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CO-OPERATION BETWEEN TRANSMISSION AND DISTRIBUTION SYSTEM OPERATORS

INNOVATION LANDSCAPE BRIEF

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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**

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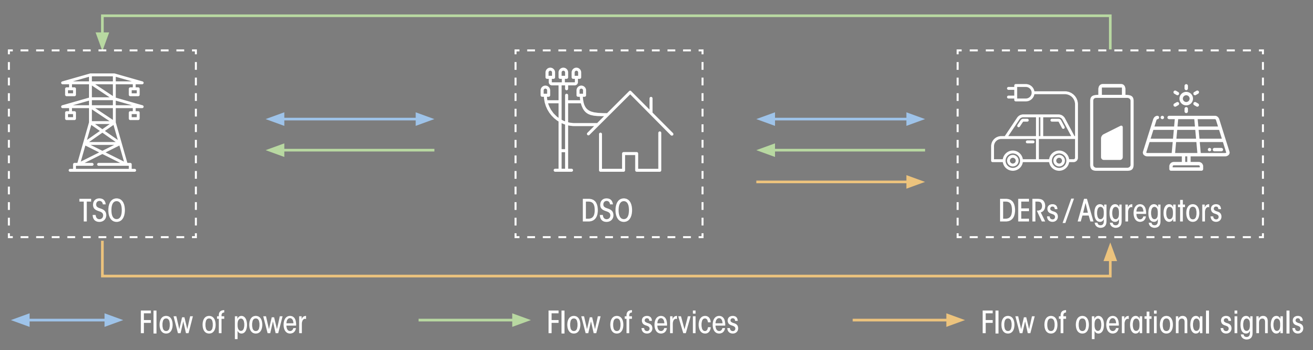
1 BENEFITS

Increased interaction between distribution system operators (DSOs) and transmission system operators (TSOs) can enable:

- Better utilisation of distributed energy resources (DERs)
- Increased system flexibility
- Optimisation of investments in grid infrastructure



2 KEY ENABLING FACTORS

- Introduction of data exchange platforms
- Digitalisation
- Clearly defining the new role of DSOs

3 SNAPSHOT

→ Various TSO-DSO co-operation projects have been piloted in the European Union

- SmartNet project includes Denmark, Italy and Spain
- CoordiNet project includes Greece, Spain and Sweden

→ Colombia is also looking at increasing TSO-DSO co-operation in the context of increased distributed generation

TSO-DSO CO-OPERATION

Improved co-ordination between transmission and distribution system operators becomes essential to integrate distributed energy resources and gain maximum system flexibility.

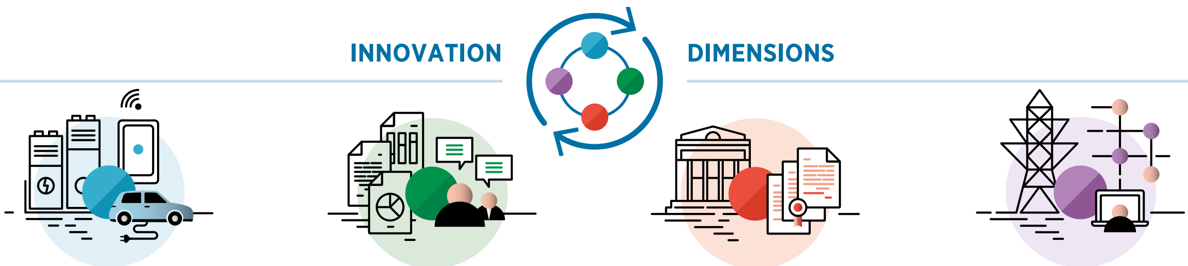
ABOUT THIS BRIEF

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, 2019a), 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.

