Cross-border cooperation for interconnections and electricity trade

Experiences and outlook from the European Union and the GCC

Prepared for
The Emirati-German Energy Partnership

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Authors: *Dr. Karoline Steinbacher, Henrik Schult, Korinna Jörling, Dr.-Ing. Tobias Fichter, Konstantin Staschus, PhD, Jonas Schröder, Artur Lenkowski*

Navigant Energy Germany, A Guidehouse Company
Albrechtstr. 10c
10117 Berlin
Germany

guidehouse.com

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ACER	Agency for the Cooperation of Energy Regulators
ASEAN	Association of Southeast Asian Nations
ATC	Available Transfer Capacities
BEMIP	Baltic Energy Market Interconnection Plan
BNetzA	Federal Network Agency
BRI	Belt and Road Initiative
CBA	Cost benefit analysis
CACM	Capacity Allocation and Congestion Management
CBCA	Cross-Border Cost Allocation
CEC	Clean Energy Corridors Initiative
CEF	Connecting Europe Facility
CWE	Central Western European
DSO	Distribution System Operators
EBGL	Electricity Balancing Guideline
EC	European Commission
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
FACTS	Flexible Alternating Current Transmission System
FTR	Financial Transmission Rights
GCC	Gulf Cooperation Council
GCCIA	Gulf Cooperation Council Interconnection Authority
GDP	(German Onshore) Grid Development Plan
GEI	Global Energy Interconnection
GEMS	GCC Electricity Market System
ICO	Installed Capacity Obligations
INEA	Innovation and Networks Executive Agency
IRENA	International Renewable Energy Agency
HVDC	High Voltage Direct Current
ISO	Independent System Operator
ITC	Interconnection Transmission Code
ITO	Independent Transmission Operator
ITVC	Interim Tight Volume Coupling
KAPSARC	King Abdullah Petroleum Studies and Research Center
KSA	Kingdom of Saudi Arabia
LCOE	Levelized Cost of Electricity
LNG	Liquified Natural Gas
MoU	Memorandum of Understanding
MRC	Multi-Regional-Coupling

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NDP	Network development plans
NOIS	Nordic Balancing Market
NPS	Nord Pool Spot
NRA	National Regulatory Authority
NSI	North-South Electricity Interconnections
NSOG	North Sea Offshore Grid
NWE	North Western Europe
OTC	Over-the-counter
O-GDP	(German) Offshore Grid Development Plan
PCI	Projects of Common Interest
PCR	Price Coupling of Regions
PETA	Power Exchange and Trading Agreement
PTR	Physical Transmission Rights
PX	Power exchange
RES	Renewable Energy Source
RIP	Regional Investment Plans
RSC	Regional Coordination Centres
RSCI	Regional Security Coordination Initiatives
SAPP	Southern African Power Pool
SIEPAC	Central American Electrical Interconnection System
SWE	South Western Europe
TEN-E	Trans-European Networks for Energy
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
UAE	United Arab Emirates
UK	United Kingdom
UCPTE	Union for the Coordination of Production and Transmission of Electricity
UTT	Unit Transmission Tariff
WAPP	Western African Power Pool
XBID	European Cross Border Intraday solution

PREFACE

Ministry of Energy and Industry
United Arab Emirates

Today, renewables, alongside new technologies and services are transforming the power sector. This transformation, the energy transition, requires a more responsive and interconnected power system. In the UAE, the power sector is also changing fast. The power fleet is being diversified through inclusion of solar, nuclear, and coal, making a completely gas-fueled fleet a thing of the past.

The energy transition demands action from all fronts, whether it is governance, infrastructure, operations or cross-border cooperation. For instance, in the power sector specifically, the UAE aims to maximize penetration of solar power. Higher shares of solar power will require a more flexible power system and the single most important factor for that are interconnected power grids. The grids are the enablers for power system flexibility as they connect all flexibility options, whether it is storage, dispatchable gas plants or curtailable demand loads.

In the future, the electricity grid networks shall be globally interconnected. These grid interconnections shall allow us to use geographically distant but highest potential renewable energy resources, smooth out variability from load as well as renewable power generation, reduce curtailment of renewable power, maximize utilization of existing generation assets, provide better supply security and reliability, and improve affordability and access to power. Additionally, energy commerce via interconnected grids promotes peace, regional economic growth, job creation, and local industry. The interconnected grids shall incentivize power trade and sharing of resources for the mutual benefit of all actors. In this respect, the availability and non-discriminatory access to the grid is extremely important.

The four utilities operating within UAE are interconnected together as well as with the wider GCC interconnected grid network. However, the level of trade locally and regionally could be substantially higher than current levels. The UAE Ministry of Energy and Industry has given a key consideration to development of strong inter-emirate and inter-GCC grid networks as well as power trade. In this respect, there are strong possibilities of collaboration between the UAE and Germany, a country extremely interconnected and interdependent to the fully established European power market.

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Coupling national electricity systems through interconnectors offers tremendous benefits. These include increased security of supply, major cost savings and the efficient system integration of variable renewable energy sources. Renewables accounted for almost 40% of German electricity generation in 2018, a share which is targeted to reach 65% by 2030. This means that Germany will continue to work with international partners in the European Union and beyond to further increase the connection of markets and grids.

Other regions, including the Gulf, are also making efforts for more connected electricity systems. The operation of transmission grids and energy markets have for this reason been of special interest in the Emirati-German Energy Partnership since its inception in 2017. For example, study tours and expert workshops in the UAE and Germany have explored energy market dynamics and the governance of transmission grids.

The current study was conducted on the occasion of another bilateral expert workshop on interconnection grids on the sidelines of the 24th World Energy Congress in Abu Dhabi, UAE. This study will serve as a fact basis and provide inspiration for the future exchange on interconnectors and electricity trade. The Federal Ministry for Economic Affairs and Energy is looking forward to the discussions with stakeholders and continue the successful dialogue with the UAE in this topic and beyond.

The Federal Ministry for Economic Affairs and Energy is delighted about the vivid Emirati-German Energy Partnership. The Energy Partnership will continue to serve as a platform for the exchange between ministries, businesses, and researchers in both countries, which is an important element for a successful global energy transition.

ABSTRACT

The Energy Partnership between the United Arab Emirates (UAE) and the Federal Republic of Germany (Germany), established in January 2017, has contributed to a deepened dialogue on energy system transformation between the two countries. Both are aiming to increase the share of renewable energy in their electricity systems and to transform their energy systems while doing so, and the issue of cross-border electricity infrastructure, trading, and regional collaboration is gaining in importance in both countries. While Germany is embedded in an ever more integrated European electricity system, regional integration in the UAE is a more recent effort but has seen significant steps ahead within the Gulf Cooperation Council Interconnection Authority (GCCIA).

Beyond concerns regarding the integration of renewable energy, cross-border cooperation yields economic advantages and also has geopolitical implications. The present report presents lessons-learnt and insights from cross-border cooperation on electricity interconnections in the European Union (EU) and the GCC, with emphasis on Germany and the UAE within each of these regional entities. It identifies best practices and principles for good governance of interconnections that can be relevant in other regional contexts. It provides relevant insights into the dynamics of cross-border electricity trade as both the EU and the Gulf countries are looking to expand the reach of their electricity systems beyond their borders, considering trade with neighboring countries and regions.

1. INTRODUCTION: BENEFITS OF CROSS-BORDER COOPERATION IN ELECTRICITY

The present study focuses on efforts to enhance regional electricity grid infrastructure and cross-border trading, presenting the EU's experience in creating an internal market for electricity and the GCCIA's ambition to promote regional electricity trade and cross-border interconnections in the Gulf region.

Regional cooperation in the electricity sector has different meanings depending on the context. Due to the focus of this study on electricity trade, cross-border cooperation is understood as collaboration involving governments or administrative bodies of at least two countries with a direct electricity interconnection. Collaboration can be realized in various forms from intergovernmental meetings to dedicated institutions with legal mandate. Collaboration in the field of electricity often involves private actors, particularly grid operators and utilities.[2]

As is reflected in the structure of the study, regional cooperation on electricity involves a physical, infrastructure dimension as well as a market dimension with rules and regulations to facilitate cross-border electricity trade. Within these two main aspects of regional cooperation, a number of topics can better be addressed in regional fora than unilaterally. These include cooperation on security of supply through adequacy assessments,[3] needs for national grid expansion and planning that consider the regional dimension or cooperation on the promotion of renewable energy, as is being envisaged in Europe with cross-border auctions for renewables.

As energy systems are changing in Europe and the Gulf region, there are numerous benefits to be expected from regional cooperation. First of all, larger, more interconnected electricity systems can contribute to security of supply by providing fallback options in case power plants fail or supply runs short in a single country. Using differences in supply and demand patterns in various countries also brings the potential of economic efficiency gains if electricity is traded regionally rather than produced and supplied within the borders of a single country. Finally, cross-border cooperation is a major facilitator for the integration of renewable energies. With differences in demand peaks and renewable energy production patterns across countries (wind availability, solar radiation), the intermittent infeed of renewable energies can be balanced across larger territories and thereby make it easier to increase their share in the electricity system.

The importance of regional cooperation in the profound transformation energy systems underway in Europe and the Gulf region, as well as globally, is recognized in IRENA's report on the Geopolitics of the Energy Transition.[4] Whereas oil & gas are traded globally, electricity will remain a regionally traded commodity for the foreseeable future due to losses in long-distance transport.[5]

This stronger role for regional cooperation is heavily interlinked with the development of renewables and the larger share electricity will play as compared to gas and oil in the future energy system. The Global Commission on the Geopolitics of the Energy Transition therefore states "*Renewables will configure new geographies of connections and dependencies between countries and regions. […] the weight of energy dependence will shift from global markets to regional grids*."[6] Another difference between the old energy system based on oil and gas and more regionally interconnected grids is that "*electricity trading tends to be more reciprocal"* whereas "*oil and gas flow in one direction, from an exporter to an importer.*"[7]

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[2] DIW (2015). Regional cooperation in the context of the new 2030 energy governance.

[3] BMWI (2015). Pentalateral Energy Forum Support Group 2 – Generation Adequacy Assessment.

[4] IRENA (2019a). A New World – The Geopolitics of the Energy Transformation.

[5] Nonetheless, global electricity network interconnections are being studied since a few years ago, notably by CIGRE, Global Electricity Network Feasibility Study, WG C1.35, Technical Brochure Aug. 2019 (also see the reference list therein)

[6] IRENA (2019a). A New World – The Geopolitics of the Energy Transformation. S.46

[7] Ibid. S.51

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The importance of regional cooperation and its manifold benefits are reflected in various initiatives across the globe to strengthen cross-border cooperation for electricity. In Europe, Scandinavia has established a common power pool, with numerous other regional initiatives such as the Pentalateral Energy Forum in Western and Central Europe growing in importance, and all of them forming part of the integrated European electricity market described in this report. In the Gulf region, the GCCIA has pushed for a stronger integration of grids and the introduction of cross-border trading. Both regions are in the focus of the present study. Elsewhere, the countries of the Association of Southeast Asian Nations (ASEAN) are developing cross-border interconnections and looking into opportunities to enhance security of supply and renewables development by working together. Power pools like the Southern African Power Pool (SAPP), Western African Power Pool (WAPP) or the Central American Electrical Interconnection System (SIEPAC) have been established in Africa and Latin America. The North American synchronous interconnections cover both USA and Canada, with some interconnections to Mexico as well. Russia is synchronously interconnected to many of its neighbors, and India has recently achieved a nationwide interconnection. IRENA, with its Clean Energy Corridors (CEC) initiative, promotes regional power trade from Ethiopia to South Africa.[8] Regional grids with specific purposes, such as the connection of offshore wind energy in the North Sea Offshore grid, or the trade of solar power from Northern Africa (Desertec idea) are under development or have been proposed.

IRENA has put the creation of regional power grids for the integration of renewable electricity high on its agenda as renewables go hand-in-hand with increasing cross-border transmission capacity and market opportunities.[9]

The study is organized as follows. First, chapter 2 starts with an introduction into the motivations for Europe to pursue closer cooperation on electricity infrastructure, trading, and market integration, followed by a closer look at developments and rules governing cross-border electricity trading in the EU. The chapter closes with a focus on cross-border infrastructure in the electricity system, both in terms of investing in it as well as in terms of rules for the use of this infrastructure. While the focus of the study is on the EU, chapter 3 introduces the developments taking place in the GCCIA region both in terms of cross-border trade and infrastructure development. Chapter 4 derives general principles that are to be considered for fruitful cross-border collaboration.

[8] IRENA (2013a). Working Together to build an East and Southern African clean Energy Corridor.
[9] IRENA (2019a). A New World – The Geopolitics of the Energy Transformation.

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2. CROSS-BORDER COOPERATION ON ELECTRICITY IN EUROPE

2.1 Motivations for cross-border cooperation in Europe

Cooperation in the field of electricity supply has a long tradition in Europe. The EU's experience with the creation of an ever more interconnected European electricity system, both from an infrastructure and from a market perspective, is at the core of the present report.

The first European cross-border interconnection became operational in 1921 for the transmission of electricity from France via Switzerland to Italy, representing a distance of roughly 700 km.[10] Cross-border cooperation on electricity has been pursued systematically in Europe since soon after World War II. In 1955, cross-border electricity exchange was possible up to a capacity of about 100 MW and electricity supply was mainly a national task. In the 1960s, the uniform 380 kV grid extended across Western and Central Europe and provided an important instrument for effective mutual aid in the case of power system failures, and for seasonal trading between coal-fired versus hydro plant-dominated regions. The oil crises in the 1970s forced energy utilities to adapt their strategies to the new situation on the primary energy market and the advance in telecommunication in the 1980s enabled cross-border electricity exchange.

In 1951, the Union for the Coordination of Production and Transmission of Electricity (UCPTE) was established by representatives of eight countries[11] in Western Europe. In the beginning, the aim of the organization was to contribute to economic growth through enabling an effective energy use by enabling the interconnection of electricity grids. Over the next decades, the UCPTE—through its joint elaboration of standards and procedures and the coordination of grid planning—significantly facilitated cross-border electricity trade and paved the way for the common EU electricity market as pursued by today's EU institutions and its Member States. Under the EU's Third Energy Package the UCPTE together with other organizations merged into the European Network of Transmission System Operators for Electricity (ENTSO-E) in 2009.[12]

The key benefits for the interconnected electricity system that have been observed during the European cross-border cooperation on electricity over the last 70 years are:

- **Trading benefits:** The interconnection of electricity systems extends the access to power plants that can be used to cover the domestic demand of electricity beyond the national fleet. Trading benefits can be realized if the import of electricity is cheaper than the operation of domestic generation facilities.

- **Reliability benefits:** The rare case of an unplanned and simultaneous outage of several power plants, and a lack of renewable or fossil resource availability, might lead to a shortfall in generation capacity so that electricity demand can no longer be covered. To safeguard against this scenario, countries in Europe formerly organized reserve capacities on the national level (generation adequacy). The interconnection of electricity systems allows for a common reserve on overall system level (system adequacy) and reduces the necessary capacity volume, and therefore overall societal costs, to assure security of supply.[13] Furthermore, an interconnected electricity system provides reliability benefits for the everyday instantaneous balancing of supply and demand as national transmission system operators (TSOs) can share balancing reserves and devices for power flow control across borders (e.g., FACTS or HVDC[14] links), which reduces overall societal costs.[15]

[10] UCTE (2003). The 50 Year Success Story – Evolution of a European Interconnected Grid.
[11] Belgium, Federal Republic of Germany, France, Italy, Luxembourg, the Netherlands, Austria and Switzerland
[12] UCTE (2003). The 50 Year Success Story – Evolution of a European Interconnected Grid.
[13] This is one of the key emphasized benefits of GCCIA also.
[14] High-voltage direct current
[15] ENTSO-E (2019a). Electricity Balancing.

- **Competition benefits:** The interconnection of electricity systems creates a bigger and more liquid market allowing for new business cases that would not have been possible in a smaller market and increases the competition between generation companies. In electricity markets that are large and diverse enough, functioning competition leads to lower supply costs for final customers.

