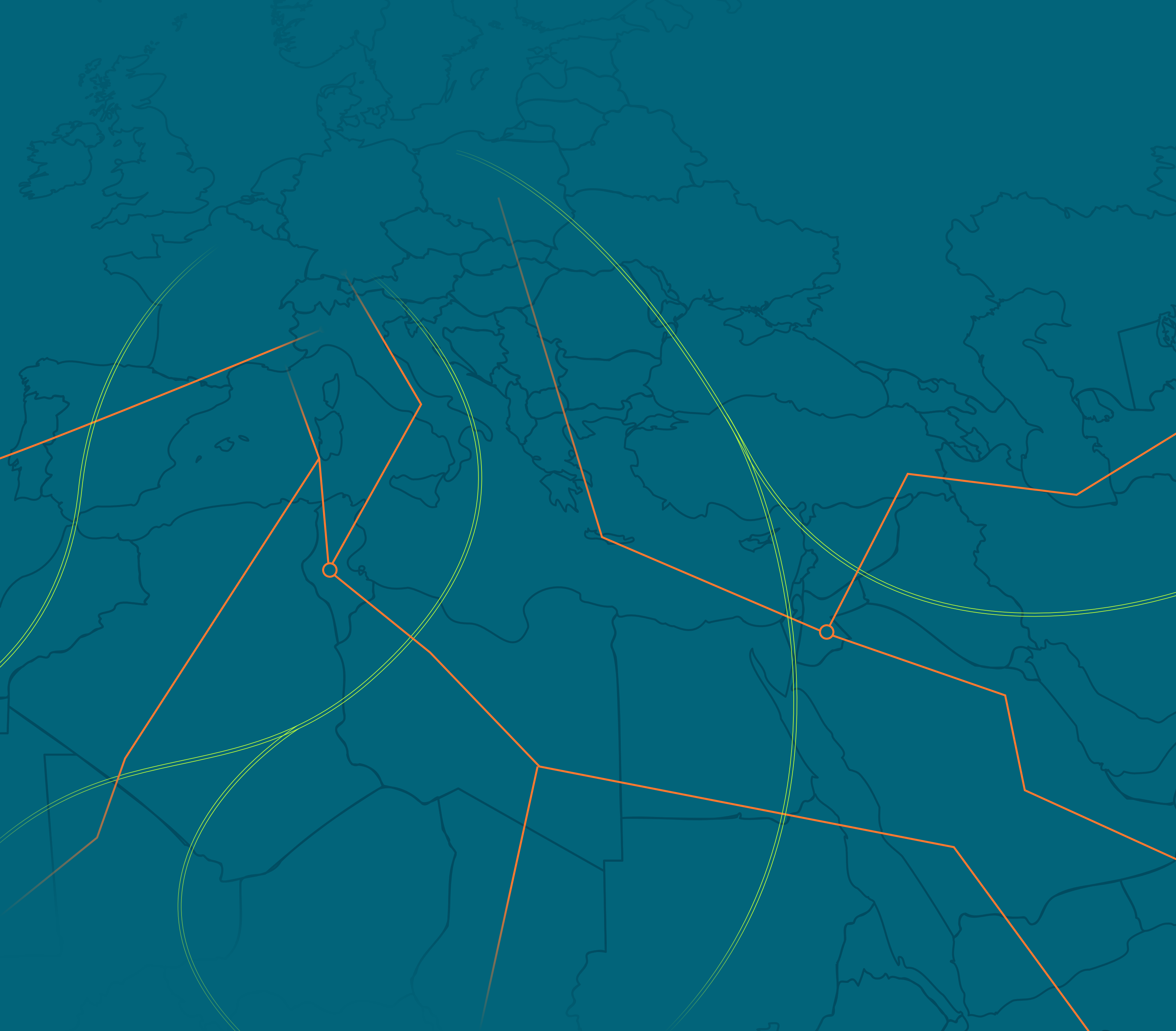
ADVANCING CROSS-BORDER ENERGY INFRASTRUCTURE BETWEEN EUROPE AND THE MENA REGION



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ABBREVIATIONS

ACER	Agency for the Cooperation of Energy Regulators
CAPEX	Capital Expenditures
CBA	Cost-Benefit Analysis
CBCA	Cross-Border Cost Allocation
CEEAG	Climate, Energy and Environmental Aid Guidelines
CEF	Connecting Europe Facility
CEF-E	Connecting Europe Facility - Energy
CfD	Contract-for-Difference
DG MENA	Directorate-General for the Middle East, North Africa and the Gulf
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EFSD+	European Fund for Sustainable Development Plus
EIB	European Investment Bank
ENNOH	European Network of Network Operators for Hydrogen
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
EU	European Union
EUR	Euro
FEED	Front-End Engineering Design
FID	Final Investment Decision
GCC	Gulf Cooperation Council
GCCIA	Gulf Cooperation Council Interconnection Authority
H2	Hydrogen
HVAC	High-Voltage Alternating Current
HVDC	High-Voltage Direct Current
IMEC	India–Middle East–Europe Economic Corridor
IPCEI	Important Project of Common European Interest
IsDB	Islamic Development Bank
KfW	German Credit Institute for Reconstruction (Kreditanstalt für Wiederaufbau)
MedTSO	Association of the Mediterranean Transmission System Operators
MEFED	MENA-Europe Future Energy Dialogue
MENA	Middle East and North Africa
MDB	Multilateral Development Bank
MoU	Memorandum of Understanding
NIP	Neighbourhood Investment Platform
NRA	National Regulatory Authority
OPEX	Operational expenditures
PCI	(EU) Project of Common Interest
PMI	(EU) Project of Mutual Interest
RAB	Regulated Asset Base
SAIDI	System Average Interruption Duration Index
TEN-E	Trans-European Networks for Energy
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
UAE	United Arab Emirates
USD	US Dollar

EXECUTIVE SUMMARY

Connecting Europe and the Middle East and North Africa (MENA) region via interconnectors and hydrogen pipelines contributes to a secure, sustainable, and affordable energy system. Diversification of energy supply through regional interconnection enhances energy security. Increased interconnection also enables the large-scale integration of renewables taking advantage of the regional variances in the potential for wind and solar energy. Lastly, an interconnected energy system reduces the need to build out additional generation capacity, thereby decreasing the overall societal costs of the energy transition.

While interconnections offer multiple benefits, the implementation of projects has been limited given their complexity. Interconnection projects involve multiple countries, each having their own vested sometimes diverging interests. In addition, by connecting to MENA countries challenges arise from difference in, amongst others, the energy market, the grid codes, and revenue models. In the MENA region interconnectors suffer from low utilisation because they are mainly operated to provide reserve capacity and grid stability during emergencies while in the EU, they offer capacity for cross-border electricity trading resulting in a much higher utilisation. These elements create a high risk profile for interconnection projects making them unattractive for investors.

De-risking interconnection projects is key to implement ambitious cross-border infrastructure development plans between the MENA region and Europe. While the EU, its Member States and development banks already have a set of mechanisms in place to support energy infrastructure projects, they are not targeted enough when it comes to electricity interconnectors and especially hydrogen corridors. The smart pooling of existing support, e.g. Connecting Europe Facility - Energy (CEF-E), Global Gateway and concessional financing from development banks, and new mechanisms, e.g. an EU-MENA investment facility, would de-risk projects and bring in private investments.

Next to tailored funding options, strong regional cooperation is another key element to advance cross-border energy infrastructure. To promote electricity trade between the MENA region and Europe, exchange procedures need to be established and market rules need to be adapted and introduced. For example, the absence of spot market electricity price signals in many MENA countries is a key barrier to electricity trade with the EU-internal electricity market. The introduction of electricity market elements in MENA countries could facilitate cross-regional trade with the EU-internal electricity market. In the meantime, first steps to ensure high utilisation of new electricity interconnections include the development of bilateral electricity exchange operations and the harmonisation of grid codes. This enables the market-driven build-out of cross-regional energy infrastructure.

For interconnection projects to be successful, engaging with impacted communities and strengthening local value creation is key. Next to governmental and private sector stakeholders, engaging with local communities early on in the project is critical to gain support from civil society. Interconnection projects have the potential to bring economic growth and prosperity, e.g. through investments in renewables and hydrogen production but also in new industries. Leveraging these potentials to stimulate green growth, both in the MENA region and in the EU, should be a key consideration of energy infrastructure planning.

1. REGIONAL ENERGY INTERCONNECTION OFFERS MULTIPLE BENEFITS

By 2050, Europe wants to become the first climate neutral continent. The transformation of the European energy system goes hand in hand with strengthening cross-regional electricity and hydrogen networks. In addition to implementing ambitious domestic renewable energy and hydrogen targets, Europe's future energy supply will include diversified imports of renewable electricity and hydrogen. Cross-border infrastructure connecting EU Member States with neighbouring regions is a key component for a secure, sustainable, and affordable energy supply.

The interconnection of national energy markets in Europe has been pursued very successfully by the EU and its Member States. Linking Europe's national electricity systems physically, but also through comprehensive harmonisation of market rules, has enabled the EU to increase its security of electricity supply, lower energy prices, and integrate more renewables into its energy systems. The annual welfare gains from cross-zonal electricity trading in the EU have been estimated to EUR 34 billion in 2021. Likewise, market integration in the EU by means of interconnection and cross-zonal trading reduces price volatility to one-seventh of the volatility in isolated markets.[1]

To encourage electricity interconnections across Europe, the EU set out an interconnection target of 15% by 2030. This means that each country should have in place electricity interconnections that allow a capacity equivalent to at least 15% of domestic electricity production to be transported across its borders to neighbouring countries. In 2021, 16 countries reported being on track to reach that target by 2030 or have already reached the target.[2] As of 2026, EU countries are additionally required to ensure that at least 70% of the interconnection transmission capacity is offered for cross-border electricity trading.[3] In the absence of appropriate network development and redefinition of bidding zones, congestion in national electricity grids can trigger re-dispatching of power plants and countertrading using interconnections. Transmission system operators (TSOs) can meet the minimum 70% target by efficiently managing or avoiding network congestions. To reach both targets, more interconnections are needed in some regions.

