Energiewirtschaftliches Institut
an der Universität zu Köln

[EWI Policy Brief]

# Derisking hydrogen investments

## Analysis of the costs and risks of hydrogen imports from the Mediterranean and the MENA region

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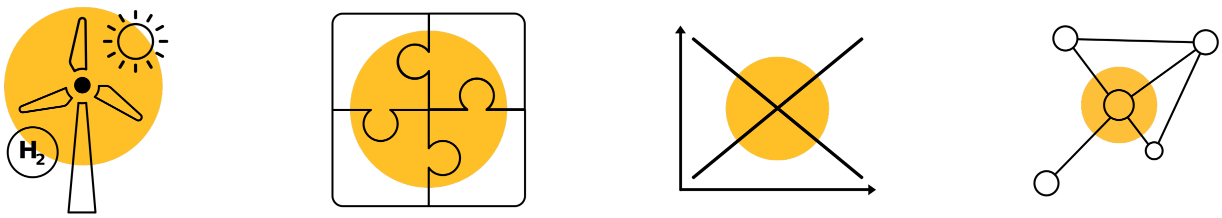

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# Core Statements

This policy brief compares countries from the Mediterranean and Middle East and North Africa (MENA) region in terms of their green hydrogen import costs, potentials, and country risks from the German point of view. Further, the analysis uses the Idea of Markowitz's Portfolio Theory to examine the trade-off between import costs and investment risks and security of supply. The following implications for the German hydrogen import strategy can be drawn:

- When hydrogen is imported from the Mediterranean and MENA region, imports from EU member countries along the Mediterranean coast should be prioritized
- Pipeline-bound imports from North Africa and non-EU Mediterranean countries are cost-effective and a suitable diversification for risk mitigation
- The construction of a pan-European pipeline infrastructure is crucial to enable cost-efficient imports from the southern EU and North Africa
- Maritime imports reduce the dependency on pipelines but are not cost-efficient if liquid hydrogen is imported
- Aligning the import strategy with geoeconomic and geostrategic objectives offers benefits

# Background

Several hundred TWh per year of green hydrogen are needed to meet Germany's long-term global climate targets and decarbonize all sectors (Kopp et al. (2022)). Germany will depend on hydrogen imports as national renewable energy potentials are insufficient to meet a demand of this quantity (EWI (2021)). In the short term, 45 to 90 TWh of hydrogen and derivative imports are required by 2030 (Bundesregierung (2023)). Therefore, ensuring a secure and cost-effective supply of green hydrogen is crucial for the German energy transition.

Next to the cost of hydrogen, the security of supply is a strategic concern. In its *Updated National Hydrogen Strategy*, the German government announced the development of a dedicated import strategy with the objective of establishing diversified import structures and avoiding new dependencies (Bundesregierung (2023)). Hydrogen investments face various barriers, especially those investments dedicated to building up international supply chains. With the green hydrogen market still in its early development phase, many final investment decisions are yet to be made.

Every country worldwide has access to renewable energy sources (RES) and, thus, could potentially produce green hydrogen. The countries of the Mediterranean and MENA region have vast RES potential and are in relatively close proximity to Germany (Fraunhofer CINES (2023)). Moreover, existing natural gas pipelines and plans for a Mediterranean hydrogen supply corridor position the region as a promising potential hydrogen exporter for Germany (Guidehouse Nether-

