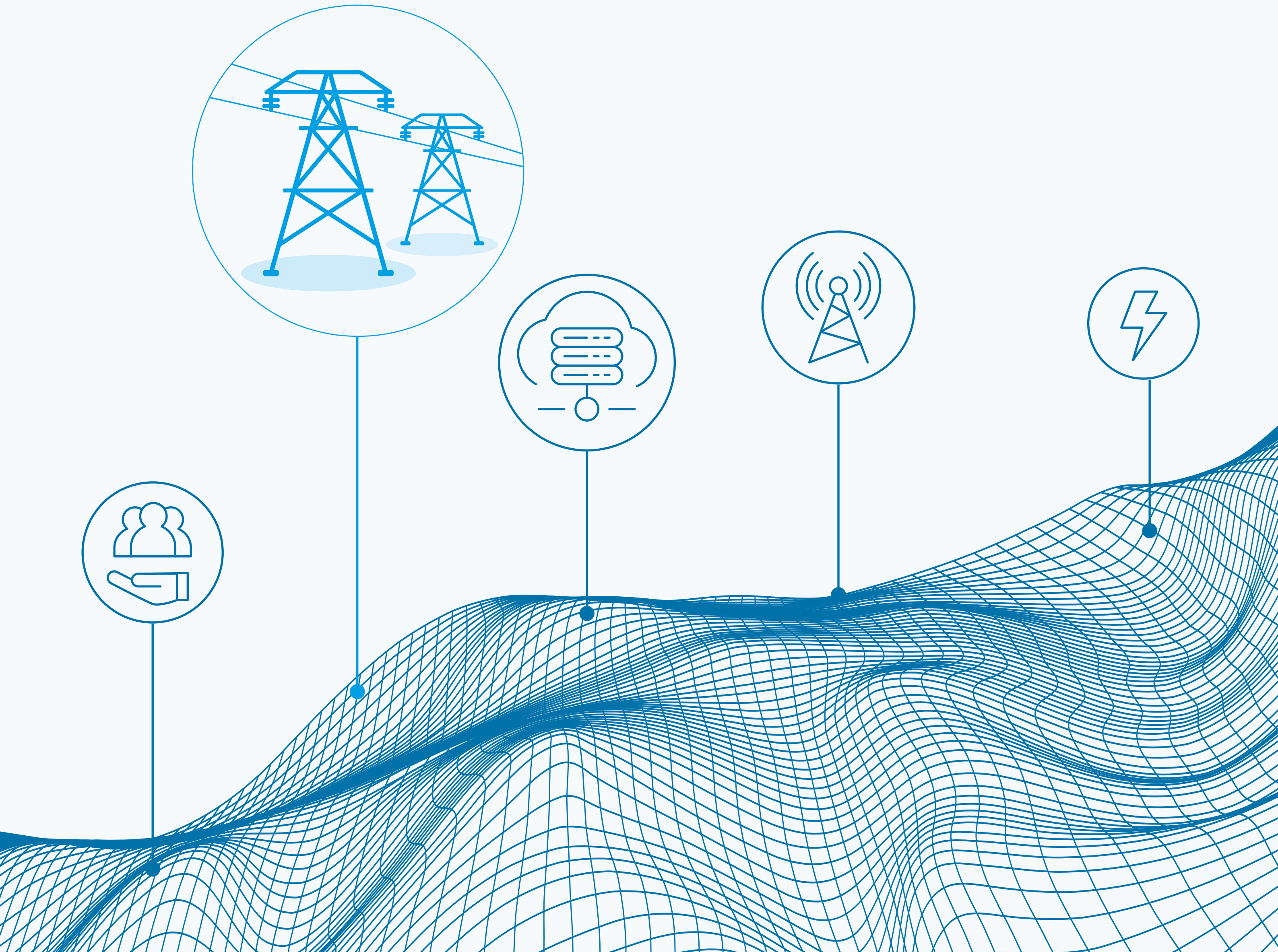
IRENA

International Renewable Energy Agency

FUTURE ROLE OF DISTRIBUTION SYSTEM OPERATORS

INNOVATION LANDSCAPE BRIEF



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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**

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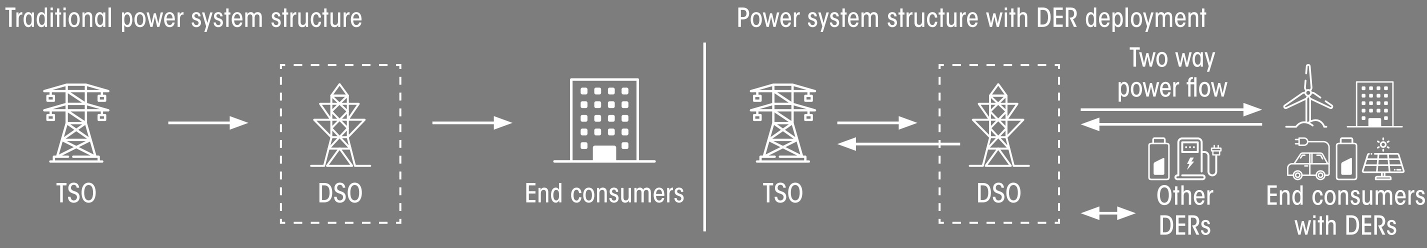
1 GROWING RESPONSIBILITIES FOR DSOs



Conventional roles of DSO

- Connection and disconnection of DERs
- Planning, maintenenace and management of networks
- Management of supply outages
- Energy billing (only if vertically integrated)

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Emerging additional roles of DSO

- Peak load management through DERs
- Network congestion management
- Provide reactive power support to TSOs
- Procure voltage support
- Technical validation for power market

3 SNAPSHOT

- UK Power Networks **reduced peak demand by 60 %** by aggregating DERs through a virtual power plant.
- The European Union's draft Electricity Regulation requires DSOs to facilitate the integration of distributed energy resources
- The **US** and **EU countries** are front-runners in expanding DSO responsibilities

2 KEY ENABLING FACTORS

- Deploying smart meters
- Real-time monitoring
- Leveling the playing field for aggregators, prosumers and other flexibility providers
- Establishing local market places for flexibility

WHAT ARE DSO's NEW OPPORTUNITIES?