The European electricity network consisted of more than 400 interconnectors by the end of 2023 and is the world's largest interconnected grid. Currently, Europe has around 93 GW of cross-border transmission capacity with a further

23 GW in construction or in advanced permitting as of November 2024. The need of additional interconnector capacity between 2025 and 2030 has been determined to reach 64 GW (+55%) by the European Network of Transmission System Operators for Electricity (ENTSO-E). This would cost around EUR 10 billion in total but should lead to around EUR 5 billion in societal savings and reduce emissions by 14 million tonnes (Mt) CO_2 per year.[4]

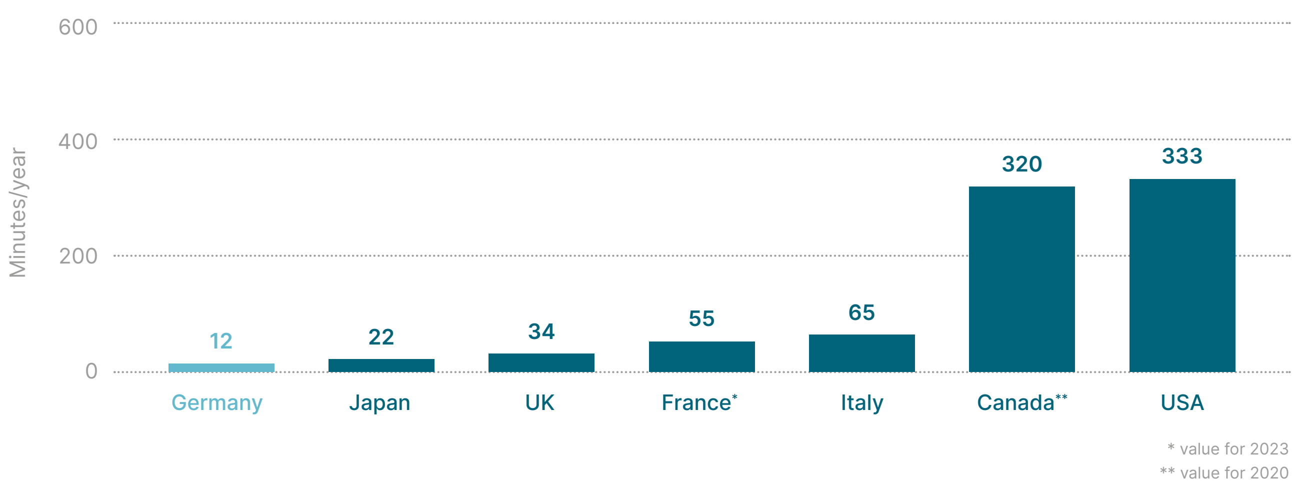
Interconnections are essential to maintain highest security of supply standards and to ensure affordability of electricity within Europe. Germany achieves the highest security of supply among G7 countries together with Japan with regard to the System Average Interruption Index (SAIDI), an indicator that measures the duration of unplanned electricity outages per year. The SAIDI-performance of the G7 countries is illustrated in *Figure 1*. The high performance in terms of security of supply is also remarkable against the backdrop that Germany has the highest share of renewable electricity generation (58% in 2024)[5] among the G7 countries.

The EU supports its Member States in attaining interconnection targets notably by tasking ENTSO-E to coordinate the trans-European electricity transmission expansion planning and the European Network of Transmission System Operators for Gas (ENTSOG) as well as the European Network of Network Operators for Hydrogen (ENNOH) with the planning of gas and hydrogen infrastructure.[6] This is accomplished through the biennial development of the Ten-Year Network Development Plan (TYNDP) and the identification of key European electricity transmission and storage as well as hydrogen and gas infrastructure projects known as Projects of Common Interest (PCIs). Priority projects between EU and non-EU countries are referred to as Projects of Mutual Interest (PMI). PCI and PMI projects benefit from favourable treatment, including expedited planning and permitting processes as well as financial support.

Increased interconnection with the MENA region is a no-regret option given its close proximity and abundant potential for renewable energy production. Regional integration offers significant opportunities to accelerate the local energy transition, generate revenues from trade in green electricity and hydrogen, as well as provide future-proof jobs. Interconnections are of strategic importance to enable trade, provide flexibility for a higher uptake of renewable production, and increase security of supply.

Electricity interconnections between Europe and the MENA region are already in place with many more projects in various stages of development. Two electricity interconnections between Spain and Morocco are the first projects connecting Europe and the MENA region, commissioned already in 1997 and 2006 respectively. Since then, only the Great Sea Interconnector connecting Greece via Cyprus to Israel has reached construction phase. The project forms part of the India-Middle East-Europe Economic Corridor (IMEC). The ELMED electricity interconnector between Italy and Tunisia is in the permitting process. Eight additional electricity interconnection projects between the EU and the MENA region are included under consideration in the latest TYNDP published by ENTSO-E in March 2024.

Figure 1: Duration of unplanned electricity outages based on SAIDI for G7 in 2022.



Source: Guidehouse based on BNetzA, Ofgem, Enedis, ARERA, OCCTO & EIA.

Developing an integrated pan-European hydrogen network by 2030 is crucial for achieving Europe's energy transition goals. Early investments in hydrogen infrastructure support a competitive energy transition while enabling large-scale renewable energy and hydrogen deployment. Cross-border infrastructure plays a pivotal role in the hydrogen value chain, ensuring connectivity between producers and offtakers while providing the investment certainty needed to drive hydrogen market development.

The EU is expected to become a large importer of hydrogen and the MENA region is anticipated to play a key role to meet that demand. In 2022, the European Commission (EC) published the REPowerEU plan, targeting 20 Mt of renewable hydrogen use by 2030. Thereof, 10 Mt shall be produced domestically within the EU, and 10 Mt imported.[7] This ambitious target underscores the anticipated role of renewable hydrogen in the future energy system of the EU. Hydrogen corridors stretching beyond European borders are poised to play a significant role in meeting the EU's future hydrogen demand. Pipelines are the most cost-effective option for transporting hydrogen, making them a cornerstone for meeting the hydrogen import target of the EU. Many MENA countries have the potential to produce low-cost renewable hydrogen at scale and the proximity of the region allows for hydrogen pipeline connections to Europe.

1.1. Electricity and hydrogen corridors

There are several corridors for electricity and hydrogen under development between Europe and the MENA region with the aim to strengthen energy trade and to contribute to green growth. While the hydrogen corridors are in an early planning phase, electricity corridors already exist today.

Electricity

Electricity exchange between Europe and the MENA region has enormous potential but remains at low volumes. In addition to a lack of physical interconnections beyond the two existing interconnectors between Spain and Morocco, the different national energy market frameworks in the MENA region do not yet allow for an efficient use of interconnection capacity and commercial electricity trade at larger volumes. Currently, the two interconnectors between Spain and Morocco are the only power connections between North Africa and Europe in the 'West Mediterranean Corridor'. An important share of the energy imported by Morocco from Spain is exported to Algeria, with both Morocco and Algeria benefiting from the lower energy marginal prices observed in Spain. For Spain, the interconnection reduces the marginal price of electricity in the national market. The interconnections include two 400 kV High-Voltage Alternating Current (HVAC) transmission lines that have a combined capacity of 1,400 MW. A third 400 kV HVAC interconnection with 700 MW capacity is planned to be commissioned in 2026 for an expected additional investment cost of EUR 150 million, split equally between Morocco and Spain.[8] Between 2004 and 2017, Morocco's net electricity imports from Spain varied between 10 and 14% of the national electricity demand. In 2018 and 2019, the direction of flows reversed and Spain became a net importer with a balance of around 1.2 GWh. Currently, Spain is net exporting electricity to Morocco. The Morocco-Spain interconnection reached an average utilisation rate of the exchange capacity of 77% in 2017.[9] This utilisation is particularly high compared to other electricity interconnections within the MENA region.[10]

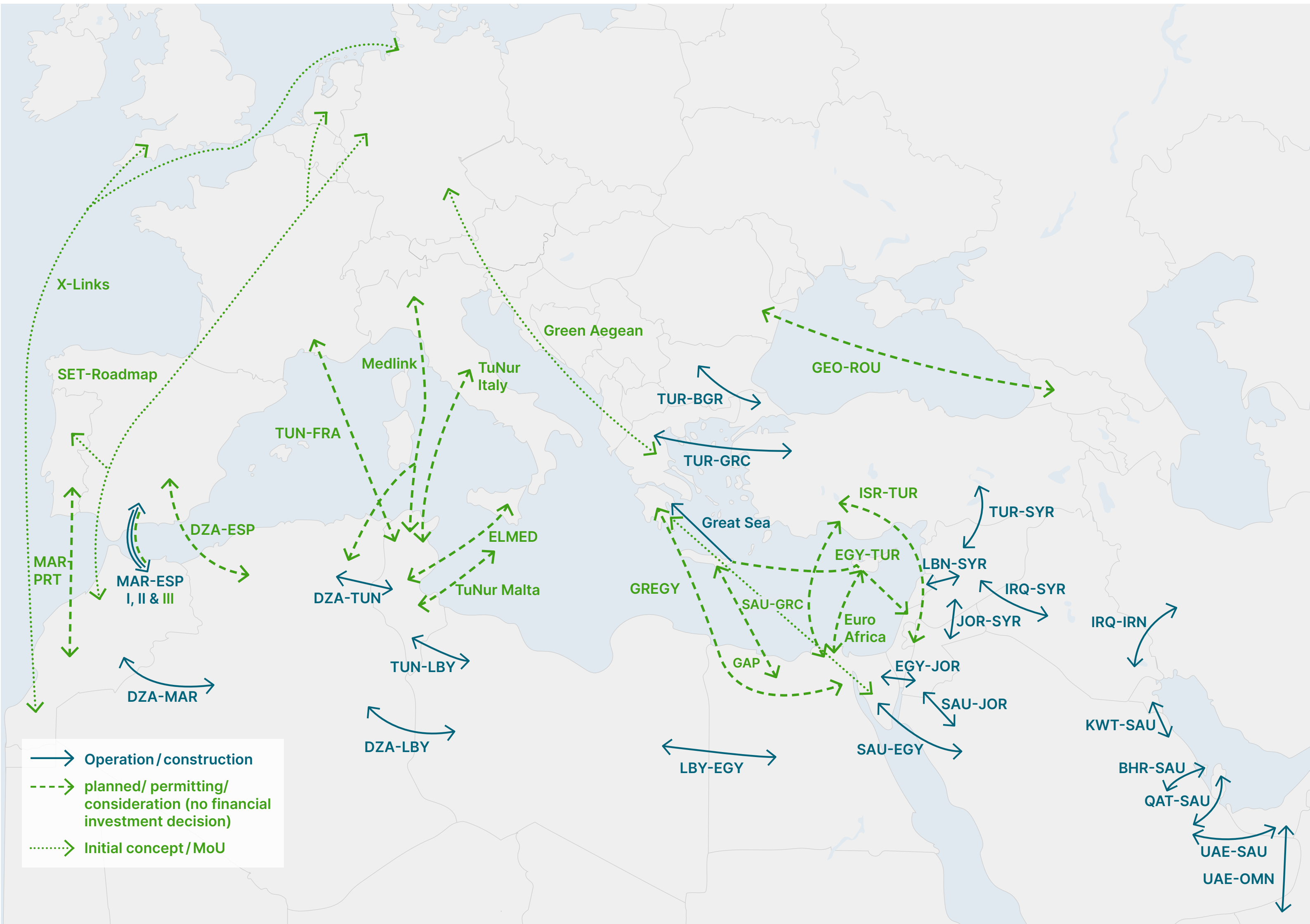
New cross-border electricity interconnections are typically developed as high-voltage direct current (HVDC) transmission lines. Previously, interconnectors were deployed as HVAC transmission lines. HVDC is more efficient for long distance electricity interconnections with lower transmission losses but higher initial costs due to the need for converters. It is ideal for connecting asynchronous electricity grids.[I] HVAC is more commonly used for shorter distances, has lower upfront costs, integrates easily in existing grids but suffers more losses over long distances. The significant decision parameters between HVAC and HVDC interconnections are distance, cost, and grid integration needs.