- **RE integration benefits:** The generation of RES depends on the availability of natural resources, such as wind and solar radiation, and varies between countries and regions. A broader distribution of RES in an interconnected electricity system leads to a more constant infeed (so-called spatial smoothing) and implies reliability benefits as residual load[16] following is less challenging for the dispatchable generation fleet, an advantage that gains relevance especially at higher RES penetration rates. In times of abundant generation from renewables in one part of an interconnected system, excess electricity does not need to be curtailed at zero value and can be exported to other parts where their value at the same time is higher, for example due to a low availability of domestic resources or because of different demand patterns. Cross-border cooperation on electricity increases the ability of a national energy system to integrate RES and also allows countries that are reliant on fossil fuel imports a reduction of their import dependency.

2.2 Creating a common market for electricity

Cross-border electricity trading is a key aspect of the common electricity market that is being established by the EU. The creation of the EU common electricity market started with the liberalization of Member States' national electricity sectors more than two decades ago. The objective was to transform a monopolistic and conservative industry into an efficient and innovative market that is open to new players, technologies and business models. The UK was the first EU Member State starting to liberalize its electricity sector in 1990. Most Member States initiated the liberalization in 1996 and ended the process about 10 to 15 years ago.[17]

2.2.1 Principles of the common electricity market

Core elements of the liberalization of the electricity sector are the separation of generation, transmission, and distribution services to ensure fair and non-discriminatory grid access for all users, and thus a more competitive and viable market. The subsequent European harmonization of the national liberalized electricity sectors for the creation of the EU common electricity market has been driven significantly by the institutions of the EU. The harmonization has brought the development of new organizations for regulating cross-border electricity networks and national electricity markets as well as for the ongoing harmonization of electricity sector regulation.

Prior to the liberalization of European electricity markets, a uniform 380 kV grid had already been established across Western and Central Europe. The UCPTE network covered 16 countries and had become the largest synchronous interconnected system in the world. Eastern European countries in 1992 started to undertake efforts to reach a synchronous connection of both energy systems.[18]

[16] Residual load = load – infeed of power plants using variable renewable energy sources (mainly solar PV, wind power and run-off-river hydro power)
[17] UCTE (2003). The 50 Year Success Story – Evolution of a European Interconnected Grid.
[18] Ibid.

In Focus: The liberalization of European electricity markets

Market liberalization entailed significant changes to the regulatory framework of the European electricity sector. Key principles that have been pursued for the liberalization of EU electricity markets are outlined in the following:

- **Distinction between potentially competitive and natural monopoly parts** of the electricity system: Whereas transmission and distribution grids feature increasing returns to scale, e.g., because of transfer at higher voltage levels being cheaper per kWh, generation of electricity and supply to customers has not been a natural monopoly since about the 1980s, when the advent of combined cycle combustion turbine technology ended the increasing returns to scale that had existed in prior decades. EU electricity market policy therefore focused on providing non-discriminative access to all generators and suppliers competing with each other, to the grids they depend on for reaching their customers.

- **Third-party grid access** implies that non-discriminatory grid access is provided to diversified sources of energy. This led to the introduction of competition in electricity generation and brought the creation of wholesale electricity markets. Efficient market mechanisms govern power plants' operation planning at minimal costs and allow market participants to hedge their risks.

- **Competition in electricity retailing:** Final consumers can choose between different electricity suppliers on the retail electricity market. Retailers can either sell own generated electricity or resell electricity from the wholesale electricity market.

- **Promotion of cross-border electricity trade:** Increase of cross-border electricity trade due to concrete interconnection capacity and interconnector utilization targets for each Member State. Funding of cross-border interconnections, creation of forward markets and advance in calculation procedures for the allocation of interconnection capacity.

- **Independent national regulators and retail markets:** Member States are required to designate a single National Regulatory Authority (NRA) to oversee the national energy market and regulation. They are responsible for regulatory decisions on a more detailed level than within usual legislative processes and monitoring.

- **Unbundling of network and system operation from generation and supply:** Before electricity market liberalization, vertically integrated, state-owned utilities coordinated electricity supply alongside the entire value chain. A core element of the single electricity market was the reduction of market concentration due to the separation of utilities' generation and supply operations from their transmission networks. The EU provided three options in its Third Energy Package to weaken market power of the formerly integrated electricity utilities:

  1. **Ownership unbundling** is the advocated option by the EU and involves the separation of companies' generation and supply operations from their transmission networks[19].

  2. **Independent system operator (ISO):** Under this option, ownership of transmission networks is allowed to energy utilities, but operational control must be transferred to an ISO.

  3. **Independent transmission operator (ITO):** This model also allows utilities to retain their transmission networks but requires them to be operated as an independent stock company under an own brand name and with strictly autonomous management.

[19] Transmission networks transport electricity on national or regional level, typically using voltage levels between 220 kV and 380 kV in Europe. Distribution networks deliver electricity from generators and transmission grids to final consumers on local level, typically using voltage levels below 220 kV.

- **Incentive regulation of transmission and distribution:** Network operators remain under regulation to prevent them from realizing monopoly profits. Under incentive regulation, the NRA decides on the calculation and parameters that determine the remuneration to network operators for their activities—especially their allowed rate of return on capital invested—and sets the price for access and use of the grid for consumers and third parties.

Today, not only wholesale but also retail electricity markets have been liberalized in all EU Member States except Bulgaria and Malta, which are still in the liberalization process.[20] The EU common market for electricity has been established for the benefit of more than 530 million people and electricity trade between European countries is possible without restrictions, except for the availability of cross-border transmission capacity. Being close to completion of the liberalization of national electricity markets, the EU and its Member States are now facing the harmonization of the electricity sector regulation for the implementation of the common electricity market, the digitization of electricity markets with empowerment of consumers and prosumers, and the system integration of ever more RES.

2.2.2 Governance of cross-border cooperation

The harmonization of electricity market rules requires a coordinated policy framework among Member States. To facilitate the joint development of common electricity sector regulation, new institutions have been created for regulating cross-border electricity networks and national electricity markets. The development and implementation of common market rules has stimulated the creation of regional cooperation mechanisms and bilateral cooperation.

2.2.2.1 Governance of cross-border cooperation at the EU level

Cooperation on EU level in the field of electricity facilitates the coordination mainly between Member States, their NRAs, TSOs, and prospectively distribution system operators (DSOs). In focus of the collaboration is the harmonization of national electricity market rules through legislative processes (e.g., Electricity Regulation or Electricity Directive), subordinated technical regulations (EU network codes) and common decisions on terms, conditions and methodologies by the NRAs with the overarching aim of establishing an integrated EU electricity market.

To foster the cooperation between national regulatory authorities, the EU mandated its Member States to establish national regulatory authorities and created the Agency for the Cooperation of Energy Regulators (ACER).

The **Agency for the Cooperation of Energy Regulators (ACER)** is an institution to support the development of the EU common electricity and gas market and was launched in 2011 by mandate of the EU based on the ACER Regulation.[21] The main objective of the organization is to foster cooperation among European energy regulators and to establish a common regulatory framework for an integrated market for electricity and gas. ACER monitors the work of ENTSO-E and its EU-wide network development plans as well as the functioning of the common markets for electricity and gas in general and of wholesale energy trading in particular. The organization also played a role as an independent facilitator for regional cooperation in the field of electricity market integration and will also take over the supervision of regional cooperation of TSOs. To fulfill its mission, ACER can issue non-binding opinions and recommendations to national energy regulators, TSOs, and the EU institutions. In areas defined within European legislation ACER can take binding individual decisions in specific cases and under certain conditions on cross-border infrastructure issues. Upon request from the

[20] European Commission (2014). Electricity market liberalization.

[21] REGULATION (EU) 2019/942 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 establishing a European Union Agency for the Cooperation of Energy Regulators (recast)

European Commission, ACER, together with ENTSO-E, develops draft framework guidelines which serve as basis for the drafting of network codes.[22]

The harmonization of electricity market rules is the heart of an effective common electricity market. TSOs play a pivotal role in this process and thus contribute to the design and implementation of market rules.

For the promotion of cooperation across Europe's TSOs and to support the implementation of EU energy policy, the **European Network of Transmission System Operators for Electricity (ENTSO-E)** has been established by mandate of the EU. ENTSO-E is the successor of six regional associations of electricity system operators and became operational in 2009. Currently, 43 transmission system operators from 36 European countries are represented. The objective of ENTSO-E is to set up the EU's internal electricity market, ensure its optimal functioning and support the EU energy and climate agenda. ENTSO-E is therefore committed to develop responses to the challenges of a changing power system while maintaining security of supply. For achieving these objectives, ENTSO-E develops policy positions, supports the development and implementation of common European network codes, facilitates technical cooperation between TSOs, carries out short-, mid- and long-term system adequacy assessments, develops long-term pan-European network plans, and coordinates R&D planning for the electricity sector.[23] ENTSO-E operates as a non-profit organization and is financed by its members. TSOs contribute to the budget according to the number of countries and their population.

A **European Association of Distribution System Operators** will be established along the same lines as ENTSO-E. DSOs will be able to join the EU DSO entity and thereby amongst other things participate in the development of European network codes.

Network codes are sets of rules in various areas of electricity market regulation. Their aim is to facilitate the harmonization, integration, and efficiency off the European electricity market in order to facilitate the achievement of EU energy and climate policy objectives. Network codes are drafted by ENTSO-E (and for some topics in future also by the DSO entity), with the drafting process taking place under the guidance of ACER and are finally enacted by the European Commission taking into account the view of Member States and the European Parliament. Following their adoption, network codes are European regulations that are directly legally applicable in each EU Member State. The national regulatory authorities, individually and often jointly across regions or all of Europe, are tasked with approving the specifics and the implementation of many of the methodologies for which network codes provide general rules. Table 1 provides an overview of Network Codes of the European electricity system.

Table 1: Overview of European Network Codes[24]

Connection	Operations	Market
Requirements for Generators	Emergency and Restoration	Capacity Allocation and Congestion Management
Demand Connection	Operations	Forward Capacity Allocation
High Voltage Direct Current Connections		Electricity Balancing

[22] ACER (2011). Mission and objectives.
[23] UCTE (2003). The 50 Year Success Story – Evolution of a European Interconnected Grid.
[24] ENTSO-E (2019b). Transparency Platform

2.2.2.2 Governance of cross-border cooperation at the regional level

In addition to and beyond the official European legislative framework, the harmonization of national electricity markets has stimulated regional cooperation in the field of energy and climate policy among different players in European countries. Often cooperation started in the form of voluntary initiatives, forums or conferences and was then in some cases formalized by setting up an institutional framework (e.g., ENTSO-E or ACER). Regional cooperation mechanisms facilitate the coordination between Member States mainly in the context of cross-border system operation, pan-European electricity market organization, regional grid development planning, and security of supply and adequacy assessment. There are various of initiatives and organizations for regional cooperation on different levels in the European electricity sector.

The geographical scope for the governance of regional cooperation is dependent on political considerations and does not follow a one-size-fits-all approach. In some cases, an EU-wide harmonization has taken place by organizing regional cooperation formats (top-down). In other cases, a group of countries took joint initiative, and their approach was then, in case of success, replicated throughout Europe (bottom-up). Therefore, the setup of regional cooperation mechanisms with regard to the definition of regions and their governance should not always be formalized and may remain dynamic. For example, the coupling of intraday and day-ahead electricity markets started as a regional project and is now growing to a European platform.[25] [26]

Selected regional cooperation mechanisms are described below:

- **Electricity Regional Initiatives (RIs)** have been launched in 2006 by ACER's preceding organization, the European Regulators Group for Electricity and Gas, with the final aim of establishing an integrated European electricity market in a bottom-up approach by enabling regional cooperation between NRAs, TSOs, and other stakeholders. There were seven RIs, whereby countries could be engaged in multiple initiatives to ensure that all countries at the electrical borders of an RI are included. Especially, the Central Western and the Northern European regions proceeded quickly in testing and establishing regional wholesale electricity markets.

  In 2011, the European Council set out a common vision for the completion of the common electricity market by 2014.[27] The definition of network codes and clear target models for the further development of the EU electricity market implies a switch from the previous regional cooperation approach towards a harmonization of market rules on EU level. The following step for the RIs in establishing a common EU electricity market was to harmonize market rules across regions by contributing to the elaboration of joint EU network codes.

- ENTSO-E mandated TSOs to found **Regional Groups** for ensuring system stability in the European grid and to promote the integration of electricity markets by developing joint procedures and tools. There are five permanent regional groups for system operations based on synchronous areas, namely Continental Europe, Nordic, Baltic, Great Britain, and Ireland-Northern Ireland. ENTSO-E Regional Groups are organized in committees according to their responsibilities. The System Operations Committee, for example, amongst other tasks elaborates proposals for joint operations and network codes. Different ENTSO-E Regional Groups are defined for system development and markets.

- In reaction to this challenge, national TSOs have been cooperating voluntarily since 2009 in **Regional Security Coordination Initiatives (RSCIs)**. The aim of the cooperation in RSCIs such as CORESO and TSCNET is to support national TSOs in regional capacity calculations, short- and medium-term adequacy forecasts and the joint development of network models. The participation of TSOs is limited to checking the calculations for errors and authorizing the

[25] ENTSO-E (2015). The Multiple Shapes of Efficient Regional Cooperation.
[26] DIW (2015). Regional cooperation in the context of the new 2030 energy governance.
[27] EC (2014). Completion of the Internal Energy Market.

use of the results. As some of their main roles, RSCIs coordinate outage planning and perform operational planning (n-1) security analyzes covering the entire region, i.e., identifying potential security violations in system operations which an individual TSO might not be able to see in its security analysis of more limited geographic scope. Although the results are included in the calculations of national TSOs, many factors are added to reflect local conditions. RSCIs have not been set up for operational network procedures and are also not equipped for this purpose.

With the recast of the EU Internal Electricity Market Regulation[28] that entered into force in July 2019, **Regional Coordination Centres (RSCs)** as new cross-border regulatory organizations will be established. This legislative act implies an institutionalization of the voluntary regional cooperation in the form of voluntary RSCIs. The organization of RSCs is nominated by TSOs within a region and approved by the national regulatory authorities. RSCs shall act independently of national interests and the interests of TSOs. The operation of the electricity system remains within the responsibility of national TSOs.

- The **Pentalateral Energy Forum** is the intergovernmental framework for voluntary regional cooperation towards improved electricity market integration and security of supply in the Central Western Europe electricity market region, formed by Austria, Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland since 2005. The aim of the forum is achieving a closer cooperation and collaboration with regard to coupling of the respective national electricity markets, operation of the electricity system, security of supply, and risk preparedness, as well as development of common political views on certain aspects of the future electricity system in the region. On the European level, the Pentalateral Energy Forum is an important region in the context of ACER's, the European Commission's and ENTSO-E's regional market integration initiatives and has a strong track record regarding the coupling of day-ahead markets and regional generation adequacy assessment. In 2018, a first regional electricity crisis exercise was completed. The added value of this regional forum between ministries, TSOs, regulatory authorities, the European Commission, and market actors lies in its ability to move faster than institutionalized initiatives among all EU Member States, to reach more specific recommendations and to act as a development center for new ideas. Similar regional cooperation schemes with focus on electricity market integration exist in Scandinavia (Nordic Council Energy Working Group), Northern Europe (NEED), Central and Eastern Europe (V4, CEEE Forum), around the Baltic Sea (BEMIP) and the Mediterranean Sea (MedReg).[29]

- Germany initiated the **group of electricity neighbors** to engage in high level regular dialogue with its neighboring countries. The group includes Germany, all of its neighbors, plus Norway and Sweden, which are or will be connected to Germany via undersea cables. The European Commission also attends the meetings on a regular basis. The cooperation has existed since 2014 and allows neighboring countries to participate in the German national debate on the energy transition (e.g., coal phaseout), but also discuss relevant issues of European electricity policy.[30]

[28] EU (2019). Regulation 2019/943 of the European Parliament and of the Council on the internal market for electricity.

[29] DIW (2015). Regional cooperation in the context of the new 2030 energy governance.

[30] BMWi (2019a). Press release: Let's be good neighbors.

