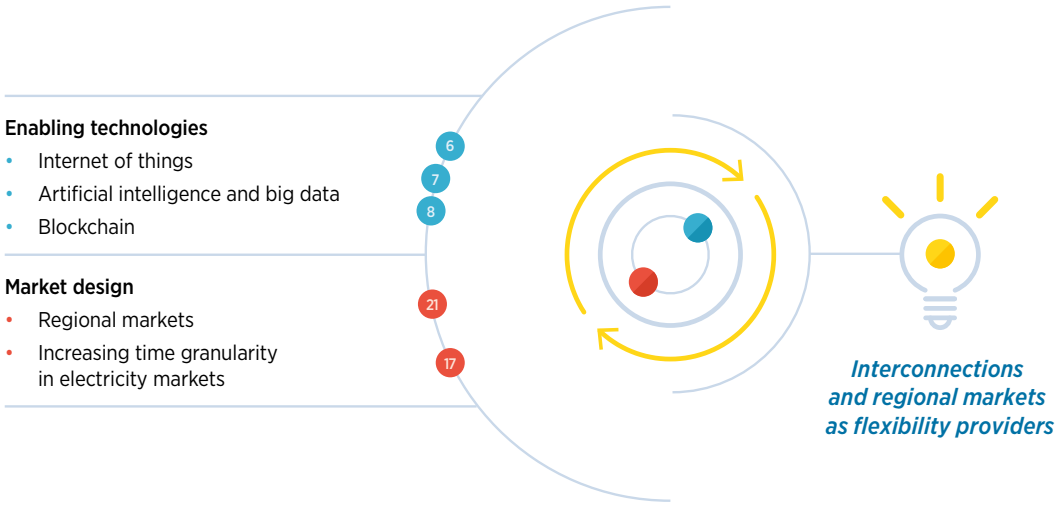
SOLUTION III

Interconnections and regional markets as flexibility providers

Figure: Synergies between innovations for unlocking flexibility though interconnections and regional markets



Creating a regional market by taking advantage of the interconnections between power systems is a very effective way of increasing flexibility in power systems. Increased transmission capacity and interconnections allows electricity to be transported more readily within a balancing area, meaning that more of an area's resources can be used to help balance supply and demand. Consequently, operators in different systems can buy and sell electricity and other grid services from one other, creating regional markets (Aggarwal and Orvis, 2016).

In terms of **market design**, creation of the regional electricity market will require harmonisation of the rules of all participating markets to allow electricity to flow freely in response to price signals. Truly integrated regional markets imply harmonised rules in the wholesale market, the ancillary service market and the capacity market across the region. In general, when a diverse portfolio of energy resources is balanced over a wide geographical area, fluctuations in the output tend to be localised, greatly minimising variability in the electric grid. Also, regional markets take advantage of the spatial complementarities among renewable energy sources. *(Key innovation: Regional markets)*

There are multiple ways to improve co-ordination among different systems, such as:

- **Reserve sharing**, whereby multiple balancing-area authorities maintain, allocate and supply the same set of operating reserves for each balancing area.
- **Co-ordinated scheduling**, in which balancing-area authorities exchange energy over shorter time scales (short-term dispatch on a 5-minute to 1-hour time scale). This increases dispatch efficiency by making available a larger array of resources for commitment. Co-ordinated scheduling requires increased communication and planning and the design of market mechanisms to compensate participants for energy production.
- **Consolidated operation**, or the merging of two or more balancing areas into one system operator. This combines all of the time scales of system operation including unit commitment (24 hour), short term dispatch (5 minutes to 1 hour) and reserves provision (Zaman, 2018). *(Key innovation: Increasing time granularity in electricity markets)*

Enabling technologies can help a regional market operator to handle orders from all participating countries in a transparent manner. With increasing penetration of VRE, increasing granularity of the power market in terms of time and space can help in integrating more VRE in the grid. As the granularity increases, the modelling of power markets becomes increasingly complex. Interlinking power markets in a particular region can lead to further complexity, as the market/system operator needs to ensure the participating country's energy security before power can flow through the interconnections. The number of bidders and contracts also will increase greatly once the power markets merge.