With DERs available, a DSO can boost **grid flexibility** and **reduce** network investment needs

FUTURE ROLE OF DSOs

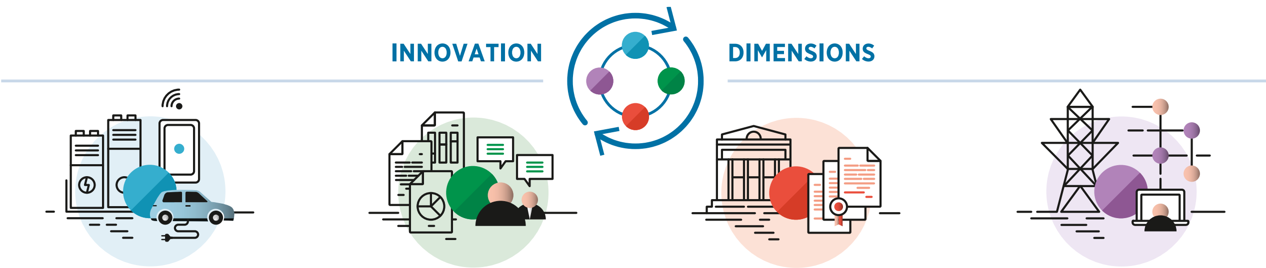
With more distributed energy resources (DERs), the role of distribution system operators (DSOs) expands towards optimisation of local generation and consumption.

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 solutions. 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 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

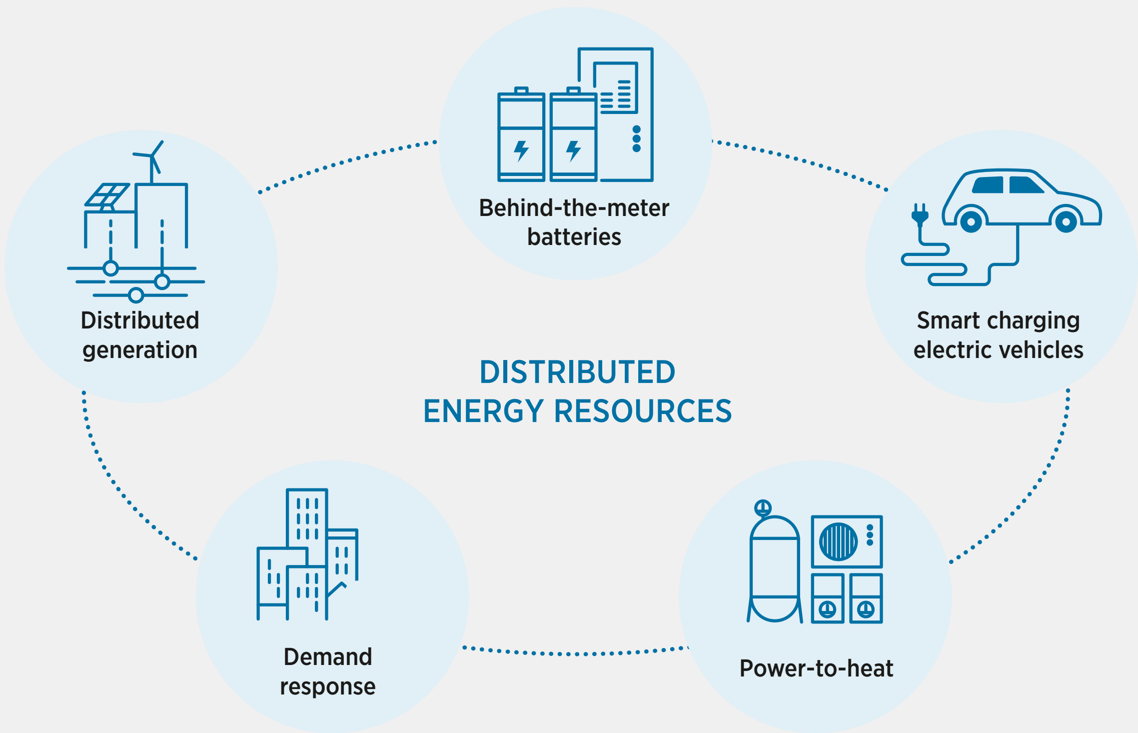
25 Future role of distribution system operators
26 Co-operation between transmission and distribution system operators

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

29 Virtual power lines
30 Dynamic line rating

This brief examines a key area of innovation in system operation, as distribution system operators (DSOs) take on greater responsibilities. The future role of DSOs will reflect the need to utilise the increased volume of distributed energy resources (DERs) in electrical distribution networks.

Distributed energy resources (DERs) are small or medium-sized resources, directly connected to the distribution network (EC, 2015). DERs include distributed generation, energy storage (small scale batteries) and controllable loads, such as electric vehicles (EVs), heat pumps or demand response.



