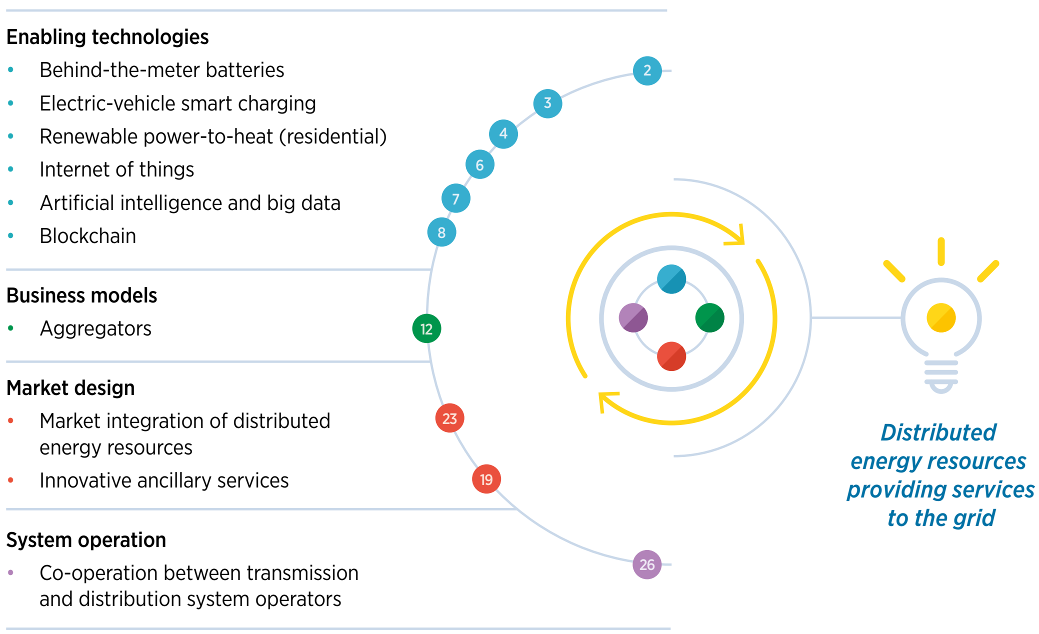
SOLUTION VI

Aggregating distributed energy resources for grid services

Figure: Synergies between innovations that permit grid services based on distributed energy resources



Distributed energy resources consist of various resource types and technologies that may be located at low- to medium-voltage networks, including distributed generation plants such as rooftop solar PV, and other **enabling technologies** such as behind-the-meter batteries, EVs, residential heat pumps and demand response, among others. *(Key innovations: Behind-the-meter batteries; Electric-vehicle smart charging; Renewable power-to-heat)* In most of the systems, these resources are operated based on a "plug-and-forget" approach. With further deployment, this approach can harm the system.

Regarding **market design**, an emerging, powerful solution to increase grid flexibility is the better management of distributed energy resources to respond to the system's overall condition. A key innovation to achieve this is to enable these resources to participate in the wholesale market, the ancillary service market and the capacity market (if established) and be exposed to market price signals. This can be done either via aggregators or by decreasing the capacity limit in such markets. Distributed energy resources should be allowed to participate in the day-ahead and the intraday energy markets, in the same way that supply-side generators bid in these markets.

Some wholesale market operators in the US have experienced success with this approach. For example, PJM, the largest market operator in the country, has successfully enabled demand response in order to bid into its ancillary service markets to provide regulation services. ERCOT gets only half of its spinning reserves from demand response. In December 2017 the NYISO released a concept proposal for market design that would enable the participation of distributed energy resources in the wholesale as well as the ancillary service markets. As per this proposal, distributed energy resources will be treated in the same way as other market resources. They will be able to participate in capacity reserve markets, regulation service markets, etc., either directly or via the aggregators of the small-scale distributed energy resources (<100 kW) (NYISO, 2017). *(Key innovations: Market integration of distributed energy resources; Innovative ancillary services)*

- Allowing distributed energy resources to participate in wholesale markets would turn consumers into active participants, with incentives to act to the benefit of the entire system and facilitating the integration of these renewable energy generators into the system. To allow this interaction, innovations in **system operation** are needed: distribution companies may act as market facilitators by technically validating the offers submitted by the distributed energy resource to the upstream markets, and ensuring that no distribution constraints are violated.