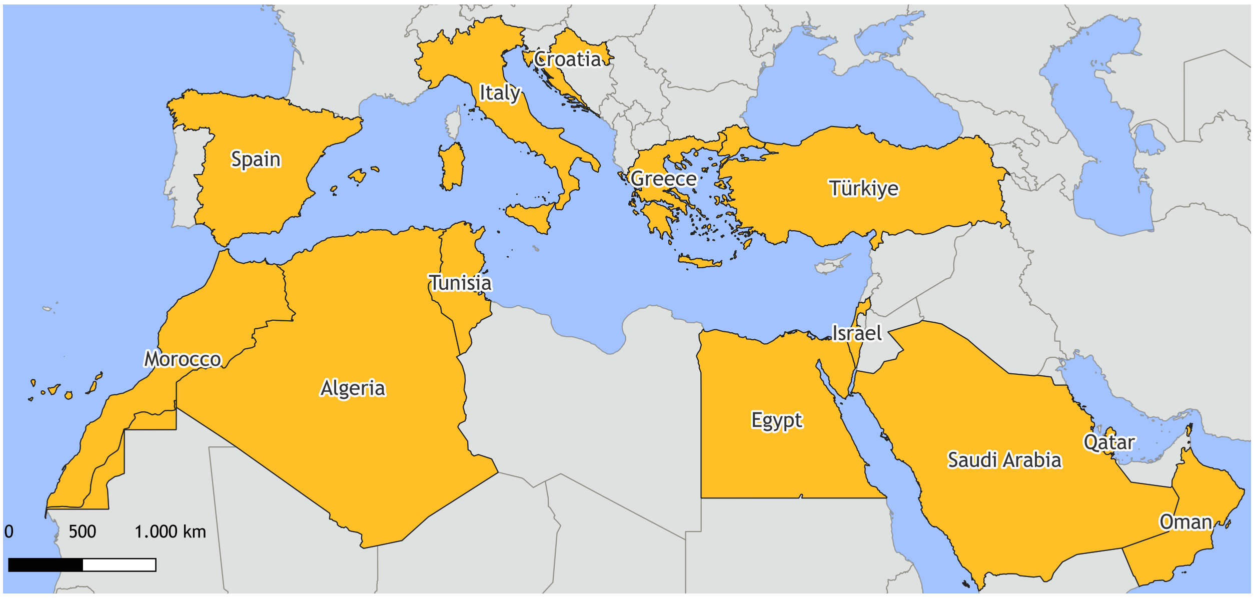


**Figure 1: Countries of the Mediterranean and MENA region included in the analysis.**
Source: Own illustration

lands B.V. (2022); European Commission (2022)). However, investments in and hydrogen imports from countries of the Mediterranean and MENA region face challenges and risks.

# Country-specififc cost and risk assessment

In the following, selected countries from the Mediterranean and MENA region (see Figure 1) are assessed as potential hydrogen suppliers for Germany. These countries' hydrogen production potentials and import costs are calculated based on the *EWI Global $H_2$ Cost Tool* (EWI (2020)) and discussed together with their *EWI Future Energy Score* (EFES) (EWI (2023a)). RES potentials of the analyzed countries are clustered according to their cost and risk efficiency and evaluated based on the idea of the portfolio theory by Markowitz (1952). Implications for the German hydrogen import strategy are identified to support decision-makers in making cost and risk-efficient hydrogen investments.

## Assessment of green hydrogen import costs and potentials

We quantify the import cost and production potentials of green hydrogen using the *EWI Global $H_2$ Cost Tool* introduced by Brändle et al. (2021). The production cost in each origin country is estimated for water electrolysis powered by dedicated RES which can either be onshore wind, offshore wind, or photovoltaics (PV). The electricity production costs are calculated based on country-specific RES capacity factors, investment cost, operating cost and production potential. For each RES type, the generation potentials are divided into quality classes based on capacity factors. The production cost calculations use uniform weighted average cost of capital. Thus, the country-specific risk of investments is not included in the costs. Overland transport costs are calculated via retrofitted natural gas pipelines. Maritime transport costs are calculated via the shipping of liquefied hydrogen. The import costs do not include storage costs to balance the intermittency of the production from renewable energies. In order to be able to interpret the costs, it is important to understand that the import costs are based on scenarios and are projections, not forecasts. Therefore, the analysis focuses on the relative cost comparison between the countries and not on the absolute costs.

