IRENA
International Renewable Energy Agency

REGIONAL MARKETS

INNOVATION LANDSCAPE BRIEF

ISBN 978-92-9260-131-7

Citation: IRENA (2019), *Innovation landscape brief: Regional markets*, International Renewable Energy Agency, Abu Dhabi.

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

Acknowledgements

This report was prepared by the Innovation team at IRENA's Innovation and Technology Centre (IITC) and was authored by Arina Anisie, Elena Ocenic and Francisco Boshell, with additional contributions and support by Harsh Kanani and Rajesh Singla (KPMG India).

Valuable external review was provided by Hanspeter Höschle (VITO), Luiz Barroso (PSR) and Hélène Lavray (Eurelectric), along with Carlos Fernández, Martina Lyons and Paul Komor (IRENA).

Disclaimer

IRENA
International Renewable Energy Agency

1 HOW IT WORKS

Regional markets require the harmonisation of market rules for electricity to flow freely in response to market-based price signals. The deeper the integration, the more rules needs to be harmonised. There are different stages of market integration:

- **Early stage of market integration**: Bilateral contracts
- **Shallow market integration**: + Harmonisation of wholesale market rules
- **Deep market integration**: + Harmonisation of ancillary service markets, and possibly capacity markets

2 BENEFITS

- Increased flexibility through expanding balancing area
- Advantages of spatial complementarity of VRE generation
- Co-ordinate generation planning
- Reduce system operation cost

3 KEY ENABLING FACTORS

- Physical interconnections with sufficient capacity
- Regional mindset, strong institutional arrangements and governance model
- Robust IT system for market operation

4 SNAPSHOT

→ The Western Energy Imbalance Market (EIM) in US helped to avoid curtailment of 760 TWh of RE and provide more than USD 565 million since its inception in 2014.

REGIONAL MARKETS

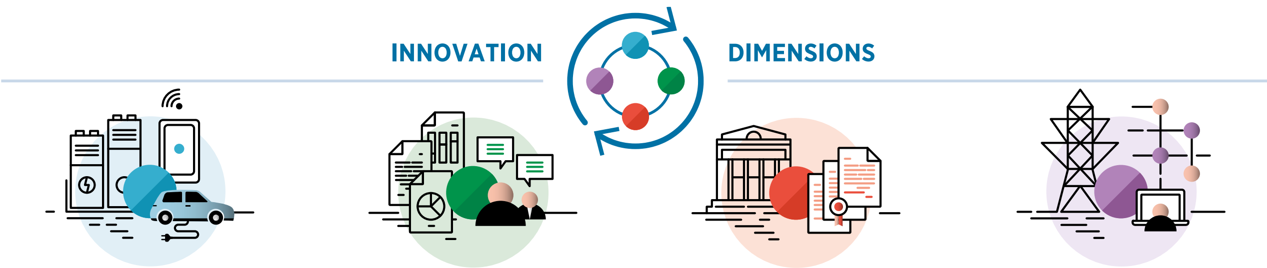
Coupling markets creates a **larger balancing area** with **wider resource diversity.**
This facilitates the integration of variable renewables.

ABOUT THIS BRIEF

This brief forms part of the IRENA project "Innovation landscape for a renewable-powered future", which maps the relevant innovations, identifies the synergies and formulates solutions for integrating high shares of variable renewable energy (VRE) into power systems.

The synthesis report, *Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables* (IRENA, 2019), illustrates the need for synergies between different innovations to create actual flexibility solutions for power systems. Solutions to drive the uptake of solar and wind power span four broad dimensions of innovation: enabling technologies, business models, market design and system operation.

Along with the synthesis report, the project includes a series of innovation landscape briefs, each covering one of 30 key innovations identified across those four dimensions. The 30 innovations are listed in the figure below.



ENABLING TECHNOLOGIES

1 Utility scale batteries
2 Behind-the-meter batteries

3 Electric-vehicle smart charging
4 Renewable power-to-heat
5 Renewable power-to-hydrogen

6 Internet of Things
7 Artificial intelligence and big data
8 Blockchain

9 Renewable mini-grids
10 Supergrids

11 Flexibility in conventional power plants

BUSINESS MODELS

12 Aggregators
13 Peer-to-peer electricity trading
14 Energy-as-a-service

15 Community-ownership models
16 Pay-as-you-go models

MARKET DESIGN

17 Increasing time granularity in electricity markets
18 Increasing space granularity in electricity markets
19 Innovative ancillary services
20 Re-designing capacity markets
21 Regional markets

22 Time-of-use tariffs
23 Market integration of distributed energy resources
24 Net billing schemes

SYSTEM OPERATION

25 Future role of distribution system operators
26 Co-operation between transmission and distribution system operators

27 Advanced forecasting of variable renewable power generation
28 Innovative operation of pumped hydropower storage

29 Virtual power lines
30 Dynamic line rating

This innovation landscape brief applies to liberalised, open electricity markets, where the vertical integrated utilities are unbundled and there is competition in electricity generation. It provides an overview of regional markets, a market design innovation, that allows electricity to be transported more easily within a larger balancing market area across several control areas. In this way, a wider geographic diversity of resources can be used to balance supply and demand by taking full advantage of weather and resource diversity and differences in load patterns.

The brief is structured as follows:

I Description

II Contribution to power sector transformation

III Key factors to enable deployment

IV Current status and examples of leading initiatives

V Implementation requirements: Checklist

I. DESCRIPTION

A regional market is the outcome of establishing a higher hierarchical level of organisation of several national, sub-national or local systems, so that their original spontaneous interactions become stronger and subject to well-defined, commonly agreed rules (Perez-Arriaga, 2013). In addition to the liberalisation of markets in the broader sense, the last two decades have witnessed a trend towards the creation of regional electricity markets via the integration of existent national markets. Some of the examples include the European Union's (EU's) Internal Electricity Market (IEM), the Central American Electricity Market (Mercado Regional de Electricidad, or MER), the Western Energy Imbalance Market (EIM) in the United States, the Australian National Electricity Market (NEM), the market in the Mekong Delta region in Viet Nam, the West African Power Pool (WAPP) and the South African Power Pool (SAPP).

The establishment of regional markets started long before the takeoff of VRE. Their role has been to enhance the security of supply and reduce costs as liberalised and integrated markets allow relatively free cross-border flows, enhance competition in power generation and supply, and offer more choices for consumers. Regional markets are gaining more importance, as these bring additional benefits to the grid integration of VRE. A well-integrated regional market can create locational and temporal[1] synergies between renewable energy sources and demand patterns across the entire region. Regional markets can also facilitate the investment planning in generation assets by exploring the existing advantages of different geographical locations, provided appropriate co-ordination rules and regulatory frameworks are in place.

The creation of a regional electricity market requires the harmonisation of market rules so electricity can flow freely in response to market-based price signals. There are different levels of regional market integration, as described in Table 1. Deepening the level of market integration requires the harmonisation of different market rules. Figure 1 depicts the relationship between increased market integration levels and the corresponding harmonisation needed for various market design features.