This role would be similar to what a system operator does today with the wholesale market results. Close co-operation and co-ordination between transmission and distribution system operators in the electricity system becomes key for taking advantage of the increasing flexibility options available in a decentralised system. As electricity flows are changing significantly, and as more and more balancing reserve capacity is located at the distribution level, the distribution system operator needs to co-operate with the transmission system operator responsible for balancing the entire system. *(Key innovations: Co-operation between transmission and distribution system operators)*

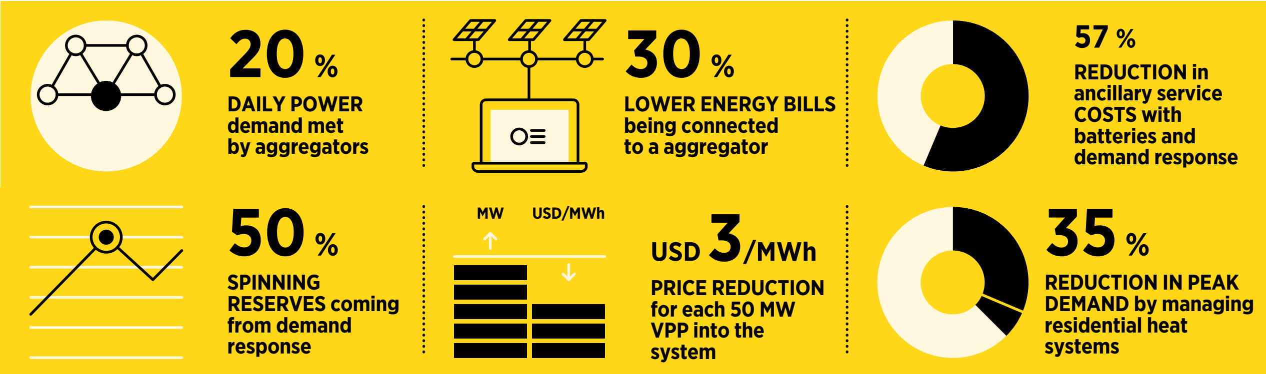
- The amount of voltage or frequency support provided individually by different resources can be small. **Business models** that enable the aggregation of these resources can effectively make them behave like a single, large, predictable source by co-ordinating the behaviour of a large number of distributed devices, using ICT devices (the concept of virtual power plants, or VPPs). A VPP is basically a system that relies on software and a smart grid to remotely and automatically dispatch and optimise the distributed energy resources. In orchestrating distributed generation, solar PV, storage systems, controllable and flexible loads, and other distributed energy resources, VPPs can provide fast-ramping ancillary services, replacing fossil fuel-based reserves. PJM in the US shows that 80% of the distributed energy resource capacity comes through VPPs. *(Key innovation: Aggregators)*

- Digital **enabling technologies** enable distribution automation that is needed to manage the unintended consequences of decentralised assets, such as reverse power flows. However, this may not be enough. Direct control over distributed energy resources, through VPPs, will better enable grid operators to balance intermittency and power flows. Digital systems will support this process by improving the monitoring of end-devices and the data integration among utility systems. Distribution automation and digital systems are already being introduced to the grid, with distributed energy resource management systems (DERMS) and VPPs close behind.

For example all Nordic countries are moving towards the implementation of data hubs for electricity meter data and market processes. Governments and regulators in Denmark, Finland, Norway and Sweden have given transmission system operators the responsibility of introducing a data hub for each of the electricity retail markets. The Danish data hub is fully implemented and handles all communication between suppliers and the distribution system operators. The Norwegian data were scheduled to go live in February 2019. According to the respective national transmission system operators, the Finnish data hub will go live in spring 2021 and the Swedish data hub in the beginning of 2021 (NordREG, 2018).

The data hubs will connect all of the smart meters on the distribution network, making it possible to extract information on what is going on in the network. This will reduce the cost of billing and, more importantly, make it possible to use the information to run the system more efficiently. Aggregators will use this information and create services that can serve both the customers and the grid, extracting more flexibility from consumers. This would digitalise demand in such a way that it would be manageable through markets and aggregators.

Machine learning is still in the experimental stages. Blockchain technology can aid in making the process more efficient. *(Key innovations: Internet of Things; Artificial intelligence and big data; Blockchain)*



Impact on demand:

- **20% of daily power demand can be met and 30% savings on energy bills can be achieved by aggregators in South Australia.**

The South Australian government and Tesla are developing a network of 50 000 home solar PV connected into a aggregator. The VPP is expected to meet around 20% of South Australia's average daily power demand (250 MW). Additionally, the new power plant is expected to lower energy bills for participating households by around 30%, and it will benefit all South Australians with lower energy prices and increased energy stability (Government of Australia, 2018).