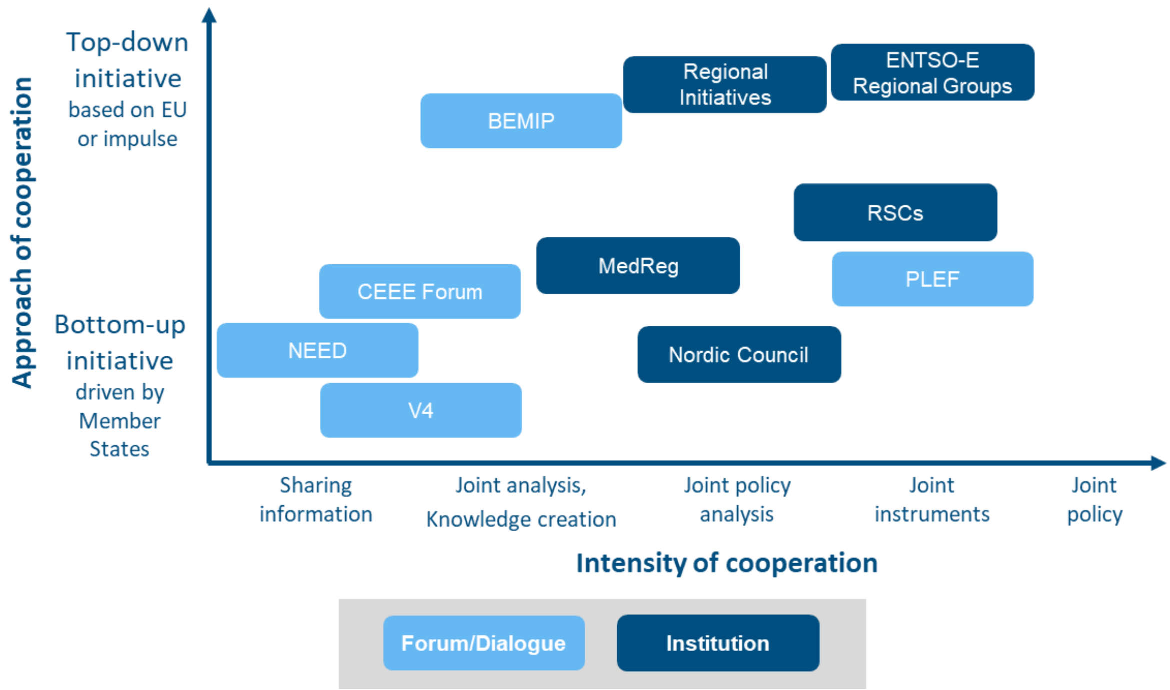

Figure 1: Typology of regional cooperation mechanisms in the EU electricity sector.[31]

2.2.2.3 Governance of cross-border cooperation at the bilateral level

The German Federal Government maintains close **bilateral energy and climate policy cooperation** with many EU Member States but most noticeably with immediate electricity neighbors. With some Member States, this cooperation has been substantiated by the agreement of a joint memorandum of understanding (MoU). Bilateral cooperation on electricity mostly concerns the planning and operation of grids, interconnectors and power plants, joint research projects, and knowledge exchange.

In the current legislative period, for example, the existing and profound energy and climate policy cooperation between France and Germany was strengthened within the framework of the "Meseberger Declaration" and the Declaration on Energy Cooperation. Cooperation projects with France have been established, inter alia, in the Franco-German energy platform, in the internal energy market and in energy research. In addition, there is an intensive exchange of knowledge and experience within the framework of the German-French Office for the Energiewende.

In October 2018, Belgium and Germany signed an MoU, which included, among other things, Energy Cooperation. The MoU aims at cooperation in resolving the particular supply security situation in winter 2018/19. Furthermore, Belgium and Germany elaborate bilateral action plans to agree on certain cross-border measures that can only be implemented jointly. One of the measures is the optimization of cross-border redispatch which is carried out by a consortium involving Navigant experts on behalf of BMWi. The cross-border action plan under development deals with the implications of the phaseout of nuclear energy in Germany by 2022 and in Belgium by 2025 and the consequences of a gradual elimination of electricity trade restrictions on the basis of the EU electricity market regulation. Both will have an impact on electricity trading and the grid situation.[32] Another important topic of the bilateral cooperation between Belgium and Germany is the realization of the first direct link between both electricity networks due to the planned BeDeLux interconnector.[33] Formalized bilateral cooperation further exists with the Netherlands and the Czech Republic. A 1,400 MW

[31] DIW (2015). Regional cooperation in the context of the new 2030 energy governance.
[32] BMWi (2019b). Draft of the German Integrated National Energy and Climate Plan (NECP).
[33] Elia (2019). Interconnector BEDELUX.

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undersea interconnection to Norway will facilitate the transport of German power to and from the Norwegian hydropower facilities by 2020. An increase of cross-border transmission capacity is being planned with other countries as well, such as Sweden and the UK.

2.2.3 Organization of the European electricity market

Electricity can be traded Over-The-Counter (OTC) and on power exchanges in the EU electricity market. OTC trading occurs outside of exchanges based on a contractual agreement with terms as agreed between two the parties. Trading partners agree on the price and amount between themselves. OTC trading includes long-term contracts, comparable to the forward market, and short-term ones comparable to the spot market. The organization of the wholesale electricity market is illustrated in Figure 2.

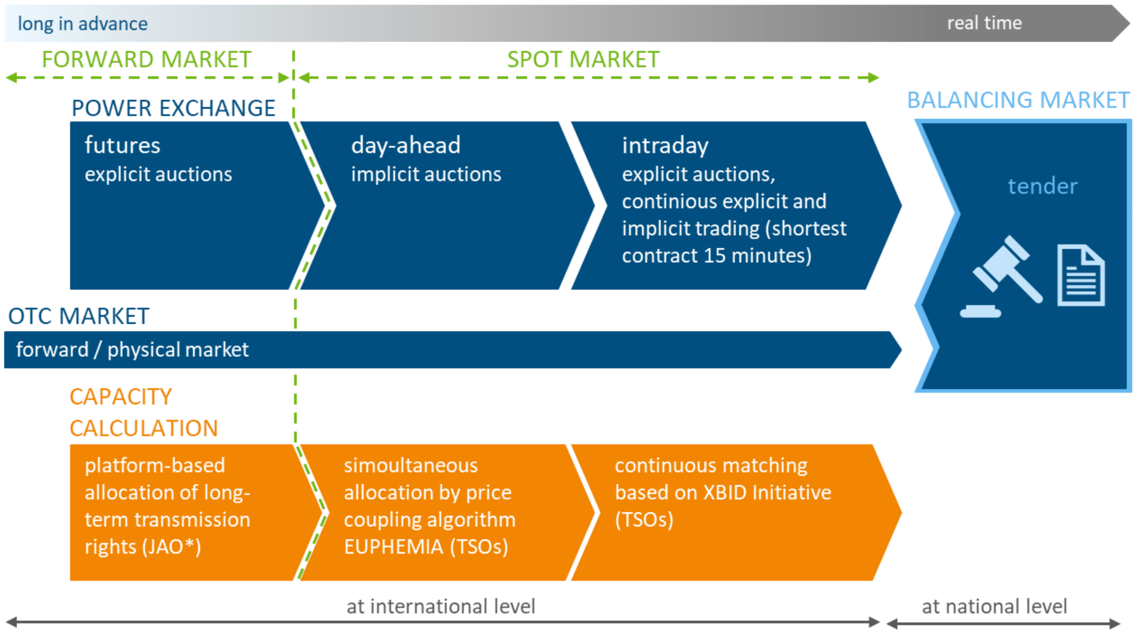

Figure 2: Organization of the European wholesale market for electricity.[34]

Trading on European wholesale electricity markets is organized by private energy exchanges. The wholesale electricity market is divided into several submarkets that differ in their time horizon until the delivery of electricity. The futures market provides long-term products for electricity delivery up to 6 years in advance to delivery. The spot market consists of two submarkets, the day-ahead market and the intraday market. On the day-ahead market, market players trade in electricity for the following day. Bids and offers specifying the amount and supply time must be submitted by midday. The exchange then determines the wholesale price for each hour of the next day and accepts the winning bids and offers. On the intraday market, electricity can be continuously traded until 60 minutes before delivery time on cross-border connections. Within countries, different lead times are applied ranging from 5 minutes in Austria, Belgium, and the Netherlands, and up to 30 minutes in Switzerland.[35]

The procurement of balancing energy is carried out by Member States in national responsibility. In Germany, unforeseen deviations from the dispatch schedule are offset using balancing capacity that has previously been contracted by TSOs on the balancing market. When the actual consumption does not match generation, TSOs correct the imbalance between supply and demand by procuring different types of control reserves: primary control reserve (frequency containment reserve) must be fully available within 30 seconds, secondary control reserve (frequency restoration reserve) within 5

[34] Source: Own illustration by Navigant

[35] EPEX SPOT (2019). Intraday Lead Time Overview.

minutes, and tertiary control reserve (replacement reserve) within 15 minutes. The procedures for the procurement of balancing energy are different among Member States. The implementation of the Electricity Balancing Guideline adopted at the end of 2017 is a first step in harmonizing balancing procedures on the EU level.

Even though trading on power exchanges makes up for about 20% of the common electricity market's total trading volume,[36] the wholesale electricity price set by the exchanges is an important reference value for the electricity market. Prices for trading products on the different submarkets still can vary considerably, as explained in the following section.

2.2.4 Promoting cross-border electricity trade through market coupling

The common electricity market of the EU is based on zonal pricing. On the wholesale market, electricity can either be sold within a country or across borders, and with the latest progress on market coupling, a market participant does not need to specify anymore, whether his bid or offer is meant for the country or internationally. Several market zones with own power exchanges exist, which are more and more growing together for the purposes of matching bids and offers across all of Europe, leaving mostly settlement as a national task for exchanges. Cross-border electricity trade volumes are growing in short-term submarkets, especially in day-ahead markets and to a lower extent in intraday markets due to time constraints for exchanging information. To enable cross-border electricity trade in all submarkets, the EU is constantly working on improving infrastructure and optimizing procedures such as market coupling.

Market coupling is the European term for implicit cross-zonal electricity trade organized in day-ahead and intraday markets and is an important element for the realization of the fully integrated European internal electricity market. The aim of market coupling a crucial simplification of cross-border trading through combining the trading of electricity on the PX with the allocation of cross-border transmission capacity in a single PX process. This avoids generators, traders, and suppliers having to procure transmission capacity in a separate process from concluding the actual trades, which in the past has often led to significant losses of economic welfare, besides making the trading processes significantly cumbersome and risky. Market coupling thus optimizes the capacity allocation of cross-border interconnections in the same PX algorithm applied across the entire coupled area, based on the net transfer capacities calculated by TSOs or based on flow-based coupling.

Market coupling has been implemented in Europe in a bottom-up approach initiated by the Pentalateral Energy Forum. First efforts focused on the integration of day-ahead trading based on volume coupling. Market coupling first started in 2009 on two interconnectors between Germany and Denmark. The German-Swedish interconnection Baltic Cable was integrated a few months later.

Volume coupling is a coordinated day-ahead auction for determining power flows but not prices in a sequential approach across two or more power markets. In a first step, cross-border electricity flows are calculated centrally. The central calculation[37] of cross-border electricity flows was performed based on Available Transmission Capacities (ATCs)[38] of interconnectors as determined by TSOs and on anonymous order books as notified by energy exchanges.

The ATC is the part of the total transfer capacity of an interconnection that remains between two interconnected areas for further commercial activity after considering notified power flows and transmission reliability margins. Volume coupling is an ATC-based approach in which transfer capacities are pre-calculated on a daily basis for each bidding zone border by the concerned TSOs.[39] Energy exchanges receive the determined import and export volumes and, in a second step, conduct

[36] BNetzA (2019b). Wholesale prices.
[37] The central calculation of optimal power flows was conducted by the European Market Coupling Company (EMCC), a joint venture of TSOs (Energinet.dk, TenneT TSO, 50Hertz Transmission) and electricity exchanges (EEX, Nord Pool Spot).
[38] For further details on the ATC approach refer to: ENTSO-E (2010).
[39] EPEX SPOT (2011). CWE Flow based Questions and Answers.

price calculations independently so that the price authority remains with them. This method does not require significant changes to the existing market procedures.[40]

Market coupling was enhanced towards **Interim Tight Volume Coupling (ITVC)** and the coupled area was extended by Belgium, France, Luxembourg, Estonia, Finland, Norway, the Netherlands, and Estonia. By 2010, the integrated day-ahead market supplied 1,816 TWh of power production, covering approximately 60% of Europe's electricity consumption.[41] Until 2015, Norway, the Netherlands, Spain, Portugal, and Italy also joined the market coupled area.

The next step in the integration of European day-ahead markets was the implementation of **price coupling**. Price coupling started between France, Belgium, and the Netherlands. Germany and Luxembourg joined the coupled area in 2010, completing the Central Western Europe (CWE) region. The Pentalateral Energy Forum, consisting of the energy ministers of the seven countries, till this day serves as an important voluntary regional cooperation mechanism for the integration of CWE electricity markets. A significant advance in day-ahead market coupling took place in 2014, when Price Coupling in North Western Europe (NWE)[42] and, in a common synchronized mode, in South Western Europe (SWE)[43] went live. This implies that on all exchanges involved, electricity will be traded using the same method.

Price coupling determines both prices and flows centrally for participating countries in a simultaneous approach. First, transmission capacity is optimized at the national level. In a second optimization step, prices and power flows are determined considering imports, exports, and national flows. Local energy exchanges receive both the volume to import and export and the price to be cleared. The underlying procedures have been developed by the Price Coupling of Regions (PCR), an initiative of European power exchanges and TSOs. The aim of the PCR initiative is to harmonize the European electricity markets based on the single price coupling algorithm referred to as EUPHEMIA,[44] calculate electricity prices across Europe and allocate cross-border interconnection capacities. The many participating power exchanges (PXs) all use EUPHEMIA, taking turns on a weekly basis, to match bids and offers across the entire coupled region.

Another milestone was the introduction of **flow-based market coupling** in day-ahead markets. In the CWE region, cross-border capacity allocation has been changed to the flow-based approach in 2015. The flow-based market coupling is recognized to be more efficient than volume or price coupling in maximizing the global social welfare. Transfer capacities are calculated at several interconnections simultaneously, considering the effects of highly interlinked networks. Flow-based market coupling allows TSOs to reduce safety margins due to the more accurate consideration of the underlying physical laws which in principle leads to an increase in transfer capacity that can be made available to the market. In this way, flow-based market coupling contributes to an increased price convergence between market zones while ensuring the same security of supply level as ATC-based approaches.[45] Flow-based market coupling has been defined as the target model for the EU common electricity market in the CACM Regulation. An overview of the flow-based capacity allocation and price calculation process is provided in Figure 3.

[40] Elia (2011). CWE Market Coupling ATC & CWE-Nordic ITVC.

[41] ENTSO-E (2010). A decisive step towards a single European Electricity Market.

[42] NWE region covers Belgium, Denmark, Estonia, Finland, France, Germany/Austria, Great Britain, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland (via the SwePol Link), and Sweden.

[43] SWE region covers France, Portugal and Spain.

[44] Acronym of Pan-European Hybrid Electricity Market Integration Algorithm

[45] EPEX SPOT (2011). CWE Flow based Questions and Answers.

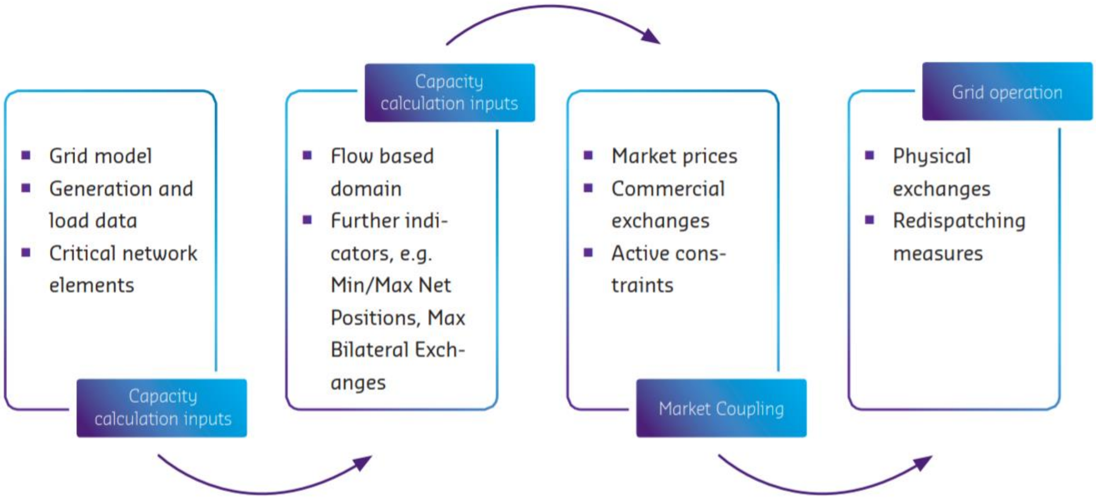

Figure 3: Overview over flow-based capacity calculation and allocation.[46]

Since the launch of the PCR in the CWE region, two extensions of the price-coupled area have taken place: In May 2014, Spain and Portugal joined and in February 2015, Italy coupled with France, Austria, and Slovenia. Today, the extended coupled area is called **Multi-Regional Coupling (MRC)** and covers 19 countries, standing for about 85% of European power consumption.[47] Cross-border capacity allocation in the MRC area is based on the ATC-approach. Only in the CWE region has this approach been replaced by flow-based market coupling.