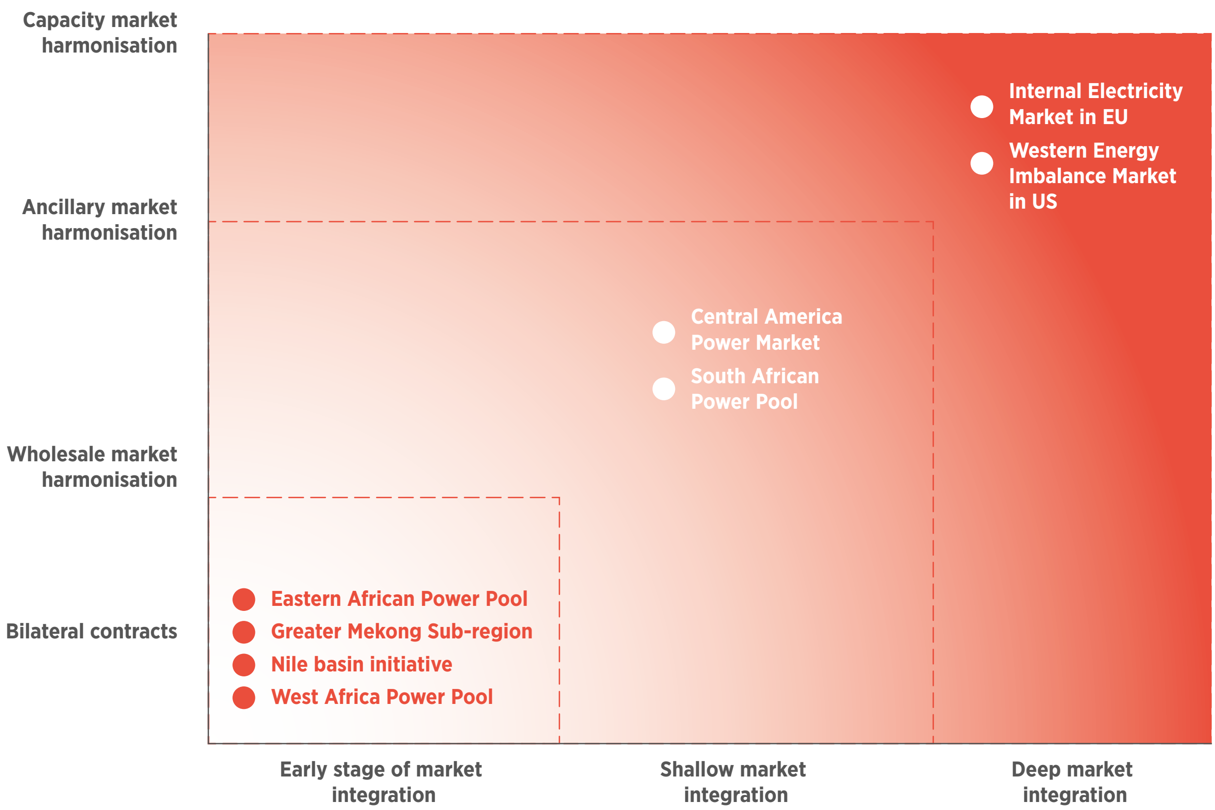
1 When participating electricity markets are not in the same time zone.

Table 1 Different levels of regional market integration

Market integration level	Interconnectivity level	Trading arrangements	Harmonisation rules
Early stage of market integration	Physical interconnection between two countries	Long-term, bilateral, over-the-counter (OTC)[3] power purchase agreements (PPAs)	Simple rules agreed for the operation of the interconnected system
Shallow market integration	Physical interconnection between several neighbouring countries	Long-term PPAs supplemented with short-term wholesale markets	Harmonisation of market rules, grid codes, and transmission tariffs
Deep market integration	Full synchronous operation of a multi-country interconnected system	Well-functioning markets with competition achieved through trading in different timeframes and various markets (OTC vs. power exchanges, capacity vs. power markets, day-ahead vs. intraday markets, etc.)	Regional regulatory agencies, regional market operators and harmonisation of market rules, grid codes, and transmission tariffs

Source: Adapted from ESMAP (2010)

Figure 1: Market integration levels depending on the regional market design



2 OTC trading refers to bilateral contracts signed outside an organised market place (*i.e.*, power exchange).

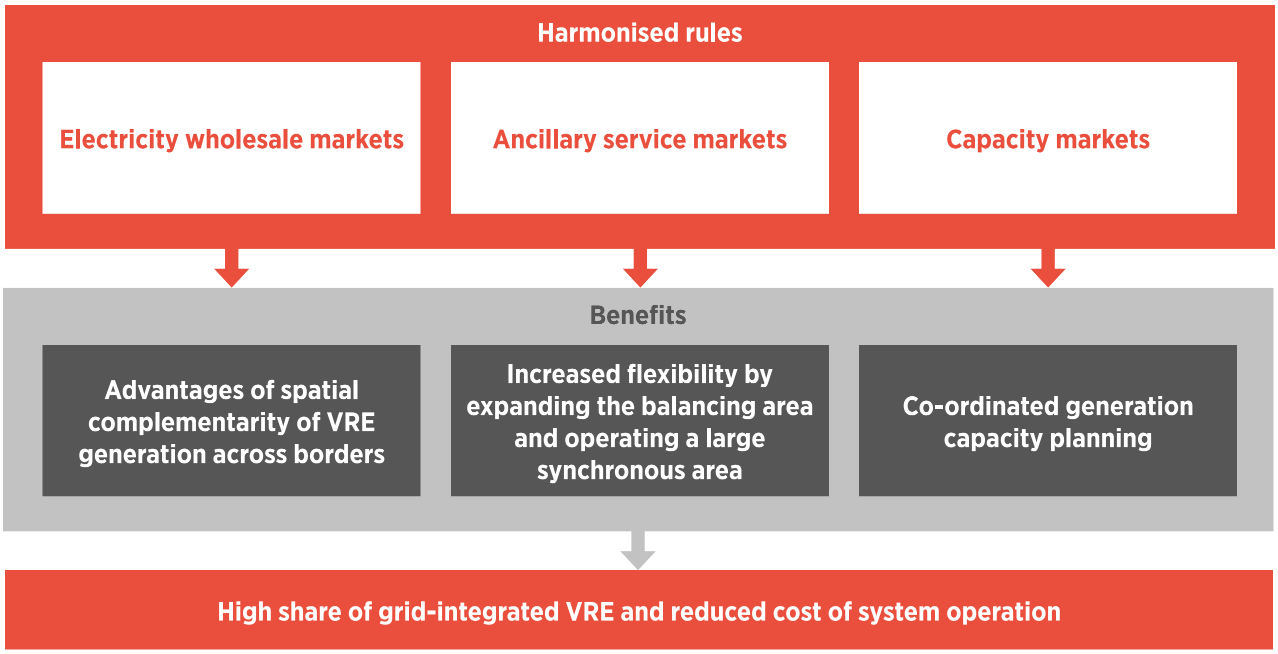
II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

In general, each jurisdiction lays down its own required standards for power quality and subsequently on the required quantity of reserve, as well as institutional and policy frameworks. A truly integrated regional market implies harmonised rules across different markets, as well as different trading time frames. For example, in the ideal case, a well-functioning and deeply integrated regional market would have harmonised rules across the entire region for the wholesale electricity market, ancillary service market and the capacity market.

Similarly, in the wholesale electricity market as well as the ancillary service market, all time frames (long term and short term) would have the same regulatory framework. A well-functioning regional market would require participating power systems to agree on various regulatory aspects, including time and space granularity, cost sharing and recovery, a strategic road map, and contractual details such as the co-operation between system and market operators, etc. (ENTSO-E, 2018a).

Harmonising rules among different markets improves flexibility in the power systems involved by increasing the trading opportunities for market participants, increasing the balancing area, reducing the balancing costs, taking advantage of complementarities between different renewable energy sources and helping to plan the best-suited generation capacity investment across multiple power systems. Figure 2 shows the key benefits of deeply integrated regional markets.

