#NoTransitionWithoutTransmission

Green Grids Initiative

Principles for Interconnector Development

Phase 2

Contributions from the Green Grids Initiative (GGI) Asia-Pacific Working Group

Edited by Sebastian Mitchell, Matthew Wittenstein,

and Marcus Stewart

Principles for Interconnector Development

Background:

The Green Grids Initiative was launched at COP26 alongside the Government of India's One Sun One World One Grid ambition with the overarching aim of accelerating the construction of the new infrastructure needed for a world power by renewable energy. This includes supporting the development of long-distance cross-border transmission lines, which are needed to connect renewable energy generators and demand centres within and across continents, underpinned by effective and mutually beneficial cross-border power trading arrangements.

In the process of increasing the global supply of renewable energy resources, electricity interconnectors have a key role to play. A recent report by Transition Zero identifies up to $3trillion of benefit of global levels of interconnection.[1] They allow system operators to more effectively react to changes in supply due to the variable nature of many renewable energy resources, in particular wind and solar PV, and help manage peak demand through the sharing of surplus power and reserve capacity. And they provide access to high- and rapidly growing demand centres. In this way, interconnectors can aid, in a cost-effective manner, the development and integration of low carbon and green energy generation.

However, in many parts of the world progress on the development of large-scale interconnectors is slow or entirely stalled. In many cases this is not because of an absence of interest or ambition, but rather because of the scale or complexity of the task. The principles for interconnectors presented in this document aim to provide guidance to States that are actively seeking to, or are merely interested in, developing large-scale interconnectors. The document was produced by the Green Grids Initiative (GGI) Asia-Pacific Working Group, but offers insights and recommendations based on global experiences, and is therefore designed to hold universal principles for interconnector development applicable in many regional contexts. The principles are built around and linked to the key steps of the life cycle for developing interconnectors. These steps come with supporting best practise recommendations and relevant tools for development.

Please note that there are a number of models for interconnector development, but this document will cover common forms of development from the states and developers writing this document.

Overview:

Interconnector development is a complex and time-intensive process, and many proposed projects stall or fail because of barriers to progress within each stage or failure to adequately consider individual stages within the context of the project's entire life.

The lifecycle of an electricity interconnector (or grid infrastructure connecting two or more power systems) can be divided into four main stages:

1) Concept
2) Project development
3) Project construction
4) Operations
5) Decommissioning

[1] https://www.transitionzero.org/press/transitionzero-cables-decarbonise

These may be further divided into sub-stages detailing the specific actions that must be considered and taken to fully develop, operate, and eventually retire an interconnector.

The GGI Principles for Interconnectors document is an effort of the GGI to provide a set of guiding principles (best practices) for developing interconnectors across its lifecycle.

A full overview of the life cycle and proposed draft principles to inform and guide the development of interconnectors at each lifecycle stage, are presented in Figure 1.

Figure 1: Interconnector lifecycle and associated principles

Lifecycle stage	Sub-stage	Principle
1. Concept	1.1 Preliminary feasibility studies 1.2 Feasibility studies	Preliminary or feasibility studies should address: • technological specification, • supply profile, • demand profile, • social implications, • environmental implications, • Economic benefits and opportunities, • Supply chain. and because of the particularly long development time of interconnectors, and the high amount of political will required for them to get built, governments need to help facilitate these sub-stages.
		Studies could be conducted by one or more credible third party/parties although these are sometimes done in-house and should include a wide range of technical, economic, and social implications of interconnector development. Studies should include seabed surveys (if subsea cables are being developed) and onshore cable route and converter station planning as applicable.
		Feasibility studies should include input from national and local governments, impacted grid owners (if applicable) and operators, and other relevant stakeholders.
		The risk study should assess how community issues can be overcome or otherwise assess the possible alternatives available. Compensation schemes can be put together for local communities affected by project development, with cable routeing, landing points, substation and converter station points.
		Interconnectors should be considered a part of larger power system plans / a broader grid planning process. Such planning should show the benefits of interconnection at an optimal level
		Cost benefit analysis (CBA) should measure the social economic welfare (SEW) of the project including consumer surpluses, producer surpluses and congestion income.

		When working with communities, best practice includes early engagement with affected communities, clear messaging and transparency, consideration of benefit sharing options.
		Coordination between two countries can be of issue, and so it is helpful if governments can initiate discussion at the political level.
	1.3 Permitting	Permitting should include all the relevant permits required for the project from the infrastructural aspect from both countries [and any third countries] along the interconnector route, throughout the lifecycle of the project.
		Permitting reform or even review and presentation of existing permitting requirements can be helpful. A lot of regulations haven't considered two-way power interconnectors. If governments can initiate and share a study of the permitting requirements, it can help developers quantify the risk.
	1.4 Regulatory approval	Regulatory approvals are needed for the project such as licensing and any other government approvals.
	1.5 Approval mapping	All approvals need to be identified. Develop a power purchase agreement, also known as a Transmission Service Agreement. In order to agree preliminary financing, there must be agreed planning, agreed regulation, agreed permitting, and agreed permit mapping. Stakeholders should be consulted throughout the process. Projects that receive a major project status will streamline the permitting and grant review process. The counterparty for the revenue contract is really important for financing. A developer will often want a sovereign entity to guarantee revenues.
	1.6 Financial planning	[To be developed in Phase 3]
	1.7 Capital raising strategy	[To be developed in Phase 3]
	1.8 Preliminary financing	The development phase is the most uncertain phase of any large project, as such projects are greatly assisted by the availability of development grants
	1.9 Peer-to-peer dialogue	Vehicles of cooperation for a proposed interconnector project should be built at the technical and political levels and supported by intergovernmental organisations and other collaborative platforms.
		Encourage standardised / harmonised approaches among stakeholders.

		Share relevant data and other information in a transparent and trusted manner.
		Share risks in an equitable and appropriate manner.
		Present studies to the Government officials in a succinct and easy to understand manner.
		Do no harm principle: any proposed interconnector projects are proceeded by a feasibility study that considers the impact of the project on the interconnected states and communities living at the connecting points and route, the transmission line, and affected grids.
		Secondary trickle-down benefits must be traceable and measurable.
2. Project development plan	2.1 Cost-sharing	After the respective countries are convinced of the trade potential and the necessity of the transmission system, developers will discuss with them the method of sharing costs/ transmission charges between the countries**.**
	2.2 Financing modality	Have enough revenue to service debt
	2.3 Project financing	[To be developed in Phase 3]
	2.4 Project implementation / execution	Coming to a major milestone: permits, licences, construction, tender all need to be completed and need to be signed with a construction company, the relevant regulator, and financial players in contracts.
	2.5 Project monitoring	Suggest regular progress reporting to the relevant authorities.
	2.6 Project Regulation	Regulatory frameworks for managing the costs and revenues associated with the project apportioned to each country will likely be required and developed / agreed on a trilateral basis.
3. Construction	*Lifecycle stage 3 to be completed in PHASE 3 of document.*	
4. Operation	4.1 Operation protocol	A trilateral agreement covering the associated principles, processes and parameters for the coordinated operation of the interconnector must be agreed trilaterally and then regularly reviewed and updated as operating conditions evolve.
	4.2 Agreed operating protocol for the integrated transmission system	[To be developed in Phase 3]
	4.3 Trading arrangements	Trading arrangements must be agreed between connecting states in a binding agreement.
	4.4 Operation	Develop clear lines of communication for emergencies, planned outages, and shared maintenance.

		There should be a legal framework agreement underpinning the trade over an interconnector.
5. Decommissioning Action	5.1 Planning the interconnectors decommissioning	Parties should aim to develop a project with as long a life as possible from the outset, ensuring that permits are valid beyond even initial estimates of technical life.
	5.2 Assessment of prolonging life	[To be developed in Phase 3]
	5.3 Decommissioning of transmission infrastructure	There is little evidence of previously decommissioned interconnectors, but the safe disposal of materials should be key.
	5.4 Agreed procedure for the decommissioning of all relevant transmission infrastructure at end of life	**Planning and preparation:** This involves assessing the technical, economic, environmental, and social impacts of decommissioning, identifying the best available techniques and methods, obtaining the necessary permits and approvals, and engaging with relevant stakeholders and authorities. Adhering to approvals, permits, regulations and standards set by the connecting market states on decommissioning is key. **Execution:** This involves carrying out the physical removal of the interconnector components, such as cables, converters, substations, and towers. Depending on the type and location of the interconnector, this may require different techniques and equipment, such as cutting, pulling, burying, or recycling. The execution phase should also ensure the safety of workers and the public and minimise the disruption to the electricity system and the environment. These considerations should include the safe removal of any hazardous materials from the site of the interconnector. Considerations should be made on whether the disruption of areas such as the seabed for removal outweighs the recycling of the metal in the cable in environmental and financial cost. **Restoration:** This involves restoring the site to its original or agreed condition, such as by filling in trenches, replanting vegetation, removing waste and debris, and monitoring for any residual impacts or hazards.

Introduction

Interconnectors are defined as any grid infrastructure connecting two or more power systems which operate under the authority of different legislative, regulatory and/or system operation regimes. Under this definition, interconnectors could, for example, connect different sovereign countries, or different states/provinces within a country, or even different utilities within a state or province. This definition recognizes that countries may vary significantly in terms of size and degree of power system unification.

The potential benefits of increased electricity interconnection to a power system are manifold, allowing for increased economic development and prosperity through reduced energy costs and expanded access, the integration of higher shares of renewable energy resources (renewables) and a reduction in their curtailment, and increased energy security. For example, the Economic Research Institute for ASEAN projected that the ASEAN power system could achieve net savings $9.1bn by 2035 through an integrated transmission system[2]. In the vision of the GGI OSOWOG, interconnectors can be built to support connectivity and flexibility between markets and sources of developing renewable power. Therefore, grid connections are encouraged to be built in tandem with planned renewable energy production projects.

In the Asia-Pacific region, interconnectors have primarily been developed on a bilateral basis and are typically utilized under bilateral, often unidirectional, transfer agreements. These arrangements are generally not flexible enough to be an enabling tool of the energy transition. Increasing electricity interconnection in this region would provide many technical benefits, including reinforcement of system stability, opportunities for sharing of ancillary services and optimization of the energy mix, while reducing system vulnerabilities, fuel import dependencies and the impact of resource constraints.

This document seeks to formulate a set of principles and protocols that will provide a coherent framework for guiding the development of interconnectors in such a way as to accelerate their construction and to enable more flexible, and multilateral trading arrangements as required for the parties involved.

The principles themselves are linked to specific steps and sub-steps of the interconnector's life cycle and are presented in the following format:

Lifecycle stage:

Lifecycle sub-stage:

Principle:

Case study or example tool:

[2] Economic Research Institute for ASEAN, 'INVESTING IN POWER GRID INTERCONNECTION IN EAST ASIA' (2014).

Vision

Under the overarching vision of the GGI the primary driver for the development of interconnectors should be to support connectivity and flexibility between markets to enable the development of renewable energy resources, accelerate the energy transition, or otherwise contribute to reducing greenhouse gas (GHG) emissions from the power sector in line with Paris Agreement targets.

This document is intended to provide a set of principles and guidance on best practises in the successful development of interconnector projects, from their inception, through their development and operations, and ultimately to their decommissioning at end of life.

The principles are intended to be action oriented. They have been developed through expert consultation and include or are based on relevant case studies, examples, and references to tools that could be employed to support the development of new interconnectors.

The primary audiences for this document are government ministries responsible for enabling, guiding, or otherwise engaging in the development of interconnectors. It is hoped that this document will also be useful to other relevant stakeholders.

The principles will focus on how governments can support the development of interconnectors at each lifecycle stage. To start, these principles will focus on interconnector planning and construction, though it is also important to recognize that early stages of development can be impacted by later stages, and vice versa, and that this document will therefore continue to evolve and be expanded. The current document is currently in its second phase of development with a third expected in 2024.