INNOVATION DIMENSIONS



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

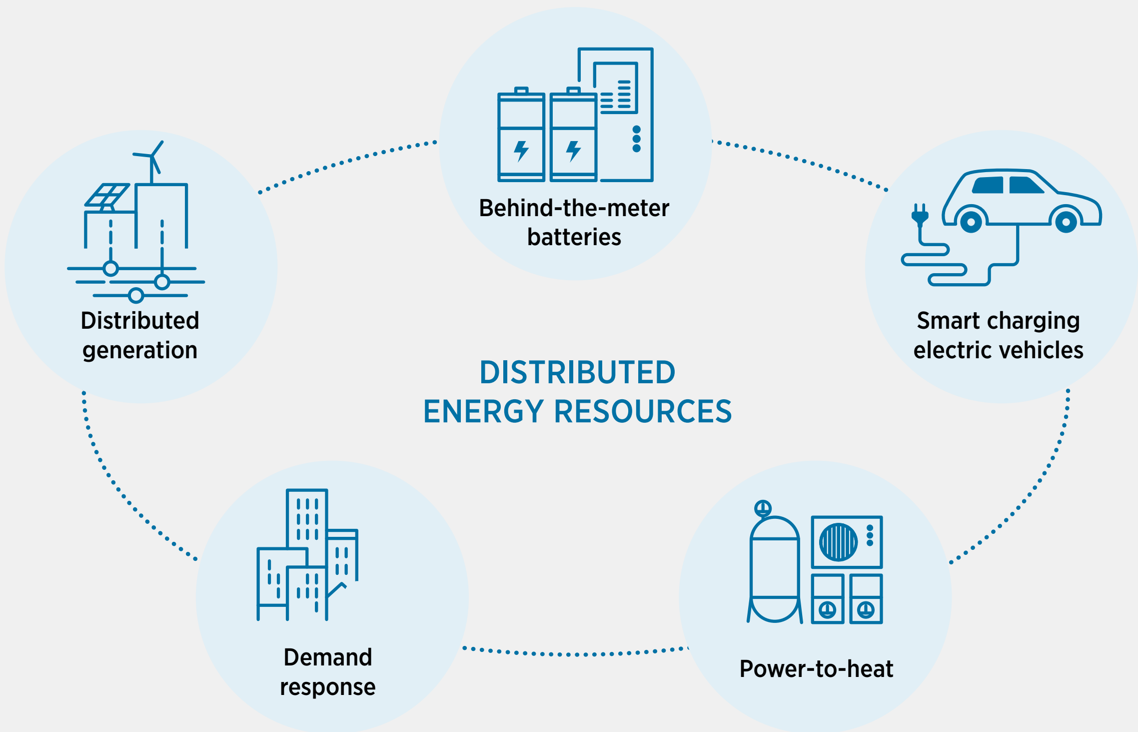
27 Advanced forecasting of variable renewable power generation
28 Innovative operation of pumped hydropower storage

29 Virtual power lines
30 Dynamic line rating

While in some power systems, generation, transmission and distribution of power are performed by a single vertically integrated (and sometimes state-owned) organisation, in other power systems these functions are performed by separate organisations. This innovation landscape brief applies mainly to power systems in which the transmission and distribution of power are the responsibility of two distinct entities.

This brief provides an overview of co-operation between transmission system operators (TSOs) and distribution system operators (DSOs) to integrate distributed energy resources (DERs) into the grid to achieve a higher penetration of renewable energy in the entire system. The brief further describes possible TSO-DSO co-operation schemes, as well the potential impact of such co-operation, in the context of power system decentralisation and VRE integration.

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



The brief is structured as follows:

I. DESCRIPTION

In the traditional model of centralised power generation, the flow of electricity is unidirectional, that is, from power plants to end consumers through power transmission and distribution networks. Traditionally, the TSO[1] has been responsible for operating the electricity transmission network and transporting electricity from centralised generation facilities to regional/local distribution networks to meet the demand of various DSOs. These are, in turn, responsible for delivering reliable and secure power to end users within specified constraints of voltage and frequency.

The deployment of renewable generation technologies connected to the distribution network has resulted in the bi-directional flow of electricity through the network. In addition, the emergence of distributed storage and demand response practices has also changed the net load and flows in the system. In this new context, with the deployment of DERs, the role of the DSO needs to expand to harness the flexibility offered by these new technologies on the distribution system. If the regulatory framework allows it, DSOs can themselves operate the DERs, or they can act as neutral market facilitators and provide high-resolution price signals to the market players that own flexibility assets, supporting the TSOs.

The roles of, and interaction processes between, DSOs and TSOs need to be redefined to increase the integration of DERs within the power system. This is particularly the case in systems where there is a lack of clear distinction between their respective responsibilities in the new context of increasingly decentralised systems. At the same time, congestion on the network needs to be managed and reduced, and the system as a whole needs to be balanced in an optimal way.

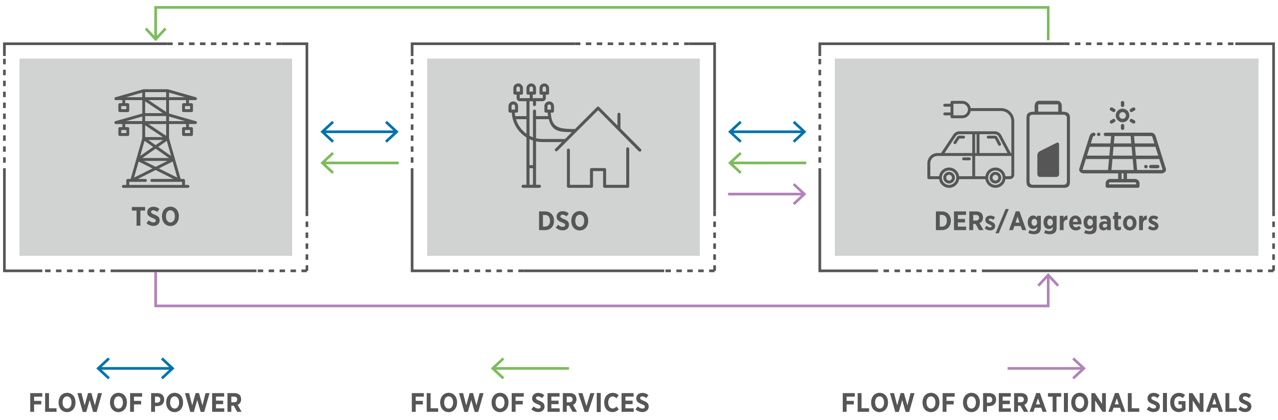
DSOs should evolve from the traditional operational approach to DERs, known as "connect and forget", to being neutral market facilitators, enabling DERs to provide services to the system by participating in wholesale markets. Increased co-operation between DSOs and TSOs becomes central in this new paradigm (see the *Innovation Landscape Brief: Future role of distribution system operators* [IRENA, 2019b]).