The current European electricity market is covered either by the MRC with 47 bidding zone borders or by 4M Market Coupling (4MMC) with three bidding zone borders.[48] 4M-MC day-ahead price coupling is ATC-based and covers the Czech Republic, Slovakia, Hungary, and Romania.[49] The main goal of the 4M-MC initiative is the integration into the MRC. However, currently there is no agreement among all the concerned parties on how to merge the two existing market coupling initiatives.[50]

Pursuant to the CACM Regulation, the day-ahead market coupling still needs to be established on 10 bidding zone borders.[51] The implementation of European Network Codes will formalize the approach and facilitate the coupling of markets to cover all Europe.

The latest development in Europe targets the implementation of a cross-border electricity market for the intraday timeframe. The creation of a common European intraday market for short-term electricity trading is an important step for the integration of the rapidly rising share of intermittent renewable energy generation in Europe and the next step for realizing a common European electricity market.

For enabling a single intraday market, the **European Cross Border Intraday solution (XBID)** has gone live in 2018 after years of methodology and software development. The XBID solution allows the continuous matching of orders that are entered by market participants in one bidding zone with those submitted by market participants in any other bidding zone, as long as sufficient cross-border transmission capacity is available.[52] The launch of XBID in June 2018 included 14 countries,[53] all from

[46] Amprion (2018). Flow based Market Coupling.
[47] Amprion (2014). Multi Regional Coupling (MRC).
[48] ACER (2019). Monitoring report on the implementation of the CACM Regulation and the FCA Regulation.
[49] HUPX (2017). 4M Market Coupling overview.
[50] ACER (2019). Monitoring report on the implementation of the CACM Regulation and the FCA Regulation.
[51] Ibid.
[52] Amprion (2019a). Cross-border intraday (XBID) Project.
[53] Countries participating in the first go-live of XBID: Belgium, Denmark, Germany, Estonia, Finland, France, Latvia, Lithuania, Netherlands, Norway, Austria, Portugal, Sweden and Spain.

the Continental European region. The inclusion of seven additional countries from the Eastern European region is foreseen for end-2019.[54] The further expansion of XBID is under preparation.[55]

The current state of intraday and day-ahead market coupling in Europe is illustrated in Figure 4.

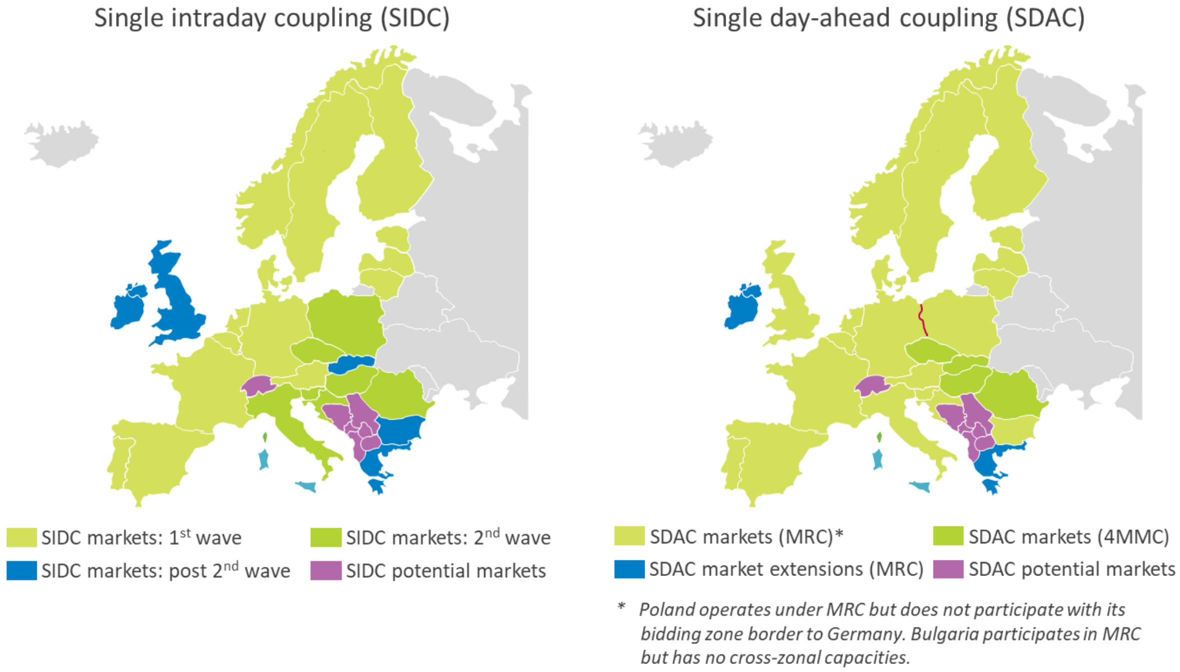

Figure 4: Progress in the coupling of day-ahead and intraday markets.[56]

As a result of market coupling, a single power station sets the price for the whole European continent, if the transmission network is not congested. For example, on Monday, 11 April in 2016 at 10 p.m., the day-ahead price for electricity was €27.86/MWh in France, Germany, Austria, Belgium, the Netherlands, Spain, and Portugal. In Northern Italy and UK, prices were higher due to insufficient cross-border transmission capacities.[57]

Market coupling contributes to an optimal use of interconnectors and facilitates congestion management. Figure 5 shows the constant increase in the utilization of interconnections in the day ahead market timeframe in times of significant price differentials (>€1/MWh) since 2010, about the time when market coupling started in Europe. The efficiency in the use of interconnectors in the day-ahead timeframe increased from approximately 60% in 2010 to 86% in 2017 thanks to the market coupling of two-thirds of European borders, covering 22 European countries by the end of 2017.[58]

[54] Countries participating in the second go-live of XBID: Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania and Slovenia.

[55] Amprion (2019b). Ein Jahr XBID und Information zur zweiten Go-Live-Welle.

[56] ENTSO-E (2018a). First joint report on the progress and potential problems with the implementation of intraday and day-ahead coupling as well as forward capacity allocation.

[57] Léautier, T. and Crampes, C. (2016). Liberalisation of the European electricity markets: a glass half full.

[58] ACER (2018). Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2017 – Electricity Wholesale Markets Volume.

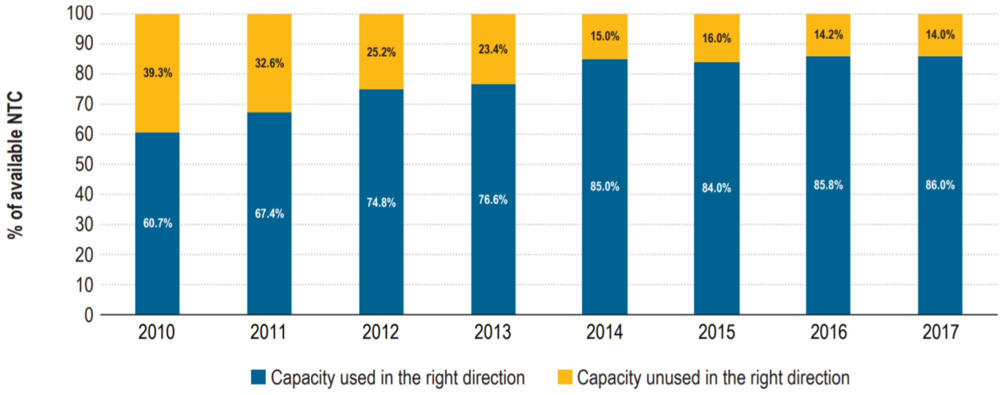

Figure 5: Utilization of interconnections in day-ahead market timeframe in times of significant price differentials (>1 Euro/MWh) on 37 European electricity borders.[59]

Further benefits of market coupling include converging electricity prices in the coupled areas in case of sufficient border capacity, a reduction of price volatility, and a smoothing effect on negative or positive price spikes implying a higher security of supply, especially with regard to increasing intermittent renewable energy generation. Since the launch of flow-based market coupling in the day-ahead timeframe, price convergence increased. In the first half of 2019, price differences were smaller or equal to €5/MWh in 80% of the hours in CWE countries as indicated in Figure 6.

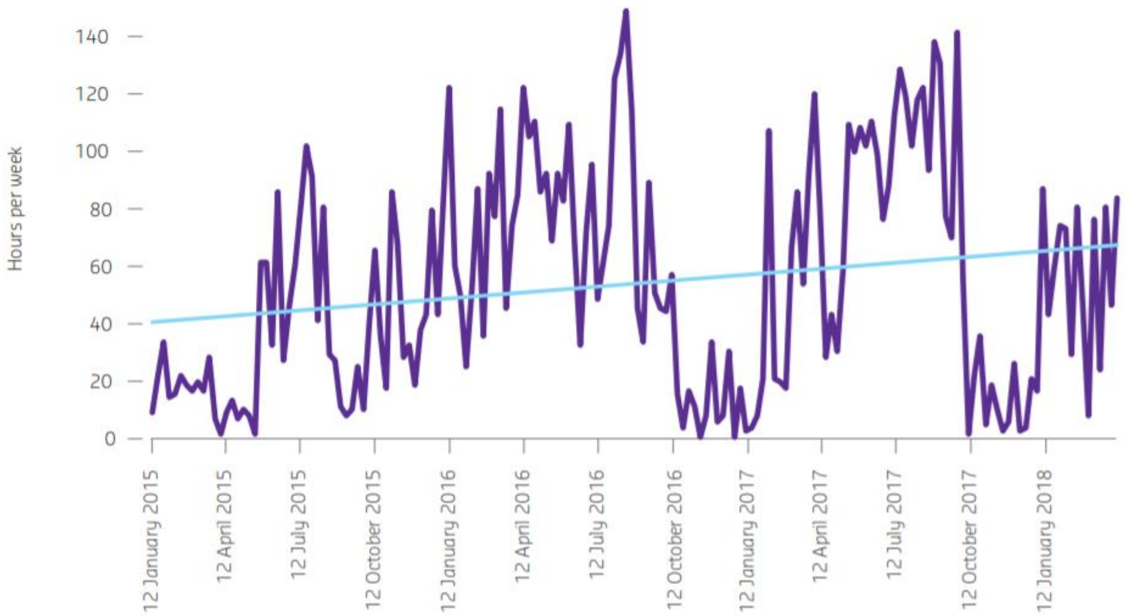

Figure 6: Hours per week with full price convergence between CWE countries (price spread = 0).[60]

The further integration of the EU electricity market and the implementation of the new European legislative framework and the network codes will be the main topics in upcoming years to enhance the European common electricity market. The welfare benefit still to be gained through the implementation of day-ahead market coupling on the remaining 12 out of 40 EU borders is estimated

[59] ACER (2018). Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2017 – Electricity Wholesale Markets Volume.

[60] Amprion (2018). Flow based Market Coupling.

at €250 million/year.[61] A trend that can be observed when evaluating the European integration of intraday markets through XBID is a faster growth in the geographical dimension and a quicker increase in trading volumes, in comparison to the integration of day-ahead markets through the different stages of market coupling. The integration of forward and balancing markets on a European level is also under preparation. With increasing generation from intermittent RES, a joint balancing market will offer further welfare benefits to be gained through market coupling. It can be expected that the ongoing trend of increasing trading volumes on futures and spot markets for electricity (see Figure 7) will continue with the advance of market coupling in the different submarkets and the prospective expansion of their coupled areas.

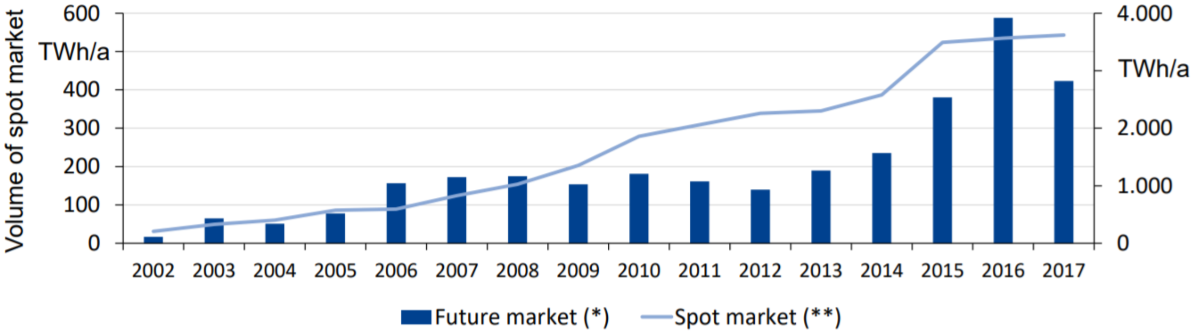

Figure 7: Annual trading volumes at EEX futures and spot market.[62]

[61] CEER (2017). Cross-border wholesale markets and network interconnection.
[62] Moser, A. (2018). Single European Electricity Market – Where Do We Stand?

2.3 Governance of cross-border electricity infrastructures in Europe

2.3.1 A European transmission grid as the basis for cross-border trade

To establish a common electricity market among several countries, a regional transmission grid needs to be developed. Regulation and procedures should be successively harmonized in regional cooperation and with the support of independent multinational institutions. A key requirement for integrating national electricity markets is the extension of interconnector capacities to allow for cross-border electricity trade and realizing the associated benefits, such as increased security of supply, a reduced need to build new power plants, lower electricity prices, and cost-effective integration of growing shares of renewable energy sources.

The EU called for its Member States to achieve an electricity interconnection of at least 10% of their installed capacity by 2020. Currently, 17 countries are on track to reach that target by 2020 or have already achieved the target.[63] For 2030, the EU set out a 15% electricity interconnection target. The EU supports its Member States in attaining these targets by tasking ENTSO-E to coordinate the trans-European electricity transmission expansion planning through the development of a biennial 10-year network development plan (TYNDP) and defining key European electricity transmission and storage projects, so-called projects of common interest (PCIs), which benefit from favorable treatment such as financial support and accelerated planning and permit granting.[64, 65]

To ensure achieving the interconnection target, the German Government has committed TSOs to publish joint national onshore and offshore grid development plans every second year.[66] To keep track of the progress of all federal grid expansion projects, the Federal Network Agency (BNetzA) has been appointed to publish a quarterly report. In addition, regular meetings take place between the concerned ministries holding the responsibility for energy and the environment, the BNetzA and representatives of the German Federal States. The national grid development plans of Member States are used as input for the European-wide TYNDP developed by ENTSO-E.

2.3.2 Interconnections planning and implementation processes

ENTSO-E coordinates and facilitates the development of the pan-European electricity grid. With the Regulation (EC) No 714/2009 (updated several times since 2009), the EC has tasked ENTSO-E with developing a non-binding, communitywide, 10-year network development plan (TYNDP) on a biennial basis with the aim to provide a vision for the necessary development of the pan-European high voltage transmission network to achieve the Energy Union goals, i.e., a secure, affordable, and sustainable energy supply for all Europeans. The first TYNDP for the pan-European power system was published in 2010 by ENTSO-E. A collection of scenarios about the future European energy system is in the center of the TYNDP. Since 2018, the ENTSOs for electricity (ENTSO-E) and gas (ENTSO-G), together with a wide scope of stakeholders, jointly develop these long-term scenarios (up to the year 2040 and for the 2020 edition even to 2050) in order to create a more comprehensive view on the requirements of the future European energy system. The details of the TYNDP for the European electricity transmission network is prepared by the six ENTSO-E system development regional groups. It summarizes all projects planned in the communitywide transmission system by national TSOs, regional TSO groups and project promoters, identifies system needs in order to deliver the Energy Union and analyzes transparently the cost and benefits of transmission and storage projects across Europe under different scenarios (see Figure 8).