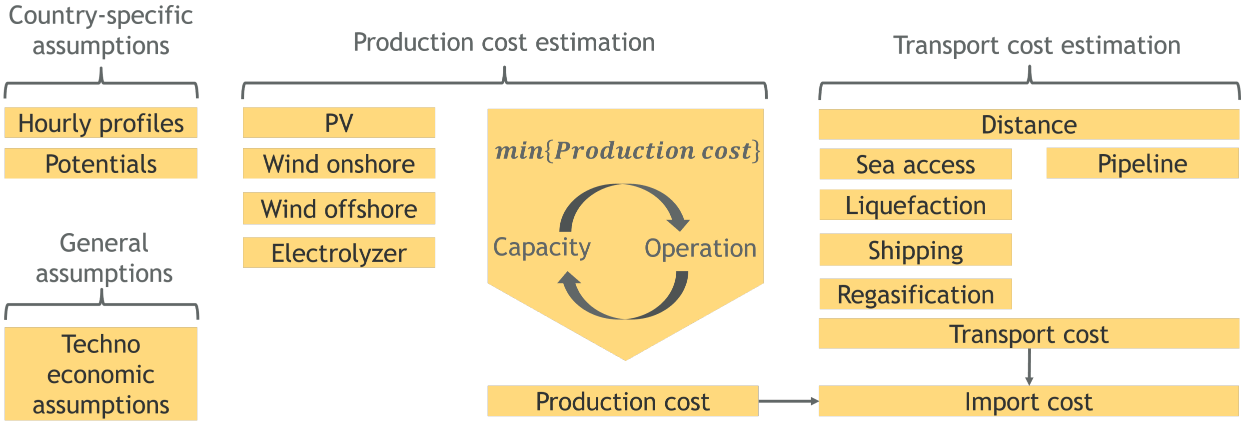


**Figure 2: Methodology for green hydrogen import cost estimation. Techno-economic assumptions include lifetime, efficiency, availability, capital expenditures and operating costs.**
Source: Own illustration based on Brändle et al. (2021)

### Assessment of the country performance with the EWI Future Energy Score

The *EWI Future Energy Score* intends to supplement the cost-based approach and helps to compare countries with each other by assigning them a score between 0 and 100. The EFES considers factors that pose a risk to stable and reliable future energy markets which may challenge or threaten the export of commodities like hydrogen and its derivatives. The score is based on four sub-indicators: political, economic, social, and energy. Scores are calculated for 86 countries for the years 2017 to 2021 and are based on an extensive data set of country-specific variables (EWI (2023a)). The EFES can be applied as a first step in assessing the potential security of investments and the security of future hydrogen supply chains. A higher score can be interpreted as better conditions for investments and lower risks for the security of supply of resulting hydrogen imports from the respective country.

### Identification of efficiency clusters

The portfolio theory by Markowitz (1952) considers the trade-off between risk and return and offers a framework for making investment decisions. The efficient frontier introduced by the