Figure 1 summarises possible interactions between DSOs, TSOs and DER owners, showing the flow of power, services and operational signals between them in a context where DERs are allowed to participate in electricity and ancillary service[2] markets.

1 *Different nomenclatures are used in different regions for system operators: transmission system operator (TSO), independent system operator (ISO), independent transmission operator (ITO) or regional transmission organisation (RTO), among others. For the purpose of this brief, TSO is used to refer to any kind of entity responsible for operating the electricity transmission network.*

2 *"Ancillary services" are services necessary for the operation of a transmission or distribution system. Ancillary services are typically procured by TSOs and can be clustered into frequency ancillary services (balancing of the system) and non-frequency ancillary services (voltage control and black-start capability) (IRENA, 2019c).*

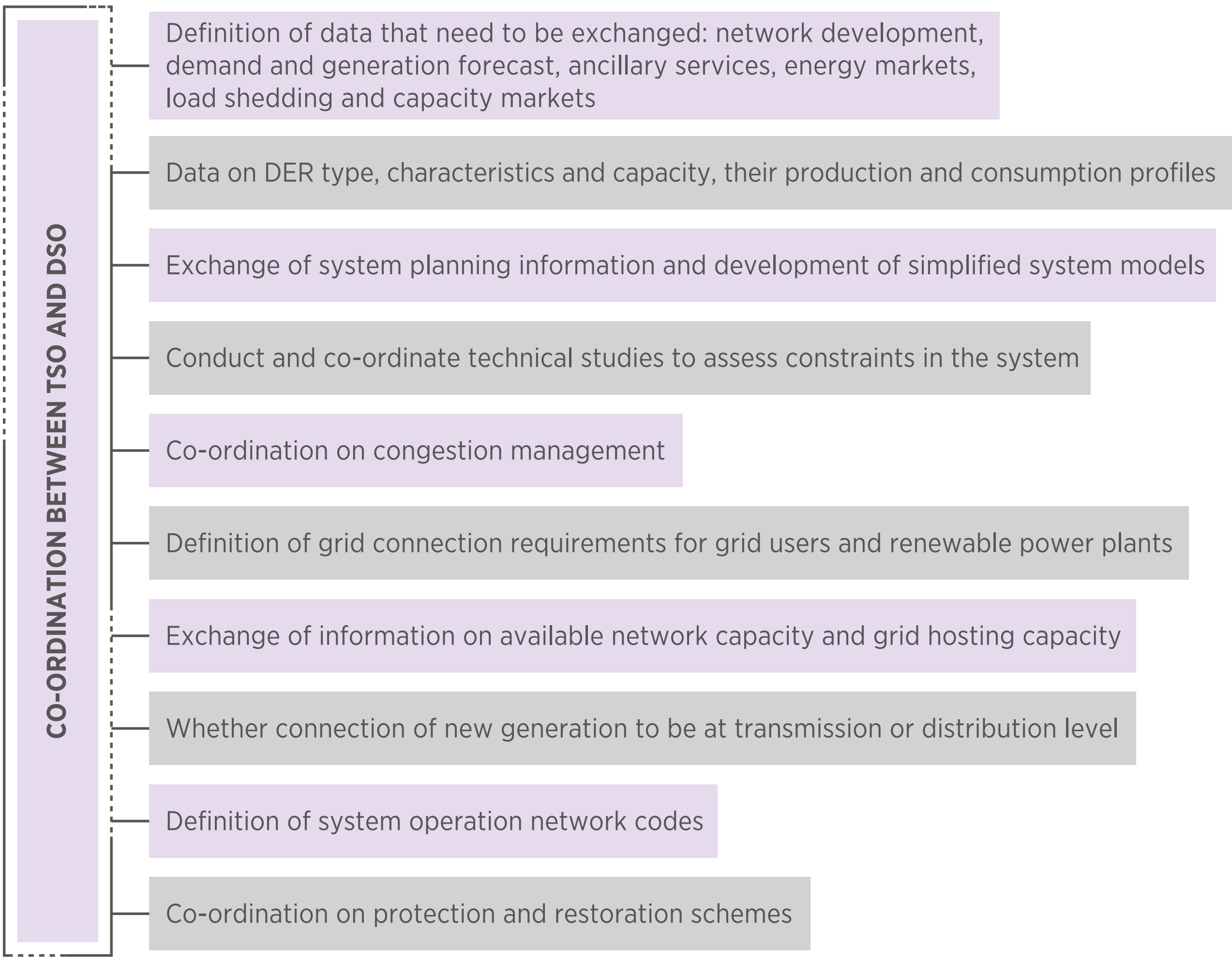
Figure 1 Interaction model between system operators and DERs



Source: Adapted from Birk et al. (2017).