The rest of this document is organised as follows.

First, the lifecycle of an interconnector is described at a high-level. The lifecycle is broken down into four main **stages**: **concept**; **project development**; **operation** and **decommissioning.** A related document, attached separately, provides relevant definitions, additional detail on steps within each stage, and also highlights specific "gates" that each project must pass through to move from one stage to the next.

Within each stage, lifecycle **sub-stages** are articulated. Then, **principles** relevant to various sub-stages and/or stages are presented.

Interconnector Lifecycle Stages and Associated Principles.

This document outlines the main steps that are required to develop cross-border transmission infrastructure, or "interconnectors".

The steps required to be taken to develop a cross border transmission system are as follows:

1 Concept

1.1 Preliminary studies

Study on the feasible trade of power between two countries bilaterally, and also regional trade of power across the Region. Socio-economic studies to show the gains obtained by the two countries in case of bilateral power exchange/ to show the gains obtained by each country of the Region, in case of regional power trade.

Some projects may have two feasibility studies, one done by each country's authorities at each end of the link to assess the socio-economic welfare benefits. Sometimes, for the benefit of having a common knowledge basis, these studies may be conducted jointly. Where the developers of the project are commercial entities, doing so on the basis of merchant revenues from selling the capacity of the interconnector to energy traders, then they will likely conduct a separate analysis of the commercial feasibility of the project. Where the developer is a state-owned-entity then the two assessments may be merged into one.

Power can flow in one or both directions over interconnectors for optimal utilization of the power resources between the two countries within a region taking advantage of the differences in electricity demand and supply between countries. Interconnectors reduce the need for reserve capacity for the two connected countries and surrounding region and can also be used to extend supply, in case of a blackout, in order to quickly restore supply. Therefore, interconnectors provide gains for the region as a whole. Any gains would have to be distributed in an equitable manner. The anticipated power needs and trade between the countries would dictate the transmission capacity of the interconnection. Besides this, interconnection also provides for the expansion of renewable energy, by increasing the size of the available wholesale market resulting in a reduction of greenhouse gas emissions.

Preliminary feasibility studies are employed to capture a wide range of factors for a proposed interconnector's development.

Principle:

An interconnector feasibility study should to the greatest extent possible address and incorporate the following considerations:

- **technological specification,**
- **supply profile**
- **demand profile,**
- **social implications,**
- **environmental implications.**
- **Economic benefits and opportunities**
- **Supply chain**

Study considerations should include the technical reality of grid connections beyond the desired capacity and focus on a range of factors including technical, fiscal, security, social and environmental impacts on the communities that the project seeks to serve.

Because of the particularly long development time of interconnectors, and the high amount of political will required for them to get built, governments may need to facilitate this lifecycle stage. This can be by either doing or subcontracting the work on this themselves, with the aim of identifying suitable projects. Or by creating a very clear process for the full lifecycle development of projects by the private sector.

Case Study:

Projects of Common Interest (PCI)

EU Projects of Common Interest (PCIs) are selected in regional groups on the basis of well-defined criteria and through a call for applications every two years. The work on PCIs is coordinated by regional groups, dedicated to electricity, offshore grid development and more.[3] PCIs are key cross border infrastructure projects that link the energy systems of EU countries. They are intended to help the EU achieve its energy policy and climate objectives. Projects identified as PCIs benefit from accelerated permit granting, improved regulatory conditions, lower administrative costs, and increased visibility to investors. Critically, PCI projects are able to receive European Commission CEF (Connecting Europe Facility) funds to be realised[4].

Projects are selected as PCIs on the basis of five criteria.

- Significant impact on at least two EU Member States
- Enhances market integration and contributes to the integration of EU Member States' networks
- Increases energy market competition by offering alternatives to consumers
- Enhances security of supply
- Contributes to the EU's energy and climate goals and facilitate the integration renewable energy resources.

Example:

The Celtic Interconnector

The proposed Celtic Interconnector, when built, will connect the Republic of Ireland and the Brittany region of France. It will enable the transmission of 700 megawatts of electricity, the equivalent of supplying power to around 450,000 homes. It will also be the Republic of Ireland's first direct energy connection to continental Europe, and therefore will enhance the country's security of supply, provide access to lower cost sources of electricity, and facilitate Ireland's transition to a low-carbon energy future by enabling the integration of higher shares of renewables and providing access to low-carbon sources of electricity outside of the Republic of Ireland's borders such as nuclear power from France.

The project is also an example of infrastructure co-deployment, as it will also include development of a fibre-optic communications link between Ireland and France.

In 2019, the project was awarded €530.7 million from the Connecting Europe Facility, after receiving PCI status, to complete the design and delivery of the Celtic Interconnector by 2025 and has also received EU funding at earlier planning stages. More information is available on the Celtic Interconnector factsheet.[5]

[3] https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/selection-process_en
[4] https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/key-cross-border-infrastructure-projects_en
[5] https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/pci-examples-and-their-benefits_en

1.2 Feasibility studies

Principle:

Studies could be conducted by one or more credible third party/parties although these are sometimes done in-house and should include a wide range of technical, economic, and social implications of interconnector development. Studies should include seabed surveys (if subsea cables are being developed) and onshore cable route and converter station planning as applicable.

Principle:

Coordination between two project partners can be difficult, and so it is helpful if governments can initiate discussion at the political level, and subsequently be invited to regularly participate in cross-party discussions at key technical junctions.

Example:

Technical:

- Peak flows and year-round power flows
- Extremes – complete flow reversal in one trading time stamp to another, emergency scenarios like wide-area or prolonged power loss due to climate or geopolitical disasters
- Loss of link, N-1 criteria, and frequency stability
- Potential for transient instability risk
- HVDC terminal controls, frequency converters, reactive power devices, etc as needed based on incumbent grid and technical evaluation (costs will vary if additional technical measures are required to address the concerns, e.g. congestion, voltage issues, etc)
- Climate resilience, especially in regions prone to climate impact (cost assumptions may diverge for such technical specs).

Assessment off connection points:

- It should be assessed whether a project is realistic from the outset, otherwise after a review of location and connection points, developers should look at alternatives to connect grids in more geologically appropriate locations, or to accommodate grid stability.

Human capital and technical resources:

- To determine the estimated headcount needed for each aspect of project e.g., financing, commercial, engineering and design, development, regulatory approvals, construction etc. The necessary technical experts should be booked to plan cable laying routes, and construction.
- Technical resources needed such as infrastructure components, cable components, software, generation components etc.

Permitting:

- Comprehensive list of permits needed for the project, from pre-construction to commissioning.

Regulatory and approval mapping:

- Comprehensive list of regulatory approvals needed for the project such as licensing and any other government approvals.

Financial plan / capital raise strategy:

Preliminary finance:

[To be expanded in Phase 3]

Supply-chain

The necessary materials and specialised cable production facilities for interconnectors should be procured in an adequate timeframe sufficient to meet a project's need. As demand for transmission infrastructure increases, projects should take into account that the expertise and materials needed may fall short of demand leading to increased competition. This may necessitate further planning and some higher costs. Contracting experts and materials in advance of project development, as well as incorporating contingency planning, will become more important, and it may become more common for developers to hedge bets on project success when applying to governments for licences.

It is also crucial to ensure upfront that there is sufficient supply such that the project target delivery date can be met, especially for large projects.

There is currently a supply chain gap in global HVDC cable production capacity, approximately one third of what should be available to meet demand by 2030. It is therefore important to understand and develop the supply chain strategy for a project at an early stage.

Vendors may not be able to support asset replacement of converters in the future - if the replacements are happening at the same time as they are building out new infrastructure. This problem has already started to be seen on asset replacement work around the world.

Supply chains must consider the need for components throughout the lifetime and not just initial construction. If an interconnector needs to update or fix components, it will face long waiting times for key components needed for expanding the global transmission system. As demand increases for such components needed for both construction and maintenance, interconnectors may need to veer away from a pure vendor model of supply and seek to independently supply itself with components on each line to ensure efficient running.

HVDC equipment may have 15-20 generations of technology cycled in use through its lifespan and will need to ongoing equipment changes and supply changes for these, not to mentioned issues of damage, posing a risk that needs to be considered by developers. The fix and fail approach of hoping a vendor can replace parts may not be safe for future security of supply. As with AC systems the owners developing spares holding, maintenance capability and monitoring to life extend and ability to fabricate or reverse engineer may be explored. Asset replacement represents an opportunity for new supply side entrants to be brought into markets.

Multiple vendors are needed as the HVDC networks grow and the supply chain issues tighten. This would help to cater for the next connection and maintenance project, so that existing ICs are not being trapped in a market with a limited number of vendors.

Control system software for hardware onshore also needs to be replaced every 15 years and updated more routinely.

Geography

The feasibility study needs to identify technically feasible routes that take into account geography, geology, topography, connection to existing grid, and potential grid reinforcements.

Additional technological supporting elements

Feasibility studies could map out the need for renovating existing, or building new, converter stations and substations for connecting two national grids by an interconnector transmission line.

Carbon emissions reduction

A primary objective and benefit of interconnection projects would be to reduce emissions by promoting the use of renewables through interconnection. In locations generating renewable power in excess of domestic demand, a neighbouring market in short supply could utilise the surplus via an interconnector without the need for this power to be curtailed. Utilising excess renewable power in this way negates the need for using more fossils fuels and reducing carbon emissions. In addition to the use of excess power, the price arbitrage between markets makes interconnectors a cost-effective tool for decarbonising the connecting markets. The extent of emissions reduction and life cycle analysis should be assessed in the feasibility study for developers to determine the environmental benefits. This will also aid the assessment by governments in the respective jurisdictions of such projects in their decision making.

Profits and commercial benefits

The value of the project can be assessed in two ways:

1. By fiscal viability for investors. Developers need to make a return on a project, or

2. allow a large enough socio-economic benefit (including climate benefit) to the economy of the countries to be (further) interconnected and therefore worth subsidising.

Principle:

Feasibility studies should include input from national and local governments, impacted grid owners and operators, and other relevant stakeholders.

Principle:

Studies could be conducted by one or more credible third party/parties although these are sometimes done in-house and should include a wide range of technical, economic, and social implications of interconnector development.

Principle:

Feasibility studies should include input from national and local governments, impacted grid owners (if applicable) and operators, and other relevant stakeholders.

Principle:

Interconnectors should be considered a part of larger power system plans / a broader grid planning process. Such planning should show the benefits of interconnection at an optimal level, as described by National Grid ESO.

Case study:

UK Centralised Strategic Network Plan

In Great Britain, the energy regulator Ofgem are developing the Centralised Strategic Network Plan (CSNP). A new electricity transmission network plan with an output that will be delivered by the new Future System Operator (FSO). They have published the following description of this process:
In the CSNP, the FSO will consider the onshore and offshore electricity transmission networks in Great Britain (GB) as well as cross-border electricity interconnectors and offshore hybrid assets and make recommendations on how the system should develop to decarbonise the electricity system by 2035, which is critical for meeting the UK's overall 2050 Net Zero target[6].