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[63] European Commission (2017). Electricity interconnection targets.

[64] EU (2013). Regulation (EU) 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009.

[65] EU (2009). Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003.

[66] Netzentwicklungsplan Strom (2019). Grid Development Plan – Power.

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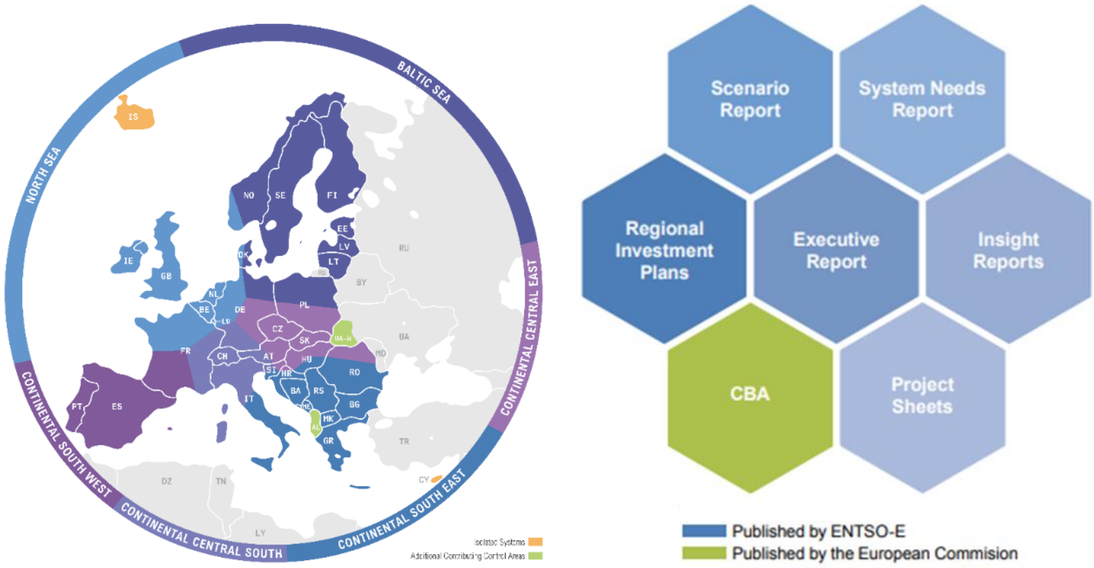

Figure 8: The six regional groups which jointly prepare the TYNDP for the pan-European transmission network (left) and specification of the TYNDP 2018 document package (right).[67]

The assessment of each individual transmission and storage project included in the TYNDP is conducted by a combined multi-criteria and cost-benefit analysis approved by ACER and the EC. The assessment is based on network, market and interlinked modelling methodologies and is described in detail within the ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects.[68] Figure 9 shows the schematic process for assessing projects included in the TYNDP.

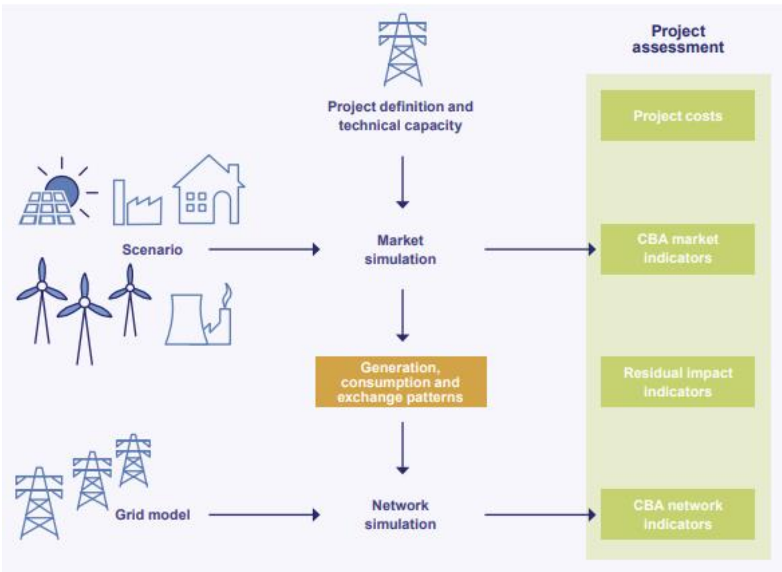

Figure 9: Schematic project assessment process within the TYNDP.[69]

Projects included in the TYNDP are assessed based on project costs, cost benefit analysis (CBA) market indicators, CBA network indicators, and residual impact indicators. "CBA market indicators"

[67] ENTSO-E (2018b). TYNDP 2018.

[68] ENTSO-E (2018c). 2nd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects - FINAL – Approved by the European Commission 27 September 2018.

[69] ENTSO-E (2018c). 2nd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects - FINAL – Approved by the European Commission 27 September 2018.

and “CBA network indicators” are the direct outcome of market and network studies, respectively, which are based on defined scenarios within the TYNDP and derived from sophisticated electricity market and transmission network models. Project costs and residual impact indicators are obtained without the use of market or network simulations.

The combined multi-criteria and cost-benefit analysis describes the impacts of both the added value for society and in terms of costs in a standardized way. This allows to compare the overall impacts (positive and negative) of each individual project included in the TYNDP on the European transmission network. The assessment framework is based on eight benefit indicators, two cost indicators and three indicators for residual impact (see Figure 10). The defined criteria to assess individual projects have been selected on the following basis:

- They enable an appreciation of project benefits in terms of delivering the Energy Union
- They provide a measurement of project costs and feasibility
- They are as simple and robust as possible

It is important to emphasize that the TYNDP is primarily a planning tool, aiming to support informed decision-making leading to strategic investments in electricity transmission and storage projects at regional and European level. The outcomes of the study are not legally binding, i.e., it cannot be used to oblige the construction of infrastructure.

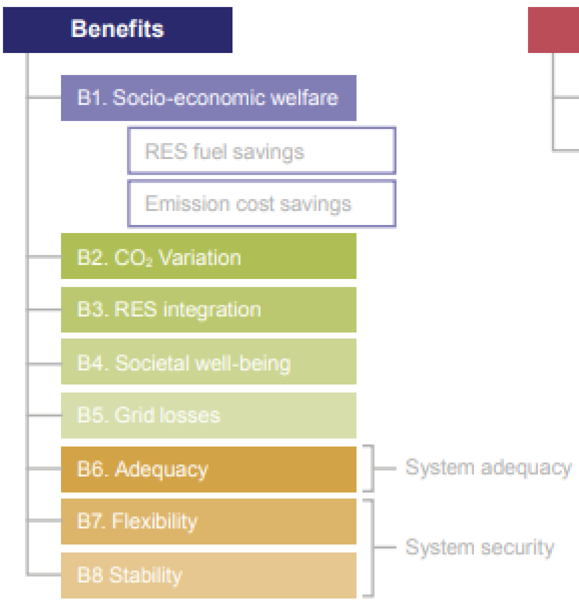

Figure 10: Main categories of the project assessment methodology applied within TYNDP.[70]

The obligation to maintain and develop a secure, efficient and economic electricity transmission grid lies with the TSOs of each Member State. Accordingly, national TSOs are obliged to present to their respective NRAs electricity network development plans (NDPs). These national NDPs, with regional investment plans of regional TSO groups, serve as main input for the communitywide TYNDP developed by ENTSO-E. Figure 11 shows the process of developing the German onshore and offshore NDPs.

[70] ENTSO-E (2018c). 2nd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects - FINAL – Approved by the European Commission 27 September 2018

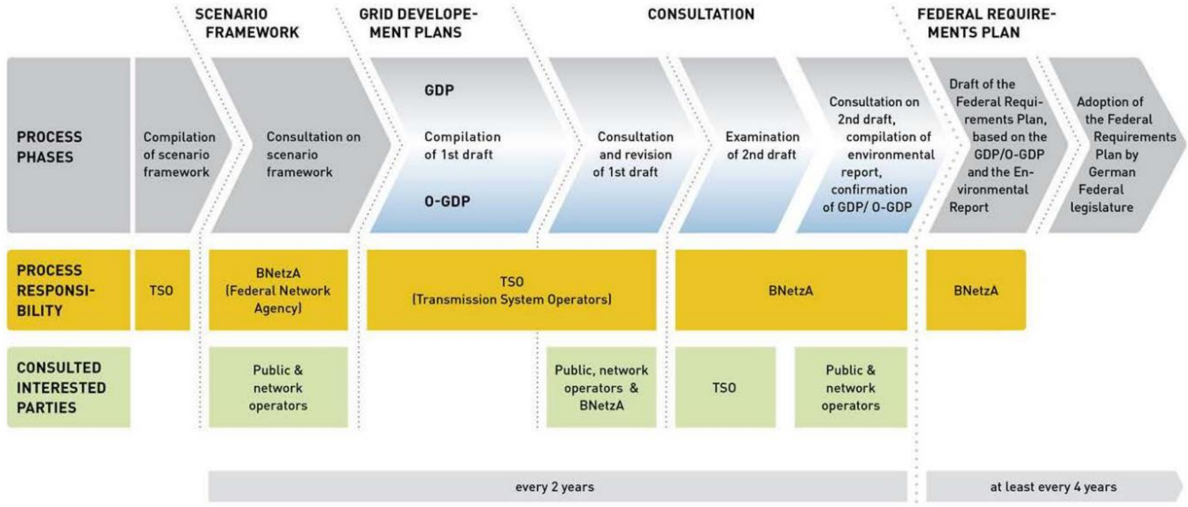

Figure 11: Process for developing the German onshore grid development plan (GDP) and offshore grid development plan (O-GDP).[71]

The communitywide TYNDP prepared by ENTSO-E is based on the binding individual NDPs of Member States and non-binding regional investment plans (RIPs) of the six regional groups, while considering community aspects. ACER and NRAs assess consistency between the NDPs of the Member States and the TYNDP and monitor the implementation of transmission and storage projects. In the case a transmission project is not delivered by a TSO but any other legal entity (e.g., merchant interconnectors), the NRAs organize tender procedures for third-party investments (see Figure 12).

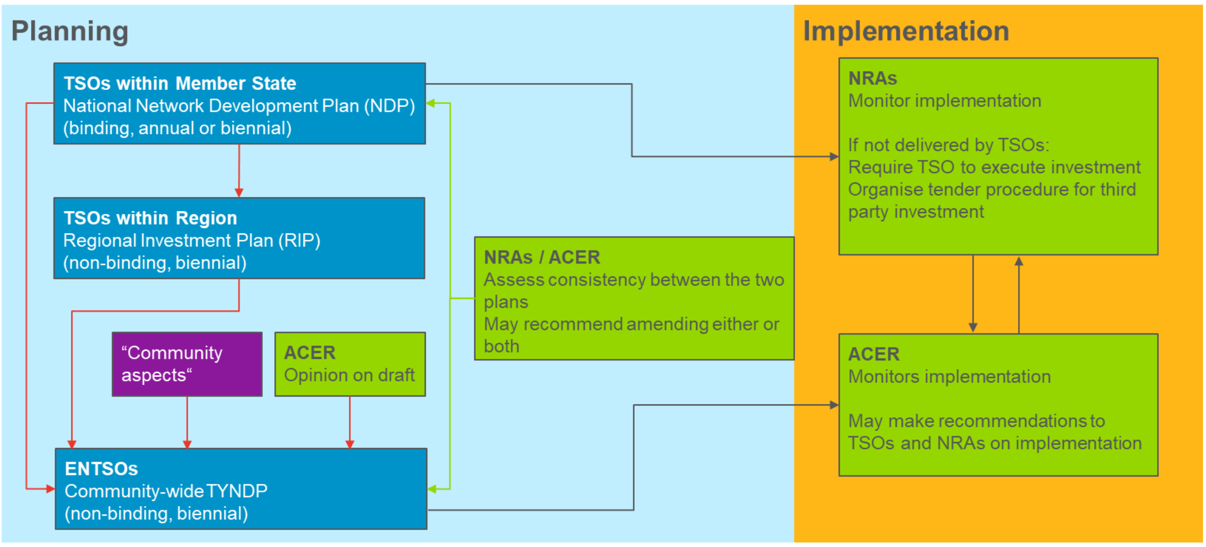

Figure 12: EU infrastructure investment: planning and implementation (own illustration based on ACER).[72]

[71] Netzentwicklungsplan Strom 2030 (2017). Basic presentation NEP 2030, second draft, English version
[72] ACER (2013). The completion of the internal market and the way ahead: ACER's view, Vienna Forum, Wien, 8 March 2013

2.3.3 Projects of common interest

The Trans-European Networks for Energy (TEN-E) strategy supports the EU objective of creating an internal energy market, particularly by supporting projects have strong non-economic benefits but that are not fully commercially viable and need public support. The overall strategic aims are to connect isolated regions, strengthen cross-border interconnections, and integrate renewable power. Through achieving these, the Commission expects to bring €600 billion of socio-economic benefits through avoided generation costs, more competitive wholesale prices, and economic growth and job creation.[73] The strategy identified four priority corridors in the trans-European electricity grid (see Figure 13) requiring urgent infrastructure development:

- **North Seas offshore grid (NSOG):** Integrated development of an offshore electricity transmission grid and related cross-border interconnectors in the North Sea, Irish Sea, English Channel, Baltic Sea, and neighboring waters with the aim to transport electricity generated from renewable offshore energy sources to centers of electricity demand and storage and to increase cross-border electricity exchange.

- **North-south electricity interconnections in western Europe (NSI West Electricity):** Strengthening of interconnections between EU countries in this region and with the Mediterranean area with the aim to integrate electricity from renewable energy sources and reinforce internal grid infrastructures to facilitate market integration.

- **North-south electricity interconnections in central eastern and south eastern Europe (NSI East Electricity):** Developing cross-border interconnections and domestic transmission lines in north-south and east-west directions to complete the EU internal energy market and facilitate the integration of renewable energy sources.

- **Baltic Energy Market Interconnection Plan in electricity (BEMIP Electricity):** Cross-border interconnections between Member States in the Baltic region and the strengthening of internal grid infrastructure, to break-off the energy isolation of the Baltic States and to facilitate European market integration and deployment of renewable energy in the region.

[73] EC (2019a). Trans-European Networks for Energy.

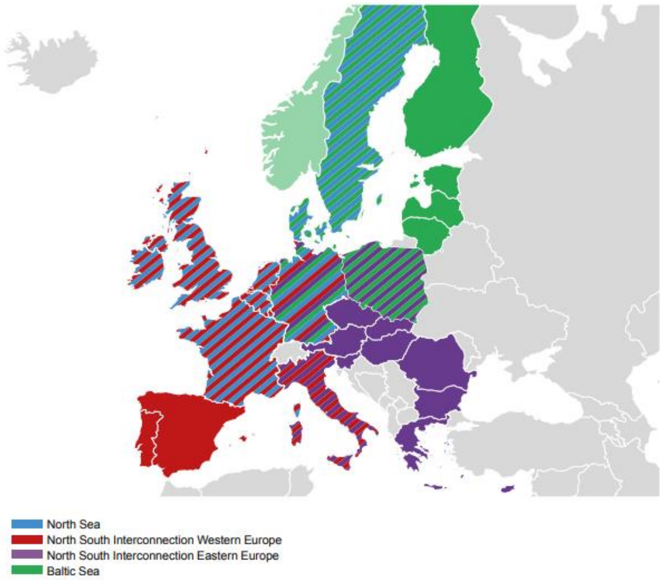

Figure 13: Trans-European Networks for Energy (TEN-E) electricity priority corridors – Regional Groups.[74]

The primary tool of the EU to facilitate trans-European electricity transmission projects in order to achieve its interconnection targets and the Energy Union goals are so-called PCIs, which are governed by TEN-E regulations. The EU maintains a list of PCIs for the electricity, gas, smart grids and CO_2 networks, which are key to meet EU's climate and energy objectives. The latest PCI list was approved in November 2017 and contains 173 projects, of which 106 are electricity transmission and storage projects. Figure 14 shows map of electricity transmission and storage PCIs across Europe.