Figure 2: Benefits of deeply integrated regional markets



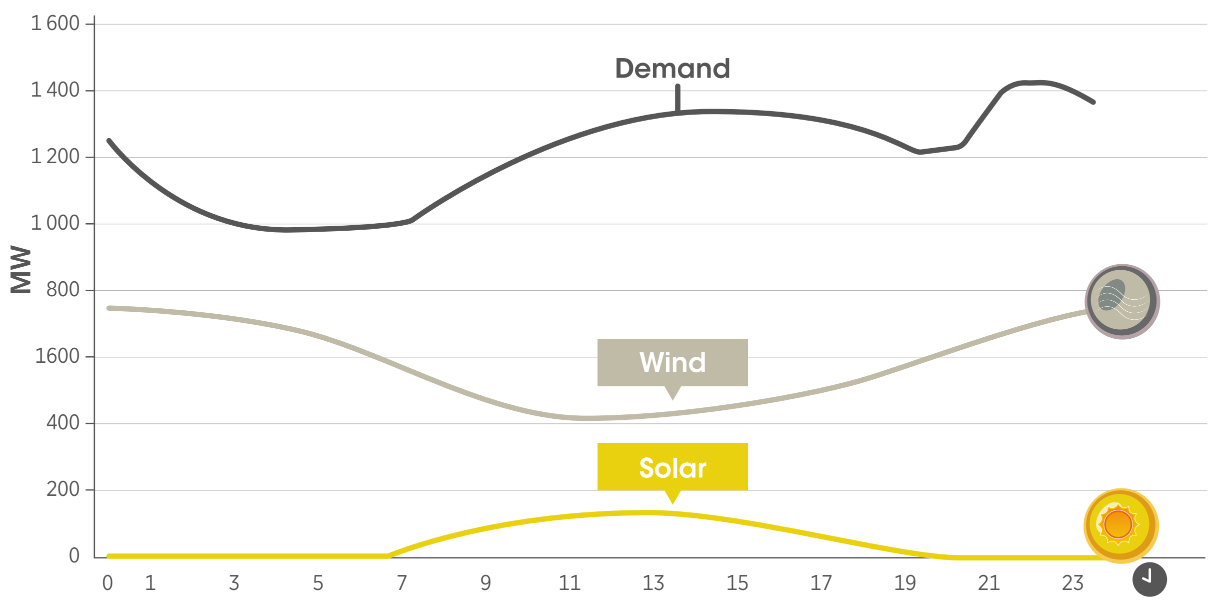
Advantages of the spatial complementarity of VRE generation across borders

Harmonised rules in the wholesale electricity markets, such as harmonised gate opening and closure times and market time units (scheduling intervals) of the day-ahead and intraday markets, allow all market participants in the region to submit their bids and offers within the same trading intervals, therefore increasing their trading opportunities. Considering the available transmission network capacity, supply and demand orders are matched more efficiently from an economic point of view within a wider regional market with different demand patterns, especially when the participating regions are in different time zones. This allows greater integration of wind and solar PV generation, as it reduces the VRE curtailments that are more likely to occur in smaller systems.

Regional markets enable synergies in spatial complementarities of VRE sources. For instance, when the wind does not blow in France, the sun might be shining in Spain. The possibility of importing electricity from Spain in such cases could reduce the need for local flexibility or balancing reserves in France. Better integration of markets allows power systems to take advantage of clean electricity sources beyond the borders of the system, allowing for the co-ordination between different renewable energy resources. (Newbery, Pollitt and Ritz, 2017).

Complementarity patterns have been observed between wind and solar at both daily and seasonal scales. Figure 3 shows the expected daily profile of demand, wind and solar PV generation in Uruguay. It highlights the complementarity between wind generation, which decreases during daytime hours, and solar generation, which increases during the same hours (IRENA, 2016). In regional markets, such complementarity can be even stronger because abundant solar resources are usually distant from abundant wind resources.

Figure 3: Daily complementarity between renewable energy sources in Uruguay



Source: Chaer et al. (2014) and IRENA (2016)

Central American countries have expanded their transmission systems to facilitate the incorporation of large amounts of renewable energy. They have jointly developed a regional transmission line, the Central American Electrical Interconnection System (SIEPAC), to enable international power exchanges (ECA, 2010). The SIEPAC was completed at the end of 2013 and allows for the trade of electricity among Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama. This facilitates the incorporation of large amounts of renewable energy by capitalising on different VRE resources and demand profiles in different countries. The region's dependence on hydropower has led to concerns about energy security, especially given recent extreme droughts that resulted in electricity shortages. The creation of SIEPAC, along with a higher penetration of renewable power, helped Central American countries to cope with droughts without any rationing of electricity[3] (Lippmann and DiPippo, 2017; IRENA, 2016). SIEPAC also resulted in the establishment of a regional electricity market, a regional system operator and a regional regulator.

Regional markets can help reduce the overall operation costs of power generation because they allow for the more efficient use of existing assets across countries, dispatching the most efficient generators in the region. Generators operate in a more stable point that is closer to their most efficient operation point, which leads to further reductions in operation costs. Such resource sharing and diversification of resources in regional markets lower the risk associated with a shortage of any given fuel, ensure the regional supply at a lower cost, and in some cases, even avoid expensive shortages.

Increased flexibility by expanding the balancing area and operating a large synchronous area

System balancing refers to actions taken by the transmission system operators (TSOs) to ensure that system frequency is maintained within a pre-defined range (Emissions-EUETS, 2009). Supply and/or demand may vary due to unexpected events (*e.g.*, an increase/decrease in power supply from conventional generators, VRE, weather-determined high-power demand, etc.), causing imbalances in the system. In this context, ancillary services are defined as services necessary for the operation of a system (ENTSO-E, n.d.) and can be clustered into frequency ancillary services (balancing), and non-frequency ancillary services (voltage control and black-start capability).

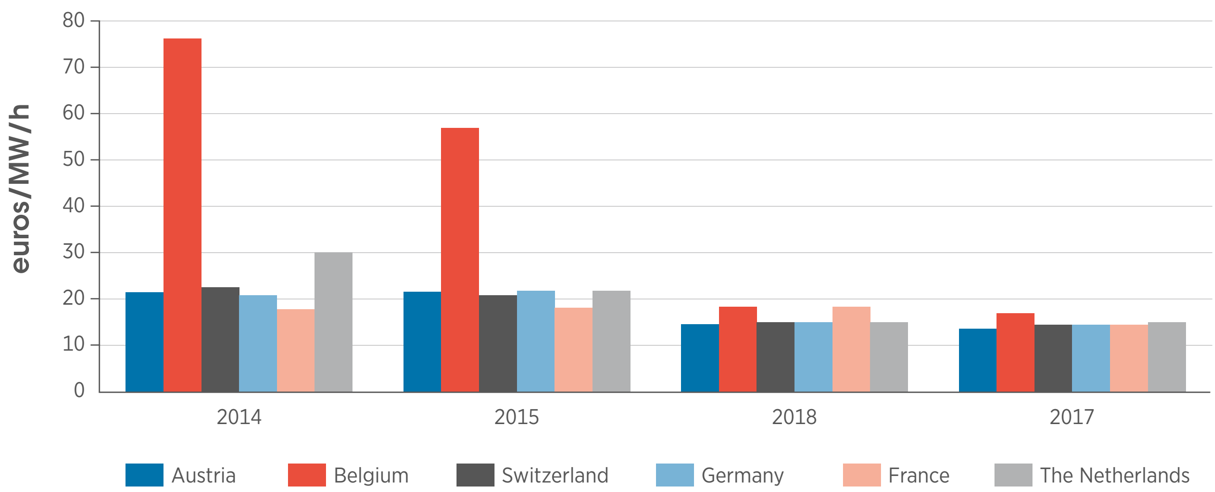
Trading ancillary services with neighbouring TSOs within a regional market is key to increasing the overall flexibility of the transmission system and reducing balancing costs. Large power grids can absorb more fluctuations in power demand and generation compared to smaller grids, leading to more flexibility in the system (Pariente-David, 2014). Regional markets result in a larger underlying power grid, which thereby helps to reduce the reserve requirements. The development of regional markets allows electricity to be transported more easily within a larger balancing area, meaning that more resources are available to be used to balance power supply and demand. Harmonising products and rules in the ancillary service market across different countries allows access to a broad range of services from an expanded balancing area, giving system operators more flexibility, which allows them to ensure the security of supply at a lower cost.