Case study:

UK Holistic Network Design

Great Britain's National Grid Energy System Operator (ESO) have designed the UK's approach to planning a future network with integrated renewables. The approach is published as below:

The Pathway to 2030 Holistic Network Design (HND) is a major step for Great Britain in delivering cheap, clean energy from offshore wind. It sets out a single, integrated design that supports the large-scale delivery of electricity generated from offshore wind, taking power to where it's needed across Great Britain. The HND facilitates the connection of 23GW wind, helping to deliver the Government's ambition for 50GW connected offshore wind by 2030. This is a first step towards more centralised, strategic network planning that is critical for delivering affordable, clean and secure power, as we journey towards our net zero future. The Pathway to 2030 Holistic Network Design delivers significant benefits, enabling the connection of this level of new offshore wind could:

- *Deliver £54bn investment in Great Britain's network infrastructure.*
- *Create up to 168,000 jobs by 2030, according to independent research.*

Compared to connecting wind farms individually, the recommended network design should:

- *Save consumers £5.5bn (£2.18 per year for every British energy consumer) in costs from 2030 by increasing network capacity and reducing the need to pay to turn down excess wind generation (we call this paying "constraint costs").*
- *Reduce the impact on the seabed with up to a 30% smaller footprint from cables to shore.*
- *Reduce CO_2 emissions by 2 mega tonnes between 2030 and 2032 – equivalent to grounding all UK domestic flights for a year.[7]*

Case study:

Tunisia-Italy (Tun-Ita) interconnector

The Tun-Ita project is aimed at supporting two markets. Firstly Tun-Ita will support the flexibility of the European energy market in the medium term, relieving stress from the Northern bottleneck of Italy's electricity grid connection with the rest of the EU. Secondly, in the long term, the project will help the Tunisian grid to decarbonise, and eventually export renewable power to the rest of North Africa allowing for regional security and decarbonisation benefits for both European and North African grids.

[6] Ofgem CSNP: Consultation on framework for identifying and assessing transmission investment options. Pg.4

[7] https://www.nationalgrideso.com/future-energy/pathway-2030-holistic-network-design

Projects such as the Tun-Ita interconnector will be built in the same timeframe that Tunisia is building the Tataouine solar plant. Interconnectors cannot be built in isolation from wider regional grid support considerations and should play a role in the wider machinery of regional energy supply and flexibility. The proposed Tun-Ita interconnector has been incorporated by ENTSO-E in its Ten-Year Network Development Plan (TYNDP). By including Tun-Ita, the TYNDP is able to account for and demonstrate the potential of the interconnector to help relieve grid congestion in Northern Italy, thereby revealing the potential for this transmission line to help enable pan-European flexibility expansion in response to the growth of renewables.

See the below Tun-Ita case study for an example of two markets being connected for the first time and the reasoning behind it:

Italy

In 2022 Italy imported 13.6%[8] of its electricity, experiencing congestion at its northern border. This has required Italy to build further supporting energy infrastructure in the south of the country. As Italy decarbonises its economy, increased electrification will increase demand that supply must also keep pace with.

Developing further interconnection has become increasingly important for countries such as Italy who look to develop a secure, and low carbon energy market in line with the EUs 2050 carbon reduction[9] targets and National Energy and Climate Plans[10].

In addition to increasing interconnection with North Africa, the project serves to, under specific conditions, reduce the limitations currently present with Italy’s power exchanges on the border with France, Switzerland, Austria, and Slovenia. By providing the South of Italy with a new power supply point, Tun-Ita will effectively increase the transmission capacity of Northern Italy by at least 500 MW at its borders and reducing the regional ‘bottle neck’[11].

Tunisia

Tunisia shares some electricity interconnection with Algeria, but its supply is overwhelmingly sourced from its domestic gas generation[12] as well as gas interconnectors to Libya and Algeria[13]. Tunisia is also developing [14] a new connection project Number.5 DZ-TN-LY’, adding a further 1000 MW of capacity with Algeria and Libya. [15], adding a further 400 kV and 1000 MW of capacity with Algeria. Tunisia is therefore well placed to secure supplies of energy to Europe via the Tun-Ita connection.

Tunisia is developing renewable generation projects such as the newly developed Tataouine photovoltaic (solar) power plant in the south of the country. Tataouine started production in

---

[8] Data provided by British Embassy Rome
[9] https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en
[10] https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en
[11] https://tyndp2022-project-platform.azurewebsites.net/projectsheets/transmission/29
[12] US Energy Information Administration https://www.iea.org/countries/tunisia
[13] Summary by worldometer of US Energy Information Administration and BP intel

[15] https://masterplan.med-tso.org/interconnections2030.aspx

2022 and will have a maximum installed capacity of 10 MW and will supply 20 GWh of energy per year to the national grid[16].

Principle:

Cost benefit analyses (CBAs) should outline the social economic welfare (SEW) of the project including consumer surpluses, producer surpluses and congestion rent.

An interconnector may raise prices in one country and lower prices in the other leaving congestion rent as the revenue captured by the interconnector. Congestion rent is the main source of revenue for merchant interconnectors. Congestion rent is driven by the average price differential, (structural value), the price volatility (volatility value), and correlation between prices. It is important that governments and regulators agree how the costs and benefits of the interconnector are allocated.

Interconnector development may bring private commercial and/or consumer and producer socio-economic benefits, through cable congestion rents, grid flexibility decreasing the overall cost of power prices over time for consumers, and reduced curtailment of connected renewable power sources.

Secondary Benefits

A feasibility study will assess how a newly proposed interconnector project will provide competition to existing interconnectors in the region, and the further need to provide grid flexibility in that market.

Where congestion rates apply; the more transmission capacity built between two markets, the smaller the incremental congestion rent will be, and so the smaller the incentive to build another interconnector. The degree of congestion rent 'cannibalisation' is an important factor for whether to build additional interconnection. When there is complete market saturation no further congestion income is generated.

Principle:

Cost benefit analysis (CBA) should measure the social economic welfare (SEW) of the project including consumer surpluses, producer surpluses and congestion income.

Case study: The Gulf Undersea India Transmission System

The below extract is from Climate Comparative Growth's paper on developing a connection between the Arabian Gulf states and India. It lays out the socio-economic welfare (SEW) benefits of developing interconnection between two markets, one with a surplus and one with a shortfall of energy demand:

India has seen rapid increases in GDP, energy access, and population in recent decades, more than doubling its overall energy consumption since 2000. Meanwhile, India produces approximately 70% of its electricity from coal. With electricity demand only projected to grow in the coming years, the Government of India has pledged to install 450 GW of renewable energy by 2030. The Gulf Cooperation Council (GCC) countries, meanwhile, have comparatively small populations with excellent renewable energy resources, particularly solar. The ability to trade power between these two regions could potentially provide India with a highly reliable carbon-free power source. At the

---

[16] ENI https://www.eni.com/en-IT/operations/tunisia-tataouine.html & ENI https://www.eni.com/en-IT/media/press-release/2019/05/eni-and-etap-partner-to-develop-renewable-energy-projects-in-tunisia.html

same time, it can motivate the shift to low carbon economy in the GCC and add a new market for its solar power[17]*.*

A feasibility study will take an extensive view on the need for an interconnector including the current energy demand and supply of the affected markets. The need for interconnection is primarily based on the need for importing and exporting power. This need may increase with increased decarbonisation of the economy and penetration of renewables.

One of the significant decarbonisation benefits of increased electricity interconnection is reducing curtailment of renewable energy sources. By building additional interconnection, a route is provided to export surplus renewable power that would have otherwise been curtailed, possibly at high cost.

Socio-economic benefits

Besides potential commercial benefits where relevant, interconnectors may provide significant socio-economic welfare benefits. The European Commission highlights that *'the socio-economic value of electricity interconnectors comes from their ability to increase the efficiency of the electricity systems by reducing the costs of meeting electricity demand and in parallel improving security of supply and facilitating the cost-effective integration of the growing share of renewable energy sources'*[18]*.*

Security of supply

Security of supply may be a prime reason to develop market connections that fall short of commercial viability (where price differentials between markets are not significant) for development.

Financial support required for project development.

Interconnection can be supported under a government led regulated asset base (RAB). RAB models can come in varying forms. In the UK the cap and floor regime is the regulated route for electricity interconnector development in Great Britain (GB). It is a market-based approach which aims to incentivise developers to deliver interconnector capacity by limiting developers' exposure to electricity market price risk[19].Both RAB and Cap and Floor provide certainty of revenues to the project. Other support models can help on the structuring side, such as using climate finance to reduce some of the project risk and make the project more attractive to private finance.

[17] Technoeconomic energy system data for modeling of India and the GCC countries, Extract, Miles Weinstein, Youssef Almulla, Avinash Vijay, Abhishek Shivakumar, Will Usher, Chris Arderne, Adam Hawkes, Mark Howells, https://www.researchsquare.com/article/rs-320312/v1.

[18] Report of the Commission Expert Group on electricity interconnection targets, November 2017, https://energy.ec.europa.eu/system/files/2017-11/report_of_the_commission_expert_group_on_electricity_interconnection_targets_0.pdf

[19] Ofgem, Cap and floor regime handbook, 2021, https://www.ofgem.gov.uk/sites/default/files/2021-09/Regime%20Handbook.pdf

Geopolitical risk assessment

Developers may consider if a project is viable in a location affected by geopolitical instability.

A project in a conflict zone may struggle to attract financial backing due to the risk of infrastructure becoming damaged - affecting the short to long-term fiscal profits of the project. Investors in energy infrastructure are likely to be risk adverse needing a high financial incentive for a high-risk project or may otherwise invest elsewhere. A model of state backed projects in conflict zones may be a more realistic option, with a willingness to risk infrastructure damage to achieve national goals for energy security and flexibility.

Depending on the geopolitical stability of a region after a change in regime, the geopolitical shift may not affect the development of energy infrastructure between states, as seen in the development of the Tun-Ita project, where agreements on project cooperation were signed both before and after the significant 2011 change in political landscape in Tunisia: allowing the project to continue development.

The extent to which a state may rely or over-relies on a single large piece of energy infrastructure, such as an electricity interconnector, for grid stability will impact the feasibility study in any nation no matter the risk of geopolitical conflict. The risk of one large project failing for the grid, and risk to fiscal viability of a project at risk of destruction or damage can be considered in its development for the single project and national grid as a whole.

When building an interconnector in a conflict or former conflict zone, the route and connecting point of the cable may disrupt land and / or sea ordinances which will also need to be considered during the planning and building of an interconnector for safety, route planning, and construction.

Developers may also be encouraged to build new energy infrastructure in response to geopolitical conflict, leading to altered directions of energy flow, supply, or demand in a region.

The feasibility study should outline the level of geopolitical risk associated with an interconnector project. This assessment would cover if the connecting states are satisfied with the risks posed to the interconnector, the mitigating actions to protect the asset, preventative measures that could be taken to avoid such risks such as commitment against expropriation of resource, and whether these combined factors make for a viable project.

Communities

There may be some resistance to the route and landing sites of an interconnector from communities living and working along its length or place of grid connection. Local communities are often worried about how the disruption to land in building can leave lasting effects including:

- Loss of environment and cultural reverence for said sites.
- Disrupting buried waste / toxic waste sites.
- Miseducated perceptions of an interconnector’s magnetic field posing a community health risk

Principle:

The risk study should assess how community issues can be overcome or otherwise assess the possible alternatives available. Compensation schemes can be put together for local communities affected by project development at the points of cable routeing, landing points, substations, and converter station points.

Principle:

Best practice includes – early engagement with affected communities, clear messaging, transparency, and consideration of benefit sharing options.

Environment

One of the significant wider benefits provided by interconnectors are the avoided renewable energy supply curtailment. If building additional interconnection provides a route to export renewable power that would have otherwise been curtailed, possibly at high cost, then this is a significant wider benefit to the utilisation of renewable power sources.

Environmental damage that cannot be recovered from, including the permanent displacement of rare or common fauna and flora, should be taken into account, considering the ways in which to prevent the damage from becoming worse or reversing damage after the construction is complete. Some flora and fauna may only be found at a proposed site of development which may necessitate a change in the infrastructure's route, habitat relocation, or other substantial mitigation measures: an environmental impact assessment may be required to assess these factors further.