Optimising both the consumption and the generation of electricity that is locally produced provides a great advantage for the distribution system, decreasing the need for other costly flexibility measures. In addition, the rapid growth of grid-connected distributed energy resources can be supported and enabled by harnessing the benefits that they can provide to the system. This brief focuses on expanding the role of distribution system operators to include the market-based procurement and operation of distributed energy resources, providing flexibility services.

The new role of DSO would include, depending on the regulatory framework in place:

- DSOs as neutral market facilitators (e.g., by avoiding ownership of electricity storage and EV charging infrastructure);
- Market-based procurement of grid services from distributed energy resources; and
- Benefiting from distributed energy resources by optimising the use of existing distribution grids and deferring new investments, either through direct control (operation) of distributed energy resources or through market-based price signals to other actors in the electricity system, such as aggregators.

The brief is structured as follows:

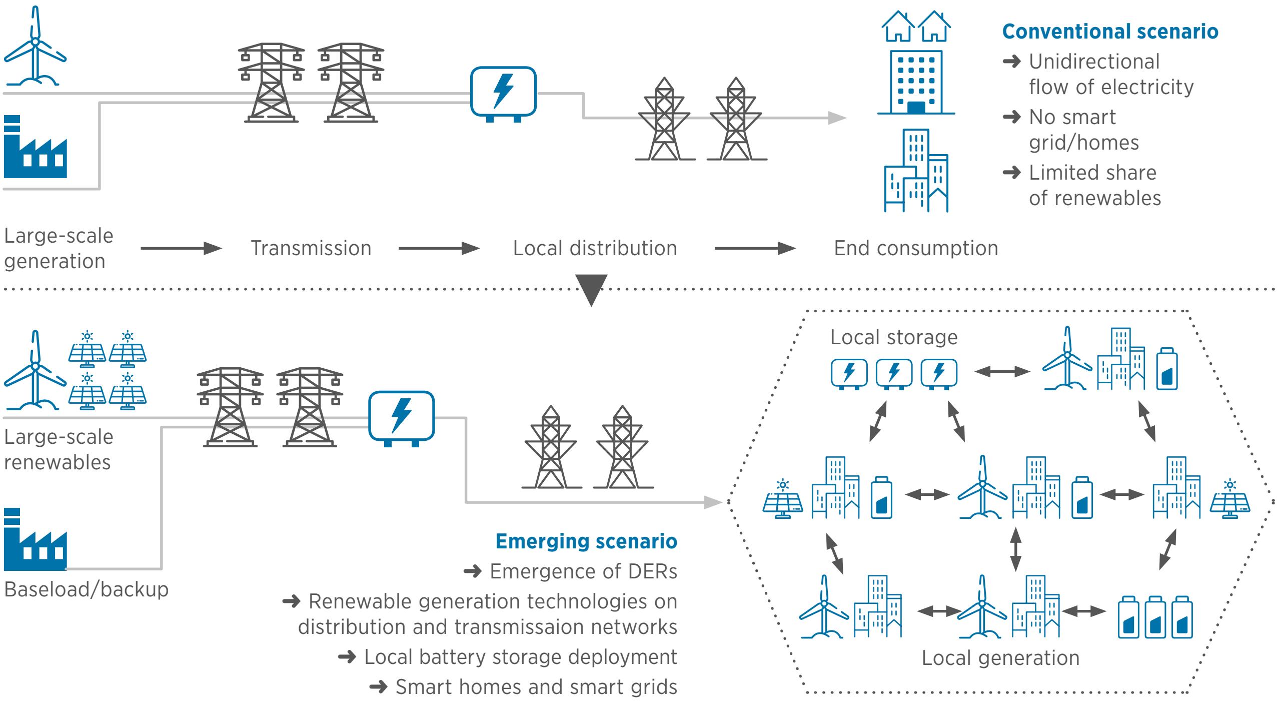
I. DESCRIPTION

Traditionally, electric power systems have been centralised structures organised into generation, transmission and distribution, placing customers at the end of the supply chain. This is a unidirectional structure where electricity generated by large power plants is transported via transmission and distribution networks to be delivered to customers. However, recent decades have witnessed the emergence of distributed energy resources (DERs) such as rooftop solar PV installations, micro wind turbines, battery energy storage systems, plug-in electric vehicles and smart home appliances that are becoming active participants in the electricity system.

The increasing penetration of decentralised energy resources and the emergence of new market players – such as prosumers, aggregators and active consumers – will usher in a new era. To take advantage of these new opportunities and to keep pace with both the transformation of the power sector and changing customer needs, distribution system operators will need to adjust their current role. Changing the regulatory framework for the DSOs – introducing new incentives to adapt the operation of distribution networks to the new paradigm of DERs – is key for the success of the energy transition.

Figure 1 depicts the difference between the conventional power system and the emerging scenario due to the deployment of DERs.

Figure 1 Conventional scenario versus emerging scenario in the power system due to the emergence of distributed energy resources



With the emergence of distributed energy resources – such as distributed generation, demand-side response and storage – the role of DSOs will expand. As such, DSOs could have access to the distributed flexibilities connected to their grid for the benefit of both the distribution grid and consumers. In their new role, DSOs could operate the distributed energy resources, if the regulatory framework allows it. If not, DSOs could at least act as neutral market facilitators and provide high-resolution price signals to the market players that own such flexibility assets. Having access to distributed flexibilities would have a two-fold objective of optimising the use of the distribution networks and minimising the need for future grid investments.