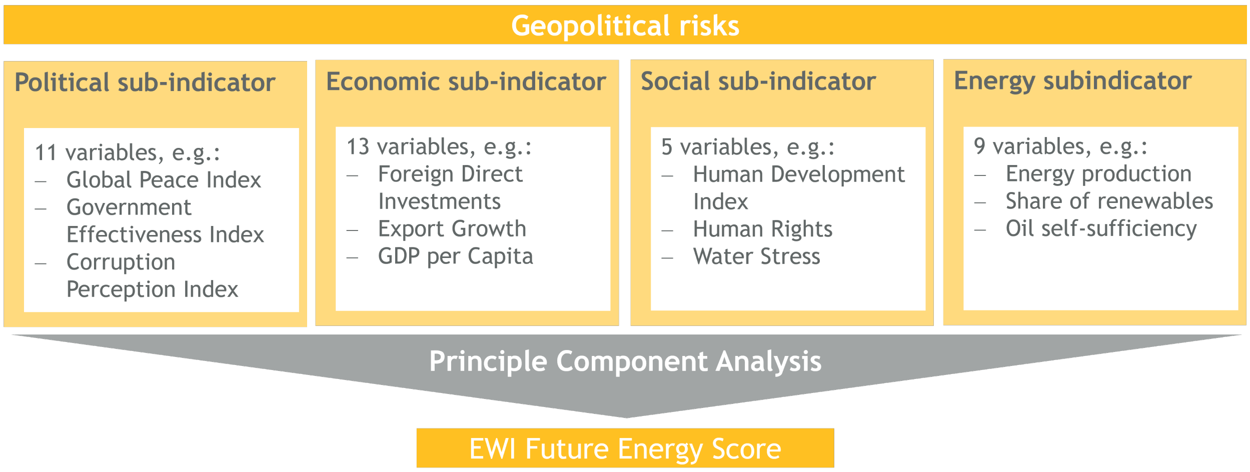


**Figure 3: Approach of the EWI Future Energy Score.**
Source: Own illustration

portfolio theory represents different combinations of assets in a portfolio based on their expected return and risk. Portfolios on the efficient frontier are considered ”efficient” because they provide the maximum expected return for a given level of risk or the minimum risk for a specified level of expected return. Portfolios that are not on the efficient frontier are considered inefficient because they either have lower returns for the same level of risk or higher risk for the same level of return. Drawing from the idea of the efficient frontier, import costs are interpreted as returns and EFES as risk. Thus, efficient hydrogen potentials are characterized by minimal import costs at any given EFES while maximizing the EFES for every level of import costs. The analyzed hydrogen potentials are manually classified into recognizable clusters according to their cost and risk efficiency. This results in four clusters - the efficient, risk-efficient, cost-efficient, and inefficient cluster.

Figure 4 shows a comparison of costs, risks, and technical potentials of the analyzed countries in the Mediterranean and MENA region. The x-axis shows the EFES of the origin countries. The y-axis shows the supply costs of green hydrogen from the respective origin country to Germany. The size of the bubble shows the technical potential, which is the maximum annual quantity that can be produced at the given cost, taking into account technical limitations.