Summarising benefits and losses

When assessing the factors that make interconnectors worth building, developers will weigh the advantages and disadvantages of proceeding. The GGI wishes to encourage the cost benefit analyses of interconnector projects to be beyond financial in lead, keeping in mind the importance of the GGI vision for interstate flexibility to enable the flourishing of an international renewables market.

1.3 Permitting

[Placeholder for expansion in phase 3]

Principle:

Permitting should include all the relevant permits required for the project from the infrastructural aspect from both countries [and any third countries] along the interconnector route, throughout the lifecycle of the project.

Depending on the complexities of interconnector routes and jurisdictions it passes, permitting may be required from multiple authorities for various purposes such as land use approval, cable laying approvals, permits to clear land if required etc. The timelines for these permits should thus be taken into account to ensure critical paths are on track.

Principle:

Permitting reform or even review and presentation of existing permitting requirements can be helpful. A lot of regulations haven't considered two-way power interconnectors. If governments can initiate and share a study of the permitting requirements, it can help developers quantify the risk.

Example:

As permitting may well be a critical path item, the preferred framework for gaining planning approval should be determined at the earliest stage possible following commitment from key sponsors/ nations. Often there is only one established permitting framework for each jurisdiction. This could be a central approach – in which case the relevant authority should be approached (to initiate the process) as soon as all suitable project data (national benefit etc) is available. Some territories have a more devolved approach in which case stakeholder engagement / environmental studies and engineering studies to establish siting etc should be undertaken at the earliest opportunity.

1.4 Regulatory approval

Principle:

Regulatory approvals are needed for the project such as licensing and any other government approvals.

Understanding the route to approval.

Responsibility for regulatory approval for interconnectors is often divided between governments and independent energy regulators. The specificities of their roles often vary between jurisdictions. The Regulatory Energy Transition Accelerator (RETA) is currently running a Flagship Project looking at energy regulators' roles in facilitating interconnectors[20].

Interconnector project may be 'first-of-a-kind' for the jurisdictions involved – in this case a regulatory framework which provides the necessary environment for investment, while also protecting consumers and wider stakeholders will be required. The energy regulator, which has up until now not dealt with interconnectors, will need to be empowered to do so. Bilateral or multilateral working arrangements with counterparts in the interconnecting jurisdiction will need to be established. This workstream will require close collaboration between policymakers, regulators, wider industry (Grid owner, system operator, connected parties etc.) and the developers to ensure the correct framework evolves. Time should be built in for the necessary changes to legislation and industry codes.

Given the nature of interconnectors crossing different jurisdictions, and the challenges of bilateral and multilateral engagement in regulation, many jurisdictions have seen the need for regulatory oversight across borders. This could take the form of a coordinating binding entity, a central binding entity, or a unified institution.

Economic, environmental, and safety regulation.

Regulatory protection for consumers / wider industry may include limits on how interconnector capacity can be marketed (to facilitate competition), what level of returns can be made by developers (to protect consumers) and how any excess returns are utilised. In addition, regulation may determine how interconnection is charged for use of, and required upgrades/ maintenance of, associated grid infrastructure. In addition, the requirements for efficient and safe operation of the interconnection and associated penalties (licence revocation / fines / investigations etc).

1.5 Approval mapping

This is the interaction between the business models and the financing of the project. If the business model is around the power purchase agreement (PPA) for the renewables going to a market for use – then PPA that end is the model. The developer will then need to assess if it's of a high enough quality and quantity to explore project financing or is there another way of doing this such as arbitrage trading or other reasons to build an interconnector. A regulatory model that can compensate for a lack of arbitrage can the model its debt or be underwritten by consumers (PPA).

20 https://www.iea.org/reports/institutional-architecture-for-regional-power-system-integration.

Principle

All approvals need to be identified. Develop **a power purchase agreement, also known as a Transmission Service Agreement.**

In order to agree preliminary financing, there must be agreed planning, agreed regulation, agreed permitting, and agreed permit mapping. Stakeholders should be consulted throughout the process. Projects that receive a major project status will streamline the permitting and grant review process.

The counterparty for the revenue contract is really important for financing. A developer will often want a sovereign entity to guarantee revenues. In order to agree preliminary financing, there must be agreed planning, agreed regulation, agreed permitting, and agreed permit mapping. Stakeholders should be consulted throughout the process. Projects that receive a major project status will streamline the permitting and grant review process.

The counterparty for the revenue contract is really important for financing. A developer will often want a sovereign entity to guarantee revenues.

Case Study: Australian REZ Network

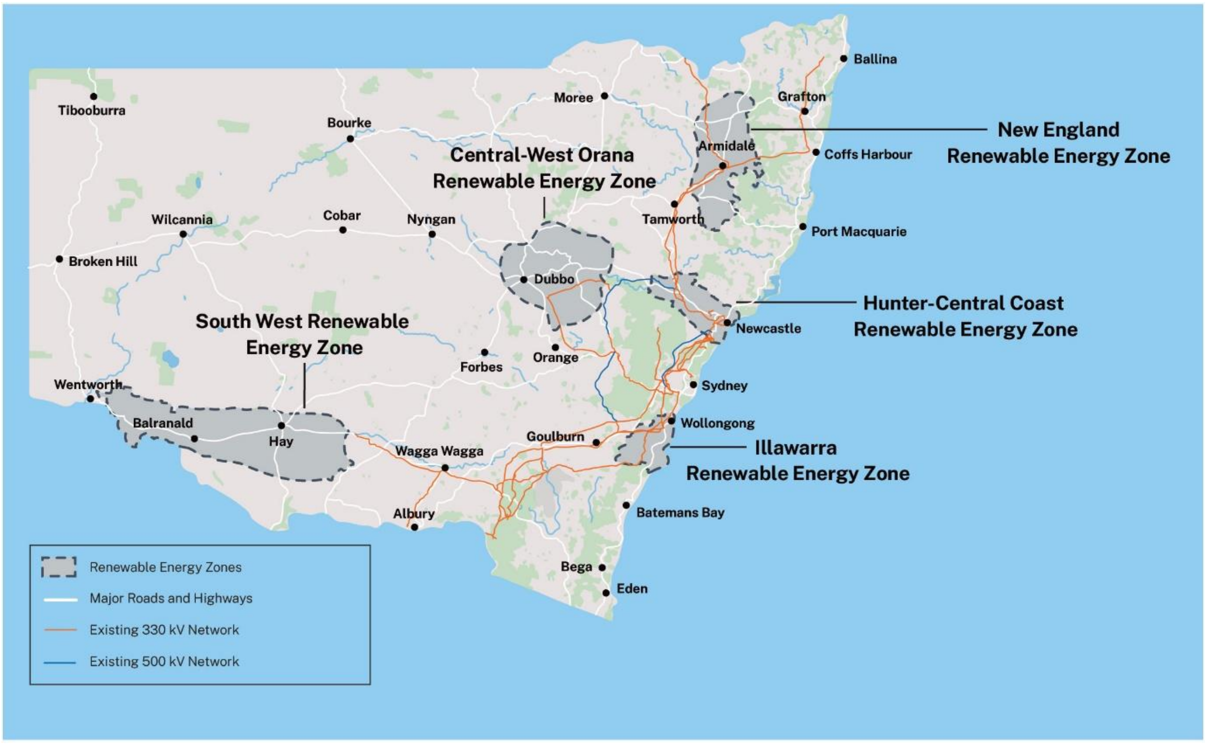
Australia's new Renewable Energy Zone (REZ) network operator model is an example of a purchase agreement. The following text is taken form the REZ website in the context of this document:

In the REZ, the government vehicle is the revenue counterparty to the transmission operator, collecting the transmission fees on their behalf. Renewable Energy Zones (REZs) will group new wind and solar power generation into locations where it can be efficiently stored and transmitted across New South Wales (NSW). Five zones have so far been identified and will keep NSW electricity reliable as coal-fired power stations retire, delivering large amounts of new energy to power our regions and cities21. These REZs will help deliver lower wholesale electricity costs and place downward pressure on customer bills through increased competition, while also supporting new local jobs and business opportunities during construction and operation. REZs will reduce carbon emissions by delivering a greater mix of renewable energy to the National Electricity Market (NEM), supporting New South Wales and Australia's net-zero ambitions.

REZs are complex and multi-faceted, involving a combination of careful strategic planning, technical and regulatory design, community engagement and industry-focused policies and programs. Strategic, upfront land-use planning and coordinated community consultation are central to REZs and will help ensure a strategic approach to electricity infrastructure development. We work on the ground with communities and collaborate with a range of NSW Government entities and other parties to get the most up-to-date data layers and undertake strategic land-use planning when preparing to declare a REZ. NSW needs increased transmission capacity so that new, clean sources of power from REZs in regional NSW can deliver electricity to demand centres, predominantly located along the eastern, coastal regions of the State. The government will provide network solutions including transmission upgrades to REZs to open up the best renewable energy and storage resources, allowing for new generation, transmission and storage to be built in a coordinated manner. They will also ensure regulations are designed for the benefit of the communities that host REZs. For example, new generation projects within or supporting REZs will need to compete to secure access rights to new transmission. These new renewable energy projects are likely to be more successful in gaining access

[21] https://www.energyco.nsw.gov.au/renewable-energy-zones/what-renewable-energy-zone

through competitive tender process if they can demonstrate local employment opportunities and compatibility with existing agricultural land uses.



New South Wales, Australia, Renewable Energy Zones[22].

1.6 Financial planning

Due to interconnection size and complexity, large capital investments are required which may often go beyond the existing capabilities of financing that is available within local markets. Furthermore, determining the role and potential quantum of private and public sector financing.

In terms of financing interconnection projects, it important to first consider the sources of funding available to finance the project. Corporate finance is often considered the traditional form of financing for interconnector projects, whereby debt is raised on the strength of a utilities balance sheet. The use of project financing is often seen as the alternative form of financing, whereby funding is secured based on the commercial viability of the project itself. Both the use of corporate and project finance has its merits and challenges; however, the choice is heavily dependent on the interconnector business model.

It is important to note the use of project financing is often regarded as option in circumstances where the utility is considered high risk due to its credit rating and the local markets are deemed as insufficient to provide adequate funding. For project financing to be viable, lenders will require a reliable offtake arrangement, such as a long-term capacity contract with an investment-grade rated offtaker. These are relatively rare due to the size of the commitment involved. In addition, lenders will seek to lend to a Special Purpose Vehicle (SPV) which faces minimal construction and operating risk – in order to protect debt service payments. One alternative is for the regulatory structure to guarantee that revenues for the project will be (at least) sufficient to cover debt service payments (such as the 'cap and floor' regime in the UK – see step 2.6).

[22] https://www.energyco.nsw.gov.au/renewable-energy-zones/renewable-energy-zone-locations

In terms of sources of capital that are available for an interconnector project, which include the following[23]:

- **Government Budgetary Allocation**
  The allocation of a governments' budget for developing a country's transmission infrastructure varies from country to country, with the allocation usually drawn from a country's fiscal budget. The deployment of funds is highly dependent a country's law and public procurement of infrastructure. In most circumstances, the source of funds will directly come from government's balance sheet and availability of cash, as a result a government ability to finance interconnection project is contingent on a country's fiscal constraint and overarching priorities. It is important to note, financing interconnection has becoming increasingly rare due to the complexity of the budget government allocation process.
- **Debt**
  Financing interconnection is highly dependent on long term funding, due to interconnection lifecycle involves construction and development process. Debt financing involves both private and public debt. Public debt is deemed as an important source of financing due to existing restriction of local private debt sources. For example, local commercial banks who provide debt financing often lending to infrastructure projects which are highly creditworthy and have consistent cash flow.
- **Concessional financing**
  Concessional finance has been defined as a loan financing whereby its terms will include long amortisation schedules, extended grace periods and low or subsidised interest rates. Multilateral development banks (MDBs) and donor-backed funds typically provide concessional finance to government via the Ministry of Finance with loans lent to the transmission utility.
- **Loans provision from Development Finance Institutions**
  Development Financial Institutions (DFIs) are classified as institutions that are majority owned by national governments. These institutions also include MDBs. DFIs sources of capital are commonly from national and international development funds and can often utilise government guarantees in their finance provision. The ability to do this ensures their creditworthiness, resulting in having the ability to raise large amount of capital from international capital markets and offer long dated loans on competitive terms.
- **Equity**
  As part of project finance structures, project owners are often required to invest at least 20-30% of equity investment in exchange for shares in the project company. The investment will allow project owners to earn dividend over the life of the project. The form of financing is often seen as an additional vehicle to incentivise equity owners to ensure that the transmission assets are constructed and perform as contractually specified.