Several new electricity interconnections are planned to connect Europe and the MENA region but only few have reached a final investment decision (FID). Electricity interconnection projects in the Mediterranean can be clustered to regional infrastructure corridors.[11] The 'West Mediterranean Corridor' links the Iberian Peninsula to Morrocco and Algeria with the Morocco-Spain interconnection in successful operation. The 'Central Mediterranean Corridor' connects Italy and France to Algeria and

[I] *Synchronizing two asynchronous AC-power grids is the process of matching frequency and phase to be able to transfer power via AC lines. HVDC interconnections are able to transfer power also between asynchronous electricity grids.*

Tunisia with the ELMED interconnection between Italy and Tunisia being the most advanced project in this corridor. In the 'Eastern Mediterranean Corridor', new interconnections are planned between Greece, Cyprus, Egypt, and Israel. The GreatSea Interconnection is the most advanced project in this corridor. An overview of existing and planned electricity interconnections is provided in *Figure 2*. In the following, an electricity trading corridor between the energy exporting Gulf countries and Europe is being examined.

Figure 2: Selected existing and planned electricity interconnections projects in the EU-MENA region.



INTERCONNECTOR PROJECTS (SELECTION)

West Mediterranean Corridor

- MAR-ESP interconnection I, II, III (two in operation, third under consideration)
- MAR-PRT interconnector (ongoing feasibility study)
- DZA-ESP interconnector (feasibility study conducted)
- SET Roadmap (MoU 2022 between FRA, GER, PRT, ESP & MAR)

Central Mediterranean Corridor

- ELMED interconnector (construction planned for 2024)
- TUN-FRA interconnector Medusa (construction planned for end of 2025)

Eastern Balkan Corridor

- GEO-ROU interconnector (ongoing feasibility study)
- Green Aegean interconnector (ongoing feasibility study, AUT, GRC, SVN, GER)

East Mediterranean Interconnectors

- GreatSea interconnector (under construction since 2022, PCI project status)
- EuroAfrica interconnector (under construction)
- GREGY interconnector (in development since 2008, expected to be operational in 2028)
- GAP interconnector (MoU 2023 on company level)
- ISR-TUR interconnector (feasibility study conducted)

Others

- X-Links (ongoing feasibility study)

Source: Guidehouse based on ENTSO-E, Med-TSO, SET-Roadmap & Masen.

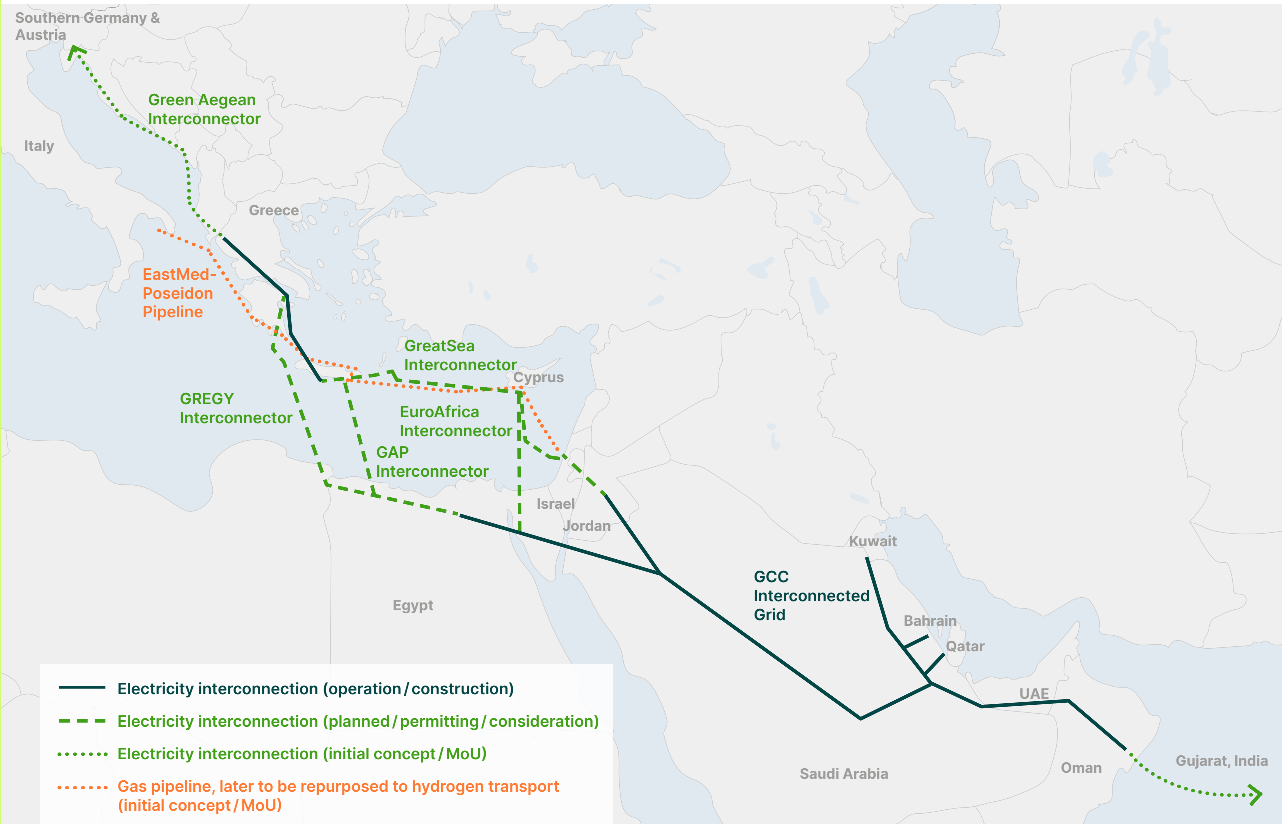
Electricity corridor between Europe and GCC

Several electricity interconnections are being developed to link Europe via Greece with Egypt, Israel, and the Gulf region. The GreatSea Interconnector (Greece-Cyprus-Israel) and additional interconnections between Israel, Jordan, and the Gulf Cooperation Council (GCC) or alternatively between Greece, Saudi Arabia, and Egypt could link up Europe to benefit from the significant potential of the Gulf states and Egypt in renewable energy production. Construction of the Great Sea Interconnector has already started. The multiterminal electricity import corridor is illustrated in *Figure 3*.

The GreatSea electricity interconnection is proposed as a two-way HVDC multiterminal link with a capacity of up to 2 GW between mainland Greece, Crete, Cyprus, and Israel. The construction of the undersea cables between Greece and Crete started in 2022 and is scheduled to be completed in 2027. The electricity cables will follow mostly the same route as the planned EastMed pipeline which shall allow imports of gas first and hydrogen later from the Middle East to Europe. The combined cost of just the GreatSea Interconnector and the EastMed pipeline amount to around USD 6.5 billion for the pipeline and USD 3.9 billion for the interconnector. Currently, Greece's TSO IPTO is seeking to secure financing for the interconnector from Crete to Israel. In 2022, the European Commission approved EUR 657 million of funding for the construction of the interconnector while the Cypriot government has committed additional EUR 100 million. TAQA, Abu Dhabi's energy holding company, signed a Memorandum of Understanding (MoU) with IPTO in December 2023 to explore the possibility of becoming one of the shareholders in the HVDC interconnection between Greece and Cyprus. Greece's Ministry of the Environment and Energy announced in February 2024 that the US International Development Finance Corporation has also expressed interest in participating in the GreatSea Interconnector.

The GreatSea Interconnector is integrated in the India-Middle East-Europe Economic Corridor (IMEC), a proposed economic route from India to Europe through the United Arab Emirates (UAE), Saudi Arabia, Israel, and Greece. Saudi Arabia has pledged USD 20 billion for the financing of the IMEC corridor that also includes train and internet infrastructure. To promote the implementation, Saudi Arabia's TSO National Grid and Greece's TSO IPTO established the project company, Saudi Greek Interconnection, in September 2023 based on shareholder agreement with equally split ownership.

Figure 3: Energy corridor from Germany to GCC.



The company was formed to conduct commercial viability and other studies for the development of an HVDC interconnection between Greece and Saudi Arabia. For an interconnection between India and the GCC, a MoU has been signed. The GCC-India interconnection is being discussed between India, UAE, Saudi Arabia, and Oman.

The electricity corridor via Israel requires interconnections between Israel, Jordan and Saudi Arabia. A MoU signed between Israel, Jordan and the UAE in November 2021 envisages the export of 600 MW of Jordanian solar electricity, with an investment from the UAE state-owned renewable energy developer Masdar, in exchange for supply by Israel of 200 million cubic meters of desalinated water. The war in Gaza however has halted bilateral cooperation between Jordan and Israel. For the interconnection between Jordan and Saudi Arabia, both countries have completed economic and technical feasibility studies in May 2024.

An alternative route of the electricity corridor from Europe to the GCC is emerging via interconnections from Crete to Egypt and Saudi Arabia. A 3 GW HVDC electricity interconnection between Egypt and Saudi Arabia is under construction and expected to be completed in July 2025. Two interconnections between Crete and Egypt are already under consideration in ENTSO-E's TYNDP. The Greece-Africa Power Interconnector (GAP Interconnector) promoted by IPTO is planned to be completed before 2030 and includes AC and DC lines with 2 GW transmission capacity. The GREGY Green Energy Interconnector concerns a 3 GW HVDC interconnection scheduled to be completed by 2035.

The existing GCC cross-border grid connects the six GCC members via a transmission line. It is administered by the GCCIA, a joint stock company subscribed to by the six GCC states. The interconnection grid has a total capacity of 2.4 GW with varying capacities for each county's interconnection. While most linkages operate at 400 kV, the connection between the UAE and Oman is operated at 220 kV. Saudi Arabia is connected to the GCC interconnection with a 1.2 GW HVDC line.

