000 (Destatis, 2022c). The UAE is in a good economic situation. At United States dollar (USD) 36,284, GDP per capita is well above the global average. After an inflation rate of over 12 % in 2008, the UAE economy deflated in 2020 with an inflation rate of -2.1 %. The UAE's inflation rate fluctuates significantly. At 38.3 % of the GDP, the UAE's gross public debt is relatively low (Destatis, 2022c). The UAE has a good credit rating of AA (S&P Global Ratings, 2022).

The country has made great improvements over the past decades in terms of market economy. The government has implemented numerous market liberalisation measures. UAE is the most

economically free country in the MENA region and is economically better off than the global average (The Heritage Foundation, 2022e).

The economic diversification strategy is having an impact. Only 30 % of GDP comes from the oil and gas sectors (Bertelsmann Foundation's Transformation Index (BTI), 2022c). Despite the economy's diversification, the UAE remains economically affected by uncertainties in the global oil and gas markets (Allianz Trade Economic Research, 2022).

Social factors

Poverty and inequality affect only a small part of the population; thus, this does not pose a risk to the UAE's social stability. Youth unemployment was 10.7 % in 2021. A risk to social stability exists when very well-educated young people cannot find suitable jobs.

The UAE is one of the countries with a particularly high level of water stress. Water scarcity poses a threat because it can fuel conflict and migration.

Bilateral factors

The UAE is Germany's largest trading partner in the region. Both governments announced the expansion of economic cooperation to develop green hydrogen (Federal Foreign Office, 2021; Fischer, 2022). Currently, there is no trade agreement between the EU and the UAE.

3.4 Chile

COUNTRY PROFILE CHILE

Basic Data		Change
Population	19.212.632 (2021)	0,5 % (2021)
GDP per capita	16.503 USD (2021)	11,67 % (2021)
Inflation rate	4,52 % (2021)	
Trade agreement	In place	
Credit rating	A (S&P, 2022)	

Political Factors

Wars & Conflicts (2022)

Institutional Stability (2020)

Economic Factors

Economic Freedom (2022)

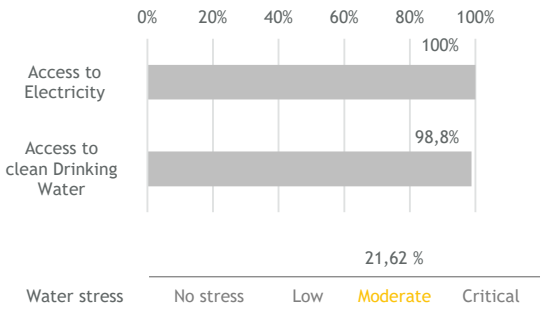
Corruption (2021)

Energy Economics - Energy Intensity

	MJ/$ BIP	
Chile	6,27	(2019)
EU	4,59	(2019)
Germany	5,31	(2019)

Social Factors

Conflicts Over Resources (2020)



Social Inequality & Tensions

Poverty rate	0,4 %	(2019)
Gini Index (income inequality)	44,9	(2020)
Unemployment rate	9,1 %	(2021)
Youth unemployment rate	21,4 %	(2021)

Bilateral Factors

Economic Relations (2021)

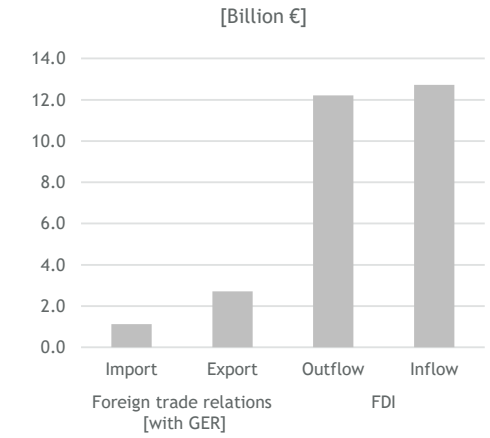


Figure 7: Overview of relevant information and indices for geopolitical risks - Chile

Source: Own illustration based on sources cited in Table 1

Possible transport route

Hydrogen or hydrogen derivatives can be transported from Chile through the Panama Canal and then across the Atlantic to Germany. Alternatively, continental transport would be possible, e.g. by rail or road transport to the east coast of Latin America, bypassing the Panama Canal. There are repeatedly pirate attacks along the coasts of Peru, Ecuador and Colombia (ICC, 2022). Most attacks occur in territorial waters, near ports and inland waters (One Earth Future, 2020).

Political factors

Chile is one of the world's peaceful countries (see Global Peace Index in Figure 7). Chile has been in dispute over territorial issues with Bolivia and the United Kingdom for some time. Chile is not involved in any international conflicts or wars. However, domestic conflicts pose a challenge to the country. The violent conflict persists between indigenous people, the government, and forestry corporations over territories and autonomy (HIIK, 2022). Chile has a high terror index, ranking 18th out of 163 countries in 2021. There have been repeated attacks by extremists of the Mapuche indigenous group (IEP, 2022). Violent protests also continued in 2022, following the social unrest of 2019 (HIIK, 2022).