Efficient co-operation between DSOs and TSOs is critical for the participation of DERs in the wholesale power markets. The DSOs should also act as, or enable, a data exchange platform between TSOs and DER owners, providing visibility to the TSO on the type and availability of DERs. Figure 2 summarises some of the key areas of co-ordination between TSOs and DSOs.

Figure 2 Important areas of co-ordination between TSO and DSO



Source: IRENA (forthcoming a).

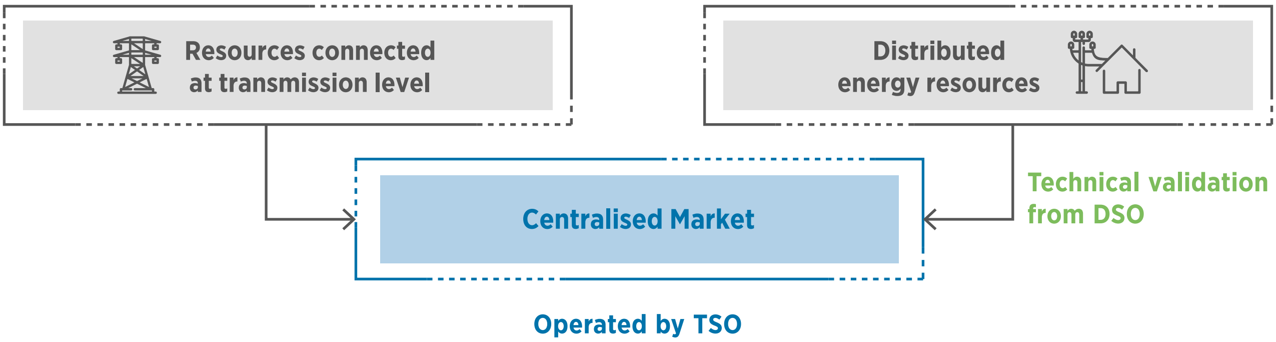
Possible co-ordination schemes between DSO and TSO for the procurement of ancillary services from DERs

For the efficient operation of a grid with a significant share of electricity from DERs, information sharing between TSOs and DSOs is essential to maximise the benefits that DERs can provide to the system and facilitate their integration into the system. Information sharing between TSOs and DSOs allows them to identify where connected entities can and should take action to support the needs of the power system. Any co-operation scheme should be well designed and implemented so that the actions taken by the DSO and TSO do not have counteracting effects (Migliavacca, 2018a).

The European Union-funded project "SmartNet" has identified five different models for system operators to co-ordinate the participation of DERs in the ancillary service market. The schemes are listed in Table 1. The co-ordination models differ according to the market design and the responsibilities of the system operators in the market. While these models correspond to five types of interaction, many variants of them are possible.

Table 1 Co-ordination models for TSOs and DSOs in Europe

1 CENTRALISED ANCILLARY SERVICE MARKET MODEL



Description	Market organisation	Allocation principle of DER flexibility	Role of DSO	Role of TSO
A common market for ancillary services for both resources connected at transmission and distribution level, procured by TSO.	TSO (common market).	TSO priority.	DSO plays a limited role, checks for constraints in the distribution grid and provides technical validation, without being involved in the process of acquiring services.	TSO acquires ancillary services directly from DERs. TSO manages the ancillary service market. Resources at distribution level are aggregated and compete with other centralised resources in the market.