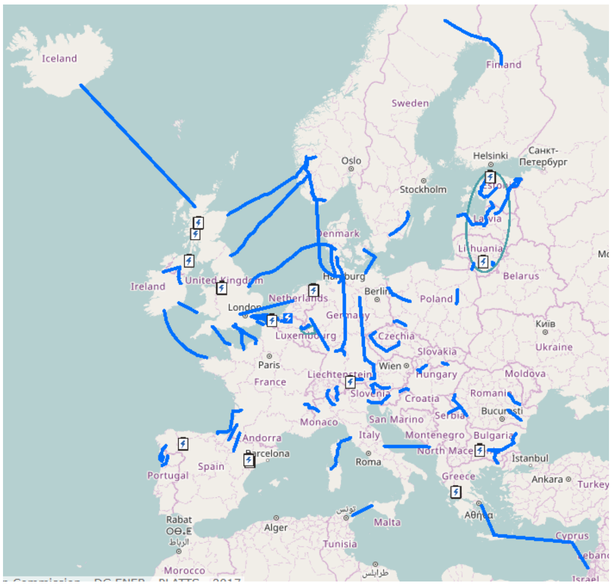

Figure 14: Map of electricity transmission and storage PCIs.[75]

The EU's Regulation[76] on guidelines for trans-European energy infrastructure specifies how trans-European projects in the electricity and gas grids are prioritized and listed as PCIs. The TYNDP

[74] ENTSO-E (2018b). TYNDP 2018.

[75] EC (2019b). Project of common interest – Interactive map of electricity transmission and storage projects.

developed by ENTSO-E is used as the sole basis to derive the list of PCIs for the European electricity sector. PCIs are selected from the TYNDP overall list of transmission and storage projects by the European Commission (see Figure 15).

There are 12 regional groups (composed of representatives from Member States, national regulators, TSOs, ACER, and ENTSO-E) that adopt regional lists of proposed PCIs, each selected to close gaps in the European transmission grid and implement the energy infrastructure priority corridors. All projects on a regional list need to have received approval from the Member States to whose territory they relate. The Commission advises whether the number of proposed projects is manageable and later approves projects that fulfill PCI criteria by entering them into a "Union list" of PCIs, which is reviewed every 2 years. The PCI selection criteria are:

- The project is necessary for at least one of the energy infrastructure corridors defined within TEN-E
- Overall benefits outweigh the project's costs (assessed through a cost-benefit analysis)
- In the case of electricity projects, the project needs to contribute to at least one of the following: market integration (e.g., lifting isolation of a Member State, reducing cross-border transmission bottlenecks), sustainability (e.g., integration of renewable energy sources) and security of supply (e.g., interoperability)

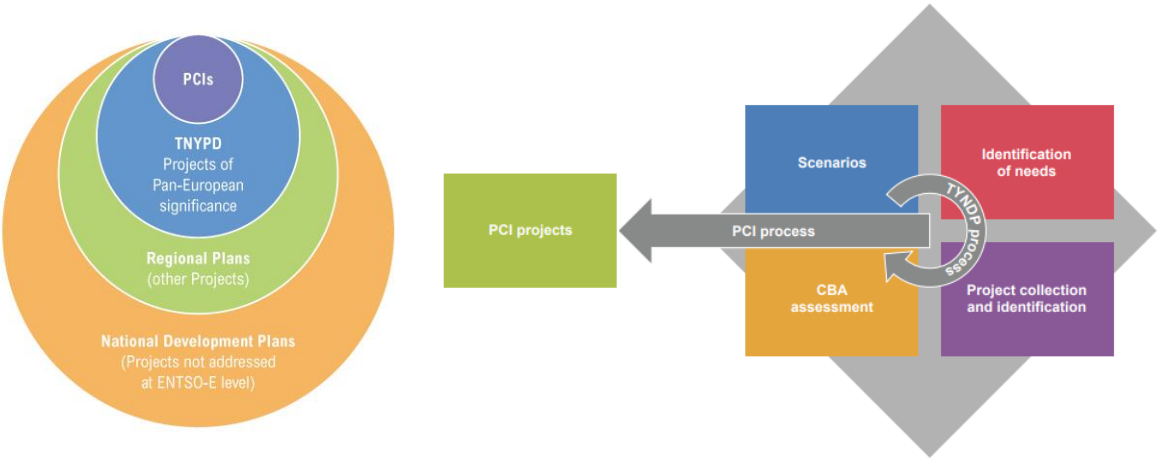

Figure 15: TYNDP provides inputs to the PCI process.[77]

Approved PCI projects must be included by ENTSO-E in its TYNDP and receive priority status, which provides several benefits, including:

- Simplified and accelerated permitting process which is limited by a maximum of 3.5 years
- Ability to participate in the Cross-Border Cost Allocation process
- Securing additional incentives in case of higher-risk projects
- EU financial support through the Connecting Europe Facility (CEF)

[76] EU (2013). Regulation (EU) 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009.

[77] ENTSO-E (2018b). TYNDP 2018.

There are several financing support mechanisms for trans-European interconnection projects. As a first step for strategic European transmission interconnection projects, the TEN-E provides financing for feasibility studies to gauge high level costs and benefits of a project and enable further support, i.e., selection as a PCI and EU financing. The CEF funds priority projects in the field of energy, transport and critical data infrastructure. Energy projects are selected based on their contribution to the implementation of the strategic infrastructure priority corridors as specified in the TEN-E strategy. The Innovation and Networks Executive Agency (INEA) is responsible to implement the CEF program. In the 2014-2020 budget, €5.12 billion of the total €30 billion have been earmarked for the development of trans-European energy infrastructure projects and several PCIs have been elected for financing through the CEF. In 2018, the Commission proposed to renew the CEF for 2021-2027 with a revised budget of €42 billion, of which €8.7 billion have been earmarked for energy. Further EU mechanisms can be used to part-finance the investment, e.g., European Structural and Investment Funds or the European Fund for Strategic Investment.[78]

Cross-border Cost Allocation (CBCA) is a financial tool used to facilitate the implementation of PCIs. The costs and benefits of an interconnector for the two participating TSOs are assessed through a cost-benefit analysis. If the net benefits are not allocated to either of the host countries but are allocated to other Member States then some or all the investment can be financed through an EU program, e.g., the CEF. When two TSOs cannot agree on the terms of the relative cost allocation, ACER can step in as the deciding body providing its third-party cost-benefit assessment.[79]

2.3.4 Ownership models and income mechanisms for cross-border interconnectors

Cross-border interconnectors in Europe are naturally monopolies and consequently are subject to various regulation regimes. Respective NRAs of the countries that are linked by the cross-border interconnector define the applied regulatory regime, meaning that a cross-border interconnector is exposed to two NRAs.[80] Typically, each of the two involved NRAs define 50% of the regulation for the cross-border interconnector and associated costs of a cross-border interconnector are often allocated on a 50-50 rule.[81]

In Europe, **regulated (TSO-owned) and merchant (non-TSO-owned) ownership models** for cross-border interconnectors are institutionalized, where the former is the most commonly used. The applied model determines the rules for the ownership of and revenues from interconnectors and influences the investment objectives and drivers.[82]

In the **regulated ownership model**, TSOs are responsible for financing, building and operating new interconnectors which have been approved by the NRA as they contribute to maximize the net social welfare. The cost of building and operating regulated infrastructure is socialized through network charges and the TSO earns a regulated revenue calculated based on the cost of developing and running the transmission infrastructure. The costs of infrastructure development are spread across network users on a lump sum, capacity-dependent, or energy-dependent principle. Different tariffs schemes exist in Europe.[83] The specific national solution is decided domestically and approved by the NRA.

In the **merchant ownership model**, interconnectors are built and operated by independent private developers on a for-profit-basis. This ownership model is notably used in the UK by private investors to develop cross-border interconnectors, where revenues to recover investments are regulated through a cap and floor regime. As part of this mechanism, developers can propose and build

[78] EC (2019c). Funding.
[79] Energy Community (2016). Explanatory notes - On the Implementation of EU Regulation 347/2013 -MC decision 2015/09 Part II: The Cross-Border Cost Allocation Process.
[80] Kapff, L. and Pelkmans, J (2010). Interconnector Investment for a Well-functioning Internal Market - What EU regime of regulatory incentives?
[81] Ofgem (2018). Decision on the Initial Project Assessment of the GridLink, NeuConnect and NorthConnect interconnectors.
[82] DIW (2013). Policies for International Transmission Investments.
[83] ENTSO-E (2018d). ENTSO-E Overview of Transmission Tariffs in Europe: Synthesis 2018.

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interconnectors and the amount of money they earn is regulated by a revenue cap and floor. The revenue needs to ensure a minimum ROI of the transmission line for a period of 25 years. The level of the cap and floor are determined on an annual basis given depreciations, allowed ROI, capital, and operational expenditures.[84] Note that this regime is different from the merchant interconnector model legally allowed under strict conditions in Europe and also other parts of the world, whose income is dominated by congestion revenues related to price differences between the two electricity markets a merchant interconnector connects. In Europe, merchant interconnectors financed primarily through congestion revenues are rare.

Cross-border interconnectors are very capital intensive and require large upfront investments. Two different financing approaches exists: **corporate and project finance**.[85] Typically, TSOs use within the regulated business model the corporate finance approach when investing in their transmission grids. This is also generally the case when TSOs developing new cross-border interconnectors. The reason for the dominance of the corporate finance approach used by TSOs is the lower complexity and that in general better financing conditions can be secured. For merchant interconnectors the most common approach is project finance.

Equity, debt, and grants from the EU are sources to provide the required upfront investment in both the regulated and the merchant ownership model of cross-border interconnectors.

Key debt sources for financing cross-border interconnectors are loans from international financing institutions (e.g., European Investment Bank or European Bank for Reconstruction and Development), loans from commercial banks, and corporate bonds.

For large infrastructure projects, including cross-border interconnectors, banks typically require developers to provide equity in the range of 20%-40% of the total project costs. In the regulated business model for cross-border interconnectors, TSOs provide equity from cashflows of their own operation (internal equity) and when possible also from external investors (external equity).

Raising required equity by TSOs is considered as one of the challenges for cross-border interconnectors, especially when TSOs are already highly leveraged. Internal equity generated from TSOs' cashflows is typically insufficient to provide the required amount of equity and raising of external equity is often limited as in many cases European TSOs have public institutions as major shareholders. Therefore, grants from the EU (TEN-E, CEF, etc.) as direct financial contributions are an important source for financing cross-border interconnectors as such grants reduce the equity needs of the developer.

Besides the regulator-approved revenues covering interconnectors along with other infrastructure for regulated TSOs, and for the UK third-party investors, revenues can be generated from operating the cross-border interconnector. In principle, interconnectors, which connect two different markets (or market zones), can **generate income** from:

- Congestion rents
- Revenues from balancing and ancillary services between markets
- Where in place, revenues from capacity markets

Income from congestion rents represent the largest share of total incomes of a merchant cross-border interconnector. Owners of cross-border interconnectors can generate revenues from congestion rents when electricity is traded between two markets and transmission congestion between the two markets arises. The generated revenues from congestion rents depend on the electricity price differentials between the connected markets on each end of the interconnector.

[84] Ofgem (2016). Cap and floor regime: unlocking investment in electricity interconnectors.

[85] EC (2011). The structuring and financing of energy infrastructure projects, financing gaps and recommendations regarding the new TEN-E financial instrument.

Revenue collection from congestion rents depends on whether interconnector capacity between markets is allocated in explicit or implicit auctions.[86]

Explicit auctions were the original form of transmission capacity allocation in Europe, in which transmission capacity is auctioned separately and independently from the marketplaces where electricity is auctioned. The respective cross-border transmission capacities are typically auctioned on three timescales through annual, monthly, and daily auctions, in which participants bid for transmission rights and specify the volume and transmission capacity. If successful, the bidder pays the marginal clearing price (EUR/MWh) in the auction. Explicit auctions for cross-border transmission capacities can lead to an inefficient utilization of interconnectors as cross-border transmission capacities and electrical energy is traded at two separate markets, which implies a lack of information about prices of the other commodity. Inefficient utilization of interconnectors reduces social welfare and leads to less price convergence between markets and more frequent adverse transmission flows. The drawbacks of explicit auctions have caused the design of implicit auctions for cross-border transmission capacities with the aim to facilitate coupling (integration) of European electricity markets.

Implicit auctions are used increasingly in Europe due to the target model for market coupling and its geographic coverage of market coupling described above, in which the available cross-border transmission capacity is implicitly included and used to integrate spot markets in the most effective way (maximizing social welfare). In this model, market participants do not pay for the use of the interconnector. Instead, the TSOs or interconnector operator receives congestion revenues resulting from the price differential between the two markets. Such revenues originate in situations where transmission capacity between price zones is insufficient to fulfill demand, resulting in a split bidding zone. Congestion income is then calculated as the commercial flow between the zones is multiplied by the price spread between the areas. The surplus income is collected by the power exchange managing power trading in a bidding zone and paid to the TSO. Following the EU's Capacity Allocation and Congestion Management Regulation,[87] ENTSO-E published in 2017 the agreed methodology[88] to share congestion revenues among participating TSOs, which generally applies the 50-50 rule. The Inter-TSO Compensation (ITC) scheme[89] administered by ENTSO-E provides additional revenues to TSOs with large transit flows.

Income from balancing markets can be generated by interconnectors when providing cross-border balancing and ancillary services between interconnected markets. Balancing and ancillary services that can be provided by the interconnector depend on the applied technology.[90] The Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing (EBGL) defines the rules for the integration of European balancing markets.[91]

Revenues generated on capacity markets can be another source of income for cross-border interconnectors by selling capacity contracts of the respective markets. In Europe, however, capacity markets (or more in general, capacity mechanisms) are only seen and approved by the European Commission as a temporary measure to ensure the achievement of the necessary level of resource adequacy and, in many cases, interconnectors are excluded from the respective capacity mechanism.[92]

Investment objectives and drivers to invest in new cross-border interconnectors depends on the ownership model. Whereas the objective to invest in a cross-border interconnector for TSOs (regulated ownership model) is to maximize net social welfare (and earn a regulated return on

[86] TenneT (2010). Market integration - Coupling of the European electricity markets.

[87] EU (2015). Regulation 2015/1222 establishing a guideline on capacity allocation and congestion management.

[88] ENTSO-E (2017). All TSOs' Proposal for a Congestion Income Distribution (CID) methodology in accordance with Article 73 of the Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a Guideline on Capacity Allocation and Congestion Management.

[89] COMMISSION REGULATION (EU) No 838/2010 of 23 September 2010 on laying down guidelines relating to the inter-transmission system operator compensation mechanism and a common regulatory approach to transmission charging

[90] National Grid (2016). Benefits of Interconnectors to GB Transmission System.

[91] ENTSO-E (2018e). An overview of the European balancing market and the electricity balancing guideline.

[92] European Commission (2018). Press release of 7 February 2018, State aid: Commission approves six electricity capacity mechanisms to ensure security of supply in Belgium, France, Germany, Greece, Italy and Poland

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additional, regulator-approved investments in the process), investors in merchant interconnectors aim to maximize their private profits. Hence, drivers for investing in cross-border interconnectors differ between the two ownership models (see Figure 16). For merchant investors, expected incomes from congestion rents and revenues from balancing and eventually capacity markets are the sole drivers for investing. The main danger for such merchant investors—and the reason unregulated, congestion-revenue-financed merchant interconnectors are so rare in Europe—is that any future transmission investment which alleviates congestion on the same interface can reduce their revenue substantially. In contrast, for TSOs the income from the cross-border interconnector is only one part of the investment decision as issues like an overall better resource utilization, an improved security of supply, and more are considered within the investment decision.