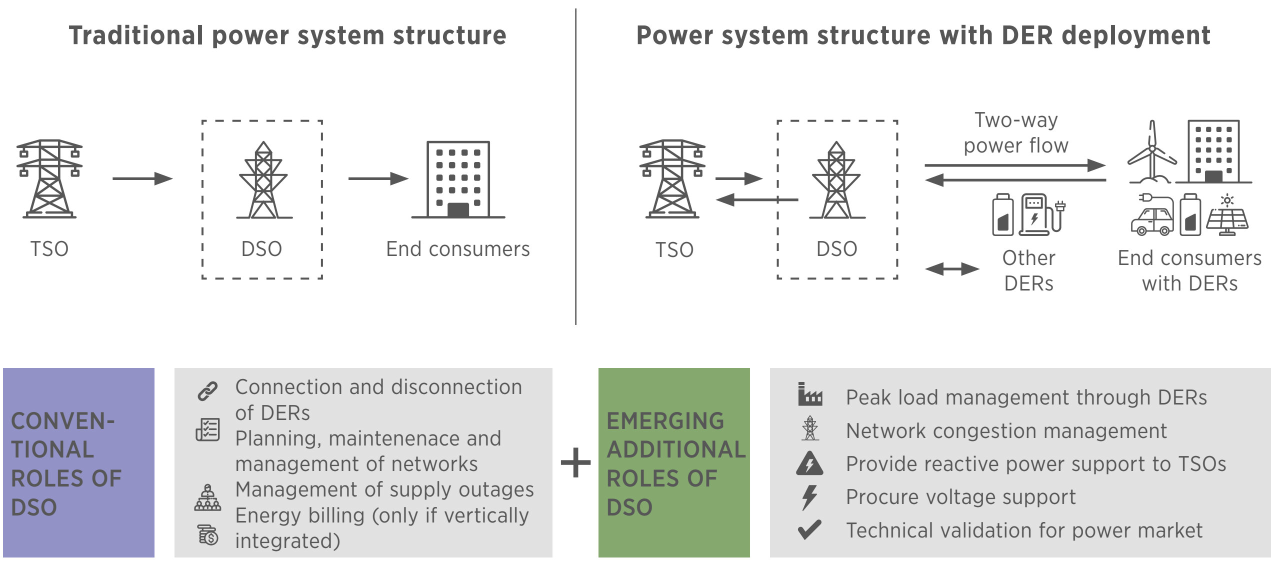
The increasing penetration of DERs could lead to a less predictable and reverse flow of power in the system, which can affect the traditional planning and operation of distribution and transmission networks. Further, increased deployment of DERs is expected to cause congestion in the distribution grid, which must be actively managed. This raises the need for a change in the role of the DSOs that have conventionally planned, maintained and managed networks and supply outages.

To effectively benefit from the available flexibility of DERs connected to the distribution network, DSOs could deepen their role as active system operators, in addition to their role as network operators. Distribution system operators could procure flexibility services from their network users, such as voltage support and congestion management to defer network investments.

In addition, DSOs might provide reactive power support to transmission system operators (TSO). For example, DSOs could, in co-operation with the TSO, define the standardised market products for the services to be procured via these flexibilities, including the definition of technical modalities for participating in dedicated markets. DSOs could use such flexibility services, among others, for the management of local congestion and non-frequency ancillary services (*e.g.*, voltage control), while TSOs would be responsible solely for frequency ancillary services.

The new role of DSOs vis-à-vis their conventional role is depicted in Figure 2.

Figure 2 The new role of distribution system operators



Some of the regulatory mechanisms that could foster this new role include:

- **Non-firm connection agreements for end-consumers** – These are connection agreements wherein the consumer agrees to have constrained power supply during peak hours, and the network fee is reduced as compared to firm connection agreements.

- **Bilateral flexibility contracts** – This refers to contractual agreements between DSOs and DER's owners to provide local system services – such as voltage control, peak shaving and congestion management – to the DSO.

- **Local markets** – This refers to local flexibility markets for distribution system services in which DERs could participate to support the distribution grid. The output of these markets could be technically validated by the DSO, in co-operation with the TSO.

A relevant initiative in this regard exists within the new regulatory framework of the European Commission's Clean Energy for All Europeans legislative package in November 2016. The revised Electricity Directive, which will enter into force in 2019 and is applicable to all European Union (EU) Member States following negotiation of the proposal, sets the regulatory framework in which distribution system operators can procure flexible services from network users (EC, 2016; EC, 2018). For example, this could be done via bilateral contracts between renewable energy owners and DSOs or via economic incentives set by DSOs (prices with some locational / temporal differentiation).