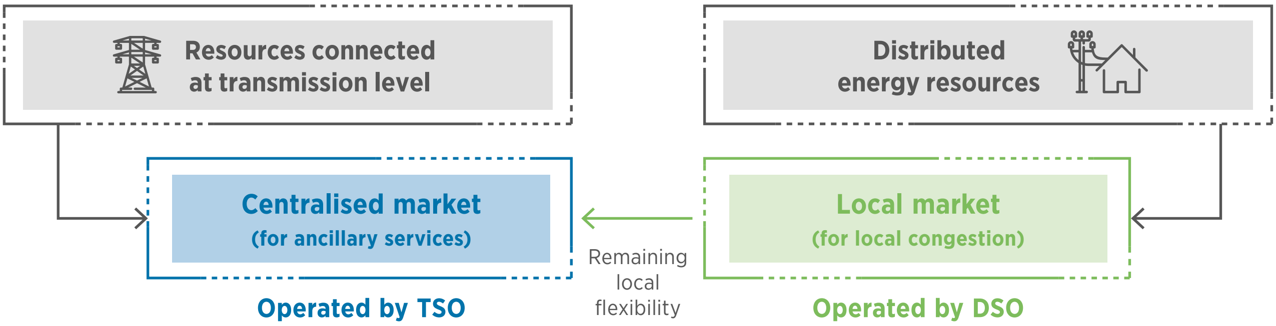
BENEFITS

- Optimal scheme if distribution networks do not experience significant congestion.
- A single market has low operational costs and allows standardised processes.
- Easier to implement under current regulatory frameworks.
- Easiest computational complexity as only the transmission grid is considered.

CHALLENGES

- Distribution grid constraints are not always respected.

2 LOCAL ANCILLARY SERVICE MARKET MODEL



Description

Separate local flexibility market for DSOs, in addition to the ancillary services market for TSO procurement.

Market organisation

TSO (centralised market) and DSO (local market).

Allocation principle of DER flexibility

DSO priority.

Role of DSO

DSO operates a local market for resources connected at DSO level and is responsible for local congestion management. DSO has priority to use the flexible resources on the local grid. DSO aggregates and transfers the remaining bids to the TSO market after all local constraints are resolved, while ensuring that only bids respecting DSO grid constraints can take part in the ancillary services market.

Role of TSO

TSO manages the central ancillary services market and can only acquire the remaining local flexibility from DSO with technical validation from DSO to ascertain feasibility of the orders.

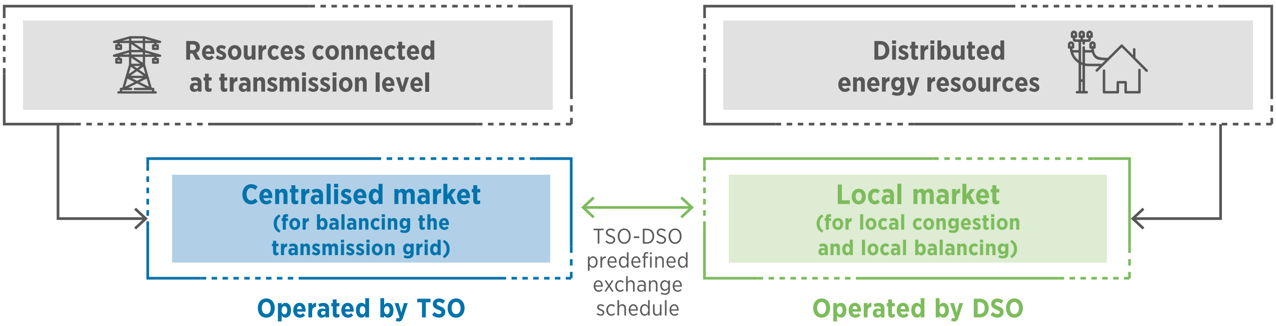
BENEFITS

- DSO has priority to use local flexibility.
- DSO actively supports ancillary service procurement.
- Local markets can have lower entry barriers for small-scale DERs.

CHALLENGES

- Centralised and local market cleared sequentially.
- Need for extensive communication between the centralised market and the local market.
- Local market should have of a “reasonable” size and guarantee a sufficient number of actors are in competition in order to prevent scarcity of liquidity and exercise of local market power.

3 SHARED BALANCING RESPONSIBILITY MODEL



Description

Similar model to the local flexibility market model with the exception that the remaining local flexibility is not offered on to TSO.

Market organisation

TSO (central market) and DSO (local market).

Allocation principle of DER flexibility

DSO only.

Role of DSO

Flexibility from the distribution grid is reserved exclusively for DSO to fulfil its responsibilities with respect to local grid constraints and local grid balancing. DSO autonomously provides balancing services and congestion management for local grid based on a predefined exchange schedule between DSO and TSO.

Role of TSO

TSO is responsible for resources connected at the transmission level, resulting in a separation of roles and responsibilities at individual TSO-DSO interconnection points.

BENEFITS

- TSO will need to procure a lower amount of ancillary services.
- Local markets can have lower entry barriers for small-scale DERs.
- Clear boundaries between TSO and DSO responsibilities.

CHALLENGES

- Defining a schedule methodology agreed by both TSO and DSO might be challenging.
- Local congestion markets should have a “reasonable” size and guarantee a sufficient number of actors are in competition in order to prevent scarcity of liquidity and exercise of local market power.
- Total amount of ancillary services procured by TSO and DSO together will be higher in this scheme.

4 COMMON TSO-DSO ANCILLARY SERVICE MARKET MODEL

Description

Common market for flexible resources connected at the transmission and distribution level, with allocation of flexibility to the system operator with the highest need.

Market organisation

TSO and DSO (common market).