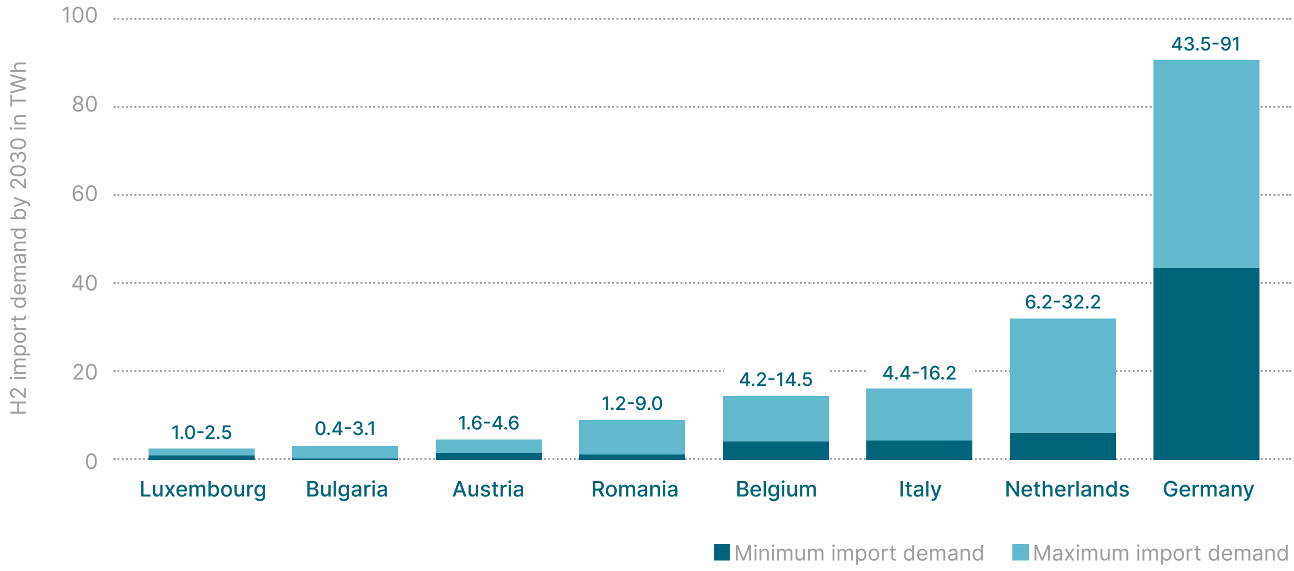
The Green Aegean Interconnector is considered a 3 GW HVDC interconnection with an option to increase the capacity up to 9 GW at a later stage. The interconnector aims to link Greece and the Middle Eastern countries with their greater solar resources to Austria and Germany with their greater wind power potential. The project costs are estimated at EUR 8.1 billion. The project is promoted by the electricity TSOs IPTO (Greece), TenneT (Netherlands/Germany), and APG (Austria). IPTO has submitted an application for the project's inclusion into ENTSO-E's revised TYNDP.

Hydrogen

Hydrogen corridors are crucial for bridging the gap between hydrogen producers and offtakers, leveraging the abundant potential for renewable hydrogen in the MENA region for local decarbonisation, and meeting the high demand for hydrogen in Europe. Utility-scale renewable hydrogen projects are being planned in the MENA region, benefiting from high-capacity factors and substantial land availability. Most of these planned projects have a strong focus on the export of hydrogen or its derivatives and Europe is seen as the key offtake market.

Germany, Italy, the Netherlands, Austria, and Belgium are expected to be among the largest importers of hydrogen and its derivatives in the EU. *Figure 4* shows that Germany leads with the highest total demand (95-130 TWh by 2030), with an import share of 50-70% according to the German Hydrogen Import Strategy.[12] By 2030, the Netherlands is projected to have a hydrogen import demand ranging from 6.2-32.2 TWh followed by Italy (4.4-16.2 TWh) and Belgium (4.2-14.4 TWh).

Figure 4: Comparison of the hydrogen import demand of EU countries.



Source: Guidehouse based on Agora Energiewende & European Hydrogen Backbone.

To meet the expected import demand, five large-scale hydrogen pipeline corridors have been proposed by the EU and gas TSOs[II], with three of these corridors set to connect the MENA region with Europe:

- The **North Africa and Southern Europe Corridor (SoutH2 Corridor)** is intended to mainly serve hydrogen demand in Italy, Austria, and Germany, with Tunisia and Algeria as the primary exporting countries. With a hydrogen import capacity of 4 Mtpa from North Africa, the SoutH2 Corridor could substantially contribute to European import demands. More than 70% of the existing gas infrastructure can be repurposed reducing the cost of the overall corridor.[13] The corridor is expected to be fully operational by 2033-2035.[14]

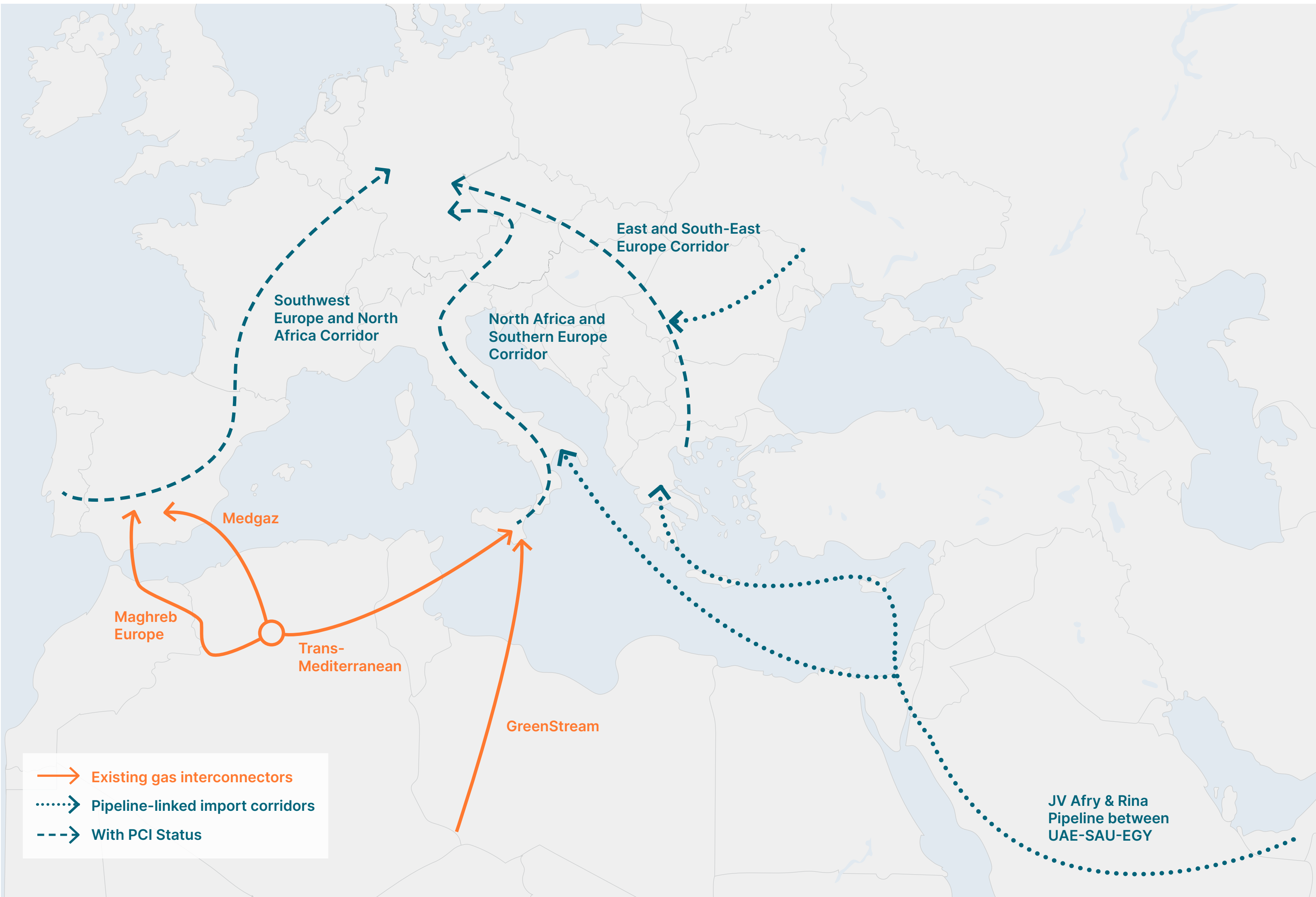
- The **Southwest Europe and Northern Africa Corridor** will connect hydrogen producers in Spain, Morocco, and Portugal to hydrogen offtakers in mainly France, Germany, and the Benelux countries. Approximately 60% of this hydrogen corridor can be repurposed from existing gas infrastructure. However, a significant portion of the pipelines in Spain and Portugal, as well as the interconnection between France and Spain will need to be newly constructed. The corridor will have 2 Mtpa of transmission capacity.[15] Currently, most of the pipelines are in the pre-feasibility or feasibility stage, with the corridor expected to be fully operational by 2040.

- The **East and Southeastern Europe Corridor** will provide mid-term access to hydrogen supplies from Eastern and Southeastern Europe, including significant imports from Ukraine, Poland, Greece, and Romania, to Central Europe. The corridor is expected to be operational by 2035-2040, encompassing 10,000 km of large-scale hydrogen pipelines across all the countries involved, with approximately 60% of these being repurposed pipelines.[16] In the long term, this corridor could also tap into the hydrogen supply potential from the Gulf region.

While many of the European segments of the Europe-MENA hydrogen corridors already have PCI status, benefiting from an accelerated permitting process, improved regulatory treatment, and possibly CEF-E funding, today, none of the segments connecting to non-EU countries hold PMI status. Tunisia is currently developing a PMI application for the SoutH2 Corridor pipeline connecting Italy and Tunisia. An overview of planned hydrogen pipelines is provided in *Figure 5*.

[II] The European Hydrogen Backbone (EHB) initiative is a coalition of thirty-three energy infrastructure operators dedicated to accelerating the development of hydrogen infrastructure across Europe.

Figure 5: Selected existing and planned cross-border hydrogen transport projects in the EU-MENA region.



Source: Guidehouse based on European Hydrogen Backbone.

EUROPE-MENA HYDROGEN CORRIDOR PROJECTS

North Africa and Southern Europe Corridor (EHB)
- PCI Status: SouthH2, SunsHyne, HyPipe Bavaria, H2ercules, FLOW East

Southwest Europe and North Africa Corridor (EHB)
- PCI Status: H2Med, CelZa, BarMar, HyFen, H2ercules South, H2ercules
- Feasibility study between ITA & TUN (applied for PMI)

East and South-East Europe Corridor (EHB)
- PCI Status: Central European Hydrogen Corridor (CEHC), Interconnector BLG-GRC

The investment costs for developing and constructing hydrogen corridors vary significantly based on the share of pipelines that can be retrofitted. Building new pipelines is, on average, four times more expensive than repurposing existing gas pipelines. An estimate on the percentage of the total pipelines that can be retrofitted for each hydrogen corridor between European and the MENA region and the associated cost are shown in *Table 1*. The overall costs are also heavily influenced by the size and length of the pipelines.[III]

Table 1: Key parameters of the EU-MENA Hydrogen Corridors.