	Regulated ownership model (TSO-Owned)	Merchant ownership model (Non-TSO-Owned)
Objective	Maximise net social welfare	Maximise private profits
Drivers	• Resource utilisation • Efficient power generation • Security of supply • Congestion rent • Revenues from balancing markets • Revenues from capacity markets	• Congestion rent • Revenues from balancing markets • Revenues from capacity markets

Figure 16: Objective and drivers for investment decisions for regulated TSO and merchant non-TSO ownership model.[93]

Income regulation for cross-border interconnectors varies across European countries and NRAs have developed tailored schemes to address costs and benefits.[94] The spectrum of regulation of cross-border interconnectors can range from completely unregulated to fully regulated. The rate of regulation determines how the revenues and the risk associated with an investment in a cross-border interconnector is distributed between the owner of the asset and society. Figure 17 shows principles of four regulatory regimes for incomes of cross-border interconnectors and how the risk of the investment is split between the owner and the consumers depending of the applied regulatory regime:

- Unregulated
- Revenue cap
- Cap and floor
- Fully regulated

A widely applied method for interconnectors in Europe is the revenue cap regulatory regime, where the maximum revenues an owner of a cross-border interconnector is allowed to retain is agreed ex ante. If the revenue increases beyond the defined cap, the additional revenues are redistributed as a

[93] Own illustration based on Bruvik, S. H. and Hernes, S. M. (2018). Integration of Electricity Markets – An Analysis of TSO-Owned and Non-TSO-Owned Cross-border Interconnectors.

[94] Kapff, L. and Pelkmans, J (2010). Interconnector Investment for a Well-functioning Internal Market - What EU regime of regulatory incentives?

lump sum to the consumers, typically in form of reduced transmission system tariffs. Within the revenue cap regulatory regime, the investor (owner) of the asset holds the entire investment risk.

As stated above, the cap and floor regulatory regime is applied in the UK to regulate private investors of cross-border interconnectors. The main features of the regime include an upper limit for revenues is defined (cap) and a minimum level (floor). Similar to the revenue cap regime, revenues which exceed the defined cap are redistributed to the consumer (via the national TSO National Grid). The floor is assured ultimately by consumers and limits the risk for the merchant investors. In the case revenues are below the floor, National Grid fills the revenue gap for the merchant investor, by increasing transmission grid tariffs of its customer.

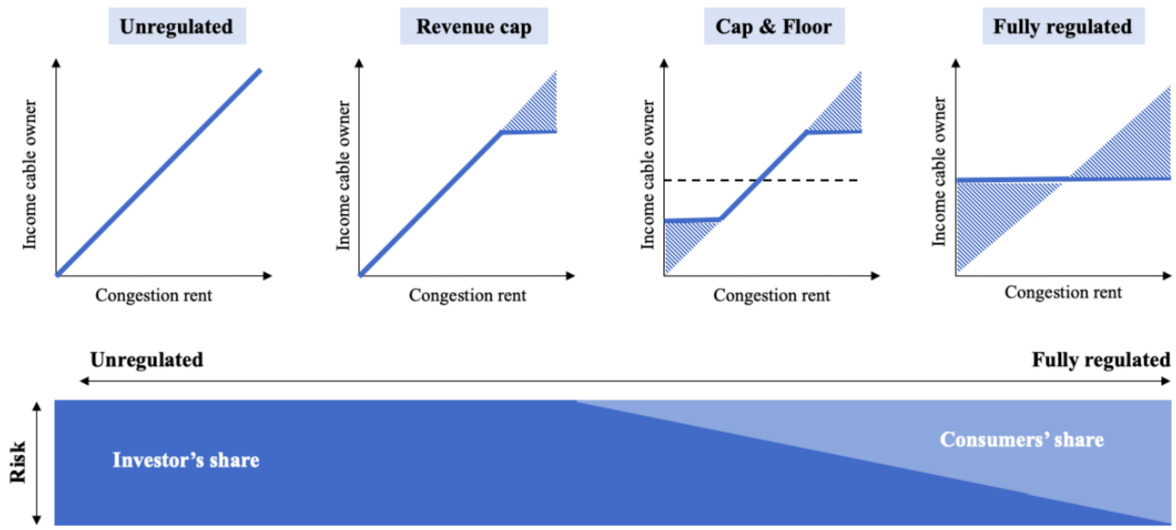

Figure 17: Possible regulatory regimes for income from congestion rents and split of risk between investors and consumers of cross-border interconnectors.[95]

[95] Bruvik, S. H. and Hernes, S. M. (2018). Integration of Electricity Markets – An Analysis of TSO-Owned and Non-TSO-Owned Cross-border Interconnectors.

2.4 Outlook

The European Internal Energy Market keeps evolving. This section summarizes current key challenges and aspects that will define the next steps in the evolution of cross-border electricity cooperation in Europe.

While the day-ahead market segment has been dominant, the intraday market's share in total trading volume recently has seen a steep increase.

The total trading volume on EPEX Spot, representing around 50% of the European electricity consumption, was 534 TWh in 2017. The day-ahead market accounts for 87% and the intraday market for 13% of the trades. Trading volumes on the day-ahead market constantly increased until 2015 and have slightly decreased since then.[96] The intraday market has been constanly growing in volume since 2004 and has been increasingly active on national and cross-border trading. Compared to 2016, the volume of the intraday market grew by 15% to a total volume of 71 TWh in 2017. Cross-border trades represent about 20% of the total traded volume.[97]

To further strengthen the intraday market segment, adjustments to the current award process in intraday trading through XBID are discussed. Currently, intraday optimization transactions are mostly defined by first-come first-serve automated responses by electricity traders who look for possibilities based on power plant or transmission equipment outages displayed within an hour of the event on ENTSO-E's Transparency Platform transparency.entsoe.eu. A value-based approach to awarding bids in the intraday market and accounting for congestion income for TSOs are aspects that are currently being discussed.

In addition to new market segments, new geographies are set to be included into market coupling and day-ahead trading in Europe.

The establishment of the common market for electricity in Europe is also facing obstacles. First of all, political priorities regarding the energy mix to be adopted in the medium- and long-term still differ substantially between Member States. While some Member States, like Germany, have reached a political agreement to phaseout coal power, others like Poland are less inclined to take such a step. Differences also exist in Member States' approaches to the role of gas in the future electricity mix, to nuclear energy, and to the share of renewables that is aimed for.

The benefits of cross-border electricity trade increase with rising shares of renewable energy in the generation mix. The Paris Agreement lays the foundation for considerable global growth in RES capacity in the next decades. The integration of intermittent renewable energy sources increases the need for interconnecting national power systems to avoid huge national overcapacities for electricity generation, transmission, distribution, and storage. The future global electricity system will be highly interconnected to allow for a balancing of the intermittent electricity generation by RES to reduce the impact of variations in regional weather conditions such as wind and solar irradiation.

[96] EPEX SPOT (2017). The Power Effect.
[97] Ibd.

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3. REGIONAL COOPERATION IN THE GCCIA

3.1 Institutional setup

To integrate their power systems, the GCC member states Saudi Arabia, the UAE, Kuwait, Oman, Qatar, and Bahrain have joined forces to develop an interconnected transmission grid. Although the development of an integrated grid is at an earlier stage compared with the EU, the process shows parallels with the European example. Going forward, there may be potential to apply lessons from the European context to the GCC region's efforts.

The existing GCC cross-border grid connects the six GCC members via a transmission line. It is administered by the GCCIA, a joint stock company subscribed to by the six GCC states[98] under the leadership of the GCCIA's CEO Eng. Ahmed Ali Al Ebrahim.[99] Figure 18 shows the geographic location of the interconnection grid.

Figure 18: Geographic location of the GCC interconnection grid.[100]

The interconnection grid has a total capacity of 2,400 MW with varying capacities for each county's interconnection as shown in Figure 19.[101] While most linkages operate at 400 kV, the connection between the UAE and Oman is operated at 220 kV. A grid topology scheme is presented in Figure 19.

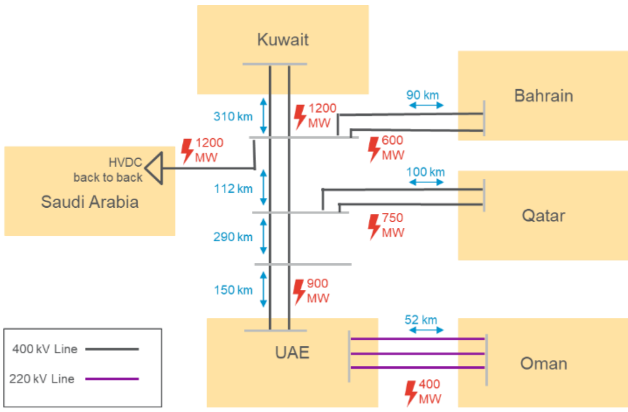

Figure 19: Schematic presentation of the GCC interconnection grid.[102]

[98] GCCIA (2001). Company Profile.
[99] GCCIA (2018). Annual Report 2018.
[100] Source: Own illustration based on GCCIA (2007) and KAPSARC (2018).
[101] IRENA (2013b). 400 kV GCC Interconnector: Overview and Comparison with Clean Energy Corridor Enablers.
[102] Source: Own illustration based on Arab Fund for Economic and Social Development (2016). Current Status of The Arab Electricity Grids Interconnection Projects.

3.2 Objectives and driving forces

3.2.1 History

The idea of creating an interconnected grid across the GCC was first discussed at the time of the GCC's foundation around 1981. Shortly after, the technical and economic feasibility of an interconnected power grid was assessed and confirmed by studies in 1982 and 1986, which triggered the draft design of a regional interconnector. The idea was not explored further until the topic resurfaced in the early 2000s.[103] In 2001, the GCCIA was founded and its articles of association and by-laws approved. The original purpose of its establishment was to strengthen the cooperation of the GCC member states, create a mechanism to prevent electricity outages and decrease costs for operating reserves.[104]

The construction of the interconnection line was completed in three phases. In Phase 1, the northern section including Kuwait, Saudi Arabia, Bahrain, and Qatar was constructed and completed in 2009. In Phase 2, links with the UAE were constructed, which would also allow Oman to join. Phase 3 linked the first two construction phases.[105] The UAE joined in 2011 and Oman finally connected to the grid via the UAE in 2013. The construction cost of US$3 billion was shared by the participating countries according to the national share of the grid's capacity that was expected.[106]

To allow for cross-border trade in addition to emergency support, the GCCIA developed an appropriate legal framework in 2009. The two key documents, the Power Exchange and Trading Agreement (PETA) and the ITC regulate the relationship between the GCCIA, electricity sellers, off-takers and transmission system operators and were approved by the GCCIA member states.[107] In 2017, a trial period for spot trade of 6 months was initiated.[108]

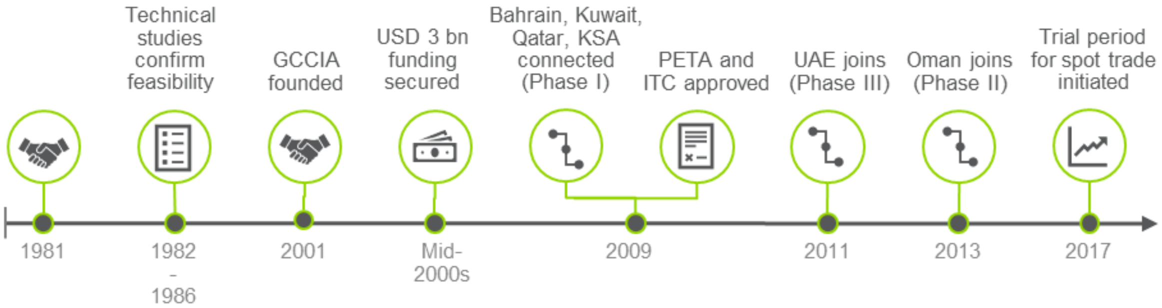

Figure 20: Timeline of the GCC Interconnection Grid.[109]

3.2.2 Driving forces for closer regional cooperation

Security of supply

Electricity consumption in the GCC member countries had almost tripled since the early 2000s. The largest producer of electricity is Saudi Arabia with over 50% of all installed capacity, followed by the UAE.[110] Because of the strong difference in temperatures and high cooling needs during the summer, the seasonal variation of load in the GCC can vary about 50% between summer and winter. The time

[103] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.
[104] GCCIA (2001). Company Profile.
[105] Arab Fund for Economic and Social Development (2016). Current Status of The Arab Electricity Grids Interconnection Projects.
[106] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.
[107] KAPSARC (2018). Assessment of the Political Feasibility of Developing a GCC Power Market.
[108] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.
[109] Own illustration
[110] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.

for peak demand also varies depending on the season.[111] Having interconnections in place increases security of supply as the pool of electricity production grows, providing diversity.

Cost-efficiency

The GCC member countries have been expanding their electricity generation capacity in the past years and continue to do so to meet increasing demand as the population is growing. Electricity generation capacity in the GCC is currently at 148 GW (2017). Over the next 5 years, an additional 76.8 GW of generation capacity will have to be added. The GCCIA estimates the cost of this new capacity at US$50 billion.[112] Other sources expect that the GCC will even require US$81 billion for the addition of 62 GW of generating capacity and another US$50 billion for transmission and distribution between 2017 and 2021.[113]

Major capacity expansion projects are underway to address this need. In the UAE, four nuclear power reactors are being constructed with a capacity of 5.6 GW. The nuclear reactors are expected to provide one-quarter of the UAE's anticipated electricity demand by 2020.[114]

To reap the potential of efficiency gains through cross-border trade in the growing GCC market, the GCCIA's board decided to work towards the commercial exploitation of the grid interconnection, going beyond the original objective to provide emergency backup.[115] Trading electricity via the GCC interconnection could help optimize the use of investments to cover electricity demand as differences in consumption and production patterns could be leveraged. In the UAE, a large baseload production from nuclear power will have to be integrated into the grid and could potentially be exported in times of low demand to supply demand centers with peak loads different from the UAE's.

The GCC interconnection grid is already saving investments. According to estimates from the GCCIA, actual capital and fuel savings totaled US$400 million in 2016 and US$300 million in 2018.[116,117] The capital and operational costs have already been exceeded by cost savings.[118] Studies by the GCCIA and others expect that electricity trading could save the GCC member states about US$5 billion in electricity sector investments and US$1.8 billion in fuel costs between 2014 and 2038.[119]

Energy mix diversification and integration of renewables

The GCCIA countries have set renewable energy targets, with some like the UAE striving for high shares of renewable energy (see Table 2). For example, in the UAE, 44% of the electricity mix should be based on renewables by 2050 according to the country's Energy Plan. As experience in Europe has shown, the balancing of intermittent renewable energy sources and their integration to electricity systems is significantly easier over large geographic areas with differences in resource availability at a given moment (e.g. due to clouds) and differences in demand patterns. This is particularly relevant if renewable energy generation production is concentrated at specific sites, e.g., in large solar parks such as Noor in Abu Dhabi with 1,177 MW.[120]

[111] GCCIA (2018). Annual Report 2018, p.111.
[112] KAPSARC (2018). Assessment of the Political Feasibility of Developing a GCC Power Market.
[113] Ventures Onsite (2018). GCC Power Market.
[114] World Nuclear Association (2019). Nuclear Power in the United Arab Emirates.
[115] Ibid.
[116] KAPSARC (2018). Assessment of the Political Feasibility of Developing a GCC Power Market.
[117] GCCIA (2018). Annual Report 2018, p.105.
[118] GCCIA (2018). Annual Report 2018.
[119] KAPSARC (2018). Assessment of the Political Feasibility of Developing a GCC Power Market.
[120] The National (2019). Noor Abu Dhabi solar plant begins commercial operation.

Table 2: GCC member states renewable energy targets.[121]

Member	Saudi Arabia	UAE	Oman	Kuwait	Qatar	Bahrain
Renewable energy target	59 GW by 2030	44% generation capacity by 2050	30% of electricity demand by 2030	15% of generation by 2030	20% of generation by 2030	20% generation capacity by 2035

3.3 Implementation of cross-border cooperation: current status

Total power flows in the GCCIA grid are composed of power exchanged to maintain the stability of national grids and power traded. Power exchanges meant to stabilize one of the member's grids are unscheduled and occur during unexpected contingencies in the grid. They are returned in kind, meaning that electricity imports during peak demand times are returned by the other country as exports during peak demand. Scheduled electricity trading is based on bilateral agreements between member states with the transactions being approved by the GCCIA. Figure 21 shows the volumes traded in the past decade.