Allocation principle of DER flexibility

Cost-minimisation for TSO and DSO.

Role of DSO & TSO

FDSO and TSO jointly manage a common ancillary services or flexibility market. The flexibility resources are acquired jointly or in co-operation so that total system cost is minimised.

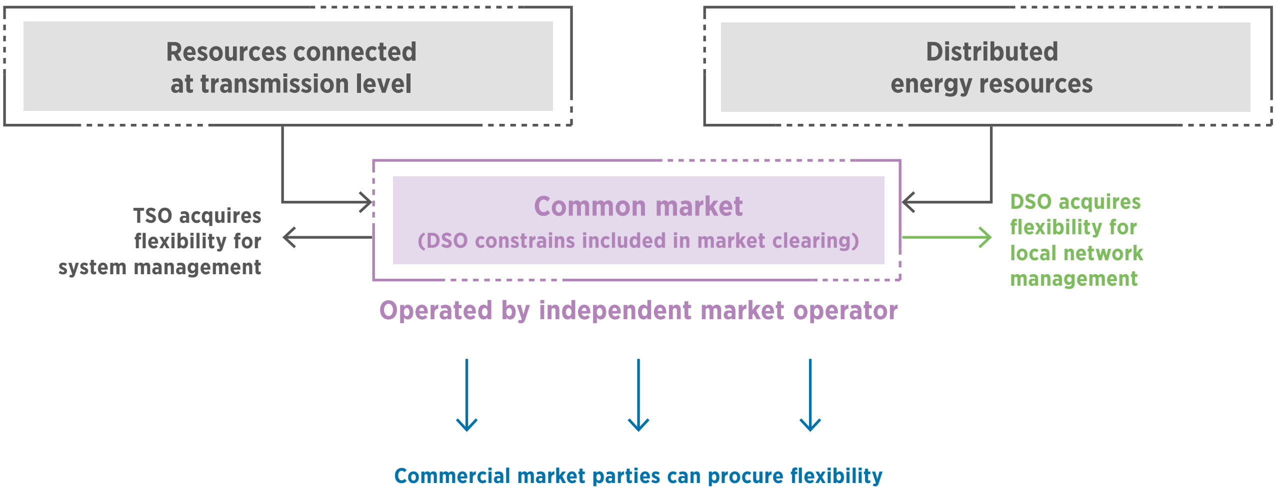
BENEFITS

- Total system costs for ancillary services are minimised.
- TSO and DSO collaborate closely, making optimal use of the available flexible resources.

CHALLENGES

- Allocation of costs between TSO and DSO might be challenging.
- High computational complexity since constraints on both transmission and distribution grids are resolved in a single mechanism.

5 INTEGRATED FLEXIBILITY MARKET MODEL



Description

Common market for flexible resources connected at the transmission and distribution level. Both regulated (system operators) and commercial market parties participate to procure flexibility. It is the most complex model proposed.

Market organisation

Independent market operator (common market).

Allocation principle of DER flexibility

Highest willingness to pay (market forces) dictates how flexibility is allocated.

Role of DSO

FDSO manages the local network by acquiring flexible resources managed by an independent market operator. DSO provides technical validation to support the power flows. This is similar to the common DSO-TSO ancillary services market, with the additional possibility for commercial market parties to regulate their position in real time.

Role of TSO

TSO also acquires resources for network flexibility from the independent market operator. The market operator allocates resources to the highest bidder.

BENEFITS

- High liquidity and competitive prices due to large number of buyers and sellers.
- Increased options for balancing responsible parties to solve imbalances.lities.

CHALLENGES

- An independent market operator needs to be established to operate the common market.
- TSO and DSO need to share data with the independent market operator.
- High computational complexity since constraints on both transmission and distribution grids are resolved in a single mechanism.

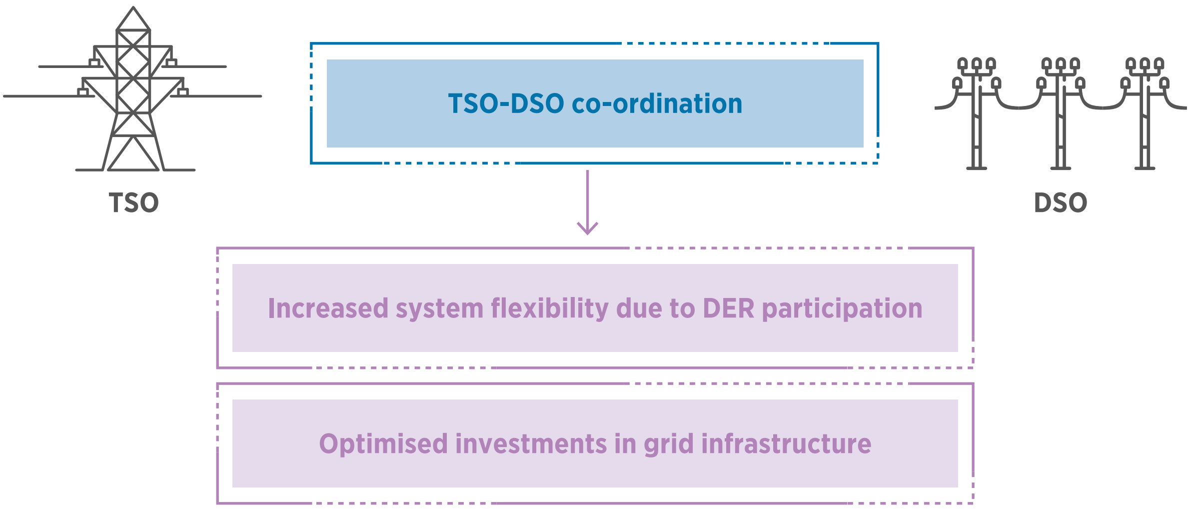
Source: Adapted from Kockar (2017); Gerard (2017); Migliavacca (2018); SmartNet (2019).