	Length	Repurposed pipelines %	Total Cost	Involved TSOs	Involved countries
North Africa and Southern Europe Corridor	~2.300 km	60%	EUR 2.99 billion	Sonatrach, Sotugat/ TTPC, TMPC, Snam, TAG, GCA, bayernets	Algeria, Austria, Czech Republic, Germany, Italy, Slovenia, Slovakia, Tunisia
The Southwest Europe and Northern Africa Corridor	~2.900 km	60%	EUR 7.25 billion	Enagás, GRTgaz, OGE, REN, Teréga, Sonatrach, Metragaz, Transgas	France, Germany, Morocco, Portugal, Spain
East and Southeastern Europe Corridor	~3.500 km	60%	EUR 8.33 billion	SFA, Bulgartransgaz, Transgaz, TSO of Ukraine, FGSZ, EUStream, GCA, NET4GAS	Austria, Bulgaria, Croatia, Czech Republic, Germany, Greece, Hungary, Romania, Slovakia, Slovenia, Ukraine

Source: Guidehouse based on Agora Energiewende & European Hydrogen Backbone.

2. KEY ELEMENTS OF ENERGY INFRASTRUCTURE DEVELOPMENT

2.1. Development phases

The development timelines for cross-border infrastructure are highly project-specific and vary based on the complexity of the project and the regions involved. Electricity interconnections require roughly at least eight years from the initial concept until commissioning.[17] Key obstacles in the planning process of electricity interconnections are lengthy and ineffective permitting procedures and public opposition. Development timelines for hydrogen corridors are even more uncertain given the novelty of the undertaking. Current expectations indicate seven years from initiation to commissioning with repurposing of existing natural gas infrastructure being a decisive factor.[18]
The development of infrastructure can be grouped into five steps:

1. Overarching **network modelling** is the foundation of any interconnection project. These include scenarios showcasing different evolutions of the

[III] The average cost of constructing new hydrogen pipelines is approximately EUR 3.1 million per kilometre. In comparison, retrofitting existing gas pipelines costs around EUR 0.7 million per kilometre on average.

energy system including the need for additional interconnection. These needs are matched by developing individual interconnector projects.

2. The development begins with the **pre-feasibility phase**, taking 1-2 years, including a study to assess the project's market, technical, economic, and environmental viability. Based on the assessments and the study, the interconnection is considered for inclusion in the national grid development plans and the EU-wide TYNDP of ENTSO-E for electricity and the TYNDP of ENSOG for hydrogen projects.[19]

3. The subsequent **feasibility phase**, taking 1-2 years, includes stakeholder engagement, forming project partnerships, and securing political and regulatory support.

4. Following this, the **Front-End Engineering and Design (FEED)** phase takes between 1-6 years. It involves detailed engineering concepts, environmental and social assessments, spatial planning and regulatory approvals, structuring financial arrangements, cross-border cost allocation, and securing funding. Several key factors significantly influence the timeline and duration of the FEED phase. One of the most time-consuming aspects is permitting for cross-border infrastructure projects, which can take up to four times longer than the actual construction of a pipeline or electricity interconnector. Environmental impact assessments, which evaluate the project's potential effects on ecosystems and biodiversity also contribute to extended timelines. Additionally, opposition from impacted communities can further delay progress. Addressing these issues often requires extensive stakeholder engagement, negotiations, and project adjustments. The FEED phase generally accounts for around 2-3% of the total project cost.

5. The **construction phase** typically takes 2-5 additional years followed by the **commissioning phase**, taking 0.5-1 year mainly involving the testing of the infrastructure and integration in existing electricity grids. The construction phase is significantly impacted by the availability of crucial materials. For instance, the production and delivery of high-voltage cables which are critical components for energy transmission, can take approximately six to seven years, depending on material availability and production capacity.

The development steps and a conceptualized timeline for electricity and hydrogen cross-border infrastructure are indicated in *Figure 6*.

Figure 6: Conceptual illustration of project phases and milestones for energy infrastructure.

2.2. Key actors

The development of cross-border energy infrastructure relies on the coordinated efforts of a diverse array of actors. These include regulators, grid operators, financial institutions, governments, and regional initiatives. Each of these stakeholders plays a crucial role in ensuring the successful planning, implementation, and operation of cross-border infrastructure.

Governmental actors, the European Commission, and regional intergovernmental bodies such as the Union for the Mediterranean (UfM)[IV] can play an important role in driving the process of energy infrastructure development. An example is the SoutH2 Corridor where Germany, Austria and Italy are actively driving the accelerated implementation of the hydrogen corridor through regular progress workshops. In October 2023, German government representatives met with

[IV] *The Union for the Mediterranean (UfM) is an intergovernmental institution bringing together the EU Member States and 16 countries from the Southern and Eastern Mediterranean with a broad scope beyond energy. With regard to cross-border energy projects, UfM facilitates dialogue, supports project development, and mobilises resources for electricity interconnections.*

government representatives from Algeria, Austria, Italy and the European Commission to discuss the progress of the SoutH2 Corridor. In February 2024, Germany and Algeria signed a MoU, to establish a bilateral hydrogen task force. Following from this, an MoU between Germany, Italy and Austria was signed in May 2024, which formalised the countries' cooperation on the development of the SoutH2 Corridor.[20]

Grid operators are central actors in cross-border energy projects. National TSOs coordinate national system planning and contribute to regional system planning. They promote interconnection projects, manage regulatory compliance, negotiate cost allocation, and supervise compliance with technical standards and grid codes. Cooperation between national transmission system operators in Europe is facilitated by ENTSO-E for electricity and by ENTSOG for gas. ENNOH will be the organization responsible for hydrogen and is planned to be operational by 2026. The organisations coordinate regional and continental energy infrastructure development, working above the national level. They harmonise grid codes and technical standards, facilitate cross-border energy trade, and promote market integration. ENTSO-E and ENTSOG (eventually also ENNOH) are cooperating to deliver EU-level integrated network planning, with increasingly aligned scenarios between the electricity, hydrogen, and gas sectors.

The Association of the Mediterranean Transmission System Operators (MedTSO) is a multilateral technical cooperation entity. The association facilitates the regional development of electricity transmission networks and the integration of power systems of countries in the Mediterranean region. Activities include a mediterranean transmission network development plan, the harmonisation of grid codes, and facilitating joint operational procedures for interconnections. The Gulf Cooperation Council Interconnection Authority (GCCIA) has been established to link power systems of GCC countries. The organization was established in 2001 as a joint stock company subscribed by the six Gulf States (United Arab Emirates, Bahrain, Saudi Arabia, Oman, Qatar, and Kuwait). Since then, GCCIA established a regional power grid connecting the six GCC countries and pursues to develop interconnections with neighbouring regions including to Europe. In addition, GCCIA aims to create a regional power market.

A National Regulatory Authority (NRA) oversees the electricity and gas sectors to ensure fair competition while maintaining a reliable energy supply. NRAs approve transmission or distribution tariffs or their methodologies in Europe. They also have a central role in infrastructure development as they oversee and approve investments in energy infrastructure, ensuring these projects are necessary and cost-effective. Mediterranean regulators collaborate to enhance the compatibility of regional energy markets and legislation, aiming for deeper market integration across the Euro-Mediterranean basin. The Association of Mediterranean Energy Regulators (MEDREG), unites 28 regulators from 23 countries, including the EU, the Balkans, and North Africa. The Agency for the Cooperation of Energy Regulators (ACER) defines guidelines for transnational energy networks and markets, but NRAs are empowered to set the rules for national energy systems.

Financial actors play a key role for cross-border infrastructure. The European Investment Bank (EIB) is a crucial anchor investor, providing security for private investors. It finances up to 50% of the total costs of infrastructure projects, ensuring substantial support and confidence for large-scale investments. Commercial banks have extensive experience in project finance and have a strong history of funding renewable energy projects. While commercial banks typically lend to generate profit, many banks have set targets to support the energy transition. European banks can benefit from policies that favour loans supporting energy transition projects. State-owned development banks such as the German Kreditanstalt für Wiederaufbau (KfW), can offer below-market rates thereby significantly lowering the cost of capital. Multilateral Development Banks (MDBs) like the World Bank, the EIB, the Islamic Development Bank (IsDB), and the European Bank for Reconstruction and Development (EBRD) are pivotal in supporting infrastructure projects in lower-income countries and regions where commercial banks may be less active, including MENA countries.

Initiatives like the MENA-Europe Future Energy Dialogue (MEFED) play a pivotal role in fostering cross-border energy cooperation. MEFED serves as a high-level forum for decision-makers from politics, business, and research, aimed at strengthening energy ties between the MENA region and Europe. At MEFED24 countries and international organisations endorsed the Thessaloniki Declaration, under which endorsing parties committed to accelerating the development of joint energy infrastructure for green electricity and hydrogen. To ensure continuous dialogue on energy infrastructure between Europe and the MENA region, MEFED established an advisory group comprising regional organizations which regularly meet to discuss progress of different infrastructure projects.[21]

2.3. Ownership models and regulatory frameworks

Cross-border electricity interconnectors and hydrogen pipelines are subject to different national regulatory regimes. In Europe, the regulatory regime to be applied for the interconnection project is developed on case-by-case basis by the responsible NRAs. Each regulator involved sets out regulation applicable for the part of the cross-border interconnector within its jurisdiction.[22] Costs and revenues of the interconnector are often allocated on a 50-50 rule, reflecting similar benefits for both involved countries.

Three ownership models for cross-border electricity infrastructure projects are institutionalised in Europe: the regulated, the merchant, and the cap-and-floor model. The applied model for the interconnection determines financing sources and revenue flows. Actors involved and their investment objectives depend on the chosen business model.

- **The regulated model, where TSOs sponsor new interconnections, is by far most commonly used in Europe for electricity interconnections.** The TSO is compensated with a regulated revenue at national level for the cost of developing and operating the transmission infrastructure. The national benefit is usually decisive for the TSO in the assessment of the project. The compensation is socialised through network charges to the final energy consumers of the national grid. Different tariff schemes exist in Europe for network charges. The specific national solution is decided domestically and approved by the respective NRA. In the regulated model, costs are not compensated sufficiently to TSOs to undertake investments in infrastructure. The higher risk profile of cross-border interconnectors compared to national transmission assets is not considered in the regulated revenue that is granted to TSOs. For both assets, interconnectors and the national grid, the regulated revenue is calculated based on a low-risk profile and the same assumptions for the weighted average cost of capital (WACC) and cost of equity. This implies that the cost of building and operating an interconnector are cross-subsidised through the TSO's balance sheet under the regulated model. Due to the increased need of expanding national transmission infrastructure, however, the financial capacity of a national TSO declines to cross-subsidise interconnectors via the balance sheet.[23]
- **In the merchant model, interconnectors are built and operated by independent private developers on a for-profit-basis.** The business case is mainly based on congestion revenues related to price differences between the two electricity markets a merchant interconnector connects. A compensation through network charges is not possible since private actors are not entitled to receive income from network charges. In Europe, merchant interconnectors financed primarily through congestion revenues are the exception. At least seven interconnectors with commercial investors have been built or are under development in Europe since 2020.[24] An example for the merchant model is the Eleclink interconnector between France and the UK. In the following box, the ownership model of the Eleclink interconnector is explained.