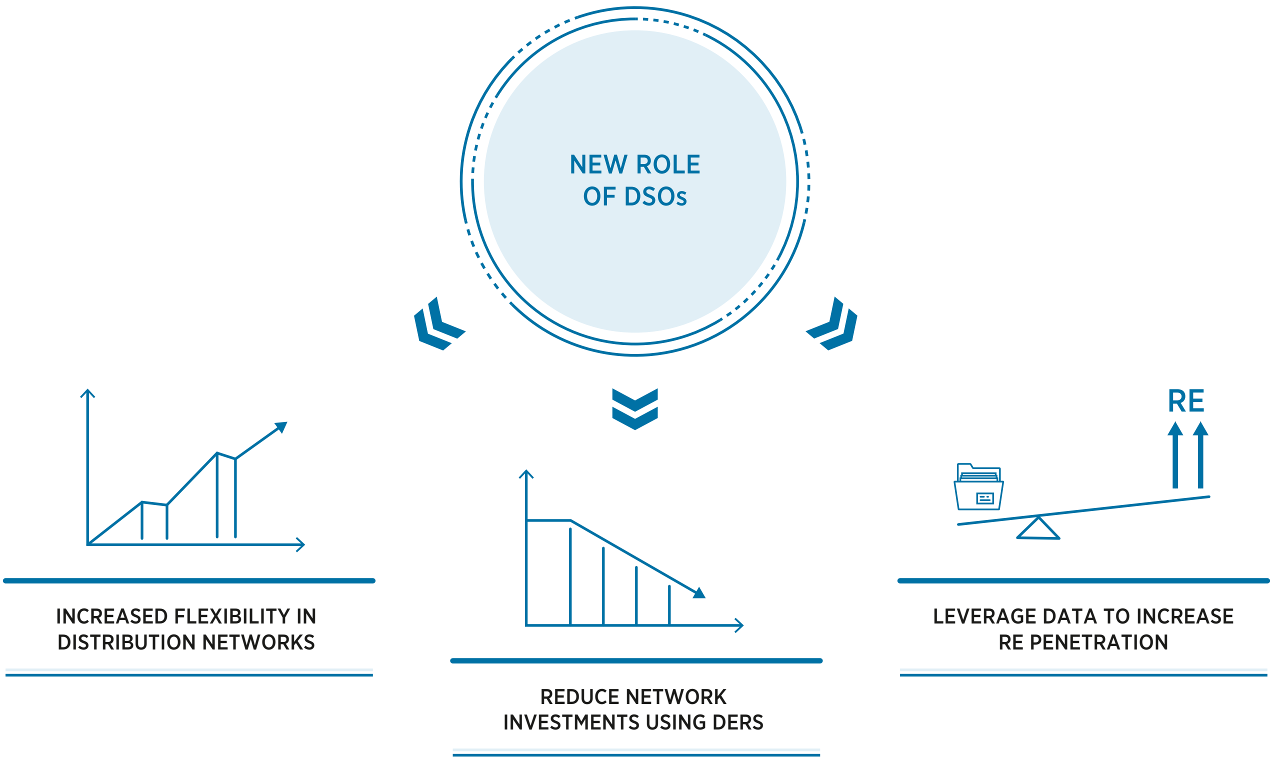
This new regulatory framework foresees that DSOs can own (and operate directly) flexible DERs only under specific circumstances. These include, for example, instances where no other parties have expressed an interest, or where the storage facility is necessary for fulfilling the DSO's obligations, and subject to the approval of the national regulator. The primary role of DSOs is to act as a neutral market facilitator for flexibility services.

In the United Kingdom (UK), variable network access for distributed generation exists in the form of non-firm connection agreements. Such agreements allow the distributor to temporarily curtail the power injection or withdrawal of an end-user for security reasons. A trade-off exists between reducing the value of renewable energy due to curtailment and the benefits reaped from swifter integration of renewables-based distributed generation. Thus, solutions should be promoted to keep the amount of curtailed renewable energy low – preventing costly grid reinforcement, increasing network hosting capacity and allowing for more rapid connection and access for distributed generation.

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

The new role of DSOs will have a significant impact on the way the power system is operated today. Figure 3 depicts some key benefits that can be reaped from this change in role.

Figure 3 Key advantages of the new role of distribution system operators



Increasing flexibility in distribution networks

Taking advantage of the increased penetration of DERs, DSOs could procure flexibility services – such as voltage support, congestion management, peak shaving, etc. – from the assets that are already connected to their distribution network. Using such services would further contribute to the integration of renewables in the distribution grid and especially the integration of variable renewable energy sources.

One way to achieve this is through the introduction of locational price signals in the distribution grids, or the establishment of local markets. Bilateral long-term contracts are a short-term solution and are easier to implement when the number of market participants is limited. The extra revenue stream for providing these flexibility services would incentivise the owners of the distributed energy resources to further deploy these resources, which in turn increases the flexibility in the distribution network.

Using distributed energy resources to avoid or reduce network investments

DSOs have conventionally invested in network reinforcement to reduce network congestion that could occur during peak demand intervals. Thus, the rules under which DSOs plan and size their grids – for example, in response to a worst-case scenario – could be modified to allow DSOs some freedom to decide whether a) to reinforce the grid, b) to offer non-firm access to their users (consumers, as well as generators) or c) to use flexibility services provided by DERs. By optimally managing DERs across the distribution network and mandating them to comply with certain communication requirements and dispatch signals, DSOs could avoid congestion and defer costly network investments.

Similarly, meeting peak load demand through locally stored or generated energy instead of transporting generation from a distant source may decrease grid congestion and defer network investments. For example, battery storage systems deployed by end-consumers could store excess energy produced from renewable sources such as solar PV or be charged using grid electricity when it is relatively cheap. Batteries can then be discharged during peak time intervals to fulfil demand. Using DERs, and in particular batteries, to avoid investments in the grid is also known as virtual power lines.

For example, UK Power Networks, a DSO operating in the UK, recently announced its plan to create London's first virtual power plant (VPP), comprising solar panels and a fleet of batteries across 40 homes in London. A trial of this concept was conducted in February 2018 wherein a fleet of 45 batteries was used to fulfil peak demand. The project is expected to provide an alternative to the traditional approach of increasing network capacity to meet peak demand (Hill, 2018).