Chile is a stable democracy with far-reaching political rights and freedoms (Freedom House, 2022). The country's political stability is better than the global average and better than in neighbouring countries, yet the situation has deteriorated in recent years. Since the 1990s, Chile has been considered particularly politically and economically stable and regarded as Latin America's economic miracle. However, the government failed to advance social redistribution in addition to economic freedom.

In heavy protests in 2019, the population made its discontent clear and demanded fundamental changes. In 2022, the proposal for a new constitutional text was rejected in a referendum. Uncertainty about the development of the Chilean constitution has led to uncertainty among investors since 2019 (Economist Intelligence Unit, 2022; Stuenkel, 2022).

Economic factors

Over the past decades, Chile has achieved significant economic growth, and poverty has been strongly reduced in the country. In 2020, the country fell into recession due to the Corona pandemic. In 2021, the GDP grew again by 11.7 %. In the same year, inflation reached 4.5 %. Over the last ten years, the inflation rate averaged 3.2 %, staying within the 2-4 % target set by Chile's central bank (Bertelsmann Foundation's Transformation Index (BTI), 2022b).

The government resorts to strong fiscal support after the Corona pandemic. In 2021, the fiscal deficit reached 7.7 % of the GDP (World Bank, 2022d). The exchange rate of the Chilean peso remained relatively stable despite the 2019 protests and the consequences of the Corona pandemic (Bertelsmann Foundation's Transformation Index (BTI), 2022b).

Chile is one of the most open economies in the world. The Economic Freedom Index ranks Chile 20th. However, the country has deteriorated regarding economic freedom since 2017, particularly in trade freedoms and fiscal health. Chile has particularly low barriers to foreign companies and investors (The Heritage Foundation, 2022c). It remains to be seen whether a new

constitution will bring changes. This can be classified as a risk for companies and investors (Allianz Trade Economic Research, 2021b).

Commodity exports dominate Chile's exports. In 2020, commodities accounted for 52 % of the country's exports (WITS, 2020). This makes Chile sensitive to changes in commodity prices, especially the global price of copper (Allianz Trade Economic Research, 2021b).

Social factors

Chile has made massive progress in poverty reduction. In 2020, 0.4 % of the population lived below the poverty line of 2.50 USD. However, in 2019 there were strong protests - including violent ones - demanding better economic and social conditions for the population. Chile has a high income inequality, as shown by the Gini index of 44.9.

In 2020, the unemployment rate decreased slightly to 9.1 % compared to the previous year. The country has a high youth unemployment rate of 21.39 %. This is higher than in the neighbouring Peru and Bolivia. Social spending as a percentage of the GDP was 11.4 % in 2019, well below the OECD average of 20 % and Germany's average of 25.9 % (OECD, 2019). In particular, education, health care and pension system measures are perceived as inadequate (O'Neil, 2022).

Indigenous groups and the Chilean government and corporations are currently engaged in a conflict over discrimination and land and resource rights (Gonzalez, 2020; Human Rights Watch, 2021; Maihold & Reisch, 2021). Environmental conflicts in Chile are on the rise. Chile has some of the driest regions in the world. The country has been experiencing a mega-drought since 2010. Water resources are repeatedly at the centre of resource conflicts due to the privatised structures of Chilean water management (Aitken et al., 2016; Boddenberg, 2020; A. A. Muñoz et al., 2020).

Bilateral factors

Germany and Chile maintain good bilateral relations. Chile is part of numerous trade and economic agreements, among others, with the EU. Germany sees Chile as an important partner in the energy transition and the market ramp-up of green hydrogen. A bilateral energy partnership and a memorandum of understanding sealed this (BMWK, 2021b). Germany primarely imports raw materials such as copper and foodstuff from Chile (Federal Foreign Office, 2022).

4 Outlook

Geopolitical risks arise from various political, economic, social and bilateral factors in exporting and transit countries. Therefore, a range of risk factors must be considered to capture hydrogen import security risk. Individual variables, such as a bilateral energy partnership as an indicator of good and reliable bilateral relations, cannot be seen as a guarantee of a secure energy supply. The individual variables in interaction can contribute to mapping the risk potential.

The analysis of the geopolitical risk potential of Spain, Algeria, the UAE and Chile has shown that each country has individual opportunities and risks. Figure 8 provides a schematic overview of the classification of the countries in the various risk dimensions.

As an EU member and a stable democracy, **Spain** is characterised by low geopolitical risks for German hydrogen imports. The European single market, the joint energy sector and potentially the possibility of pipeline transport offer numerous advantages for companies, investors and Germany's security of supply.