3 Central America is heavily dependent on hydropower and fossil fuel for power generation (Lippmann and DiPippo, 2017).

A regional balancing reserve market in deeply integrated regions can help reduce the overall power reserve requirements, as reserves are shared across the whole region. Several stakeholders in the EU, including the Agency for the Cooperation of Energy Regulators (ACER), national regulatory authorities, and TSOs within the European Network of Transmission System Operators for Electricity (ENTSO-E), developed a guideline on electricity balancing that entered into force in November 2017 (Commission Regulation, 2017). The European guideline on electricity balancing sets down the rules on the operation of balancing markets throughout the EU, referring to those markets that TSOs use to procure balancing services to keep the system balanced in real time. On top of that, the regulation provides opportunities for cross-border trading within such balancing markets. As such, this framework enables greater cross-border availability of resources for balancing the system and in turn lower costs for procuring these services.

Moreover, ENTSO-E is working on the implementation of an integrated market for balancing services in Europe, which is expected to ensure the security of the power supply while reducing the need for back-up generation (ENTSO-E, n.d.). ENTSO-E conducted a pilot to establish a common market for the procurement of frequency containment reserves (FCRs) based on the TSO-TSO model[4] in the following seven countries and involving the respective TSOs: Austria (APG), Belgium (Elia), Western Denmark (Energinet), France (RTE), Germany (50Hertz, Amprion, TenneT DE, TransnetBW), the Netherlands (TenneT NL), and Switzerland (Swissgrid). The pilot showed that with geographical extension, between 2014 and 2017, balancing capacity prices steadily decreased and converged across the markets involved in the FCR co-operation project, as illustrated in Figure 4.

Figure 4: Average prices of balancing capacity (from FCRs) in the markets involved in the FCR co-operation project



Source: ACER (2018)

4 The TSO-TSO model refers to a model for the exchange of balancing services exclusively operated by TSOs, as opposed to a TSO-balancing responsible party (BSP) model, in which a BSP has a contractual relationship with another TSO other than the TSO to which the BSP is connected.

Co-ordinated generation capacity planning

In the absence of well-functioning wholesale electricity markets or where a generation adequacy issue has been identified across a region, regional capacity markets can play an important role in co ordinating the investment plans for generation capacity. The harmonisation of rules in capacity markets across a region sends a clear price signal regarding the investment needs for capacity generation at a regional level, rather than sending several price signals at national or sub-national levels. Co ordinated planning across an entire region has several benefits, including the efficient use of renewable energy resources from areas where these are abundant, as well as the capitalisation on the spatial complementarity of such resources. Capacity-expansion models can take into account the regional integration of the system, the stochastic nature of the VRE and the ability of the system to address intermittency with minimal back-up reserves (Pariente-David, 2014).

Co-ordinated capacity planning among countries helps to lower capital investments to meet future demand. For instance, in the SAPP 2025 plan, 57 gigawatts (GW) of capacity was expected to be added at a cost of USD 89 billion (US dollar), which was USD 48 billion less than the total of the national power development plans to meet the same level of demand (ESMAP, 2010). On the contrary, if capacity markets are introduced at the national level in an unco-ordinated manner across a deeply integrated region with a well-functioning wholesale market, capacity markets could have a negative impact on the regional electricity-only market.

Regional markets can also help improve the financial feasibility of large power generators, which may otherwise not be doable. For instance, the Grand Inga project (a 20 000 MW hydro power project in the Democratic Republic of Congo), which is one of the largest clean energy power generation projects in the SAPP, will only be economically viable under the inter-country transmission capacity (IRENA, 2017). The same applies to large onshore and offshore wind projects, which may only be economically feasible if they serve the demand of a larger system.

Potential impact on power sector transformation

Regional markets bring several advantages, including better economic utilisation of the interconnections between countries and wider welfare benefits for end-customers. Efficient utilisation of the existent interconnection infrastructure helps reduce the short-term costs of integrating VRE into the power grid (Newbery, Pollitt and Ritz, 2017). Examples with potential positive impacts on power sector transformation, including enhanced security of supply, reduced system costs and efficient use of resources, are provided below:

- Across Europe, the successful exchange of balancing services resulted in the utilisation of imbalance netting[5] across borders, which covers more than half of the need for balancing energy in several European markets, including Austria, Germany, Latvia, Germany and the Netherlands. In these countries, **imbalance netting helped to avoid 83 %, 60 %, 55 %, and 51 %, respectively, of the system's balancing energy needs** in 2017. Overall, the potential welfare benefits from efficient imbalance netting and the exchange of balancing energy across European borders is estimated to be **EUR 1.3 billion per year**. In this context, the effective implementation of the harmonised rules set out in the Commission Regulation (EU) 2017/2195 establishing a guideline on electricity balancing would materialise these welfare gains (ACER, 2018), (Commission Regulation, 2017).

- Significant interconnection[6] with neighbouring countries (Germany, Norway and Sweden) allowed Denmark to integrate around **53 % of wind power** without significant curtailments in 2017 (IEEFA, 2018). Over the years, wind power generation has been curtailed only twice: for six to eight hours in 2008 and 2010, curtailing 200–300 megawatts (MW), due to an outage in one of the interconnectors (Danish Energy Agency, 2015). The excess wind power is traded with neighbouring countries, for example by using it to charge pumped hydro storage facilities (IEEFA, 2018).

- The Western Energy Imbalance Market (EIM) has helped to **avoid curtailment of almost 720 TWh of renewable energy** since its inception, thereby **avoiding the emission of 306 112 equivalent tonnes of carbon dioxide** (CO_2) (CAISO, 2018). The EIM has provided **USD 400 million in gross benefits** to market participants since its launch in November 2014 (Larson, 2018).

- The World Bank has estimated that the economic benefits of regional trade in the Western African Power Pool (WAPP) would reach **USD 5–8 billion per year** due to reduced operation costs while making power generation more sustainable by displacing baseload oil-fired power generation with cleaner sources of electricity such as natural gas, solar and hydropower (The World Bank, 2018).

- Exports of power to the United Kingdom from Ireland (via sub-sea interconnection) helped **reduce power curtailment by approximately 50 %** in 2013 (IEEFA, 2018). By 2017, Ireland's cross-border interconnections reached 7 % of total installed generation, compared to the EU target of 10 % by 2020 (although Ireland is expected to increase the interconnection to 18 % by 2020) (European Commission, 2017).

- The economic benefits of fully integrating the European market could be as high as **EUR 40 billion per year by 2030 in a high renewable energy scenario** (Newbery, Pollitt and Ritz, 2017).