[23] Understanding Power Transmission Financing Report, co-authored by Power Africa and the U.S. Department of Commerce Commercial Law Development Program

[Phase 3 Placeholder for principle]

1.7 Capital raising strategy

It is important to engage early on with the relevant stakeholders, such as technical experts, legal advisors and financial advisors early on the capital raising process, with each likely to provide the following support outlined below:

- Financial advisors: a familiarity with international financial organisations and advise on the proposed capital structure.
- Legal advisors: undertake risk assessments and project structuring.
- Technical experts: define the project definition and technical justification.

For UK interconnection, capital raising in the non-UK territory is typically via an extension to the revenue model of the TSO developer / owner. E.g., should the TSO already have a Regulatory Asset Base (RAB) model for financing TO investments, this can be extended to include the forecast costs of the interconnector project. In the UK, interconnectors are financed on a more commercial basis, with the developer in question financing costs via equity, corporate debt or project finance, and then recovering these costs and a suitable return during the operating period – this requires careful planning to ensure funds are available and credit metrics are not breached during the construction period.

1.8 Preliminary financing

Preliminary financing for electricity interconnectors is the process of securing the initial funds and resources for developing and implementing an electricity interconnector project. This process can vary depending on the interconnector type, location, and regulatory model of the interconnector project. General steps for preliminary project financing can be summarised as: [24] [25] [26]

- Step 1: Define your project objectives and scope. There should be a clear vision of what you want to achieve with your interconnector project, such as enhancing security of supply, reducing carbon emissions, or increasing flexibility. This stage should allow for the technical specification of the project such as capacity, voltage, length, and route of the interconnector, as well as the expected operational life and decommissioning costs.

- Step 2: Assess the feasibility and viability of your project. See lifecycle step 1.2.

[24] [Electricity Interconnectors Cost Assessment Guidance Document]: https://www.ofgem.gov.uk/publications/electricity-interconnectors-cost-assessment-guidance-document

IEA A capital allocation dilemma in energy transitions, Michael Waldron & Yoko Nobuoka, https://www.iea.org/commentaries/a-capital-allocation-dilemma-in-energy-transitions

[25] [Interconnectors | Ofgem]:. https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/interconnectors

[26] IEA A capital allocation dilemma in energy transitions, Michael Waldron & Yoko Nobuoka, https://www.iea.org/commentaries/a-capital-allocation-dilemma-in-energy-transitions

- Step 3: Choose your regulatory and financing model. See lifecycle 2.2.

- Step 4: Prepare a detailed business plan linked to the finance model of the project. The project should have a detailed business plan that outlines the objectives of the project, its scope, feasibility, viability, regulatory and financing model, cost structure, revenue streams, cash flow projections, sensitivity analysis, and risk mitigation strategies.

- Step 5: Seek funding and support from potential investors and partners. These may include public or private entities, such as governments, regulators, grid operators, banks, funds, utilities, developers, or suppliers.

Example:

Previously the European Union has used CEF (Funding for Projects of Common Interest) to support projects. The European Commission described their project as follows:

Projects of Common Interest are eligible for funding from the Connecting Europe Facility (CEF), the EU fund for boosting energy, transport, and digital infrastructure. The new CEF programme for 2021-2027 allocates a total budget of €5.8 billion to the energy sector. In addition to projects of common interest (PCI), it includes a new section to support cross-border projects for renewable energy. The publication "CEF Energy: supported actions 2014-2020" provides an overview of the 149 actions that received funding, amounting to a total of €4.7bn, in the 2014-2020 period. These went to electricity, smart grids, CO2 and natural gas infrastructure projects, with the aim to better interconnect energy networks and thereby strengthen the single energy market in Europe. The European Investment Bank also plays an important role in financing cross-border infrastructure projects[27].

Principle

The development phase is the most uncertain phase of any large project, as such (if privately developed) projects are greatly assisted by the availability of development grants.

1.9 Peer-to-peer dialogue

Vehicles of cooperation may be built in a fair and balanced way that brings commercial players and governments in both jurisdictions as equals from the inception of a project to the decommissioning of a project after its lifespan is spent.

Principle:

Vehicles of cooperation for a proposed interconnector project should be built at the technical and political levels and supported by intergovernmental organisations and other collaborative platforms.

Example:

ENTSO-E and MED-TSO, these are regional organisation (rather than a country specific one) and its planning activities cover the whole region - thereby allowing it to consider interconnection – bodies such as these will be key for streamlining regional network development with integrated green and renewable power generation.

[27] https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/funding-projects-common-interest_en

Principle:

Coordination between two countries can be of issue, and so it is helpful if government can initiate discussion at the political level.

Example:

"6 party meetings" between Governments, regulators, and relevant transmission system operators (TSOs) from both sides.

The development of cooperation vehicles should be governed by binding contracts, treaties, and Memorandum's of Understanding (MoUs) [see Tun-Ita case study] to ensure commitment is kept to projects that bear significant financial cost, and that the development of the project is governed in a fair and equitable manner.

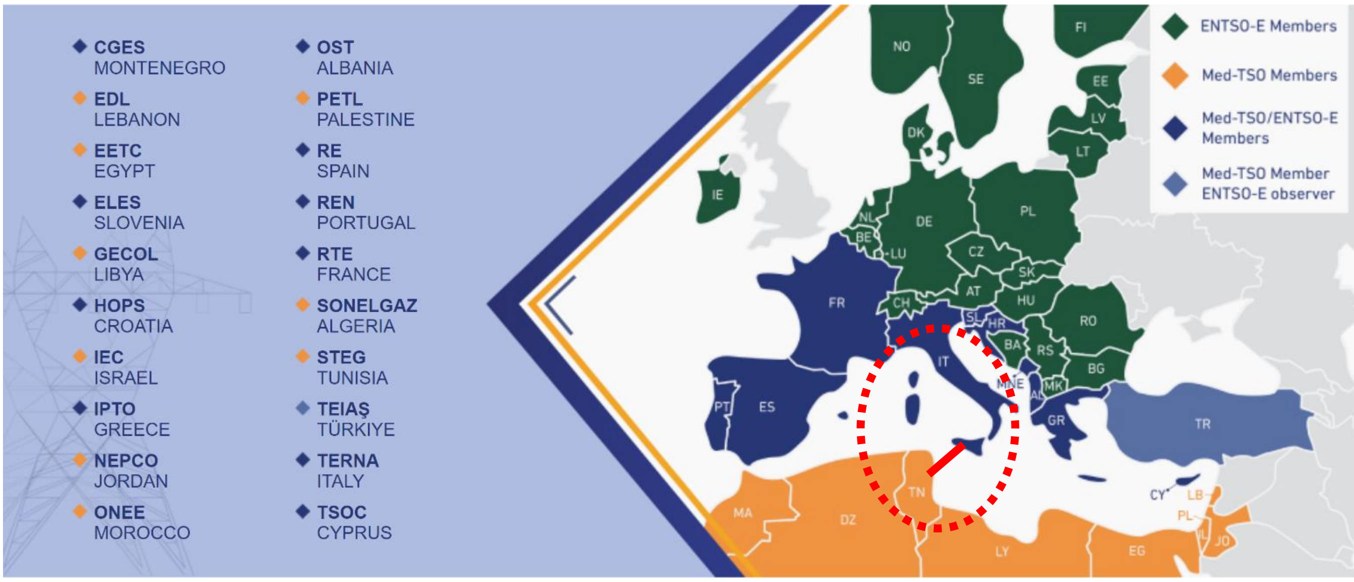
Case study:

Tun-Ita case study of how two states can utilise vehicles of cooperation**:**

Inter-TSO body

Europe and North Africa benefit from the use of two inter-TSO bodies: ENTSO-E (the European Network of Transmission System Operators for Electricity) and MED-TSO (Association of the Mediterranean Transmission System Operators (TSOs) for electricity) which are funded by the European Union, but made-up of both EU and non-EU states. ENTSO-E has a focus on the development of electricity infrastructure in Europe, and MED-TSO the infrastructure between Mediterranean states. As highlighted in the below map from MED-TSO some states belong to both organisations.

Italy is a member of MED-TSO and ENTSO-E. Tunisia is a member of MED-TSO. The two energy markets, although on separate continents have benefitted from joining a common multilateral inter-TSO body of cooperation.



[28]

28 https://www.med-tso.com/members.aspx?f=

ENTSO-E describes itself as follows:

*ENTSO-E is committed to… developing… and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with transparency and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders… Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.*29

ENTSO-E has 39 TSO members from 35 states who are responsible for the secure coordination of the European electricity system30, including identifying areas of the grid that need reinforcing such as the bottlenecked Northern Italian grid, and responding to markets changes. For example, in 2023 we still see dramatic energy market changes in Europe in the wake of Russian war in Ukraine. ENTSO-E is also responsible for ensuring the European grid is integrated with the renewables market in line with climate neutral continent goal for 2050, supporting the Italian link to the growing Tunisian renewables market.

MED-TSO was founded in Rome in 2012 as a technical platform to strategically develop the regional integration of the Mediterranean power systems through multilateral cooperation. The group focuses on regional grid development to strengthen security and socio – economic development through existing, and developing future, infrastructure.31

Under MED-TSO, the TUN-ITA project is one of a number of interconnectors being built to support the growing energy market in North Africa including the project 5 DZ-TN-LY.

Principle:

Encourage standardised / harmonised approaches among stakeholders.

These can be outlined in MoUs, intergovernmental agreements, and other documents to ensure common understanding between both parties

Principle:

Share relevant data and other information in a transparent and trusted manner.

Data sharing is fundamentally important to increasing investor confidence and enabling investment decisions. Develop data portals or common platforms where interconnectors may be presented for consideration.

Principle:

Share risks in an equitable and appropriate manner.

Sufficient documentation from treaties and MoUs should agree on the risk sharing approach and outline the shared risk and damage control measures between parties in the case of problems being faced by a project.

Principle:

Present studies to the Government officials in a succinct and easy to understand manner.

[29] https://www.entsoe.eu/about/inside-entsoe/objectives/

[30] https://www.entsoe.eu/about/inside-entsoe/objectives/

[31] https://south.euneighbours.eu/news/energy-eu-funded-med-tso-presents-mediterranean-master-plan-2020/#:~:text=Med%2DTSO%20is%20the%20Association,Networks%20of%2019%20Mediterranean%20Countries.

Third party access

Given that cross border interconnection projects are typically large scale and heavy in capital investment, it would make sense for the infrastructure to allow for open access for future parties to connect new generation sources to the grid. To allow for the new generation connection to the interconnector, power flow study needs to be carried out considering the generation quantum from the new generating station to assess power transfer capacity of the interconnector. If it is determined that the transfer capacity is inadequate, upgrading of the line/new interconnector should be recommended. This promotes the ability for resource abundant countries to export any excess renewable energy generated across to regions where energy is needed and prevents a monopolistic use of the transmission cable and ensures the maximum benefit for the region to be reaped through open access, facilitating the best outcome for the investment.

Open third-party access is often dependent on supply of energy operation which can be affected by commercial operations, lifecycle and length of project, as well as other factors.