Ownership model of the Eleclink interconnector

The Eleclink 1 GW HVDC interconnector started operation in May 2020 and uses the existing Channel Tunnel between France and the UK. To develop the interconnection, Star Capital, a private-equity firm, approached Getlink, the operator of the Channel Tunnel, with the initial concept and established Eleclink as a joint venture company in 2011. In 2016, Getlink purchased Star Capital's shares and proceeded with the development. The national TSOs were involved in the permitting but are not actively engaged in the development of the interconnection.

As refinancing of the interconnector through network charges is not permitted, the business plan solely relies on the following:

- Congestion revenues auctioning the capacity of the interconnector to market participants on both sides for their electricity transfers.
- Revenues from capacity markets providing 900 MW to the French capacity market.
- Revenues from ancillary services selling reactive power, frequency adjustments, emergency services to TSOs.

The initial development of Eleclink was purely financed on equity. After purchasing Star Capital's shares, Getlink became the sole shareholder of Eleclink and financed the construction of the interconnector through debt financing, which comprise direct loans from its shareholder. In September 2018, Getlink issued a EUR 550 million green bond partly used to finance Eleclink.

Starting operation right before the energy price shock caused by the Russian invasion of Ukraine, Eleclink significantly contributed to the European security of supply but also benefited from record scarcity pricing for interconnector capacity. The experience from Eleclink led to the development of alternative regulatory models, notably the cap-and-floor regime.[25]

- **The cap-and-floor model combines elements of both models for a more effective risk-sharing.** This business model is notably used in the UK by private investors. As part of this mechanism, developers can propose and build interconnectors and the earnings are regulated by a revenue cap-and-floor. The revenue needs to ensure a minimum return on the investment of the transmission line for a period of 25 years. The level of the cap-and-floor is determined on an annual basis accounting for depreciations, allowed return on investment as well as capital and operational expenditures.

Congestion revenue is the key source of income for all ownership models. Auctioning electricity interconnector capacity generates congestion revenues for the owners of the interconnector. Market participants on both sides of the interconnector participate in the auctions to receive transmission rights allowing to use a specified part of the scarce transmission capacity of the interconnector. European TSOs appointed the Joint Allocation Office (JAO) to operate long and short-term auctions of transmission capacity rights for electricity interconnections. The congestion revenue is typically split 50:50 between TSOs on both sides or in accordance with asset owner's shares in the investment costs of the interconnector.[26] Congestions revenues mirror the demand for interconnection capacity and thus indicate well where and to what extent investment in cross-border transmission capacity is required.[27]

Market coupling optimises the allocation of cross-border capacities of electricity interconnections between countries based on algorithm-based procedures. The aim of market coupling is to create an integrated European cross-zonal electricity market. Thanks to a coordinated calculation of prices and flows, available cross-border capacity is used more efficiently and the price difference between two or more market areas is reduced. Market Coupling utilises so-called implicit auctions, where market participants bid for the electricity on an electricity exchange without individually receiving cross-border capacity allocations. Power exchanges then take into account available cross-border capacity in the price calculation process in order to minimise the price differences across market areas.

The entry-exit-system is a market-based model used to manage gas transportation across interconnected pipelines. Entry and exit tariffs for gas are used to cover the costs of gas transmission networks. These tariffs are charged based on capacity reservations at both the entry and exit points of balancing zones. Regulators ensure that these tariffs ensure cost allocation is fair and transparent, supporting cross-border trade and market integration.

The development of hydrogen infrastructure is still in its early stages, with ownership models yet to be fully established. Nevertheless, on 21 May 2024, the Council of the EU adopted the Hydrogen and Decarbonised Gas Market Package where it set out the rules for hydrogen infrastructure ownership. The directive introduces unbundling rules for hydrogen infrastructure operators. This means the operation of hydrogen networks must be independent of other energy supply activities, such as hydrogen production and storage. To achieve this, operators can adopt familiar unbundling models from the electricity and gas sectors, including ownership unbundling, the integrated hydrogen network operator (ITO) model, and the independent hydrogen system operator (ISO) model. For horizontal unbundling, the directive mandates that a hydrogen transmission operator involved in natural gas or electricity transmission or distribution must be legally independent. This means a transmission system operator which converts parts of the infrastructure to hydrogen must do so through a separate legal entity. However, there are exceptions: Member States can waive the horizontal unbundling requirement if a public cost-benefit analysis shows it would improve transparency, prevent cross-subsidisation, and benefit network tariffs and cross-border trade.[28]

2.4. Funding options

To bridge the financing gap, the European Commission established support programmes for cross-border energy infrastructure. At EU-level, electricity infrastructure interconnectors and hydrogen pipeline projects between EU countries and non-EU countries with PMI status may receive funding through CEF-E.[V] Next to being able to apply for CEF-E funding, PMIs mainly benefit from streamlined permitting procedures. To get PMI status, the non-EU country must show a high level of convergence in its policy framework with that of the EU. Additionally, PMI candidates

Financing of ELMED interconnector

For the ELMED submarine cable interconnection between Tunisia and Italy, the CEF-E provides a grant of EUR 307.6 million to cover the total cost of EUR 920 million. A loan package of EUR 125 million for the Tunisian part is co-financed by the EBRD, the EIB and KfW. In addition, the World Bank is financing the converter station and associated transmission infrastructure in Tunisia.

[V] *The PCI-PMI Transparency platform provides an interactive map for all projects selected by the European Commission: https://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer/main.html* must demonstrate their contribution to the overall energy and climate objectives of the EU and the relevant partner countries.[29] The selection process runs every two years in multi-stakeholder regional groups and is based on pre-defined criteria and a cost-benefit analysis. The process is guided by the priority corridors defined in the EU regulation on guidelines for Trans-European Networks for Energy (TEN-E). The sixth PCI list, published in November 2023, included 65 PCIs and PMIs hydrogen corridor projects.[30] For electricity and hydrogen projects to be eligible for inclusion in the PMI list, they must be part of the latest available TYNDP.[VI]

State aid, enabled through qualifying as an Important Project of Common European Interest (IPCEI), is another option for supporting cross-border infrastructure projects. The EU approved EUR 6.9 billion of state aid through the project IPCEI Hy2Infra. The project aims to attract EUR 5.4 billion in private investments for 33 hydrogen infrastructure projects. This initiative was collaboratively prepared and submitted by seven Member States: France, Germany, Italy, the Netherlands, Poland, Portugal, and Slovakia. The project supports the development of new and repurposed hydrogen transmission and distribution pipelines, spanning approximately 2,700 km. Among the funded initiatives are cross-country hydrogen pipelines between the Netherlands and Germany.[31,32]

Energy infrastructure projects can also be financed through the EU Global Gateway initiative. The initiative is the EU's strategic investment plan to boost smart, clean and secure links in digital, energy and transport sectors and to strengthen health, education and research systems across the world. Between 2021 and 2027 it aims to mobilise up to EUR 300 billion in investments.[33] It draws on financial tools such as the European Fund for Sustainable Development Plus (EFSD+). The fund offers different risk-sharing instruments (e.g. guarantees) which amount to up to EUR 40 billion, aiming to mobilise EUR 135 billion of private and public capital to support partner countries in their efforts to achieve the Sustainable Development Goals (SDGs).[34] Within the EFSD+, the Neighbourhood Investment Platform (NIP) serves as a blending facility that combines EU grant contributions with other public and private sector resources, such as loans and equity, to leverage additional non-grant financing.[35] Additionally, EU Global Gateway utilises the Neighbourhood, Development, and International Cooperation Instrument (NDICI) – 'Global Europe'. The North African region, including key partner countries such as Algeria, Egypt, Morocco, and Tunisia, is part of the Economic and Investment Plan for the Southern Neighbourhood of the EU Global Gateway.

Development banks provide direct financing to cross-border energy infrastructure projects. The EBRD finances interconnector projects between non-EU countries for establishing energy corridors towards Europe, e.g., a EUR 37 million loan for interconnection between Macedonia and Albania.[36] The same project was also supported by KfW with EUR 50 million.[37] The EIB provides funding also to interconnection projects without immediate link to the European energy system, e.g., a EUR 113 million loan for interconnection between Ecuador and Peru (total cost: EUR 252 million).[38]

2.5. Cost-benefit analysis and cost allocation

Understanding the benefits of cross-border infrastructure projects is key for allocating costs in a fair and transparent manner. To assess whether a cross-border infrastructure project should be built in the first place, the costs and benefits of the project need to be analysed through a socio-economic cost-benefit analysis (CBA). When benefits outweigh costs over a defined period, the project has a positive net present value, adds value to society, and is worth pursuing from a societal perspective. Several CBA approaches for cross-border electricity infrastructure projects exist or are being developed. As described earlier, for a bilateral interconnection, each of the two involved regulators sets out regulations applicable for the part of the cross-border interconnector within its jurisdiction. ENTSO-E and ENTSOG defined a CBA methodology that is generally applied to the European-wide TYNDP as well as to the PCI and PMI selection processes and cross-border cost allocation (CBCA) procedures. For EU-MENA electricity interconnections MedTSO and MedReg apply an own CBA approach that is developed case-by-case based on the ENTSOE's CBA approach and the applicable regulation in the non-EU country. For the EU jurisdictions, ENTSO-E and

[VI] *The projects selected for the TYNDP 2022 and their permitting status are illustrated in an interactive map: https://tyndp.entsoe.eu/european-projects*

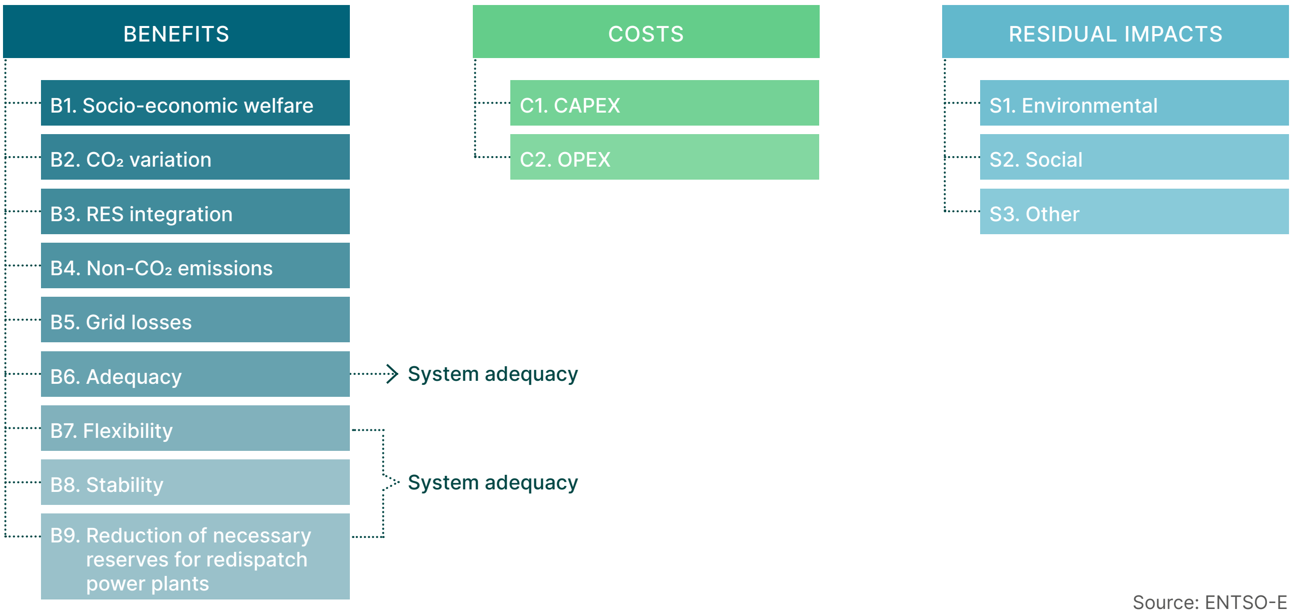
ENTSOG, CBA methodology is coherently applied.