Robust IT systems are essential for the market operator to process the orders efficiently and seamlessly. Digital innovations such as the Internet of Things, artificial intelligence and big data can play an important role in managing that complexity. Blockchain technology, as an interoperable layer of technology that allow different parts of the system to communicate at a lower cost, might facilitate transactions and payments in a large regional market, with many actors involved. *(Key innovations: Internet of Things; Artificial intelligence and big data; Blockchain)*

MORE THAN 700 000 GWh
Avoided curtailment (2014-2018)

49 %
WIND GENERATION in Denmark due to interconnections

50 %
CURTAILMENT REDUCTION due to interconnection

Impact on VRE integration:

- **715 405 GWh of avoided curtailed renewable energy in four years due to the regional market, meaning 0.5% of total VRE generation in California, US.**

The Western Energy Imbalance Market helped avoid curtailment of 715 405 GWh of renewable energy from 2014 to mid-2018, avoiding emissions of 306 112 tonnes of carbon dioxide-equivalent (CAISO, 2018).

- **49% wind power integrated into Denmark's power system due to interconnections.**

Significant interconnection with neighbouring countries (Germany, Sweden and Norway) allows Denmark to integrate around 49% wind power without major curtailment. Between 2008 and 2015 wind power generation was curtailed only twice (by 200 MW to 300 MW for 6 to 8 hours, in 2008 and in 2010) due to outage in one of the interconnectors (DEA, 2015). The excess wind power is used or stored as pumped hydropower storage by neighbouring countries (IEEFA, 2018).

- **50% reduction in power curtailment in Ireland due to interconnection with the UK.**

Export of power from Ireland to the UK (via two sub-sea interconnections) helped reduce power curtailment by an estimated 50% in 2013. Ireland has limited cross-border interconnection equivalent to just 7% of its total installed generation, which is below the target for all EU Member States of 10% by 2020 (IEEFA, 2018).

- **Regional markets unlock synergies among renewable energy generation in Europe.**

Better use of current interconnections and the deployment of new ones provides various advantages such as increased flexibility of the European system by exploiting access to hydro reserves in Norway, and by predictable solar power generation in countries like Italy, Spain and Greece (Neuhoff and Boyd, 2011).

EUR 260 MILLION
SAVINGS in Germany due to TSOs co-operation

UP TO USD 8 BILLION
ANNUAL SAVINGS due to regional trade in West Africa

EUR 40 BILLION
ANNUAL BENEFIT for integrating EU market

UP TO USD 208 MILLION
ANNUAL SAVINGS for trading balancing services within US

Impact of interconnections and regional markets on operation costs:

- **Annual savings of EUR 260 million due to increased co-operation among transmission system operators in Germany.**

The German regulatory agency's instruction to increase co-operation among transmission system operators and to collectively procure various types of balancing power from generation companies is expected to save around EUR 260 million per year (Knight, 2010). Annual re-dispatch, due to congestion, costs of EUR 138.2 million in Germany. Co-ordinating the use of transmission capacities renders annual costs of EUR 56.4 million, resulting in considerable savings on re-dispatch (DIW, 2013).

- **Annual savings of USD 5 billion to USD 8 billion due to regional trade in the Western African Power Pool.**

The World Bank estimated that the economic benefit of regional trade in the Western African Power Pool would be around USD 5 billion to USD 8 billion per year due to the reduced cost of operations while making power generation more sustainable, displacing baseload oil-fired power generation with cleaner sources of electricity such as natural gas, solar and hydropower (World Bank, 2018).

- **Economic benefit of EUR 40 billion per year by 2030 from integrating the European market** in a high renewable energy scenario (Neuhoff and Boyd, 2011).
- **Savings of USD 72 million to USD 208 million per year for trading balancing services between regions in the US.**

Special markets are developing in the US to trade grid balancing services between regions that to date have been operated independently from one another. Without needing to build new transmission capacity, but just simply by allowing trade between regions, is expected to save customers USD 72 million to USD 208 million per year (Aggarwal and Orvis, 2016).

IMPLEMENTED SOLUTION

Southern African Power Pool (SAPP)

The Southern African Power Pool (SAPP) was created in August 1995 to promote regional co-operation and co-ordination in the planning and operation of the electricity business (Beta, 2016). Currently the SAPP includes 12 Southern African Development Community (SADC) countries[3]. The pool has a total installed generation capacity of 62 GW, planned generation capacity (2015-19) of 23.6 GW and a peak demand of 55 GW. Primarily, the SAPP uses the cheapest source of power generation in the region to meet demand.