Principle:

The presentation of studies to Government officials should be in a succinct and easy to understand manner.

Engagement with the respective governments, local grid owners, and grid operators is very important, as it leads them to better understand the proposal and more chance of gaining support the project concept.

Presentations could cover the following:

Additionality

Presentations may include an overview on how local communities are not deprived and are not negatively impacted (socially, economically) by the interconnector, and benefit from the interconnector project.

Principle:

Do no harm principle

Any proposed interconnector projects are proceeded by a feasibility study that considers the impact of the project on the interconnected states and communities living at the connecting points and route, the transmission line, and affected grids.

Respective governments should encourage the development of interconnectors between new and growing sources of renewable energy, and increasingly power-consuming locations. When seeking to utilise the development of newly created energy sources, governments and developers should ensure that the domestic needs of the producing states are being met before being transported for profit. There should not be a risk of organisations monopolising national energy production for export before domestic power needs are met.

Likewise, where there is a large price arbitrage between markets which are connected for the first time, developers should ensure that energy from less economically developed markets is not being sold in excess to markets with permanently higher energy prices on the free market, which would raise the cost of the poorer energy market to unaffordable levels, thus making it inaccessible to the energy consumers in that state. These energy markets and consumers can be protected so that when providing renewables for more developed economies, their own developing economy Is not endangered or abused.

Where developers see developed trade blocs interconnecting with less developed energy markets, they should ensure that the regulation and cost of market integrations are not dictated, and equitably agreed on a fair and unmonopolised footing.

The study should also determine the benefits that the interconnector project brings to the local community, in addition to the baseline of ensuring that no harm is done.

Secondary benefits / trickle down benefits

Primary trickle-down benefits need to be understood in advance of the project's completion. Firstly, understanding interconnector benefits for domestic and connecting communities is important, with benefits including lowering supply prices, increasing mutual security of supply.

The secondary benefits of interconnector development are those which are not directly related to the primary functions of interconnectors but are derived from their impacts on the electricity system and the wider economy and society. Examples of secondary trickle-down benefits are:

- Reducing network congestion and losses: relieving network congestion and reducing transmission losses by allowing power to flow from areas with excess generation to areas with high demand. This can improve the efficiency and reliability of the network.
- Enhancing competition and innovation: Interconnectors can increase the competition and diversity in the electricity market by providing access to a wider range of generation sources and suppliers.
- Facilitating renewable integration: Interconnectors can support the integration of intermittent renewable energy sources onto the grid by providing flexibility and balancing services.
- Creating jobs and growth: Interconnectors can create jobs and growth in the economy by generating investment opportunities, stimulating trade activities, and enhancing regional cooperation.

States can evaluate the magnitude and distribution of these secondary trickle-down benefits as they may vary depending on several factors, such as the interconnector type, location, size, and regulatory model of the interconnector project; the characteristics of the connected markets; the availability and cost of alternative options; and the externalities and uncertainties involved. Therefore, it is important to conduct a comprehensive cost-benefit analysis that considers both the direct and indirect impacts of interconnectors on different stakeholders and scenarios. This can help to identify the optimal level and design of interconnection that maximises the net benefits for consumers and society.

Principle

Secondary trickle-down benefits must be traceable and measurable.

Comprehensive benefits.

The project should list out the statistics that outline benefit and harm caused by building a project for the:

- Developer
- Affected consumers
- Market needs
- Governments
- Regional needs
- Incumbent electric utilities (which may oppose interconnector projects because of increased competition)
- Local community

Cost-benefit analysis.

- Cost allocation is based on net benefits that accrue to jurisdictions, which is the norm in Europe and the United States but not the case in ASEAN states.
- Share costs of interconnectors are calculated by the benefits accrued.

Example:

High level statement of intent supporting the proposed project and/or intergovernmental agreement defining the specific terms of support among all involved countries.

An explicit expression of support by the relevant governments for the development of the interconnector project is important for moving the project past the idea stage to the development stage.

[This section will be further developed in phase 3]

2. Project development

Case Study: UK

Different approaches to the development of interconnectors have been adopted in the UK which affects funding and cost sharing. Three examples are:

1. Incorporated Joint Ventures
2. Unincorporated Joint Ventures
3. Single Developer

The BritNed interconnector is an example of an Incorporated Joint Venture approach. The owners and operators of the interconnector, TSOs Tennet and National Grid formed a specific company – BritNed Development Limited which owns and operates the BritNed interconnector. As shareholders the owners may then share costs and revenues according to their respective shareholdings in the company.

The Interconnexion France-Angleterre 1 (IFA) interconnector is an example of an unincorporated joint venture. The IFA interconnector is jointly owned and operated by National Grid and Réseau de Transport d'Électricité (RTE). In this case rather than set up an incorporated joint venture company, RTEand National Grid instead each own their share of the assets and take an agreed share of the revenues generated by those assets.

Further interconnectors connecting to Great Britain have different corporate structures. ElecLink is 100% owned by GETLink the operator of the Channel Tunnel rail link and is 100% privately funded according to its website[32]

The funding of interconnectors can be delivered by balance sheet funding from the owners, project financing or a combination of the two. Generally, there is little direct government support beyond early stage capital expenditure grants. The EU's Connecting Europe Facility (CEF) allowed partial grant funding of activities for many interconnectors in their development, for example towards seabed surveys.

The socio-economic welfare benefits delivered by a project are assessed by national governments ahead of giving the go ahead for regulatory approvals. Such approvals might be withheld if a government concludes that the project offers no or negative benefits to its economy.

2.1 Cost sharing

Principle:

After the respective countries are convinced of the trade potential and the necessity of the transmission system, developers will discuss with them the method of sharing costs/ transmission charges between the countries.

---

[32] Eleclink - who we are

The methods could be on the basis of benefits accrued by each of the countries, or a general method, when it is difficult to foresee the benefits that would accrue for the lifeline of the project (which could be greater than 50 years). This is expected to take the longest time.

Governments can sometimes take a minority or majority stake in a project. This would support funding in the higher risk stages, and generally take on some of the political risks. An additional option of this route is that the government equity in the project could thereafter be bought out at fixed times, on the achievement of certain project milestones.

Case Study: BritNed

During the early development stage (prior to incorporation of the joint venture) costs are generally allocated as incurred – for example in BritNed the Netherlands development costs allocated to TSO TenneT and GB development costs allocated to TSO National Grid. In the detailed development stage, costs increase, due to expensive physical surveys, procurement events, and other factors, and costs were shared evenly on a 50:50 basis – requiring more intensive cost-tracking and joint governance. For the construction phase, the joint venture was incorporated and capital expenditure costs relating to the project (turnkey construction, project management, insurance) were billed to the joint venture and shared 50:50 in accordance with the joint venture ownership. This required the project budget to be agreed in advance by the partners, reviewed regularly by a joint project management office (PMO) function and any changes were approved by the Steering Committee (50:50 owner membership).

2.2 Financing modality

Cost sharing should be considered on a project-by-project basis; however, a general principle would be to share costs 50:50. The financing model used for development will impact the decision to share cost or not. After the method of sharing of costs/transmission charges has been agreed, consultations with the country Governments on the method of funding such cross-border transmission system.

Suggesting various options of funding, including funding by the respective country Governments, by multilateral funding agencies, like the World Bank, ADB, etc. Private funding agencies could also be suggested, provided a proper transparent framework for competitive bidding is in place for choosing the private developer, to set up the transmission system in the most economic manner.

Case Study: BritNed

There was no Government grant funding available in the construction phase of BritNed, although EU TEN-E funding, EU policy for Trans-European Networks for Energy to develop regional state interconnectivity[33], was advanced to finance 50% of costs during the detailed development phase. Construction funding was provided by the owners 50:50 in line with joint venture ownership. This was via an agreed schedule of milestones to match the turnkey construction contract milestones and associated project management costs. Each partner determined individually how they would finance their 50% capital contributions, in the case of National Grid, this was partly from balance sheet funds and partly via a European Investment Bank (EIB) loan.

[33] https://energy.ec.europa.eu/topics/infrastructure/trans-european-networks-energy_en

Principle:

Have enough revenue to service debt.

2.3 Project financing

Once the same is agreed, to get a detailed Project Report prepared by credible agencies, for information of the country Governments for funding/bidding

This is because the funding will be through the country Governments, multilateral funding agencies or from developers Ultimately the transmission cost would have to be borne by the organisations or countries involved in developing the project depending on the approach taken.

Case Study: BritNed

Pure project financing (loans secured against the cash-flow of the project rather than against sponsor balance sheet) was not deployed in the case of BritNed. Instead, the partners used their own balance sheet funds to finance the project 50:50. In the case of National Grid and the EIB loan related to the project was secured, this was on the basis that the loan advances must be used specifically to fund the project, however it was secured against the balance sheet of National Grid and so cannot be regarded as pure Project Financing.

2.4 Project implementation/execution

Case Study: UK

Under the UK Regulatory Arrangements for interconnectors, they may only be developed subject to UK regulatory approvals. This has normally either been the granting of a licence exemption by Ofgem (for example BritNed and ElecLink) or an approved Cap and Floor regulatory arrangement being put in place (where a minimum and maximum revenue is underwritten by UK bill payers).

Without these the project may not be able to proceed and so regular dialogue between regulators and project developers take place throughout project development and construction.

Under the Cap and Floor arrangements there are three basic stages:

Initial Project Assessment (IPA): At the IPA stage preliminary information and documentation regarding the project is submitted to the GB regulator Ofgem. Based upon this information the Regulator will undertake a cost-benefit analysis of the proposed interconnector and if content that it will offer GB consumers and producers sufficient Socio-Economic welfare will award a “Cap and Floor agreement in principle”.

Final Project Assessment (FPA): Timed to coincide just ahead of or just after a Final Investment Decision is taken by the project developers far more detailed information is provided to the Regulator describing the near finalised capital costs of construction and initial estimates of operating expenditure and decommissioning expenditure. The Regulator then considers these and uses its assessment of what is an efficient level of expenditure to set the final Cap and Floor financial parameters.

Post Construction review (PCR): As the name suggests this review coincides with the completion of the majority if construction work. Its main focus is on updated submissions for operating and decommissioning expenditures and appropriate allowances for these within the Cap and Floor framework.

Alongside these milestone reporting points there is an annual submission of information in support of the milestone submissions to inform the Regulator.

Principle:

Coming to a major milestone: permits, licences, construction, tender all need to be completed and need to be signed with a construction company, the relevant regulator, and financial players in contracts.

2.5 Project monitoring

It is necessary to monitor the progress of an interconnection project until commissioning, generating periodical reports on the progress of the project, both physical and financial, up to its commissioning.

Case study NemoLink

During the development of NemoLink Ofgem, the UK's regulator, ensured that its developers alongside all interconnectors licenced under its regulated asset base (the cap and floor regime), reported on project development. This report allowed for project accountability to the regulator.

Ofgem stated that the report was required for oversight of:

1. Post construction review – this information will be used by the Authority to inform the post construction review of costs ahead of operation.

2. Building knowledge – acquiring experience and knowledge of the actual costs involved in constructing and operating an electricity interconnector licence will enable the Authority to evaluate subsequent projects more effectively.

3. Financial health – monitoring the IO's costs enables the Authority to secure that the IO is financially stable and able to finance its activities and obligations or to be prepared to respond in the event that the IO's financial health deteriorates.

4. Licence compliance – Standard Condition 25 of IO's licence requires that this information be collected. [34]

The contents of this report included:

- Introduction including background and, legal framework.
- General instructions for completing data template worksheet – including accounting policies, data entry, definitions, template errors.
- Instructions for completing the common costs, capital expenditure and operating expenditure worksheet.
- Instructions for completing availability, assessed revenue, outturn non-controllable cost, reconciliation to statutory accounts worksheets.
- Instructions for completing the supplementary information.
- Guidance and instructions for completing the commentary.
- Appendices.