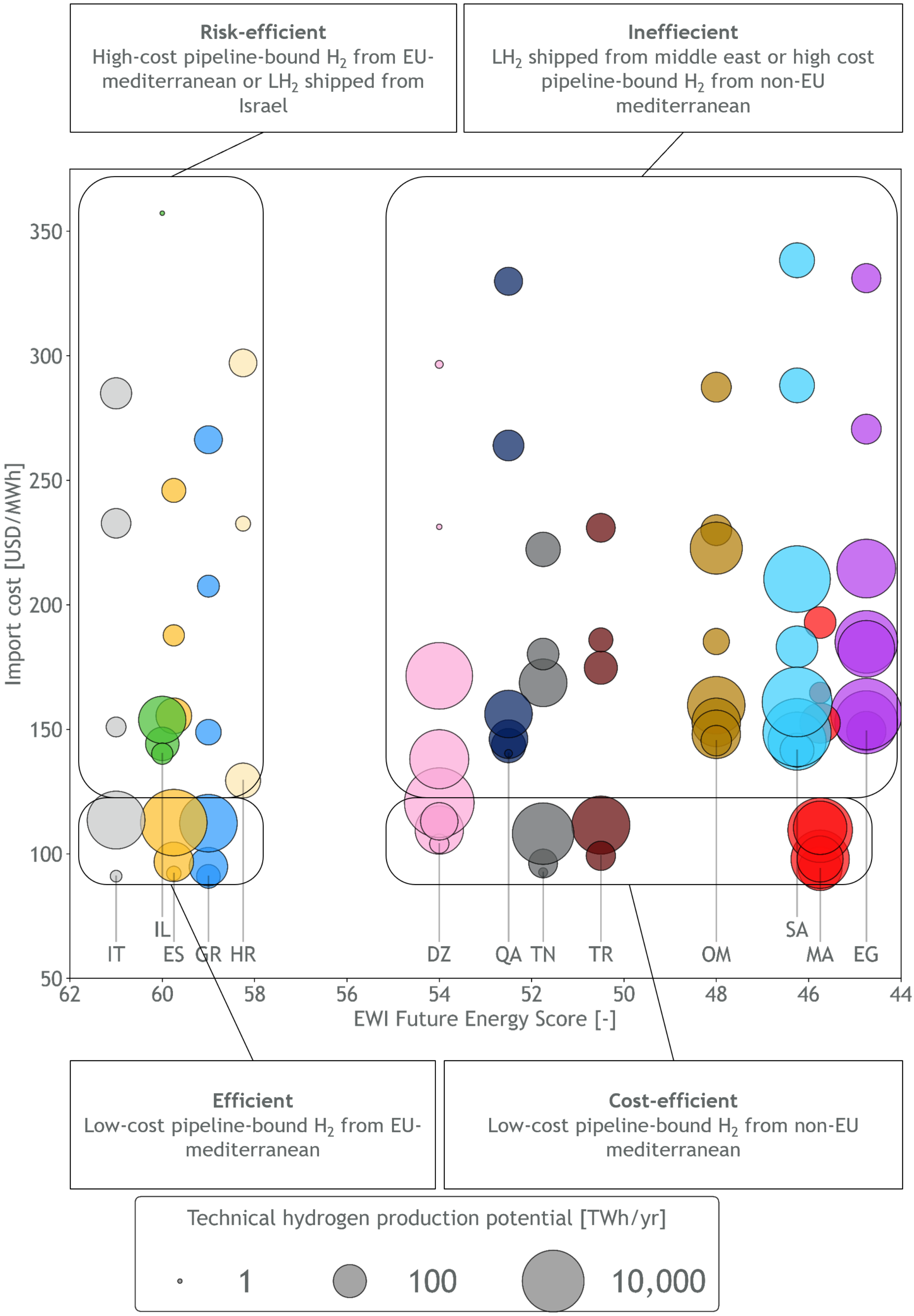


**Figure 4: Comparison of costs, risks, and technical potentials of the analyzed countries in the Mediterranean and the MENA region.**
Source: Own illustration. EFES based on EWI (2023a), costs and potentials based on Brändle et al. (2021)

### Efficient cluster: Low-cost EU-Mediterranean pipeline bound imports

The three Mediterranean EU member states Italy, Spain, and Greece are both cost- and risk-efficient. Hydrogen import costs from these countries range between 90 to 115 USD/MWh[1] for a total technical hydrogen production potential of 22,000 TWh/yr. Moreover, the countries have the lowest risk for hydrogen exports of all analyzed countries, with an EFES between 59 and 61. Italy, Spain, and Greece share similarities, which lead to low cost and risk. Their relative close proximity to Germany makes pipeline-bound exports economically viable. Existing pipeline connections can be retrofitted for the transport of hydrogen. Additionally, all three countries have relatively high political stability, stable institutions, and performed well in the social sub-indicator. Additionally, the EU single market and the monetary union carry major advantages and can reduce investment and business risks significantly.

### Risk-efficient cluster: Medium-to-high cost pipeline-bound imports from EU-Mediterranean or $LH_2$ shipped from Israel

This cluster includes the four Mediterranean EU member states Italy, Spain, Greece, and Croatia, as well as Israel. The import costs of this cluster range between 130 to 300 USD/MWh and are significantly higher than in the efficient cluster. On the one hand, costs are driven by the lower capacity factors of RES potentials compared to the efficient cluster. On the other hand, high transport costs for $LH_2$ drive the import costs from Israel. The total technical hydrogen production potential of 1,000 TWh/yr is small compared to the other clusters. All five countries are characterized by an EFES as high as in the efficient cluster, which can be interpreted as low import and investment risks. Israel performs particularly well in the economic and social sub-indicator of the EFES[2]. Croatia ranks the lowest among these five countries, mainly due to a lower political sub-indicator, among others, with a higher corruption perception and a lower performance in citizenz' voice and accountability.