- **A field trial conducted with PowerMatcher Suite in the Netherlands showed that peak demand can be reduced by 30% to 35% by managing heat systems (micro CHP and heat pumps) (TNO, 2016).**

Impact on ancillary service procurement:

- **57% reduction in ancillary service procurement in Eastern Australia by allowing the participation of batteries and demand response.**

In Eastern Australia's National Electricity Market (NEM), demand response is playing an increasingly important role in facilitating the renewable energy transition: approximately 180 MW of new demand-response resources have entered the ancillary service markets in the first half of 2018. NEM allowed independent distributed energy resource aggregators to bid into the NEM's Frequency Control Ancillary Services (FCAS) markets for the first time beginning in July 2017. The entry of the new utility-scale battery (known as the Hornsdale Power Reserve) and distributed energy resources into the markets were the major drivers behind a 57% reduction in FCAS costs between the fourth quarter of 2017 and the first quarter of 2018 (Grover, 2018).

- **50% of spinning reserves are coming from demand response in the US ERCOT system, and 10% of resource adequacy needs are covered by demand response in the PJM system.**

PJM has successfully enabled demand response to bid into its ancillary service market to provide regulation services. Also, PJM meets approximately 10% of its total resource adequacy needs from demand response. ERCOT gets half of its spinning reserves from demand response.

Impact on energy costs for consumers:

- **Reduction of USD 3/MWh in the wholesale price for each additional 50 MW of capacity brought into the system with the VPP.**

In South Australia the wholesale price is estimated to drop by around USD 3/MWh for all customers with each additional 50 MW of capacity that is brought onto the system via the VPP. The Australian VPP Tesla proposal could reduce the wholesale price by around USD 8/MWh, or around USD 90 million per year across all South Australian customers, which means 30% of the total energy bill (Frontier Economics, 2018).

Deferred investments in generating capacity:

- **The US Energy Information Administration estimated the cost of a new coal power plant at between USD 2 934 and USD 6 599 per kW depending on the technology used, and the cost of setting up a gas-fired plant at between USD 676 and USD 2 095 per kW.** VPPs can provide financial benefits to asset owners of distributed energy resources by maintaining demand and supply balance at a cost of around USD 80 per kW (Enbala, n.d.).

IMPLEMENTED SOLUTION

The VPP Next Kraftwerke, providing grid services to Elia (Belgium)

Belgium has involved demand-response solutions in its daily electricity market operations in a practical manner. The electricity transmission system operator Elia accepts distributed energy resource capacity to compensate for the mismatches between production and peak power demand, in which industrial customers are given primary importance. Transmission and distribution system operators have collaborated to develop a centrally shared IT platform, which enables the sharing of all of the data related to procuring distributed energy resources for flexibility. Through this data hub, all users and generators connected to the distribution/transmission grid can provide flexibility services to the system operators on a daily basis (Elia, 2018).

Distributed energy resource aggregator companies, such as REstore and Next Pool, provide the required capacities to Elia. This is done under stress conditions, in which hundreds of megawatts have already been contracted, in order to add flexibility to Belgian system operations. REstore aggregates flexible industrial capacities – 1.7 GW in total – and constantly monitors the grid load. At peak demand moments, companies in REstore's portfolio help to maintain grid balance by load shifting.

Through digitalisation, Next Kraftwerke is aggregating 5 000 energy-producing and energy-consuming units in the VPP Next Pool. With a total capacity of over 4 100 MW (not only in Belgium) the VPP trades the aggregated power on different energy spot markets. The VPP contributes substantially to stabilising the grid by smartly distributing the power generated and consumed by the individual units in times of peak load.

Transmission system operators, such as Elia, use control reserve to balance the electricity system. Secondary reserves need to be fully activated within 7.5 minutes and are the most important balancing product for Elia. To test whether the aggregators can provide secondary reserves in a comparable quality as the current units, a pilot project was conducted in 2017 in which Next Kraftwerke and the other participants proved that VPPs are able to fulfill technical requirements (Trilations, n.d.).

In April 2018 Elia launched its first blockchain pilot project, exploring the opportunities offered by blockchain technology as a payment system to address the business side of such complex, rapid transactions. This would facilitate remunerating the distributed energy resources for the services provided. If the pilot project proves successful it will constitute a major step forward towards establishing a Belgian electricity grid that offers a wide variety of decentralised and sustainable energy sources. This is merely an example of how digitisation can drastically change the energy sector in the coming years/decade.

Sonnen Baterie provides grid services in Germany

The sonnenCommunity is an aggregator in Germany consisting of about 10 000 customers with battery storage, solar PV generation, or both. Launched in 2015 the sonnenCommunity was used mostly for peer-to-peer trading within the VPP; however, in summer 2017 the VPP became available to the power grid to provide frequency regulation. Compared to other alternatives, such as pumped hydro storage, this distributed "virtual" storage resource can react very quickly (sub-second), making it a great provider of primary frequency services.