Principle:

Have regular progress reporting to the relevant authorities.

[34] Draft Nemo reporting guidance_final for review (ofgem.gov.uk)

2.6 Project Regulation

Principle:

Regulatory frameworks for managing the costs and revenues associated with the project apportioned to each country will likely be required and developed / agreed on a trilateral basis.

Recognising that electricity network infrastructure is normally heavily regulated by national governments and energy regulators, once it has been determined that a project is viable from the perspective of developers and governments and regulators, one or more viable regulatory frameworks for managing the costs and revenues associated with the project apportioned to each country will likely also be developed. This may cover both the construction, operational and decommissioning phases of the project.
For example, where a private investor is involved, a regulatory structure may be put in place to ensure excessive losses or returns are not incurred or made with appropriate risk and reward sharing mechanisms put in place with bill payers in each country.

Case study:

UK Cap and Floor Regulated Asset Base

The UK regulator Ofgem has created the cap and floor regime in order to encourage investment in electricity interconnectors. It strikes a balance between commercial incentives and appropriate risk mitigation for project developers.

Before the cap and floor regime was introduced, only a limited number of electricity interconnectors had been either built or proposed. Ofgem therefore created the cap and floor regime to unlock beneficial investment by reducing risks. Electricity interconnectors developed under the cap and floor regime will earn revenue from the allocation of capacity to users who want to flow electricity between Great Britain (GB) and neighbours.

The floor is the minimum amount of revenue that an electricity interconnector can earn. This means that, if an interconnector does not receive enough revenue from its operations, its revenue will be ‘topped up’ to the floor level. The funds will be transferred from the GB system operator (National Grid), which will in turn recover the sum from transmission charges applied to all users of the national electricity transmission system.

Ultimately, this means that consumers are underwriting the risk that interconnector developers are unable to generate sufficient revenues to pay for their investment.

The cap is the maximum amount of revenue for an electricity interconnector. This means that, should an interconnector’s revenue exceed the cap, the interconnector will transfer the excess revenue to the GB system operator, which will in turn reduce transmission charges. For consumers, the cap on revenues provides benefits in return for their exposure in underwriting the floor. For electricity interconnectors, it provides an investment route that complies with use of revenues requirements under legislation. There is a wide band of ‘merchant’ exposure between the cap and the floor.

Ofgem’s role is to decide whether granting a cap and floor regime to an interconnector project is in the interests of GB consumers. If so, they then regulate and monitor projects under the regime.

3 Construction

[Hold for expansion in workstream phase three to expand and complete interconnector life cycle stage 3].

Interconnectors are very large, expensive assets. They also have very long construction times. This makes project financing difficult. Construction times for an electricity interconnector will vary. For the world's longest electricity interconnector, VikingLink between the UK and Denmark, construction began in 2019 and is expected to be complete by end of 2023 (just under three years). The size of an interconnector is not the only determining factor for timing, but also the regulatory barriers, surveying time, and supply chains for materials.

Because of the size and timing of such projects, interconnectors often need more banks and institutes to shoulder the risk tolerance of these larger investments. Interconnectors can be likened to larger LNG terminals or the biggest airports, in terms of their capex and construction timelines. This makes sovereign guarantees, a government's commitment to cover payments in case of default, more important for financing. Mobilising funding from development banks or other sources might also be helpful.

4. Operation

4.1 Operation protocol

Operating Protocols should normally cover issues relating to both the physical operation and the commercial operation of the interconnector.

The protocol covers the interface, communications processes and other relevant tasks between the Interconnector and connecting transmission system operators (TSOs). The protocols will govern how the interconnector will operate in normal and emergency circumstances - and takes into account the specific requirements of the TSOs at each end of the link.

Principle:

A trilateral agreement covering the associated principles, processes and parameters for the coordinated operation of the interconnector must be agreed trilaterally and then regularly reviewed and updated as operating conditions evolve.

Physical Operation

An operating protocol relating to physical operation of an interconnector will normally be multi-party and will need to extend to the operator(s) of the interconnector itself and the operators of the grid systems at each end of the interconnector. This operating protocol will cover the provision of information about intended physical flows, operating in accordance with scheduled flow, contingency arrangements in the events of faults or other issues that may cause deviation from physical flows, and even the provision of system-to-system services whereby the interconnector may support the onshore networks to which they connect.

Separate arrangements may need to be put in place where there is more than one owner of the interconnector to clearly state the operating arrangements – for example if the interconnector is operated out of more than one control room, or if there are contingency arrangements to fall back to full operation from a single control room should one be unable to operate – e.g. in the event of a fire or other contingency issue.

Commercial Operation

In the EU all interconnectors must have their commercial operating terms set out in "Access Rules", which are approved by Regulators that set out a consistent approach to the sale and use of the interconnectors capacity for parties wishing to use it to flow electricity between markets. These Access Rules set out the rights and obligations of all parties and also what happens in the event of failure of one or other party to be able to meet their obligations.

4.2 Agreed operating protocol for the integrated transmission system

[Hold to be developed in Phase 3]

4.3 Trading arrangements

Principle:

Trading arrangements must be agreed between connecting states in a binding agreement.

Electricity can be traded over the counter (i.e., bilaterally between two counterparties) or through clearing houses known as Power Exchanges. Over-the-counter trades provide market participants with flexibility to negotiate preferred terms and pricing, which allows them to hedge against electricity price volatility. Power exchanges typically play a significant role in cross-border electricity trading and offer a trading platform to their exchange members to trade electricity across specific timeframes. Orders for buying and/or selling electricity are submitted by market participants and are then registered in an order book, which reflects the supply and demand for a specific market area at a certain moment in time. Power Exchanges calculate a market price based on these order books, and match supply and demand and make sure that the traded electricity is delivered and paid.

Electricity is traded over a variety of different timeframes. The forward market encompasses trades taking place before the day ahead of delivery (including up to months or years ahead of real time); such trades often take place over the counter. The day-ahead market is the purchasing and selling of electricity the day before the delivery. The intraday market trades closer to real time, with delivery of electricity on the same day. This is an important timeframe that allows market participants to sell excess electricity and purchase further electricity, according to needs in real-time. The day-ahead and intraday markets are operated through power exchanges. A fourth market exists, balancing market, which is not open to market participants, but reflects actions taken by the transmission system operators to keep the grid in balance close to real time, by ensuring supply is matched to demand.

An interconnector facilitates the above trading between two separate jurisdictions (cross-border electricity trading), which are defined (in the EU) as bidding zones. Bidding zones constitute the cornerstone of market-based electricity trading and are defined by the EU as the largest geographical area within which market participants can exchange energy without capacity allocation (that is, a mechanism to allocate the transmission capacity between bidding zones to market participants). Most bidding zones are defined by national borders; however, some are larger than national borders and some are smaller zones within individual countries. Transmission capacity is assumed to be unlimited within each bidding zone, which results in a uniform electricity price within that bidding zone.

A key element of cross-border electricity trading is the mechanism for allocating transmission capacity on the interconnector (i.e., available space on the interconnector) to market participants. A key distinction is the difference between explicit and implicit auctioning of cross-border transmission capacity (also referred to simply as explicit and implicit trading).

Implicit capacity allocation refers to an arrangement where interconnector capacity is auctioned together with volumes of electrical energy in the market as one product. Market participants wishing to buy or sell electricity cross-border submit bids or offers to a designated market coupling operator (typically a Power Exchange), which compiles the bids and offers received into an order book. The market coupling operator then runs a market coupling algorithm which computes the most efficient matching of buyers and sellers and determines the direction in which the interconnector flows.

Conversely, under explicit capacity allocation, electricity and interconnector capacity are sold separately. Market participants wishing to trade cross-border must execute trades in the connected markets as well as buying interconnector transmission capacity and nominating the flow direction based on their own forecasting and analysis (rather than the direction of flows being determined by a central market coupling algorithm).

Long-term cross-border electricity trading (i.e., trades taking place on the forward market) is carried out on the basis of explicit capacity allocation. At the day-ahead and intraday timeframes implicit trading has been shown to deliver significant benefits in terms of consumer welfare and reduced emissions resulting from more efficient sharing of renewable electricity between connected bidding zones. However, implicit trading is significantly more complex to implement and operate than explicit trading, given the need to develop market coupling algorithms and other technical requirements.

Shared overarching legal and contractual frameworks are another important element of cross-border electricity trading. The governments, regulators and system operators of the connected markets should put in place common system operation guidelines which govern the operation of the interconnector, notably the circumstances in which cross-border capacity may be restricted or curtailed.

4.4 Operation

[Hold to be developed in Phase 3]

The daily operation of an interconnector once built, and operating will consist of multiple tasks including:

- Understanding the operating costs from an early stage, including calculating what percentage of interconnector revenue of the capex will be going into ongoing maintenance.
- Maintaining insurance for the interconnector.
- Other operating capital expenditure (capex).
- Regular inspections of the infrastructure, equipment, and software.
- Testing of the facilities.
- Maintenance of equipment and infrastructure.
- Monitoring power flows.
- Monitoring the condition of cabling and components.
- Conducting repairs or replacements.
- Continuing adherence to established or developing regulations and standards in both connecting markets.
- Continued adherence to permits and licensing for function.

Principle:

Develop clear lines of communication for emergencies, planned outages, and shared maintenance.

Principle:

There should be a legal framework agreement underpinning the trade over an interconnector.

5. Decommissioning action

An interconnector's function will come to an end due to multiple scenarios including but not limited to:

- Critical failure of key components that are not cost effective for repair or replacement.
- Non-viable market connections from loss of power sources.
- Loss of political will to trade over interconnectors.
    - The license for use is expired and not granted renewal.
- Infrastructure has become outdated and inefficient.
- Infrastructure ceases to be safe for continued use.

There is currently no documentation outlining the decommissioning process of an interconnector.

It is an unlikely scenario that an interconnector will be decommissioned because there will only be an increase in the need for more interconnection. The only case publicly known of an interconnector being decommissioned was the original UK- France interconnector which operated between 1961 and 1984 ahead of the present IFA1 which replaced it. Since then, asset renewal rather than outright replacement has occurred (e.g. sections of cable replaced), mid -life refurbishments of convertor valve halls and control and protection.

If cables stop being used, they are designed to be lifted to sea level and then be sections of that cable to be individually disposed of. Dismantling cables in this way is not needed as cabled can be repaired in segments at a time, making parts of the line more and more new. When we consider the likelihood of decommissioning cables, there is a question of whether we replace cables, even if expensive, in high congestion areas such as the North Sea. Reusing a cable trench to reutilise the route would be benefit rather than simply coursing a new route in a congested area. Cables have joint failures and eventually get replaced in segments. Onshore network cables can be taken out of the ground and replaced in a same trench without the need for additional procedures associated with subsea work. Cables may survive use for 50 – 65 years. The whole cable might not fail in one go but may gradually be replaced joint by joint in the cable.

5.1 Planning the interconnectors decommissioning

Principle:

Parties should aim to develop a project with as long a life as possible from the outset, ensuring that permits are valid beyond even initial estimates of technical life.

This foresight would also be helpful for getting investors to take a longer view of the asset's value. With investment and environmental considerations in mind, decommissioning provisions should also consider the scrap value of an interconnector as HVDC cabling is often made of great quantities of high value copper – aluminium alloys.

5.2 Assessment for prolonging life

Case study IFA1

In 2021 the Interconnexion France-Angleterre 1 (IFA 1) electricity interconnector was given an extension from its original 25-year lifespan, 1986 to 2011, to function until 2046 [bringing it to a 60-year span]. There are many reasons for an interconnector to have an extension of life, but in this case, the UK wanted to maintain a high level of interconnection to support its continually expanding role in both importing electricity during periods of low energy production and exporting during times of high excess renewable output with neighbouring European states. The IFA 1 interconnector was given an extended lease of life in order to meet growing demands for mutual market consumption, flexibility, and market stability.