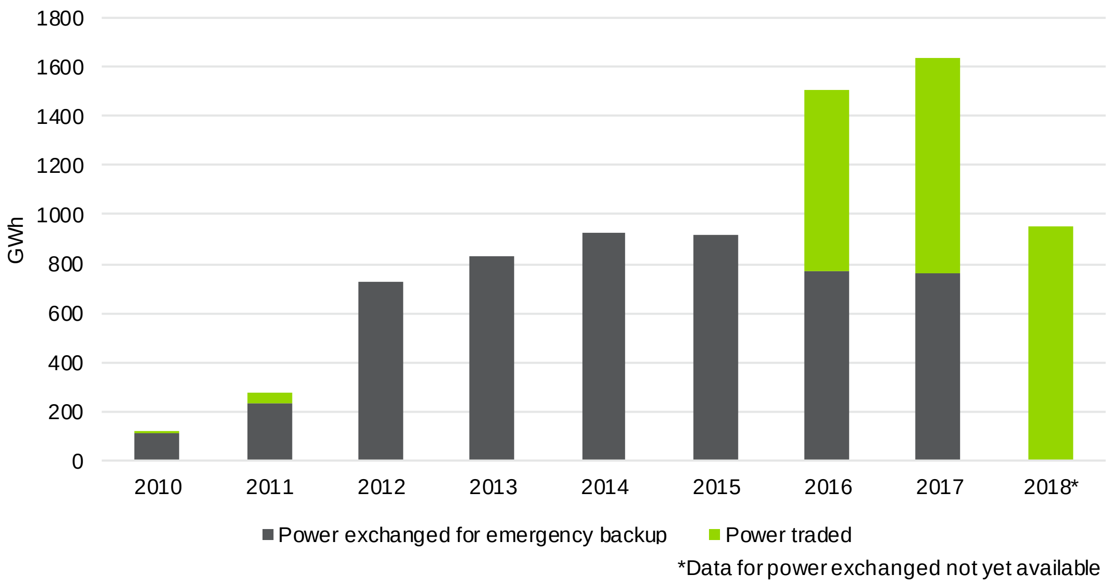

Figure 21: Volume of power exchanged & traded on the GCC interconnection grid.[122]

To maintain the stability of the grid, GCCIA interconnection provided ad hoc support in 134 instances in 2018, in the majority of cases due to generation losses between 100 MW and 500 MW.[123] The number of interventions to prevent grid emergencies has constantly fallen by over one-third since 2014, indicating that the national grids are becoming more stable.[124] As a precaution for sufficient capacities, the GCCIA members have to meet installed capacity obligations (ICO). In order to procure the required ICO capacity, member states are allowed to approach other members. Failure to meet the obligation results in a penalty. There are also spinning reserve requirements for each individual state and a common reserve, which was 664 MW in 2019.[125]

[121] Own illustration
[122] Source: Own illustration based on GCCIA (2018), Annual Report 2018, GCC Interconnector - A Unique Structure
[123] GCCIA (2018). Annual Report 2018, p.107.
[124] GCCIA (2019). Experience of GCCIA in developing GCC Regional Electricity Market.
[125] Ibid.

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The GCCIA grid was not used for commercially oriented trading between 2010 and 2015 with minor exceptions in 2010 and 2011. Trade volumes picked up in 2016 with 734 GWh traded in 2016, 878 GWh traded in 2017 and 952 GWh traded in 2018.[126] One reason for the increase was that between 2016 and 2018, the GCCIA waived transmission charges with the aim to incentivize power trade.[127] The transmission charges for using the GCCIA interconnector used to be fixed at US$5/MWh since 2010. In 2017, the GCCIA Advisory and Regulatory Committee approved new tariffs for the additional usage rights of the interconnector. It was set to US$0.5/MWh with a minimum limit of US$10,000 for each transaction.[128]

Other factors that can explain increased trade between GCC member states are price differentials with more attractive tariffs offered by a neighboring member state than the local cost of power generation and aims to relieve transmission grid congestion in certain member states.

In 2018, 15 contracts for electricity were concluded, some of which are scheduled for 2019. Trading usually takes place in the months from May to December, with peaks in July and August.[129]

The capacity of the interconnection grid is currently rather low. For instance, Saudi Arabia has a peak load of 62 GW (2018) and an interconnection capacity of 1.2 GW, which is only about 2%. In comparison, Germany has a peak load of 85 GW (2018) and an interconnection capacity with neighboring countries of 20 GW, which is about 20%.[130] Even though the capacity is comparatively low, the GCCIA interconnected system has to date remained strongly underutilized.[131]

The intended purposes of the GCCIA line, namely to provide backup electricity during emergencies caused by power system outages, to share capacity reserves, and to optimize capital investments have been satisfied. However, the potential of further benefits from trade have not been fully used.[132]

3.4 Planned evolution of cross-border electricity cooperation in the GCCIA and outlook

There are several possible development pathways for the GCC interconnection grid. Most prominently, the development of a regional power market to better use the existing infrastructure and considerations to further expand the physical grid to other countries and regions are being discussed by the GCCIA and its member states.

3.4.1 Market development

The GCCIA is promoting bilateral electricity trade and communicates the establishment of a regional spot market as its primary goal.[133] Member states are considering the introduction of day-ahead markets to leverage market efficiencies.[134]

Since 2012, formal committees on different working levels have discussed the possibility of a regional power market. To enable trading, the GCCIA developed market procedures and conditions in October 2017.[135] They establish the relationship between the GCCIA power exchange and the transmission system operators for allocation of transmission capacity, managing power flows, and more. In addition, exchange market terms and conditions were developed, regulating the relationship between

[126] GCCIA (2018). Annual Report 2018, p.116.
[127] GCCIA (2018). Annual Report 2018.
[128] GCCIA (2018). Annual Report 2018.
[129] GCCIA (2018). Annual Report 2018, p.117.
[130] WEC (2019). Energie für Deutschland – Schwerpunktthema: Energiereiche Golfstaaten Geopolitik und Energieversorgung.
[131] KAPSARC (2018). Assessment of the Political Feasibility of Developing a GCC Power Market.
[132] KAPSARC (2018). Assessment of the Political Feasibility of Developing a GCC Power Market.
[133] Ibid.
[134] GCCIA (2019). Experience of GCCIA in developing GCC Regional Electricity Market.
[135] GCCIA (2018). Annual Report 2018, p.118.

trading parties (currently the member states) and the GCC power exchange for allowing access to the trade platform, submission of bids and offers, clearing trade transactions, settling the payments, etc.[136]

In 2018, the GCC electricity market system (GEMS) was inaugurated, aiming to enable trading for day-ahead contracts.[137] It is currently used to operate the power exchange for day-ahead and intraday continuous trading.[138] The GCCIA aims for the second half of 2019 for the market to be operational. By 2022, a full-fledged market is aimed for.

Access to the GCC interconnection grid is limited to the national electricity utilities. The transmission utilities have interconnection rights and act as balancing parties. GCCIA aims to allow access to the interconnector for third parties, including generators and bulk consumers. The local transmission utilities are envisioned to remain the interconnection points and to continue to be responsible for balancing.[139] If implemented, systematic trading would enhance the utilization of existing infrastructures in the early phases. In the medium term, commercial trade of electricity would require a reinforcement of the interconnection as a significantly larger grid capacity would be needed to leverage the market efficiencies.[140]

Although a fully integrated regional market might reap substantial financial benefits, limited trade between single buyers from member countries seems to be a more realistic option in the short term.[141] For instance, in 2018, the Saudi-Emirati Coordination Council announced bilateral plans to increase the use of the interconnector between the two countries.[142]

3.4.2 Expanding the GCC interconnection grid

The potential of intra-GCC electricity trade is significant but currently ultimately limited due to the almost uniform peak demand. Integrating the power systems of regions with different peak demand times holds a much larger potential to use generation capacity cost-efficiently. This could for example be leveraged with the Levant and Northern Africa.[143]

The GCCIA recently published a study on the expansion of its cross-border grid that explores the options to expand the interconnection grid towards Europe through Jordan, Syria, and Iraq, towards central Asia and towards Ethiopia.[144]

Jordan, which could link the GCC towards Europe, recently signed a MoU with Saudi Arabia to conduct technical and economic studies for an electricity interconnection between the two countries.[145] In July 2019, Jordan, Egypt, and the GCCIA agreed to form a joint technical committee to establish a MoU with the purpose to implement a power connection project connecting the countries of the Gulf region with Europe through Jordan and Egypt.[146] Given that Egypt features a large domestic electricity market with a more diversified energy mix and very different load and consumption patterns from the GCC countries, an interconnection would be particularly useful. Former plans for a 3 GW transmission line between Saudi Arabia and Egypt have been repeatedly delayed.[147] However, both the UAE and Saudi Arabia have a strong interest in strengthening cooperation and have already established close ties. In 2016 alone, the UAE paid over US$2.4 billion

[136] GCCIA (2019). Experience of GCCIA in developing GCC Regional Electricity Market.
[137] GCCIA (2019). Experience of GCCIA in developing GCC Regional Electricity Market, p. 115.
[138] GCCIA (2019). Experience of GCCIA in developing GCC Regional Electricity Market.
[139] Ibid.
[140] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.
[141] KAPSARC (2018). Assessment of the Political Feasibility of Developing a GCC Power Market.
[142] Ibid.
[143] APICORP (2018). Electricity trading in MENA – huge potential but far behind.
[144] GCCIA (2018). Annual Report 2018, p.110.
[145] APICORP (2018). Electricity trading in MENA – huge potential but far behind.
[146] Jordan Times (2019). Steps agreed to connect power grids of Gulf, EU through Jordan.
[147] Ibid.

in foreign assistance to Egypt, including US$20.4 million for development of the country's electricity transmission and distribution network.[148]

Connecting the GCCIA to Ethiopia is another option, as Ethiopia features time-complementary solar energy as well as hydropower and hydro storage capabilities. To further explore the opportunity to connect the transmission grid with Ethiopia, the GCCIA has signed a MoU with the Euro-Africa Interconnection to create an E-Highway towards Europe.[149] The Global Energy Interconnection Development Cooperation Organization, the Ethiopian Ministry of Water, Irrigation and Electricity and the GCCIA signed an agreement in 2019 to jointly conduct research on a possible transmission route between Ethiopia and the Gulf region.[150]

In Central and South Asia, seasonal peaks in India and Pakistan are temporally shifted compared to the GCC, so that the region could potentially absorb excess solar energy from the GCC.

The Arab Fund for Economic and Social Development is currently supporting several multinational projects promoting regional power grid integration. This includes the Eight country interconnection project, the Maghreb countries interconnection project and the Gulf cooperation council power grid interconnection project.

With the aim to introduce a Pan-Arab Electricity Market, the World Bank is supporting efforts to integrate electricity markets across Arab countries. In 2019, 16 Arab countries had signed a MoU to expand bilateral opportunities for trade and gradually move towards competitive market operations. The formation of legal institutions, including a Secretariat, three sub-regional transmission system operators, regional market facilitators and the Joint Pan-Arab Advisory and Regulatory Committee is envisioned. The initiative aims to achieve a fully integrated Arab regional market by 2038.[151]

3.4.3 Outlook

A closely interconnected electricity system holds the potential to reap benefits in terms of security of supply, efficiency and sustainability in the power sector through the integration of renewable energy sources. Currently, despite tremendous potential, less than 1% of the GCC region's electricity supply is covered by renewable energy.[152] A well-functioning interconnection grid allows for the large-scale integration of variable renewable energy. This could be key for the GCC member state's ambition to reach their renewable energy targets.

To improve utilization and eventually expand the interconnection grid, some obstacles must be overcome. Some of the barriers quoted in the literature are the following:

- The price of electricity and other energy sources in many parts of the GCC region is not cost-reflective due to subsidies, which are still substantial despite efforts to reform the pricing structure. Electricity tariffs for households' range between 0.02 and 0.11 Euro/kWh in the countries of GCC compared to 0.3 EUR/kWh in Germany.[153] Distortions in the form of subsidized electricity prices, also at the utility level, can be a hindering factor for cross-border trade.
- The interconnection grid does not operate with the same voltage levels throughout the member countries: The connection between Oman and the UAE only runs on 220 kV compared to 440 kV for the other interconnectors; this limits the transfer capacity to Oman.
- Cross-border allocation mechanisms and tariffication would need to be agreed upon. This includes the harmonization of transmission charges and ensuring that transmission charges

[148] UAE Ministry of Foreign Affairs (2018). International Cooperation and Foreign Aid 2016.
[149] GCCIA (2018). GCC Interconnector - A Unique Structure.
[150] APICORP (2018). Electricity trading in MENA – huge potential but far behind.
[151] World Bank Blogs (2019). Creating the second largest regional electricity market in the world.
[152] IRENA (2019b). Renewable Energy Market Analysis: GCC 2019.
[153] Global Petrol Prices (2019). Market Data.

do not exceed delivery costs to avoid penalizing electricity distributors for imports.[154] Compensation for transits along the lines of the EU ITC scheme mentioned above, could also later become helpful.

- Harmonized rules for grid congestion management are needed (managing over-capacity or demand at peak trading times).[155] GCCIA's role as a regional regulatory body should thus be further strengthened.
- A decision on how existing long-term electricity supply contracts are to be dealt with is yet to be taken.[156]
- There are differences in local regulations, policies and utility structure. There is an ongoing/starting market liberalization/unbundling of national utility sectors (generation, transmission, distribution and retail), with Abu Dhabi and Oman having seen change in the unbundling of transmission and distribution as well as independent power producers.[157]

Ultimately, the future of the GCC interconnection grid will depend on the political will of the member states to cooperate and on the growing economic benefit of expanded trade as solar energy makes up growing parts of the electricity mix. The experiences from the European example can provide valuable lessons for the future development of the GCC interconnection, with some general principles to be derived.

[154] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.
[155] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.
[156] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.
[157] El-Katiri, L. (2018). Regional Electricity cooperation in the GCC.

4. CONCLUSION: PRINCIPLES FOR SUCCESSFUL CROSS-BORDER ELECTRICITY COOPERATION

Make benefits of cross-border trade transparent: Optimized renewable energy integration, efficiency, reliability

Regional cooperation and cross-border trades are not final objectives in and of themselves. For regional electricity trade and collaboration on electricity infrastructure to work, the benefits for each participating country and its consumers need to be made transparent. This concerns the efficiency gains to be reaped from cross-border trade, especially as the GCCIA connects to regions with differing load peaks such as the Levant. Also, security of supply—a key concern for decision makers in the Gulf region as well as in Europe—can be improved through cross-border trade, where imports from neighboring countries can make up for potential outages and shortages. Third, the importance for cross-border trade for the achievement of renewable energy targets should be made clear to decision makers and citizens alike. Larger, interconnected areas make it easier to balance variable renewable energy generation and therefore allow countries to make best use of the abundant solar and good wind resources that are available in the GCCIA. Jointly conducted studies that focus on co-optimizing generation and transmission assets across GCC could provide further insights into potential benefits from increased regional cooperation.

Set up institutions and governance mechanisms for interconnection planning

Several ENTSO-E tasks could prove useful and easy to set up for the Gulf region. Cross-border collaboration and trade require numerous decisions to be taken, both at the political and at the technical level, among decision makers, grid operators, and other relevant parties. A forum where these decisions can be made under pre-set rules and decision-making processes facilitates the implementation of cross-border trade. The GCCIA has established itself as such a regional cooperation forum. For further steps in its development and the closer cooperation of grid operators on matters such as grid planning, adequacy assessments and security cooperation as well as common rule-setting, GCCIA could examine the various tasks of Europe's ENTSO-E with the expectation that several tasks could be useful and easily set up also in the Gulf region.

Ratchet up ambitions—from interconnections to trading and common market rules

The process of increasing cross-border trade and building stronger cross-border infrastructures in Europe has been an incremental and long one. The GCC region has already taken important steps and clear political decisions to also move closer together. The promotion of larger trading volumes, the introduction of new market segments and steps such as the introduction of a regional power exchange require a discussion on common market rules and a codification of those rules as has happened in the European Network Codes process. The economic benefits of this step are increasing fast along with higher penetration rates of renewable energy.

Continue learning across regions

Lastly, cross-border electricity trade and infrastructure cooperation call for increased knowledge exchange and mutual learning between different regions. The EU and the GCC appear as natural partners for such a learning effort, as does bilateral exchange between countries like the UAE and Germany, who have established a fruitful cooperation scheme under their Energy Partnership. Exchanging lessons between both regions is all the more important as interconnecting the Gulf region's rich renewable energy potential with Europe's appetite for decarbonization—both through potential electricity exports and through the export of green molecules—appears more attractive today than ever before.

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