However, Spain will also have a high domestic demand for hydrogen on its decarbonisation path. Additionally, Germany will compete with other EU countries, such as the Netherlands or Belgium, for Spanish hydrogen. Therefore, Spain alone will not be able to cover Germany's import needs.

Algeria has great potential as a hydrogen exporter thanks to its considerable RE potential, its geographical proximity to the EU and the plans for the EU supply corridor across the southern Mediterranean. However, the country faces many domestic challenges - political, economic, and social. The tensions and conflicts in the MENA region, such as the conflict between Algeria and Morocco, threaten Germany's supply security. However, the hydrogen production could make an important contribution for Algeria to reduce its dependence on fossil energy exports and diversify the country's economy.

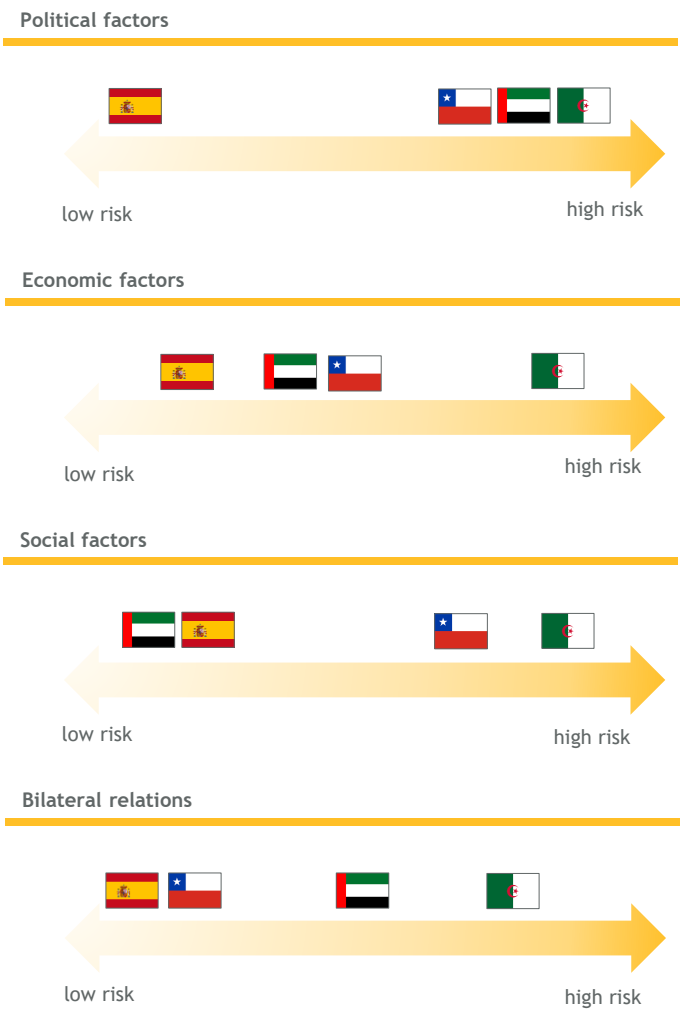


Figure 8: Evaluation of selected countries' risk potential

Source: Own illustration

A good economic situation and political stability characterise the **UAE**. However, the UAE is located in an unstable and conflict-ridden region. This also leads to transport risks for hydrogen imports due to three critical straits on the shipping route from the UAE to Germany.

Even though the diversification of the UAE economy is strongly promoted, it remains to be seen to what extent the energy transition poses a risk to the economic, social and political stability of the petro-monarchies and the region.

Chile offers particularly strong economic freedoms and therefore developed into a country that is especially attractive for investors and companies. However, social discontent and tensions caused political and economic stability to falter. The current uncertainty about the development of the Chilean constitution and, thus, the orientation of the political-economic system pose risks for hydrogen projects.

Each country has individual advantages and challenges concerning potential hydrogen imports for Germany. In addition to the various political, economic, social and bilateral risk factors of the individual countries, there are also company-specific factors. For example, long-standing cooperation between companies, a good cultural understanding and know-how in a company can influence the specific risk potential.

A comparative analysis of potential hydrogen exporters and supply routes worldwide by means of a quantitative approach seems useful to cover a range of countries and assess further hydrogen import options for Germany. Quantifying geopolitical risks entails various challenges, such as data availability, data selection, and weighting of individual risk factors. Nevertheless, this seems necessary to analyse Germany's hydrogen supply security so that hydrogen production costs alone are not used to select hydrogen exporters.

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List of Abbreviations

CPI	Corruption Perceptions Index
EDI	Economic Diversification Index
EU	European Union
FDI	Direct investment
GCI	Global Corruption Index
GDP	Gross domestic product
HDI	Human Development Index
IS	Islamic State
MENA	Middle East and Northern Africa
NGEU	Next Generation EU
RE	Renewable energies
SOEs	State-owned enterprises
UAE	United Arab Emirates
USD	United States dollar
WACC	Weighted Average Capital Costs

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