A small part of this storage is made available to the German power grid. This would therefore help reduce wind curtailment, by charging the storage batteries when there is oversupply. This reduces both variability in renewable generation and expensive grid expansion requirements. By being paid for these benefits via the frequency response market, the sonnenCommunity provides battery owners with "free" electricity in return. Since the battery is needed only sporadically, for a few minutes a week, the availability, performance and life span of the battery are practically unaffected.

In May 2017 Sonnen partnered with the German grid operator TenneT to launch the pilot project Sonnen eServices. This project integrated batteries into the power system via a blockchain solution (developed by IBM). Re-dispatch measures are necessary in Germany, where the wind energy produced in the north cannot be transported to the industrial centres in the south of the country. In this pilot project, a network of residential solar batteries will be made available to help reduce the limitations imposed on wind energy at times of insufficient transport capacity. In 2016 the measures to manage grid congestion cost Germany around EUR 800 million, a large part of which was for wind curtailment (Grey Cells Energy, 2018).

The blockchain presents the operator from TenneT with a view of the available pool of flexibility, ready to be activated with the push of a button. After this, the blockchain records the batteries' contribution. Blockchain technology could be a crucial enabler in documenting, verifying and securing transactions within a future power system composed of millions of small, decentralised power sources, including both prosumers and consumers. The platform is designed to ensure the verifiability and transparency of the transactions made by the small-scale batteries. It simplifies the way that suppliers of locally distributed flexible energy can provide services to support power grid operators in the future. It also is being tested to ensure that it can fulfil TenneT's requirements for data security, restricted access and privacy (TenneT, 2017b).

Tesla's VPP contributes to renewable energy integration and system stability in South Australia

Tesla proposed the development of a 250 MW VPP – the world's largest built – to contribute to stabilising the Australian state's electricity infrastructure and to improve the security and reliability of the grid in an area where nearly half the electricity comes from wind farms. The initiative will start with a trial in 1 100 public housing homes.

The technology involves four key components:

- Smart meters installed in every participating household to assist in controlling the rooftop solar and battery, and to measure the power flows;
- A network of rooftop solar PV systems installed on public housing (5 kW solar panel system);
- Battery storage installed on public housing in South Australia (5 kW/13.5 kWh Powerwall 2 Tesla battery); and
- A computer system to control the storage, use and transfer of renewable and battery-stored power between houses and the grid, to maximise the value for customers while delivering services to the grid when needed.

The business model is also one of the innovations. The panels and batteries will not carry any upfront charge for the participating households. Instead, it will be funded by selling electricity and with government funds. Officials will provide an AUD 2 million (USD 1.6 million) grant, as well as an AUD 30 million (USD 23.8 million) loan from the state's Renewable Technology Funds.

The impact of such a solution would be considerable in terms of renewable energy integration, with approximately 130 MW of added rooftop solar PV generation capacity and 130 MW/330 GWh of distributed, dispatchable battery storage. This approximately doubles if the roll-out is extended to a similar number of private customers.

In terms of the flexibility added to the system, the participation of 50 000 households in the programme would add 250 MW of peak capacity to the system or, alternatively, reduce the demand on the central grid by 250 MW, freeing the capacity to be supplied to other customers.

In terms of cost reduction, the wholesale price in South Australia is estimated to drop by about USD 3/MWh for all customers, with each additional 50 MW of capacity brought into the system that would not otherwise be operating. This suggests that if only the public housing customers participated in the arrangement, the Tesla proposal could reduce the wholesale price by around AUD 8/MWh, or about AUD 90 million per year, across all South Australian customers.

The savings would be approximately double if the project could achieve its full scale of production of 250 MW. Moreover, the government also has provided estimates showing that it could lower the power bills of those who sign up by 30%.

The additional, distributed, dispatchable battery storage – to be aggregated and managed in a VPP – will improve security and system stability. For example, based on the first full month of trading in December 2018, the Tesla 100 MW battery resulted in about a 75% reduction in the costs being paid by customers for frequency control services. The VPP results could be similar (Frontier Economics, 2018).

SUMMARY TABLE: BENEFITS AND COSTS FOR AGGREGATING DISTRIBUTED ENERGY RESOURCES FOR GRID SERVICES

Distributed energy resources providing services to the grid	**Low**	**Moderate**	**High**	**Very high**
BENEFIT				
Potential increase in system flexibility			●	
Flexibility needs addressed	from seconds to hours			
COST and COMPLEXITY				
Technology and infrastructure costs		●		
	ICT platform, provided that the distributed energy resources and smart meters are in place			
Required changes in the regulation framework			●	
Required changes in the role of actors				●
	active consumers, distribution and transmission system operators, new players, such as aggregators			
Other challenges	• Close co-ordination among different stakeholders, including prosumers			

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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**).