For infrastructure projects, a multi-criteria and cost-benefit analysis is included in both ENTSO-E's and ENTSOG assessment for the TYNDP that is approved by ACER and the European Commission. The assessment is based on network, market and interlinked modelling methodologies and is described in detail within the 'ENTSO-E Guideline for Cost-Benefit Analysis of Grid Development Projects' and the preliminary draft of ENTSOG's 'Single Sector cost-benefit analysis methodology'.[39] The documents are a general guide to assist in the assessment of planned projects included in ENTSO-E's and ENTSOG's TYNDP. It describes the common principles and procedures for performing the analysis of costs and benefits for projects using network and market simulation methodologies. The assessment framework laid out in this Guideline describes the structure used to differentiate the range of indicators that comprise the project assessment.

The assessment framework comprises three main categories – costs, benefits and impact(s). Costs describe the inception cost of the project or investment, i. e. CAPEX and the operating costs that incurred throughout the investment's lifecycle, i. e. operational expenditures (OPEX). The CAPEX cost typically refers to the inception cost of the project and would also include the costs of implementing mitigation measures that address environmental and social constraints. Residual impacts describe the impacts of investments that are not addressed by any of the identified mitigation measures that are contained within the cost category (typically as CAPEX). This ensures that all measurable costs associated with projects or investments are considered, and that no double-accounting occurs between any of the indicators. Monetization can be achieved through various approaches, including through data provided by project promotors (e.g. CAPEX and OPEX), through modelling (e.g. socio-economic welfare through power market modelling), through agreed parameters or through benchmarking. The composition of each of the categories is illustrated in *Figure 7* (electricity) and *Figure 8* (hydrogen).

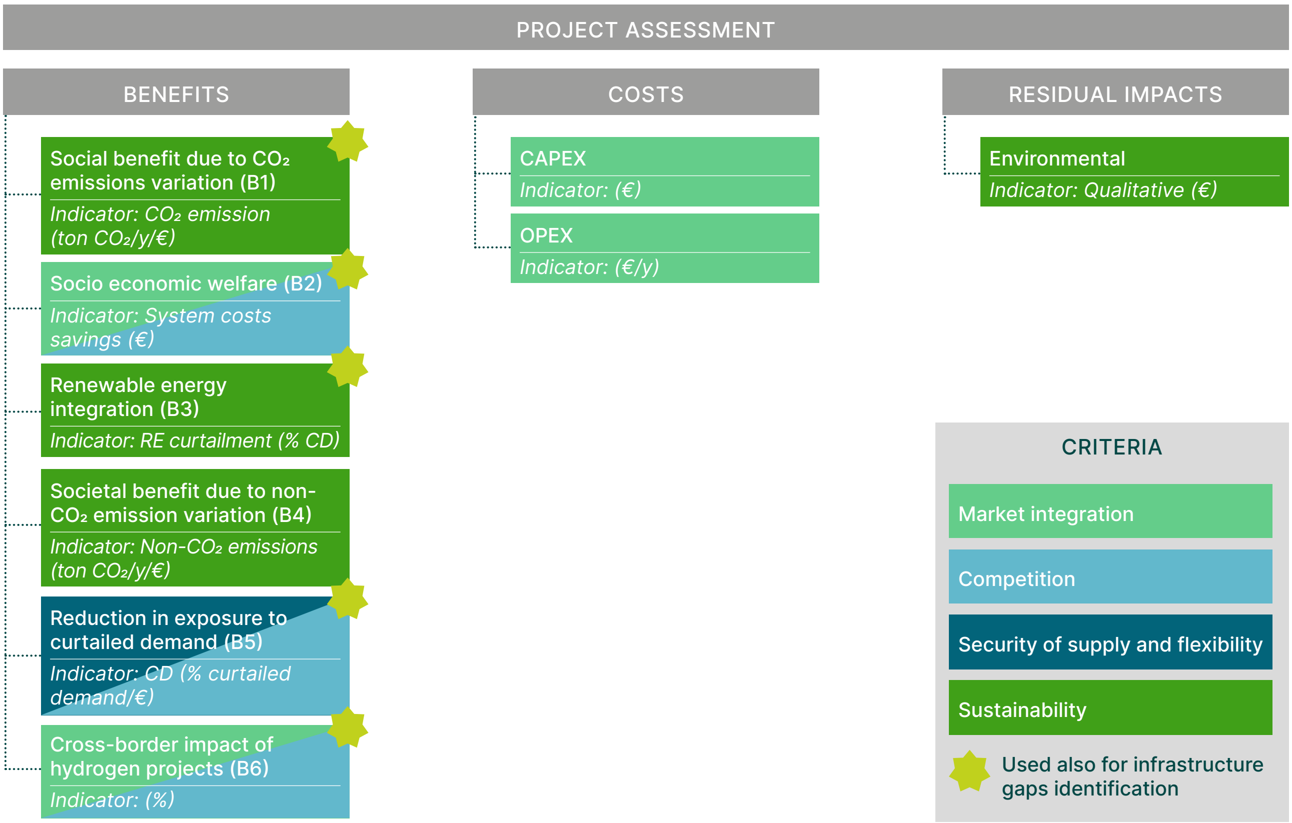
Cross-border cost allocation is finally a result of negotiations between the parties of the interconnector. The starting point is typically a 50:50 cost-sharing in case of a bilateral interconnection project. Some aspects may not be quantifiable but may still be perceived as significant by the parties and might be included in the negotiations on the cost allocation. While the CBA approach prefers a monetization for as many elements as possible, the cost allocation decision will be a negotiation outcome between countries. They should have the flexibility to highlight certain cost-benefit impacts of a project that they deem significant or to exclude indicators that they agree to be less relevant to reduce the complexity of the analysis and the negotiation. In addition, some impacts may not be quantifiable but still be perceived as significant by the involved Member States, so they may include these aspects into the negotiation on the cost allocation.[40]

Figure 7: Cost and benefit indicators used for project assessment under the ENTSO-E Guideline for CBA of grid development projects.



Source: ENTSO-E

Figure 8: CBA metric and TEN-E regulation criteria under the draft CBA methodology for hydrogen infrastructure projects by ENTSOG.



Source: ENTSOG

3. CHALLENGES FOR CROSS-BORDER ENERGY INFRASTRUCTURE

Cross-border energy infrastructure projects are capital-intensive and have a highly complex risk profile. The lack of a coordinated regional approach for the development of energy infrastructure and for cost allocation creates uncertainty for TSOs and commercial project developers. Challenges for developers of cross-border projects mainly arise from volume risk, technology risk and country risk. In the following, the key challenges for cross border energy projects are described in further detail.

Lack of regional planning

Currently, there is no shared vision for an integrated cross-border energy infrastructure network between the EU and the MENA region. Differences in the regulatory framework among exporting countries in the MENA region are significant. National strategies are often prioritised instead of working towards integrating energy sectors to facilitate cross-border energy exchange. While projects such as ELMED demonstrate progress in cross-regional energy infrastructure development, a coordinated approach for transmission system development is missing. Cost allocation is a highly complex issue for cross-border energy infrastructure projects subject to vested interests from production, transit and offtake countries. This challenge becomes even more complex as also countries that are not directly involved in interconnection projects benefit from increased network integration. Each country has varying degrees of involvement and benefits from the infrastructure, making it difficult to fairly distribute costs and, in the case of hydrogen, define the feed-in and feed-out tariffs. Long-term benefits of cross-border energy infrastructure should be decisive for financing support.

Volume risks

The volume risk for energy transport infrastructure connecting EU and MENA countries is high due to uncertainty about the utilisation of the assets. For electricity infrastructure, the volume risk emerges from the lack of harmonised electricity sectors and grid codes between the MENA region and the EU. Despite a significant increase in cross-border electricity transmission capacity within the MENA region to interconnect GCC countries internally since 2001, interconnections are often underutilised. In 2018, the utilisation of GCC interconnections was still around 5-6% compared to around 50% on average in Europe. In Europe, cross-border electricity exchange is automated with market coupling algorithms based on real-time electricity prices. Interconnections in the MENA region suffer from low utilisation because they are mainly operated to provide reserve capacity and grid stability during emergencies, rather than offering capacity for cross-border electricity trading.[41] To arrange electricity transfers on interconnections among MENA countries, TSOs tend to communicate bilaterally and develop exchange procedures on a case-by-case basis. Due to the lack of real-time electricity price signals, some TSOs balance out the amount of exchanged electricity over the course of a year.

The lack of time-differentiated, market-based electricity price signals will hamper the electricity exchange between the EU-internal electricity market and MENA countries. The introduction of electricity markets or real-time electricity price signals to facilitate electricity trading is currently not prioritized by MENA countries. The harmonisation of grid codes for electricity trade is being pursued but takes time. It is very likely that the utilisation of cross-border energy infrastructure between EU and MENA countries will increase over time but will be low in the first years of operation. Investments in EU-MENA energy infrastructure consequently suffer from a low attractiveness, especially since investment models of private actors tend to focus on the first ten years.

The overall uncertainty surrounding the ramp-up of the hydrogen economy presents a major challenge. TSOs need long-term capacity bookings to take FID for hydrogen infrastructure. However, demand is highly uncertain increasing the risk of the infrastructure becoming a stranded asset. While there is the expectation of a growing hydrogen demand, in the next 5-10 years volumes will be rather low. On the other hand, TSOs need to invest billions in building new or repurposing existing infrastructure in the short-term. If these high costs are fully passed on to the initial users, transport charges may become prohibitively high.

Timeline risks

Complex negotiations, often driven by strategic and geopolitical dissonance among stakeholders, can significantly prolong development timelines for cross-border infrastructure projects. Recurrent delays during permitting and construction phases further contribute to the risk profile of these projects. The economic risk for interconnections is higher than for domestic transmission lines, as interconnection revenues depend largely on congestion rents, whereas national transmission assets rely on stable network charges.

While grid reinforcement and optimisation of existing transmission lines can be implemented relatively quickly, new line development requires longer lead times for planning and permitting. Permitting procedures vary widely across countries, leading to inconsistent delivery timelines. Offshore interconnection projects generally progress faster during permitting but encounter slower implementation phases. Brownfield projects are often favoured over greenfield projects due to simpler permitting processes, lower societal opposition, reduced costs, and quicker execution. However, projects may face significant delays, such as those caused by legal challenges.