Leveraging data to increase renewable energy penetration

DSOs can serve as the central hub for managing consumer data related to electricity consumption, production, billing and location, as well as the type of DERs. DSOs can collect and store these data according to the prescribed regulatory standards while protecting consumer rights, including privacy. For instance, the EU's Clean Energy for All Europeans package contains, among others, common rules for data management, including a common European data format requirement, where DSOs would have to ensure non-discriminatory access to data from smart metering systems (Hancher and Winters, 2017).

Using these data, DSOs can better forecast demand, leading to better planning and system operation. Such data also can enable greater deployment of renewable energy by helping consumers understand their consumption and / or production patterns and make efficient decisions about their distribution network use. DSOs could share such data neutrally and transparently with consumers as well as third parties, according to the prescribed data-sharing regulations, to enable better decision making.

In particular, third parties such as Energy-as-a-Service (EaaS) providers could utilise such data to provide optimal energy management services to end-consumers, thereby helping them in providing more flexibility to the system as well as increasing their energy efficiency. Gathering and sharing such data would not only help DSOs in operating the grid better, but also allow third parties to explore new business models for end-consumers, while helping end-consumers play an active role in the energy system, such as through demand-side response schemes.

For example, the regulatory proceedings under New York State's Reforming the Energy Vision encourage sharing information and knowledge about the utility grid. The six utilities[1] participating in this programme recently filed a plan in which they will provide data on the distribution grid in three stages. The first stage involves upgrading the grid with smart meters, sensors and other such communication and data collection hardware.

In the second stage, the data collected by these devices will enable a marketplace between utilities and DERs. In the third stage, this will be extended to the rest of the market and will enable third-party service providers such as rooftop solar companies, Energy-as-a-service providers, etc. to leverage these data to provide better services (Trabish, 2017).

Potential impact on power sector transformation

- In the UK innovations by DSOs – including in creating smarter networks, improving transmission-distribution processes related to connections of distributed generation, planning and shared services, assessing the gaps in customer experience and considering the changing requirements of transmission and distribution systems – will enable **cost savings for the grid operator** of close to **USD 1.32 billion**[2]. These savings will also benefit consumers as the distribution cost in their final bill is reduced. The savings are estimated to be realised between 2018 and 2023 (Engerati, 2018).
- UK Power Networks is planning to transition from the traditional role of electricity delivery agent to adopting a virtual power plant framework. A technology trial led to **reduced peak demand** from the grid **by 60%** (Hill, 2018).

1 *The six utilities participating in this programme are Central Hudson Gas & Electric, Consolidated Edison (ConEd), New York State Electric & Gas, National Grid New York, Orange and Rockland Utilities, and Rochester Gas and Electric.*

2 *Original figure of GBP 1 billion converted to USD based on Bloomberg's quote for the GBP-USD exchange rate on 10 July 2018 (https://www.bloomberg.com/quote/GBPUSD:CUR).*

III. KEY FACTORS TO ENABLE DEPLOYMENT

Multiple aspects need to be changed to facilitate the transition of distribution companies from traditional distribution network owners and operators to a more active role as distribution system operators and market facilitators.

Firstly, the regulatory framework needs to define clear roles and responsibilities for DSOs and to incentivise innovation. Secondly, there is a need to standardise the collection and sharing of data by DSOs as this will be crucial in providing value-added services to consumers, as well as enabling successful system operation and management. Lastly, smart hardware backed by communication infrastructure is needed to facilitate complex interactions between DSOs and DERs.

Regulatory frameworks for the future role of DSOs

Despite the transformation of the role of DSOs, these entities will remain regulated. Therefore, regulations should allow this change by clearly defining the roles and responsibilities of DSOs, as well as of the owners of distributed energy resources. Neutrality and transparency should govern any interaction between DSOs and network users.

Further, to enable DSOs to interact with DERs and to procure flexibility services from them, appropriate regulatory frameworks must be developed. These measures should aim at developing the mechanisms that encourage innovation by DSOs, as well as developing technical specifications and amending grid codes for the provision of such services.

For example, in the UK's Office of Gas and Electricity Markets (Ofgem), the energy regulator adopted a new regulatory model called RIIO: "*setting Revenues using Incentives to deliver Innovation and Outputs*". This model has price controls for network tariffs charged by distribution network operators while providing incentives to these operators for innovation with regard to customer expectations, environmental impact, etc. The RIIO model is helping distribution network operators transition to the system operator role by encouraging innovative approaches (Ofgem, 2018).

In the state of New York, the Reforming the Energy Vision roadmap – a set of regulatory proceedings and policy initiatives – was launched in 2014 to restructure the rate-making and revenue models of state utilities so that they are better aligned with consumer interests and allow for the integration of DERs (New York State, n.d.).

Standards for data management

For DSOs to securely share customer data with third parties and market participants, standards for data management and data sharing need to evolve. Data management arrangements should serve to protect the privacy of personal data, and customers should be able to determine how their data is used.

For example, in the US state of Washington, the Public Utility Districts have released guidelines for ensuring data privacy of consumers. These guidelines mandate utilities to get permission from consumers for the collection of private data and its disclosure to third parties (WPUDA, 2016).