An assessment done by IRENA on the SAPP concluded that by 2030 the share of renewable energy can increase from 10% to 46%. This would mean that around 80% of the new capacity addition from 2010 to 2030 would be related to renewable energy technologies. The financial investment required in enhancing the interconnections would be minimal (only 0.2% of total investment required) compared to the resulting benefits of international power trade. One of the largest clean energy power generation projects in the region is the Grand Inga project in the Democratic Republic of the Congo. This 40 000 MW hydropower project can be economically viable only if the inter-country transmission capacity is enhanced.

Western Energy Imbalance[4] Market (EIM), US

In November 2014 CAISO and PacifiCorp launched the western Energy Imbalance Market (EIM) (PacifiCorp, 2018). Currently the EIM has eight active members[5], and four new members[6] are to join by 2020. The western EIM was aimed at balancing the power demand for every five minutes with the lowest-cost energy available across the combined grid. It leverages the flexible back-up resources and the demand across the combined grid. Apart from reducing the cost of power[7], the western EIM also improves the grid integration of renewable energy (EIM, 2018). The EIM has helped to avoid the curtailment of 715 405 GWh since its inception (up to the first two quarters of 2018), avoiding 306 112 tonnes of carbon dioxide-equivalent emissions (CAISO, 2018c).

XBID Project in Europe

The transmission system operators of 11 countries, along with the power exchanges EPEX SPOT, GME, Nord Pool and OMIE, started a joint initiative – single intraday coupling (known under its commercial name as the XBID project) – within the framework of European Commission Regulation 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management (CACM Guideline). The XBID project is aimed at creating a joint, integrated intraday cross-border market. The project went live in June 2018 with 14 countries[8]. It is expected to increase liquidity in the intraday markets, especially for newly joined markets, as bids/orders that were not met in local markets can now be matched with the larger integrated market.

This project also is expected to increase market efficiency since the capacity allocation and energy matching process are being done at the same time implicitly. The increased market liquidity and efficiency are expected to better facilitate the market integration of renewable energy with the grid. Also, since more resources are available in the integrated market, the need for power reserves is expected to decrease, leading to a decreased cost of power (Nord Pool, 2018). The remaining countries in the EU and in Southeast Europe are expected to join in the coming years.

3 Angola, Botswana, the Democratic Republic of the Congo, Eswatini, Lesotho, Malawi, Mozambique, Namibia, South Africa, United Republic of Tanzania, Zambia and Zimbabwe.

4 The "imbalance market" in the US is called the "balanced market" elsewhere.

5 Idaho Power Company, Powerex, Portland General Electric, Puget Sound, Arizona Public Service, NV Energy, PacifiCorp and CAISO.

6 Balancing Authority of Northern California / SMUD, Los Angeles Department of Power & Water, Salt River Project, Seattle City Light.

7 The western EIM has helped save USD 401 million in power costs from its inception to the second quarter of 2018 (CAISO, 2018c).

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

SUMMARY TABLE: BENEFITS AND COSTS OF INTERCONNECTIONS AND REGIONAL MARKETS AS FLEXIBILITY PROVIDERS

Interconnections and regional markets as flexibility providers	Low	Moderate	High	Very high
BENEFIT				
Potential increase in system flexibility				
Flexibility needs addressed	from seconds to days (with a big enough region, regional markets can deliver flexibility over longer time frames)			
COST and COMPLEXITY				
Technology and infrastructure costs				if interconnections are not in place
Required changes in the regulation framework		to partially integrate markets	to fully integrate markets	
Required changes in the role of actors		co-ordination between transmission system operators and market players in different markets – for partially integrated markets	co-ordination between transmission system operators and market players in different markets – for fully integrated markets	
Other challenges	• Political and regulatory challenges • Regional mindset and trust, strong institutional arrangements and governance model			

This document is extracted from a longer report:

IRENA (2019), ***Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables.*** International Renewable Energy Agency, Abu Dhabi (**ISBN 978-92-9260-111-9**).

The full report and related materials are available on the IRENA website (**www.irena.org**).