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

Greater interaction between DSOs and TSOs enables better utilisation of DERs in the system and increases system flexibility, while reducing expenditures on network reinforcement. The critical factor is data sharing on the capabilities of DERs connected to the distribution grid between system operators who manage real-time markets. This results in the efficient management of the wholesale and ancillary services markets.

TSO-DSO co-ordination is vital to streamline flexibility requirements, synergise planning and reduce network investment costs. The main contributions to power sector transformation from increased co-operation between DSOs and TSOs are highlighted in Figure 3.

Figure 3 Key contributions of TSO-DSO co-ordination to power sector transformation



Increased system flexibility due to DER participation

Typically, TSOs have no information about the resources connected at the distribution level, such as capacity, type, characteristics, generation and consumption patterns. As the number of DERs is expected to increase with more connected devices, such as EVs, distributed solar photovoltaic (PV) systems and heat pumps, the TSO's lack of visibility over DERs can lead to load and generation forecasting errors, which can affect the reliability of the system.

Each system operator, TSO and DSO, is responsible for the operational security and quality of supply in its own networks, and should therefore be entrusted to monitor and interact with its respective grid users. In the case of DSOs, they should interact with the stakeholders connected to their grid and gather the data collected via smart meters (generators, consumers and other DSOs).

By channelling the data and sharing it with the TSO, the TSO will have increased visibility of DER capabilities at any time and be able to use it to provide ancillary services. DSOs can further serve as market facilitators for DERs to provide such ancillary services to TSOs, via aggregators or a different market arrangement. This would help TSOs balance the entire system using all connected resources in the most optimal way (WindEurope, 2017).

Some Nordic countries are in the process of developing centralised data exchange platforms. At the same time, in this region and beyond, the role of system operators is shifting. Key responsibilities include the following:

- TSOs should work with DSOs and regulators to determine requirements for the visibility and active power management of DERs, due to their increasing impact on the overall operation and planning of the system.

- TSOs and DSOs should co-operate to solve congestion issues and share information about foreseen congestion. System-wide real-time operating procedures should be developed to achieve timely and efficient congestion management solutions.

Compensation to DER owners for provision of ancillary services to TSOs or DSOs can lead to an additional revenue stream. This can further incentivise other consumers to install DERs, thereby further increasing renewable energy deployment.

Optimised investment in grid infrastructure

Through increased co-operation, DSOs and TSOs can better align their network expansion plans and identify synergies that could result in significant cost savings on large infrastructure investment projects (CGI, 2017). Further, as increased DSO-TSO co-operation also enables effective utilisation of DERs in congestion management, DSOs and TSOs can defer or partly avoid investment in grid infrastructure.

To further facilitate the integration of renewable energy and customer connections, TSOs and DSOs should regularly exchange and publish information on their available network capacity at the TSO/DSO interface. This also helps project developers connect to the network in such a way that minimises the need for further network investment.