Smart grids and digital technologies

In the future, DSOs will need to develop innovative systems to solve network constraint issues and to manage the injection of variable power. This can be enabled through enhanced use of information and communication technologies (ICTs). The emergence of advanced digital technologies such as sensors, smart meters, artificial intelligence and robotics has unlocked new and efficient ways of managing the network. These solutions comprise, among others, automated voltage control or automatic grid reconfiguration to reduce the loading of a distribution feeder by transferring part of the distributed generation feed-in to a neighbouring one. Grid networks enabled by such technologies are often referred to as smart grids.

The deployment of smart grid technologies can enable enhanced interaction of DSOs with consumers and DERs, which is key for a system operator. The most straightforward approach is mandating DER units to comply with certain communication requirements and dispatch signals sent by the DSO. Implementation of these digital technologies also can enable the real-time exchange of information between DSOs and DERs.

One of the ways to encourage large-scale adoption of smart grid technologies is through regulatory frameworks. For example, the European Commission has mandated that all EU Member States upgrade at least 80 % of their meters to "smart" versions by the year 2020, although considerable delays are expected (thinkSPAIN, 2017). The UK plans to deploy smart meters to approximately 50 million households by 2020 (Nhede, 2018).

Italy, a leader in the deployment of smart meters, has over 30 million smart metering devices in operation. Driven by EU energy efficiency requirements (European Directive 2012/27/EU), e-Distribuzione, a power distributor in Italy, is in the process of replacing the country's current smart meters with second-generation smart meters that reflect the evolution in the field of metering and remote management. These new meters will make it possible to promote energy efficiency, increase awareness of consumption behaviour, encourage competition in post-meter services and develop a home automation market (Engerati, 2017).

Improving communication with consumers

As the role of DSOs evolves, they also need to engage consumers better through improved communication. DSOs will need to respond to a new generation of customers – who are now able to engage with their banks through web chats, order taxis using smartphones and talk to various service providers over social media – without neglecting customers who are not familiar with the new technologies.

DSOs therefore will need to focus increasingly on digital media capabilities for customer interaction and engagement. For instance, DSOs in Spain, such as Iberdrola and Endesa, have developed smartphone applications that allow consumers to check their hourly consumption, submit their real meter readings, manage their contracts and pay bills (Endesa, 2018; Iberdrola, 2018).

IV. CURRENT CONTEXT AND LEADING INITIATIVES

Key facts about the emerging role of DSOs presented in Table 1, followed by some pilot projects.

Table 1 Key facts about the emerging role of distribution system operators

Description	Key facts
Key countries incentivising the expanded role of DSOs	Countries in European Union, US
Key transformational steps being taken by DSOs	Deployment of smart meters, real-time monitoring systems, creating a level playing field for aggregators, establishing local marketplaces, etc.
Key drivers for the transition	Network capacity deferral, local congestion management, need for voltage control in light of increasing shares of renewable energy generation
Key flexibility services being procured	Demand-side response, synthetic inertia, power quality, congestion management, voltage control, reactive power support

New York's Reforming the Energy Vision

Under the state of New York's Reforming the Energy Vision roadmap, the New York Public Service Commission has mandated six large investor-owned utilities to undertake several measures to integrate DERs.

These include creating charging systems for EVs, creating online marketplaces for energy products and services, building virtual power plants and enabling connectivity of DERs to the grid, and developing storage on demand, among others. The costs for these products and services will be recovered through revised tariff structures. These utilities have launched multiple demonstration projects (New York State, 2018).

United Kingdom's Open Networks Project

The UK's Open Networks project – launched by the Electricity Networks Association, a national trade association representing the transmission and distribution networks – is expected to lay the foundation for transitioning the role of DSOs. Its objectives include developing improved processes for transmission and distribution system operators, planning and shared services, and a needs gap assessment for customers (Engerati, 2018).

Western Power Distribution, a DSO in the UK, has released a four-point plan that includes expanding and rolling out smart network solutions to higher voltages, contracting with aggregators and customers for various services, TSO-DSO co-ordination and ensuring the integrity and safety of lower-voltage networks (Engerati, 2018).

Scottish and Southern Electricity Networks' (SSEN) local flexibility marketplace

SSEN, a distribution system operator in the UK, has begun trials for a new online marketplace hosted by Open Utility to procure flexibility services for local requirements. This will enable SSEN to address local network constraints by buying flexible services such as demand response and battery storage capacity. The project is expected to be commercially operable in 2019 (Grimwood, 2018).

National Grid's Enhanced Frequency Control Capability (EFCC) project

National Grid, along with six companies (Flexitricity, Belectric, Centrica, Orsted, Siemens and GE Grid Solutions) and two universities (Manchester and Strathclyde), are working on the EFCC project under which a new monitoring and control system has been developed for grid management. This system is expected to help maintain system stability during peak hours using a range of technologies, as listed below:

- Belectric will use its solar PV plants and battery storage systems to provide response.
- Centrica will use its combined-cycle gas turbines and wind farms to provide generation response.
- Orsted and Siemens will use wind turbines to provide fast frequency response and measure the associated cost for providing this service.
- Flexitricity will use commercial and industrial customers to provide demand-side response.

This project is expected to help in the development of new services for rapid frequency response (Porter, 2018).