### Cost-efficient cluster: Non-EU Mediterranean pipeline bound imports

The non-EU countries Tunisia, Turkey, Algeria, and Morocco could export hydrogen at similarly low supply costs as the efficient cluster. Hydrogen import costs range between 90 to 120 USD/MWh for a total technical hydrogen production potential of 30,000 TWh/yr. While the distance to Germany is larger than for countries from the efficient cluster, countries of the cost-efficient cluster are still in range for pipeline-bound exports and have existing natural gas pipeline connections to Germany, which could potentially be retrofitted for hydrogen transport. The higher transportation costs are offset by lower hydrogen production costs due to large wind and solar potentials with high capacity factors.

In the cost-efficient cluster, EFES ranges from 46 to 52. All four countries pose higher risks

[1] Caloric units refer to the lower heating value. The USD refers to the USD 2019.

[2] The EFES uses data until 2021. The war in Israel, which started in October 2023, is not reflected in the data.

for hydrogen investments with potentially lower security of supply than the efficient cluster. While Tunisia and Turkey perform well in the social dimension, they score low in the energy sub-indicator. Tunisia has a low share of RES and relies on fossil fuel imports (International Energy Agency (2020)). Turkey's energy demand heavily depends on fossil fuel imports, with significant growth over the past 30 years (International Energy Agency (2021)). Morocco and Algeria perform poorly in the political and economic sub-indicator. Morocco has limitations on political and civil rights, while Algeria faces significant economic challenges. In 2021, these countries exhibited a higher perception of corruption than the EU countries and Israel.

### Inefficient cluster: Shipping from the Middle East or potentials with high costs from pipeline-bound non-EU Mediterranean

The inefficient cluster comprises medium to high-cost potentials from various countries from the non-EU Mediterranean and the MENA region, as well as countries from the Arabic Peninsula. The import costs have a wide range between 145 to 340 USD/MWh. The total technical hydrogen production potential of the cluster is 168,000 TWh/yr, which is 3/4 of the total potential of all analyzed countries. The cluster includes potentials with lower capacity factors from the previously discussed countries of Tunisia, Turkey, Algeria, and Morocco. Further, this cluster includes Qatar, Oman, Saudi Arabia, and Egypt without pipeline connections to Europe. The fossil fuel-exporting Middle Eastern countries Qatar, Oman, Saudi-Arabia, and Egypt have significant wind and solar potentials with high capacity factors. However, the long distance and absence of an existing pipeline connection requires shipping of $LH_2$, which drives the import costs.

Oman, Saudi Arabia, and Egypt perform similarly in the country risk assessment, scoring between 45 and 52 in the EFES of 2021. Egypt reaches the weakest EFES among the assessed countries, with a particularly low score in the energy and economic sub-indicator. Qatar performs better than Oman, Saudi-Arabia, or Egypt. However, the country scores low in the political dimension, driven by political and civil rights, voice and accountability. The Middle Eastern countries Oman, Saudi Arabia, Qatar, Turkey, and Egypt face various challenges, which are reflected by low scores in some of the sub-indicators of the EFES, particularly the political, energy, and economic sub-indicators.

### Interpretation of technical potentials

The reported technical potentials of the clusters in Figure 5 are very large in the context of future green hydrogen demand projections. For instance, the *Ten Year Network Development Plan 2022* of the European Transmission System Operators reports in its Global Ambition Scenario a hydrogen demand of 2,431 TWh by 2050 (ENTSOG & ENTSO-E (2022)). In theory, this demand could be completely covered by potentials from the efficient cluster as it accounts for only 11 % of the cluster's technical potential.