5 Imbalance netting refers to the process agreed among TSOs of two or more load-frequent control areas which avoids the simultaneous activation of frequency restoration reserves in opposite directions.

6 Denmark has cross-border connection equivalent to 51 % of its total power generation capacity with target to increase the interconnection capacity to 59 % by 2022 (European Commission, 2017).

III. KEY FACTORS TO ENABLE DEPLOYMENT

Physical interconnections with sufficient capacity made available to the market

The underlying requirement for functioning regional markets (regardless of the market integration level) is the availability of sufficient transmission capacity among the participating countries. As mentioned, Denmark has low curtailment levels of VRE thanks to the interconnector capacity with neighbouring countries, which is nearly equal to the peak load of 6.5 GW. The EU target is for cross-border interconnections to reach 10 % of total installed generation by 2020 (European Commission, 2017). In its Ten Year Network Development Plan, ENTSO-E is proposing investments in transmission projects worth EUR 114 billion by 2030 that would result in annual savings of up to EUR 5 billion in generation costs (ENTSO-E, 2018b).

In addition to the construction of new interconnections, another aspect that enables the integration of regional markets is a sufficient level of transmission capacity made available to the market by the TSOs. For example, in the European wholesale markets, in 2017, the cross-zonal capacity made available for trading remained significantly below an estimated "benchmark capacity", *i.e.*, the maximum capacity that could be made available to the market while preserving operational security.

Regional mindset, strong institutional arrangements and governance model

Perhaps the most challenging issue in the design and implementation of a regional market is the shift from a "national/system mind-set" of institutions and consumers towards a "regional mind-set" with the prime objective of maximising the social welfare of the entire region while ensuring that each system participating in the regional market is better off within the regional market integration. Successful regional integration requires political buy-in along with strong institutional arrangements and a governance model to address any future issues that may lead to distrust among participating entities.

For instance, important savings are to be made when the security of supply is considered at the regional level rather than at the individual country level. This requires a high level of trust among countries that, in case of supply scarcity, neighbouring countries will share generation capacity according to established rules rather than giving priority to a single country's local demand. This represents a major challenge if every country installs local generation capacity to meet its demand without benefiting from the wider regional generation capacity, therefore reducing the potential welfare benefits derived from regional integration (Perez-Arriaga, 2013).

Regional planning of resources helps optimise capital investments in the generation and transmission network. Along with a strong governance model, formal endorsement from heads of participating countries or regions may increase trust and help with future investments, as has been done in WAPP (ESMAP, 2010). Participating countries need to strictly adhere to the regional framework to reap the benefits of the integrated regional market.

For the successful implementation of a well-functioning regional market and to create trust, the regulator is required to oversee and sanction activities of market participants that would violate the set of rules agreed regionally. The regulator would need to take proactive measures to prevent predatory pricing and other forms of unruly market conduct. Cross-border agreements among institutions (dealing with power sector-related issues on the national and regional levels) are essential for sustainable regional market operations (Oseni and Pollitt, 2016). Some form of regulatory oversight has made Nord Pool and MER successful power pools (Oseni and Pollitt, 2016).

For deeply integrated markets, an appropriate institutional arrangement is necessary to facilitate the co-operation and co-ordination required to align national regulatory frameworks. This institution must work in close co-ordination with relevant national-level entities and with electricity regulators and TSOs. The European regional market offers a good example: the Agency for the Cooperation of Energy Regulators (ACER) defines the guidelines for transnational electricity networks and markets, while national regulators set the rules for system operations in electricity markets within their jurisdictions. ENTSO-E, the European TSO representative body, further develops the frameworks, *i.e.*, the grid codes, ensuring overall alignment, which are then approved and implemented by the TSOs. Similarly, in the Central American Power Market, the CRIE (the Regional Commission for Electricity Interconnection) is the regulatory body for the regional market. The CRIE's board of commissioners is composed of one commissioner from each of the six countries.

Robust information technology for market and transmission system operation

Regional market operators are expected to handle orders from all participating countries, which need to be processed in a transparent manner and for which a robust information-technology (IT) system is essential. For example, the cross-border intraday (XBID) project in Europe has created an integrated platform based on the shared order book (SOB) concept of trading modules, the Capacity Management Module (CMM) and the Shipping Module (SM). The platform allows multiple exchanges across participating regions to trade power continuously on a centralised platform (Nord Pool, 2018).

With the increasing penetration of VRE, increasing the granularity of power markets in terms of time and space can help integrate more VRE into the grid. As the granularity increases, the operation of power markets becomes increasingly complex, especially within a wider regional market. Similarly, the number of bid and ask orders, as well as the number of transactions (contracts) is also expected to increase significantly once the power markets merge at a regional level. Calculation of the available cross-zonal capacity requires an extensive alignment, and the calculation process involves more parties compared to the process within one single market area (Nord Pool, 2018). Hence, market and system operators should have state-of-the-art IT systems that can provide higher computational power at a low cost.

As the market becomes more complex and automated, market operators need to ensure a clear and transparent methodology to price the power at different times and across different locations. Clear and transparent methodologies also help create confidence among market participants, especially those with long-term investments across the value chain (*e.g.*, in generation assets).

IV. CURRENT STATUS AND EXAMPLES OF LEADING INITIATIVES

Some of the key indicators of selected regional electricity markets have been captured in the Table 2.

Table 2 Leading initiatives of regional markets and key indicators

Regional market	Participating countries/systems	Year of establishment
Central America Power Market[1]	**6 countries:** Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama	2013
European Union[2]	**23 countries (day-ahead market):** Austria, Belgium, the Czech Republic, Germany, Denmark, Estonia, Finland, France, Great Britain, Hungary, Italy, Lithuania, Latvia, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Slovenia, Slovakia and Sweden	1990s (NordPool was created)
	14 countries (intraday market): Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, Norway, the Netherlands, Portugal, Spain and Sweden	2018 (XBID Project – intraday market)
Eastern Africa Power Pool[3]	**10 countries:** Burundi, the Democratic Republic of Congo (DRC), Egypt, Ethiopia, Kenya, Rwanda, Tanzania, Libya, Uganda and Sudan	2005
Greater Mekong Sub-region[4]	**6 countries:** Kingdom of Cambodia, Guangxi Zhuang Autonomous Region and Yunnan Province of the People's, Republic of China (PRC), Lao People's Democratic Republic (Lao PDR), Union of Myanmar, Kingdom of Thailand and the Socialist Republic of Viet Nam	1995
South African Power Pool (SAPP)[5]	**12 countries:** Angola, Democratic Republic of Congo (DRC), Tanzania, Malawi, Zambia, Zimbabwe, Mozambique, Swaziland, South Africa, Lesotho, Namibia, Botswana	1995
Western Energy Imbalance Market (EIM), United States[7]	**8 active members:** Idaho Power Company, Powerex, Portland General Electric, Puget Sound Energy, Arizona Public Service, NV Energy, PacifiCorp, CAISO and Balancing Authority of Northern California/SMUD	2014

Sources:
1. Navarrete (2016)
2. ENTSO-E (2018c)
3. The Eastern Africa Power Pool (2016); Olingo (2018)
4. Asian Development Bank (2016)
5. SAPP (2016)
6. Westerneim (2019)