In order for an extension of life to occur, and interconnector will need to meet changes to both:

a) Physical hardware
b) and regulatory requirements.

The regulating bodies in both the UK and France needed to grant permits, and approvals to licence the extension of the IFA 1 interconnector before proceeding with the physical alterations that would enable the change in lifespan.

After regulatory approval, IFA 1 needed to physically upgrade its infrastructure and equipment to extend the life of the interconnector in a way that continues to be safe and efficient to operate.

In the physical elongation of life – the varying facets of an interconnector including its substation parts can be repaired and replaced overtime so that a veritable 'Ship of Theseus' occurs whereby no hardware is truly extended in use, but rather replaced overtime – however the key cabling between state control system, converters, and sometimes substations may not be replaceable in the same way without enduring costs exceeding that of building of a whole new line – at which point, if not by market need but physical, an interconnector should be considered for retirement and decommissioning for physical safety and market security purposes. There are some issues with cables being replaced as a whole, but not so many with substations replacing components over time. The component replacement for substations should take into consideration the delays from vendors as there will be a high demand for these bespoke components.

Notably, most older interconnectors, such as IFA 1, were made with 'mass impregnated paper' cables (the mass being Oil). Now we see new XLPE (standing for cross-linked poly-etheline) [polyetherimide] cables in use with a 50–60-year life span. Modern cables are plastic based and have only had around 10 years of service history to date so information on likely lifespan is more limited but there is expected to be a limited difference in serviceability. The 50–60-year design life of the new cables are yet to be tested, so we do not know how if we can extend the lifespan beyond the wear of its intended lifespan. Typical failure modes tend to occur at points of jointing, or as a result of physical damage (eg. Anchor strike/ drag events).

5.3 Replacing a cable

When replacing a whole line, the magnetic fields will change which may affect limitations on replacement. Currently relevant consultees require near zero compass deviation- which require the power cables (one at a positive polarity and the other negative) to be close together and cancel each other. Guidance providing sensible tolerance levels allow more efficient installation and better use of the seabed across projects.

Cables may be allowed to run idle on a route and cost of removal may be worse than removing. Unlike the first cable, most cables today are secure within a trench. Unlike the mass-impregnated cable, there is no obvious contamination factors that would present over time for leaving an XLPE cable where it is.

Individual cables of a HVDC arrangement either have a positive voltage polarity, a negative polarity or none at all- for some HVDC designs you just have the first two cables, for others such as the full bipole you have all three. These cables when in operation generate magnetic fields, with the positive voltage and negative voltage cancelling out when the cables are in close proximity. The further the cables are from each other the less cancellation happens and the more residual magnetic field exists.

For practical purposes of laying cables, it is not always practical to have cables perfectly next to each other- and the distance between the cables tends to get bigger in practice the deeper the cables are. The closer the cables are from each other, the greater the risk of a ship's anchor strike occurs (in subsea cables) also which is a competing consideration to the reduction of the magnetic field from the cables.

It is often a good idea to have more separation - similarly for dispersed bipole connections which save on platform costs and provide extra flexibility for offshore arrangements.

Old magnetic compasses can allegedly suffer from deviations as a result of stray magnetic fields from these HVDC arrangements. It is not the only source of magnetic fields - AC cables produce them too, and so do naturally magnetic rocks etc. What this means in practice is that projects delivering HVDC can be asked to provide no magnetic field or as close to zero as possible without consistency in what is actually needed. This delays and complicates project delivery and is another reason why you would try and replace cables in situ rather than attempt new routes for scratch.

With such magnetic field deviations in play, defence and environmental concerns need to be considered both in the replacement of, and in laying new interconnector lines.

5.4 Decommissioning of transmission infrastructure.

The decommissioning of electricity interconnectors is a process that involves the removal of physical links that allow electricity to flow across borders. Electricity interconnectors can have various benefits, such as lowering electricity bills, increasing security of supply, and reducing carbon emissions by enabling the trade of renewable energy. However, there may be situations where interconnectors need to be decommissioned, such as when they reach the end of their operational life, when they become obsolete or inefficient, or when they pose environmental or safety risks. HVDC decommissioning is no different to other types of wire replacement for example how industry has been handling AC system decommissioning for many years, which has included power electronic devices similar to the HVDC convertors, AC components similar to those on land and mass impregnated submarine cable solutions used for river crossings; there is related experience available.

The decommissioning of electricity interconnectors can have various implications for the electricity market and the decarbonisation agenda. For example:

- It can affect the supply and demand balance, the price volatility, and the security of supply in interconnected regions. This may require additional investments in generation capacity, transmission infrastructure, or energy storage to compensate for the loss of interconnection.
- It can affect the carbon intensity and emissions of the electricity system, depending on the relative share of renewable and fossil-fuel sources in the interconnected regions. This may require additional policies or incentives to promote low-carbon generation and consumption to meet the net zero targets.
- It can affect the cross-border cooperation and integration of the electricity markets that may have previously been in motion. This may require new arrangements or agreements to facilitate efficient trade and coordination among different countries and regions.

Example

In their March 2014 assessment of the Norway-UK North Sea Link (NSL) Interconnector, National Grid said the project would have a design life of 40 years, with the final requirements and impacts of decommissioning the marine cables assessed towards the end of this period35. Therefore, we can anticipate that most requirements for interconnectors will also be set out towards the end of life for the projects. This may reflect that in the long lifespan of an interconnector, the capping costs, environmental needs, and other regulation of an interconnector may change. As interconnectors are a newly utilised technology between states and markets, we are yet to see such an assessment put into motion by a developer.

Case study decommissioning the UK's first interconnector.

The UK's first electricity interconnector to the European continent commenced operations in 1961, with a 160 MW high-voltage direct current (HVDC) cable connecting the UK and France. In 1986 it was replaced by the current 2 GW IFA 1 interconnector[36]. The original cable was laid over the seabed and was often subject to damage from commercial and fishing vessels, of which the collective damage to the cable, and transmission-size-to-demand ratio to it being replaced. The Interconnector was cut from the main transmission system in 1986. It remains on the seabed today. Although this example shows how an interconnector was dealt with 43 years ago, new advancements should be taken into account for disposal and decommissioning. Notably the IFA 1 cable that connected Great Britain with France thereafter was a technological leap compared to the 1961 cable, with greater power transmission and seabed safety measures for the cable. [Further information required for phase 3].

Principle

There is little evidence of previously decommissioned interconnectors, but the safe disposal of materials should be key.

5.5 Agreed procedure for the decommissioning of all relevant transmission infrastructure at end of life.

The decommissioning of electricity interconnectors is not a common occurrence, and there is no specific guidance or regulation on how to do it by leading authorities in the UK or the EU. However, some general principles and steps can be identified. These include:

Principles

- **Planning and preparation:** This involves assessing the technical, economic, environmental, and social impacts of decommissioning, identifying the best available techniques and methods, obtaining the necessary permits and approvals, and engaging with relevant stakeholders and authorities. Adhering to approvals, permits, regulations and standards set by the connecting market states on decommissioning is key.
- **Execution:** This involves carrying out the physical removal of the interconnector components, such as cables, converters, substations, and towers. Depending on the type and location of the interconnector, this may require different techniques and equipment, such as cutting, pulling, burying, or recycling.

[35] https://www.northsealink.com/media/1105/p1568_rn3057-non-technical-summary.pdf

[36] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1086528/Electricity_interconnectors_in_the_UK_since_2010.pdf

- The execution phase should also ensure th safety of workers and the public and minimise the disruption to the electricity system and the environment. These considerations should include the safe removal of any hazardous materials from the site of the interconnector.
- Considerations should be made on whether the disruption of areas such as the seabed for removal outweighs the recycling of the metal in the cable in environmental and financial cost.
- **Restoration:** This involves restoring the site to its original or agreed condition, such as by filling in trenches, replanting vegetation, removing waste and debris, and monitoring for any residual impacts or hazards.

5.6 Responsibility for decommissioning

The responsible party, baring the cost of decommissioning may be with the developer. The share of this cost is recommended to be between be along the lines of the percentages of shared equity. The responsibility of decommissioning an interconnector may be included in the preliminary agreements develop between regulatory authorities and project developers earlier in the project.

ANNEX OF REFERENCES:

1. https://www.transitionzero.org/press/transitionzero-cables-decarbonise Economic Research Institute for ASEAN, 'INVESTING IN POWER GRID INTERCONNECTION IN EAST ASIA' (2014).
2. https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/selection-process_en
3. https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/key-cross-border-infrastructure-projects_en
4. https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/pci-examples-and-their-benefits_en
5. Ofgem CSNP: Consultation on framework for identifying and assessing transmission investment options. Pg.4
6. https://www.nationalgrideso.com/future-energy/pathway-2030-holistic-network-design
7. Data provided by British Embassy Rome
8. https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en
9. https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en
10. https://tyndp2022-project-platform.azurewebsites.net/projectsheets/transmission/29
11. US Energy Information Administration https://www.iea.org/countries/tunisia
12. Summary by worldometer of US Energy Information Administration and BP intel
13. https://masterplan.med-tso.org/interconnections2030.aspx
14. ENI https://www.eni.com/en-IT/operations/tunisia-tataouine.html & ENI https://www.eni.com/en-IT/media/press-release/2019/05/eni-and-etap-partner-to-develop-renewable-energy-projects-in-tunisia.html
15. Technoeconomic energy system data for modeling of India and the GCC countries, Extract, Miles Weinstein, Youssef Almulla, Avinash Vijay, Abhishek Shivakumar, Will Usher, Chris Arderne, Adam Hawkes, Mark Howells, https://www.researchsquare.com/article/rs-320312/v1.
16. Report of the Commission Expert Group on electricity interconnection targets, November 2017, https://energy.ec.europa.eu/system/files/2017-
17. report_of_the_commission_expert_group_on_electricity_interconnection_targets_0.pdf
18. Ofgem, Cap and floor regime handbook, 2021, https://www.ofgem.gov.uk/sites/default/files/2021-09/Regime%20Handbook.pdf
19. https://www.iea.org/reports/institutional-architecture-for-regional-power-system-integration
20. https://www.energyco.nsw.gov.au/renewable-energy-zones/what-renewable-energy-zone
21. https://www.energyco.nsw.gov.au/renewable-energy-zones/renewable-energy-zone-locations
22. https://www.energyco.nsw.gov.au/renewable-energy-zones/renewable-energy-zone-locations
23. [Electricity Interconnectors Cost Assessment Guidance Document]: https://www.ofgem.gov.uk/publications/electricity-interconnectors-cost-assessment-guidance-document
24. IEA A capital allocation dilemma in energy transitions, Michael Waldron & Yoko Nobuoka, https://www.iea.org/commentaries/a-capital-allocation-dilemma-in-energy-transitions

25. [Interconnectors | Ofgem]:. https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/interconnectors
26. Understanding Power Transmission Financing Report, co-authored by Power Africa and the U.S. Department of Commerce Commercial Law Development Program
27. https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/funding-projects-common-interest_en
28. https://www.med-tso.com/members.aspx?f=
29. https://www.entsoe.eu/about/inside-entsoe/objectives/
30. https://www.entsoe.eu/about/inside-entsoe/objectives/
31. Eleclink - who we are
32. https://energy.ec.europa.eu/topics/infrastructure/trans-european-networks-energy_en
33. Draft Nemo reporting guidance_final for review (ofgem.gov.uk)
34. https://www.northsealink.com/media/1105/p1568_rn3057-non-technical-summary.pdf
35. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1086528/Electricity_interconnectors_in_the_UK_since_2010.pdf