**Figure 5: Total technical hydrogen production potential of the efficiency clusters.**
Source: Own illustration based on Brändle et al. (2021)

However, Technical potential in the context of hydrogen production from renewable energies is the maximum achievable production potential considering technical constraints and often presents an upper limit. The actual market potential may be significantly lower due to practical, economic, social and policy-related constraints. Competition in land use between renewable energies and other sectors, such as agriculture or urban development, can impact the availability of suitable sites for renewable energies, potentially limiting the realization of technical potentials. In densely populated countries, resistance from citizens against the expansion of renewables, driven by concerns over visual impact, noise, or perceived environmental risks, may pose obstacles to the widespread deployment of hydrogen technologies. Factors such as infrastructure limitations further reduce the market potential, especially in large countries with remote potentials. Therefore, a comprehensive analysis is required to determine how much of the technical potential is realistically attainable as market potential.

**Excursus: Transport risks**

The risk quantified by the EFES focuses on the investment risk in the origin country. However, the transport routes between the origin country and Germany bear risks, too. While pipeline transport is the most economical transport option for hydrogen, an import strategy based on pipeline imports leads to a high dependency on one or a few pipelines. Hazards, such as sabotage or technical failure, can reduce the functionality of pipelines and may form a threat to Germany's energy import security. Maritime imports, while potentially less economical, offer more flexibility in case of unexpected disruptions. Nevertheless, shipping lanes from the Middle East are prone to transport risks too, as they lead through maritime chokepoints like the Strait of Hormuz, the Bab-el-Mandeb Strait, and the Suez Canal. Natural disasters, technical and human failure, as well as sabotage or international conflicts, can result in a (temporal) closure of these chokepoints (EWI (2023b)). Depending on the origin country, some of these chokepoints are circumnavigable.

# Implications for the German hydrogen import strategy

The analysis of hydrogen supply costs and country risk allows to examine the trade-off between a pure techno-economic assessment and additional factors that determine investment securitity and security of supply. Several implications for the German hydrogen import strategy can be drawn from this analysis.

**Imports from countries on the EU Mediterranean coast should be prioritized.** Mediterranean and MENA countries own vast renewable energy potentials and offer many opportunities for low-cost hydrogen imports. Potentials located on the European Mediterranean coast offer low import costs and a high country performance, which can be interpreted as low investment and operational risks. From a cost and security of supply perspective, it can be concluded that as many renewable energy instalments and hydrogen production within the EU as possible are desirable.

**Imports from North Africa and non-EU Mediterranean countries are cost-effective and a suitable diversification for risk mitigation.** For more hydrogen import diversification, investments in other countries are recommendable. From a cost-efficient perspective, investment in the cost-efficient cluster comprising hydrogen potentials in Tunisia, Morocco, Algeria, and Turkey is desirable. Besides the discussed hydrogen imports from Mediterranean and MENA countries, other regions play an important role in creating a diversified German hydrogen import portfolio.

**The construction of a pan-European pipeline infrastructure is crucial to enable cost-efficient imports from the southern EU and North Africa.** To enable low-cost hydrogen imports from southern EU states, from North African countries, and Turkey, a hydrogen import pipeline infrastructure is essential. Therefore, a swift implementation of the European hydrogen infrastructure plans is needed. If no pipeline infrastructure is available, hydrogen import costs might be significantly higher than displayed.

**Maritime imports reduce the dependency on pipelines but are not cost-efficient if liquid hydrogen is imported.** An import strategy based on pipeline imports leads to a high dependency on one or a few pipelines. Hazards, such as sabotage or technical failure, can reduce the functionality of pipelines and may form a threat to Germany's energy import security. Maritime imports, while potentially less economical, offer more flexibility in case of unexpected disruptions.

**Aligning the import strategy with geoeconomic and geostrategic objectives offers benefits** While this analysis considers techno-economic potentials of hydrogen production and country risks to identify an optimal import portfolio, other factors may additionally guide the German import strategy. These factors can be based on geopolitical and geoeconomic considerations, such as strengthening bilateral partnerships, expanding Germany's influence, and facilitating sustainable industrial development.

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