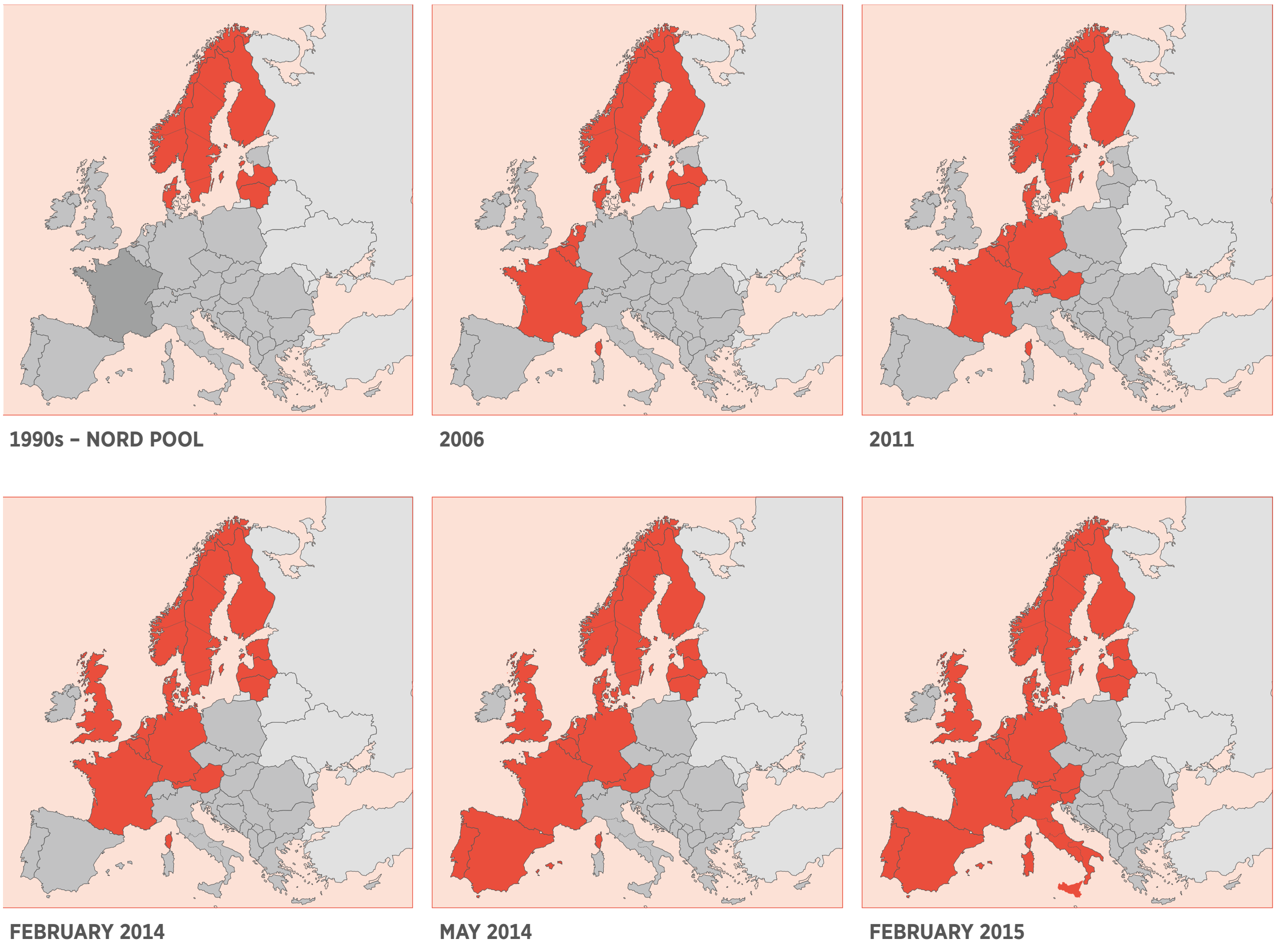
Total capacity	% penetration of VRE	Impact on VRE grid integration	Level of integration
16.5 GW (2016)	From 3 % in to 8.7 % in 2016	Increased the power generation from renewables, displacing generation from fossil fuel based plants	Shallow market integration
995 GW (2017)	14.7 % (2017)	Significant interconnection between Germany, Sweden and Norway allows Denmark to integrate ~49 % of wind power without significant curtailments Spatial complementarities between VRE in different countries and larger balancing area	Deep market integration
60.7 GW (2015)	n.a.	The Kenya and Ethiopia electricity transmission interconnector is expected to be completed by mid-2019, concluding the first phase of the region's power pool project	Early stage of market integration
118.9 GW (2012)	3 %	New interconnections expected to improve gird integration of renewables: • A North West pole connecting the PRC, Myanmar, and Thailand to replace coal and gas-fired power generation in the PRC and Thailand by hydro power from Myanmar (about 26 000 MW) • An East West pole to connect Thailand, northern Lao PDR, and northern Viet Nam to substitute Lao hydro for thermal generation (about 4 500 MW) • A Southern pole to connect southern Lao PDR to central Viet Nam, and to a lesser extent, Cambodia and southern Viet Nam to strengthen supply in these regions and to displace coal and possibly some gas-fired plants	Early stage of market integration
62 GW	n.a	A large hydro power project in the Democratic Republic of Congo (Grand Inga project: 20 000 MW) is economically viable only with interconnections (Lippmann and DiPippo, 2017)(IRENA, 2016)	Shallow market integration
		The EIM has avoided curtailment of 757 862 GWh since its inception (2014–2018), avoiding 324 284 eq. tonnes of CO_2 and has netted USD 564.88 million in gross benefits (2014–2018) for market participants	Deep market integration

Internal day-ahead market for electricity in the EU

In the EU, regional market integration is already well advanced in several aspects and further pan-European harmonisation of rules is ongoing (ACER, 2018). Significant progress has been made especially towards the implementation of single day-ahead coupling (SDAC) via the Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management (CACM), which sets the rules for co-ordinated European day-ahead and intraday markets (Commission Regulation, 2015).

The day-ahead market timeframe foresees a single day-ahead market coupling that enables cross-zonal transmission capacity to be used efficiently from an economic point of view. In 2018, day-ahead market coupling was implemented on 30 out of 42 EU borders (excluding the four borders with Switzerland), covering 23 European countries: Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Hungary, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden. The gradual integration of the European day-ahead market coupling is depicted in the figure below.

Figure 5: Gradual integration of the European regional wholesale market (day-ahead timeframe)



Source: ENTSO-E (n.d.)

Disclaimer: Boundaries shown on these maps do not imply any official endorsement or acceptance by IRENA.

Internal intraday market for electricity in the EU

An important step towards further integration of European wholesale markets across Europe was taken on 12 June 2018 with the go-live of the XBID project establishing a single intraday coupling (SIDC), which is one of the key elements of market design envisaged in the CACM Regulation. TSOs of 11 countries and 4 power exchanges (EPEX SPOT, GME, Nord Pool and OMIE) jointly started the XBID project, initially covering 14 countries.[7] A second go-live with further countries is foreseen in 2019, the objective being to extend the mechanism for XBID trading to all Europe and, potentially, interconnected countries.

The project is expected to increase liquidity in the intraday markets, as bid and ask orders that were not met in local markets can now be matched within the larger integrated regional market. This project is also expected to increase market efficiency since the cross-border transmission capacity allocation and energy matching process is being carried out (implicitly) at same time. The increased market liquidity and efficiency is expected to facilitate the integration of renewable energy into the energy market and therefore a better absorption of this energy into the grid. As it becomes challenging for market participants to be in balance after the closing of the day-ahead market, trading interest in the intraday market is increasing. Being balanced on the network closer to physical delivery time is beneficial both for market participants and for the power systems, among others by reducing the need of balancing reserves and the associated costs (NordPool, 2018).