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS	**Hardware:** • Smart meters and smart network devices • ICT infrastructure such as fibre cables, wireless communications, etc. • Battery storage devices at the distribution level, and deployment of other DERs • Upgrading network assets to handle erratic and large reverse flows of power • Active network devices such as automatic on-load tap changers for transformers, static synchronous compensators, static var compensators, etc.
	Software: • Smart meter data acquisition software • Supervisory Control and Data Acquisition (SCADA) software
	Communication protocols: • Develop common interoperable standards (at both physical and ICT layers) to increase co-ordination among aggregators, DSO, TSO and consumers
REGULATORY REQUIREMENTS	**Retail market:** • Regulations to mandate implementation of smart meters and smart grid infrastructure, where the cost-benefit analysis is positive • Clear price signals in place to guide prosumers' behaviour
	Distribution system: • Regulations incentivising DSOs to actively manage the grid • Data collection, management and sharing rules for DSOs to ensure consumer privacy
	System operation: • Defining rules for DSO-TSO co-ordination between transmission and distribution system operators
STAKEHOLDER ROLES AND RESPONSIBILITIES	**Distributed energy resource owners (*e.g.*, aggregators):** • Provide grid-related services to DSOs, if a market is established • Information exchange with DSOs related to capacity, location, type of DERs
	Distribution system operators: • Ensure a level-playing field for all flexibility providers • Procure market-based flexibility services from DERs • Securely share consumer and grid-related data with third parties as per applicable data privacy and sharing norms • Better forecasts for DER services based on past data or historical performance and weather forecasts

ABBREVIATIONS

AMI	Advanced metering infrastructure
BtM	Behind-the-meter
DER	Distributed energy resource
DSO	Distribution system operator
EV	Electric vehicle
ICT	Information and communication technology
TSO	Transmission system operator
VPP	Virtual power plant
VRE	Variable renewable envergy

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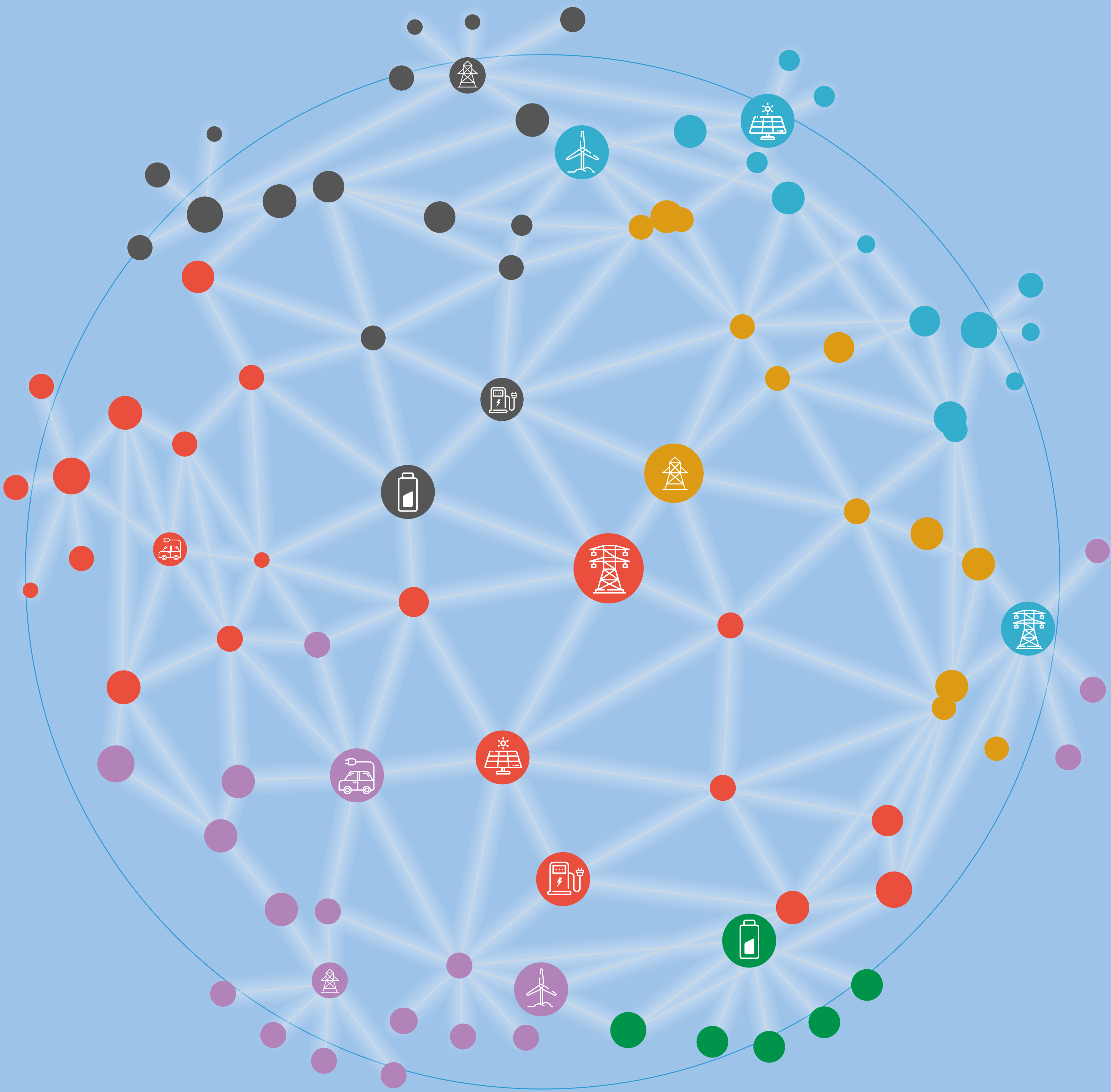

FUTURE ROLE OF DISTRIBUTION SYSTEM OPERATORS

INNOVATION LANDSCAPE BRIEF

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