Key factors which influence the timeframe of hydrogen corridors are the availability of components, the length of the pipeline and the extent to which existing pipelines can be retrofitted. The timeline between FID and the commissioning of onshore hydrogen pipelines typically spans around five years. Limited production of hydrogen-compatible materials, such as specialized compressors and valves, may lead to delays in the supply chain. Longer pipelines require more resources, planning, and construction times. Retrofitting existing natural gas pipelines is significantly faster and more cost-effective than building new pipelines.

Diverging timelines across the hydrogen value chain create challenges for TSOs to take FID. When ramping up a future hydrogen import corridor, there are interdependencies between the value chain stages of production, transport, and use. Hydrogen producers and consumers as well as infrastructure operators have different construction times for their assets. For onshore hydrogen pipelines, for example, there are around five years between the final investment decision and commissioning, whereby this period depends in particular on the length of existing pipelines to be repurposed, but also on geographical conditions, the length and diameter of the respective pipeline and the availability of components. For hydrogen producers, on the other hand, around three years can be expected between the FID and commissioning of the plants, with comparable project-specific variance. However, pipeline operators need certainty about future capacity bookings for their FID. The producers or consumers cannot provide this at the moment. The state can provide a remedy for this risk on the part of the network operator, for example through intertemporal cost allocation in the case of the German hydrogen core network.

Technology risk

Hydrogen technology still faces significant technology risks due to its relative immaturity. Green hydrogen production is still very costly and resource-intensive with large-scale production not reaching competitive levels yet. Another technological challenge centres around hydrogen transportation. Pipeline transport, especially undersea, is still unproven at scale and requires durable materials. Safety concerns, due to hydrogen's flammability and unique handling requirements, add another layer of complexity.

Country risk

The country risk is high for some countries within the MENA region. It is determined by political and regulatory stability, as frequent policy changes and regulatory uncertainties deter investment. Economic conditions such as currency stability and geopolitical relations with neighbouring countries are also highly relevant. Long payback periods of typically 10-20 years for regulated infrastructure require a stable investment environment.

4. FINANCING MODELS AND SUPPORT INSTRUMENTS FOR CROSS-BORDER ENERGY INFRASTRUCTURE

Current funding mechanisms are insufficient to drive the implementation of cross-border energy infrastructure between EU and MENA. TSOs have a limited capacity to invest in cross-border energy infrastructures as they also have to strengthen their domestic networks to accommodate for the increasing penetration of renewable energy, notably offshore wind parks. For commercial investors, cross-border infrastructure projects are not very attractive mainly because of their complex risk profile. Financing support is essential to de-risk these projects. While the EU Member States and development banks already have a set of mechanisms in place to support energy infrastructure projects, they are not targeted enough when it comes to electricity interconnectors and especially hydrogen corridors. Hereafter, five possible models are introduced based on conducted interviews and the current political and scientific discourse on financing models for cross-border energy infrastructure. The main objective of these models is to de-risk projects in order to bring in private investments and enable market-driven build-out of cross-regional energy infrastructure.

Financial Pooling

Existing financial instruments such as CEF-E, EFSD+, Member State mechanisms and concessional financing by development banks are important tools to support the build-out of cross-border energy infrastructure. However, for project developers it is often challenging to understand how to best combine various funding sources as the prohibition of cumulation may apply, i.e., it is not allowed to combine certain funding instruments. An example where pooling of different funding instruments worked well is the ELMED interconnector. The EU provided grants worth EUR 307.6 million from CEF-E and EUR 27 million from the NIP. Additionally, EIB, EBRD and KfW approved a loan of EUR 125 million. By pooling resources from various facilities, financial risks are reduced, making it easier to mobilise the significant capital needed for large-scale infrastructure projects.

EU-MENA Investment Facility

An EU-MENA Investment Facility would build on the NIP to provide financing support to cross-border energy infrastructure projects. Based on a CBA and specified criteria for cost allocation, eligible EU-MENA energy infrastructure projects could receive below-market loans, grants or guarantees from the Investment Facility. The Facility could be set up as a stock company to allow contributors to recoup their investments from the revenues during the operation of the interconnections. In such a case, the EU-MENA Investment Facility would act as a shareholder in an energy project. The redistribution of the revenues would be based on the shares held by the contributors or could be reinvested by the Facility. To increase the investment capacity, the Facility could issue green bonds to limit dependency on EU and Member State budgets.

Repayable government grants for investments in regulated assets

Repayable grants can be provided under the Climate, Energy and Environmental Aid Guidelines (CEEAG), which have the objective to build and modernise infrastructure for low-carbon energy. In this model, a government provides a grant, covering a percentage of the construction cost. Initially, this grant is deducted from the Regulated Asset Base (RAB)[VII] of a TSOs. This is significant as the RAB determines the revenues of a TSO. A lower RAB also leads to decreased revenues. However, network operators have the option to repay these grants within a specified period, which would increase their RAB. As a result, revenues would rise post-repayment, reflecting the increased RAB. This approach significantly mitigates the financial risk for TSOs while providing an opportunity for increased revenues in the long term.

Capacity bookings for hydrogen pipelines (hydrogen-specific)

Strategic capacity booking can incentivise private investment in hydrogen infrastructure by minimising the volume and the price risk (see *Chapter 3*) for TSOs. Drawing parallels from natural gas infrastructure models, this approach leverages government-backed guarantees and structured contracts to mitigate demand uncertainty and help drive initial project financing.

Governments in hydrogen-consuming countries make binding commitments to offtake a certain hydrogen volume at a pre-defined price, effectively acting as a creditworthy guarantor. This framework safeguards infrastructure investments as it provides TSOs with a steady revenue stream in the early phase of the hydrogen economy when demand might otherwise be too uncertain to justify the required capital investments.

A Contract-for-Difference (CfD) could further enhance this model. By setting up a CfD, the government ensures that any shortfall between market demand and the guaranteed baseline volume is covered financially. Over time, this mechanism has flexibility for TSOs to repay government grants or subsidies once network revenues surpass a pre-defined threshold.

Intertemporal cost allocation mechanism (hydrogen-specific)

The construction of electricity and gas grid infrastructures are currently predominantly financed through network charges paid by producers and offtakers. This works well in established markets, e.g., electricity and natural gas. For the emerging hydrogen market, the few initial hydrogen offtakers would have to bear the full infrastructure cost. To avoid prohibitively high network charges in the ramp-up phase, adjustments are needed.

One approach to support early users is to cap network charges temporarily, encouraging initial uptake by keeping tariffs manageable. This cap, or "ramp-up fee", would set a uniform, discounted tariff across all network entry and exit points, below the actual costs of running the hydrogen infrastructure. Periodic adjustments could then be applied to the fee as more hydrogen users connect to the network, gradually bringing tariffs closer to the actual operating costs. To cover the difference between actual costs and these capped fees, a deferred cost account could be established. This account would record the shortfall between operational costs and revenue generated by capped tariffs. Essentially, it serves as a ledger, accumulating the deferred costs during the early ramp-up phase. To cover liquidity needs, development banks could provide bridging loans. Government support could also play a role, potentially through grants to cover liquidity gaps or guarantees that ensure any account deficit is balanced over time.

As the hydrogen market matures and the number of network users increases, the network charges are expected to exceed the actual grid costs, leading to higher revenues. These additional revenues are then deposited to the deferred cost account. Over time, the account balance will become positive as the increased network usage helps to offset the initial deficits.

[VII] *RAB is an accumulation of the value of investments a TSO has made in its network.*

5. KEY TAKE-AWAYS FOR ACCELERATING CROSS-REGIONAL ENERGY INFRASTRUCTURE

1

In the absence of effective market mechanisms to stimulate a cross-regional energy market, financial support is required from concessional lenders, MDBs and governments. Especially in the early planning phase of a project (feasibility and FEED phase), public support is needed to mature and de-risk projects. The support can include grants, below-market loans, intertemporal cost allocation or guarantees. As one single instrument is often not sufficient, pooling different financing sources can be effective. Once a project is mature, private investors can come in and further develop and implement the project.

2

Strong political commitment is needed to accelerate cross-border energy infrastructure projects. The newly established Directorate-General for the Middle East, North Africa and the Gulf (DG MENA) is an important signal that the MENA region is on top of the agenda of the new European Commission. The Trans-Mediterranean Energy and Clean Tech Cooperation Initiative could place the support of flagship infrastructure projects at its core, driving regional energy integration.[42] A coherent vision and regulatory framework between the EU and the MENA region needs to be developed to facilitate cross-border energy projects. In addition, PMI applications for cross-border energy infrastructure projects should be supported such as Tunisia's PMI application for the SoutH2 Corridor pipeline, which connects Italy and Tunisia. Establishing an EU-MENA Investment Facility for cross-border energy infrastructure should be further explored as it could offer a powerful tool to incentivize investments in cross-regional energy infrastructure.

3

Robust scenarios for future import need to be underpinned by initial binding offtake agreements and local value creation which are the foundation for investments in cross-border energy infrastructure. Establishing domestic infrastructure for hydrogen, e.g. a hydrogen core network in Germany, can also help to create certainty on future import needs. With regard to interconnections to the MENA region, Europe will be dependent on transit countries for importing green energy. To encourage export and transit countries to contribute to the development of cross-border energy infrastructure, continuous dialogue is necessary bringing together relevant stakeholders from government, regulators, private sector and impacted communities. A particular focus should be given to local value creation, i.e. creating employment and business opportunities in communities impacted by the project. While many projects in the MENA region have an export focus, contributions to the domestic energy transitions are critical to gain support for the project. Supporting not only cross-border energy infrastructure but also the development of local grids and capacity building will ensure that domestic needs and export opportunities are balanced.

4

Regional cooperation is essential to harmonise grid codes, regulation, procedures and cross-border cost allocation methodologies. The ongoing development of an EU-MENA grid code for interoperability is a first step to optimise existing interconnections and to support new ones. Benefits from specific interconnection projects for transit and export countries are not always obvious, depend on various framework conditions, and are thus very difficult to quantify. Harmonized CBAs and integrated planning for EU-MENA energy system development will increase awareness of the benefits of cross-border energy infrastructure and facilitate the allocation of financing support to those projects with the highest system benefits. The introduction of transparent real-time electricity price signals in the MENA region would boost the trade of electricity between regions and limit the risk for excess investments in generation capacity. As setting up such a system may be a mid- to long-term solution given its complexity, procedures need to be developed in the short term that activate electricity flows between price-based EU electricity market and monopoly non-EU countries. Countries should also ensure that feed-in and feed-out tariffs for hydrogen are harmonised to ensure fair cost distribution for cross-border infrastructure projects. Cooperation between national regulators can help to set tariffs that create an integrated system which enables efficient cost sharing and reduces the likelihood of conflicting price signals.

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