Internal balancing market for electricity in the EU

Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing will play a crucial role in the further integration of the internal energy market across Europe (Commission Regulation, 2017). ENTSO-E conducted various cross-border electricity balancing pilot projects with the purpose of testing the feasibility of the European target model (*i.e.*, envisaged design for balancing markets), its intermediate steps, as well as evaluating the associated implementation impact and with the purpose to report on the experience gained.

For example, the **Frequency Containment Reserves (FCR) Cooperation** is a common market for the procurement and exchange of balancing capacity, which involves ten TSOs in seven countries: Austria (APG), Belgium (Elia), Germany (50Hertz, Amprion, TenneT DE, TransnetBW), Western Denmark (Energinet), France (RTE), the Netherlands (TenneT NL) and Switzerland (Swissgrid). As a result of this project, where FCR are procured through a common merit order list, FCR capacity prices have been steadily decreasing and converging across the participating countries.

The **Trans European Replacement Reserves Exchange (TERRE)** is the project selected by ENTSO-E to become the European platform for the exchange of balancing energy from Replacement Reserves pursuant to the guideline on electricity balancing, in which nine TSOs participate: France (RTE), Great Britain (National Grid), Italy (Terna), Portugal (REN), Spain (RED), Switzerland (SwissGrid), Czech Republic (ČEPS), Poland (PSE) and Romania (Transelectrica).

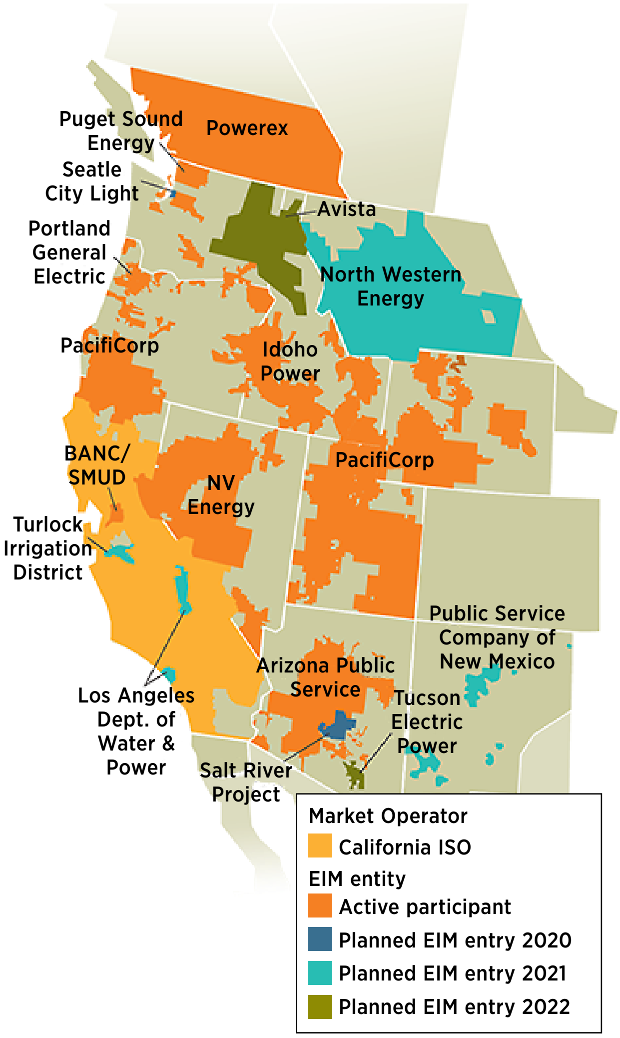
Other initiatives in Europe aim to net imbalances or exchange balancing energy across TSOs' scheduling areas, such as the project to exchange energy from aFRR (automatically activated frequency restoration reserves) between Austria and Germany. As a result, the overall cross-zonal exchange of balancing energy (including imbalance netting) almost doubled between 2015 and 2017 (ACER, 2018).

7 Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, Norway, the Netherlands, Portugal, Spain and Sweden.

Western Energy Imbalance Market (EIM), United States

In November 2014, the California independent system operator (CAISO) and PacifiCorp launched the Western Energy Imbalance Market (EIM) (PacifiCorp, 2019). The EIM is a "real time" market involving eight western states that trades the difference between the day-ahead forecast of power and the actual amount of energy needed to meet demand in each hour.

Figure 6: Western EIM active and pending participants



Source: Westerneim (2019)

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

Currently, there are nine active members[8] of this EIM with other five members[9] to join by 2021 (Westerneim, 2019). The Western EIM aimed to balance the power demand for every five minutes with the lowest cost energy available across the combined grid. The EIM leverages the flexible backup resources and demand across the combined grid. Apart from reducing the cost of power,[10] the Western EIM also improves the grid integration of renewable energy (Westerneim, 2019).

Western EIM also manages congestion on transmission lines to maintain grid reliability and makes excess renewable energy available at a low cost to participating utilities rather than forcing generating assets offline. The EIM has helped to avoid curtailment of almost 760 TWh since its inception (2014–2018), avoiding 324 284 eq. tonnes of CO_2 emission (CAISO, 2019) as Table 3 details.

CAISO's Western EIM showed benefits to the eight market participants of more than USD 62 million during the fourth quarter of 2018. That brought the total gross benefits attributable to the real-time western energy market to nearly USD 565 million since it began operation in 2014 (CAISO, 2019).

8 Idaho Power Company, Powerex, Portland General Electric, Puget Sound Energy, Arizona Public Service, NV Energy, PacifiCorp, CAISO and Balancing Authority of Northern California/SMUD.

9 Los Angeles Department of Power & Water, Salt River Project, Seattle City Light, Public Service Company of New Mexico, and NorthWestern Energy.

10 Western EIM has helped save USD 401 million since its inception in the second quarter of 2018 in power costs (CAISO, 2018).

Table 3 Maximising green energy, minimising greenhouse gases

Year	Curtailment avoided (MWh)	CO_2 emissions avoided (metric tonnes)
2015	31 082	13 220
2016	328 238	140 486
2017	161 097	68 951
2018	237 445	101 627
Total	**757 862**	**324 284**

Note: CAISO calculates CO_2 emissions reductions attributable to the EIM from avoided renewable energy curtailments based on a default emission rate of 0.428 metric tonnes CO_2/MWh.
Source: CAISO (2019)

Through increased co-ordination and optimisation, utilities like Western EMI can realise cost benefits and reduce carbon emissions. Sharing resources across a larger geographic area, even if it is only in real-time, continues to have the positive effect of reducing greenhouse gas emissions by using renewable generation that otherwise would have been turned off. Use of this energy to meet demand across the EIM footprint is likely replacing less clean energy sources. The quantified benefits from avoided curtailments of renewable generation from 2015 to date reached 324 284 metric tonnes of CO_2, roughly the equivalent of avoiding the emissions from 68 179 passenger cars driven for one year.

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS	**Hardware:** • Physical interconnection capacity among countries/systems in the region • Sufficient capacity made available by system operators to the market
	Software: • Robust IT system and higher computational power required to process bids from market participants across the entire region • Automation of various processes and information exchange related to scheduling of power plants
REGULATORY REQUIREMENTS	**Wholesale market and system operation:** • Strong institutional arrangements and a regulatory framework for cross-border co-ordination among various stakeholders (TSOs, market operators, regulators, etc.) • Co-ordination of scheduling and dispatch across different trading timeframes • Regional grid code to achieve co-ordinated operations and investment planning • For deeply integrated markets, a harmonised market design (*e.g.*, same gate opening and closure time, same scheduling intervals and products), while considering the specificities of participating countries • Effective, efficient and timely implementation of all legal provisions among participating countries • Clear, transparent and consistent pricing methodology • Surveillance of the market to ensure market manipulation does not occur
STAKEHOLDER ROLES AND RESPONSIBILITIES	• Establishment of regional regulatory agencies and market operators • Regional mindset and trust of policy makers, regulators, TSOs, market participants, etc.

ABBREVIATIONS

ACER	Agency for the Cooperation of Energy Regulators
aFRR	Automatically activated frequency restoration reserves
BSP	Balancing responsible party
CACM	Capacity allocation and congestion management
CAISO	California independent system operator
CMM	Capacity Management Module
CO_2	Carbon dioxide
CRIE	Regional Commission for Electricity Interconnection
EIM	Energy Imbalance Market
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
EUR	Euro
FCR	Frequency containment reserves
GW	Gigawatt
GWh	Gigawatt-hour
IEEFA	Institute for Energy Economics and Financial Analysis
IEM	Internal Electricity Market
IRENA	International Renewable Energy Agency
IT	Information technology
MER	Mercado Regional de Electricidad
MRC	Multi-Regional Coupling
MW	Megawatt
NEM	National Electricity Market
OTC	Over-the-counter
PPA	Power purchase agreement
SADC	Single day-ahead coupling
SAPP	South African Power Pool
SIDC	Single intraday coupling
SIEPAC	Central American Electrical Interconnection System
SM	Shipping Module
SOB	Shared order book
TERRE	Trans European Replacement Reserves Exchange
TSO	Transmission system operator
TWh	Terawatt-hour
USD	US dollar
VRE	Variable renewable energy
WAPP	West African Power Pool
XBID	Cross-border intraday

BIBLIOGRAPHY

ACER (2018), ACER/CEER – Annual report on the results of monitoring the internal electricity and natural gas markets in 2017, electricity wholesale markets volume, Agency for the Cooperation of Energy Regulators, https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/MMR%202017%20-%20ELECTRICITY.pdf.

Asian Development Bank (2016), *Greater Mekong Sub-region: Energy Sector Assessment, Strategy, and Road Map*, ADB.

CAISO (2019), *Western EIM benefits report – Fourth quarter 2018*, California ISO.

CAISO (2018), *Western EIM benefits report – Second quarter 2018*, California ISO.

Chaer, R., M. Gurin, E. Cornalino and M. Draper (2014), "Complementariedad de las Energias Renovables en Uruguay y valorizacion de proyectos para el filtrado de su variabilidad" [Complementarity of renewable energies in Uruguay and valuation of projects for filtering their variability], *Fundacion Julio Ricaldoni – Ingenieria en el Uruguay*, Montevideo.

Commission Regulation (2017), *(EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing*, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R2195&from=EN.

Commission Regulation (2015), *(EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management*, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R1222&from=EN.

Danish Energy Agency (2015), *System integration of wind power – Experiences from Denmark*, Danish Energy Agency.

ECA (2010), "The potential of regional power sector integration", *Central American Electric Interconnection System (SIEPAC): Transmission & Trading Case Study*, Economic Consulting Associates.

Emissions-EUETS (2009), E*lectricity balancing, European Union Emissions Trading Scheme*, www.emissions-euets.com/internal-electricity-market-glossary/593-balancing.

ENTSO-E (2018a), *Cross Border Intraday (XBID) trading solution pre-launch event, XBID, European Network of Transmission System Operators for Electricity*, Brussels.

ENTSO-E (2018b), *TYNDP 2018 executive report – Connecting Europe: Electricity, European Network of Transmission System Operators for Electricity*, Brussels, https://tyndp.entsoe.eu/Documents/TYNDP%20documents/TYNDP2018/consultation/Main%20Report/TYNDP2018_Executive%20Report.pdf.

ENTSO-E (2018c), *Statistical factsheet 2017, European Network of Transmission System Operators for Electricity*, https://docstore.entsoe.eu/Documents/Publications/Statistics/Factsheet/entsoe_sfs_2017.pdf.

ENTSO-E (n.d.), *Market committee, European Network of Transmission System Operators for Electricity*, www.entsoe.eu/about/market/.

ESMAP (2010), *Regional power sector integration, Energy Sector Management Assistance Program.*

European Commission (2017), *Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*, European Commission, Brussels.

IEEFA (2018), *Power-industry transition, here and now: Wind and solar won't break the grid, Institute for Energy Economics and Financial Analysis.*

IRENA (2016), *Renewable energy market analysis – Latin America,* International Renewable Energy Agency, Abu Dhabi.

IRENA (2017), *Adapting market design to high shares of variable renewable energy,* International Renewable Energy Agency, Abu Dhabi.

IRENA (2019a), *Innovation landscape for a renewable-powered future,* International Renewable Energy Agency, Abu Dhabi, http://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future.

Larson, A. (2018), "How does the Western Energy Imbalance Market work?", *Powermag*, www.powermag.com/how-does-the-western-energy-imbalance-market-work/?pagenum=2.

Lippmann, M.J. and R. DiPippo (2017), *Electricity generation in Central America: Some relevant comments on the importance of renewables, including geothermal*, GRC Bulletin.

Navarrete, M.E.R. (2016), *Estadísticas del Subsector Eléctrico de los Países del Sistema de la Integración Centroamericana (SICA) [Statistics of the electric sub-sector of the countries of the Central American Integration System (SICA)]*, CEPAL, https://repositorio.cepal.org/bitstream/handle/11362/42720/4/S1701275_es.pdf.

Newbery, D., M. Pollitt and R. Ritz (2017), "Market design for a high-renewables European electricity system", *EPRG Working Paper, Cambridge Working Paper in Economics 1726; EPRG Working Paper 1711*.

NordPool (2018), *Cross-Border Intraday: Questions & Answers (24 July)*, www.nordpoolgroup.com/globalassets/download-center/xbid/xbid-qa_final.pdf.

Olingo, A. (2018), "Phase One of regional power pool project set for completion by mid-2019", *The EastAfrican*, www.theeastafrican.co.ke/business/Phase-One-of-regional-power-pool-project-set-for-completion/2560-4699790-g706gj/index.html.

Oseni, M. and M.G. Pollitt (2016), "The promotion of regional integration of electricity markets: Lessons for developing countries", *Energy Policy*, Vol. 88, pp. 628–638.

PacifiCorp (2019), *Western Grid Coordination*, www.pacificorp.com/about/eim.html.

Pariente-David, S. (2014), *Successful grid integration of renewable energy: Integration is the name of the game, International Association for Energy Economics*.

Perez-Arriaga, I.J. (2013), *Regulation of the Power Sector, Springer-Verlag*, London.

SAPP (2016), *SAPP experience on regional power market development & operation, The Southern African Power Pool*, https://sari-energy.org/wp-content/uploads/2016/03/Session-3-Mr-Musara-BETA-SAPP.pdf.

The Eastern Africa Power Pool (2016), http://eappool.org/

The World Bank (2018), *Regional power trade in West Africa offers promise of affordable, reliable electricity (20 April)*, www.worldbank.org/en/news/feature/2018/04/20/regional-power-trade-west-africa-offers-promise-affordable-reliable-electricity.

Westerneim (2019), *Western Energy Imbalance market*, www.westerneim.com/Pages/About/default.aspx.

www.irena.org

IRENA

International Renewable Energy Agency

IRENA
International Renewable Energy Agency

REGIONAL MARKETS
INNOVATION LANDSCAPE BRIEF

IRENA HEADQUARTERS
P.O. Box 236, Abu Dhabi
United Arab Emirates

www.irena.org