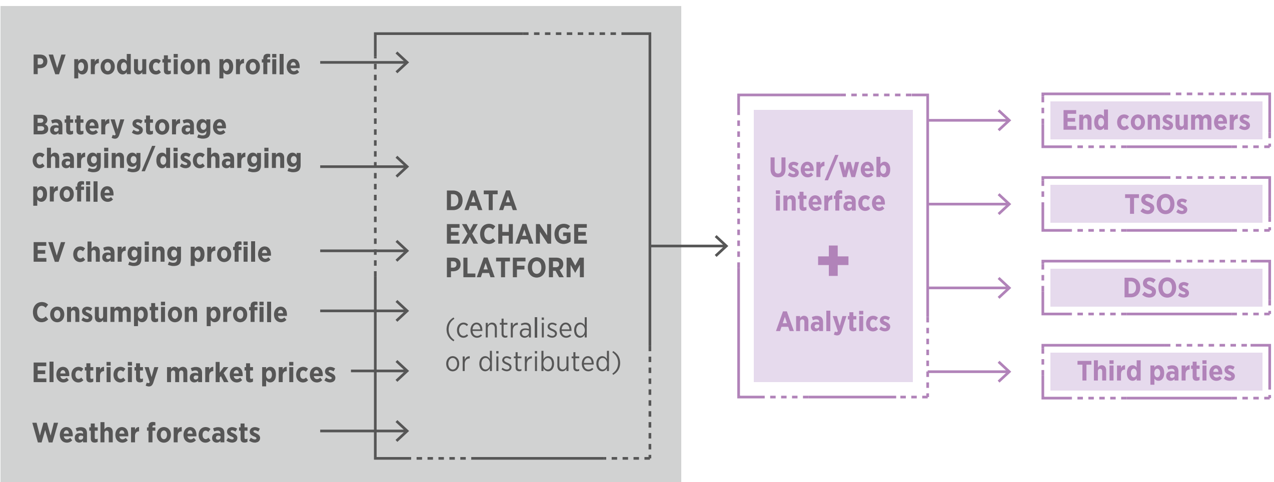
III. KEY FACTORS TO ENABLE DEPLOYMENT

Adapting the regulatory framework is key to enabling system operators to use DERs to their full potential. Regulators should define the roles of DSOs and TSOs to facilitate data collection, management and access for different stakeholders. Different co-ordination models are used in Europe, as presented in Table 1. Regulators and policy makers need to ensure that DSOs and TSOs act in a neutral and transparent manner, enabled by data exchange platforms, communication protocols and the clear allocation of roles and responsibilities between DSOs and TSOs where these entities have unbundled ownership.

Implementing data exchange platforms

In a well-functioning electricity market, one of the most critical tasks for market transparency is the sharing of consumer metering data among different stakeholders. Sharing metering data is essential for the functioning of a competitive market as it enables better decision making by DER operators, electricity retailers and other stakeholders, such as aggregators or innovative companies providing new services[3]. Furthermore, such digital data exchanges allow TSOs and DSOs equal access to real-time information on DER types and connected capacity, their consumption patterns and system characteristics, among other facts. Figure 4 depicts a schematic representation of such a data exchange platform.

Figure 4 Illustration of a data exchange platform



3 *Energy-as-a-service (EaaS) is an innovative business model where a service provider offers various energy-related services rather than only supplying electricity. Energy service providers (ESPs) can bundle strategy, procurement, financing and energy management solutions to offer a suite of services to the customer (IRENA, forthcoming b).*

The data exchange platform can be managed in a centralised or decentralised manner. A centralised data hub can be managed by system operators or a regulated third-party operator who ensures data integrity and provides non-discriminatory data access. Conversely, a decentralised platforms is managed by the local DSO, which ensures data integrity and system security. Data extracted from the data hub can be used for a variety of uses, including flexibility procurement, grid planning, system operation or network tariff determination (Thema Consulting Group, 2017).

Several European countries are planning to introduce such data exchange platforms, or data hubs, while Belgium, Denmark and Norway already have operational platforms (Table 2). In California, Silicon Valley Clean Energy launched a pilot project for an energy data exchange platform in January 2020 to demonstrate the potential of free authorised access to standardised and automated energy usage data. The platform, called UtilityAPI's Data Exchange Platform, is the first of this kind in the United States (CALCCA, 2019).

Table 2 Status of data hub implementation

Implementation	Denmark	Belgium	Norway	California	Finland	Sweden
Status	Operational	Operational	Operational	Pilot project	Planned	Planned
Year	2013	2018	2019	2020	2021	2022

Source: Fingrid (2018); NordReg (2018), Statnett (2019); Svenska Kraftnät (2019).

Digitalisation and establishing communication protocols

Digitalisation is a prerequisite for smart grid operations and for making flexibility available through market mechanisms. The deployment of information and communications technology (ICT) and digital communication are pivotal for co-operation between the DSO and TSO, to ensure reliability of service. The cost of this transition at lower voltage levels is initially expected to be high.

Internet of Things applications, artificial intelligence and big data are critical to making the exchange of information and decision-making processes as fast and efficient as possible (for more information on digital technologies see *Innovation Landscape Brief: Internet of things* [IRENA, 2019d] and *Innovation Landscape Brief: Artificial Intelligence and Big Data* [IRENA, 2019e]).

System operators should develop communication protocols to support data exchange and interoperability on a real-time basis. This requires development of IT architecture that enables fast and secure data retrieval from the hub. Such architecture should include all DSOs within a TSO's network. Furthermore, given the increased data exchange, cybersecurity systems must be implemented to protect these IT systems from external attacks (CEDEC, 2016).

Determining the new role of DSOs

With the emergence of DERs, the role of the DSO itself should expand to harness the flexibility provided by these new technologies connected to the distribution system. In their new role, DSOs could operate the DERs if the regulatory framework allows it. Otherwise, DSOs could act as neutral market facilitators and provide high-resolution price signals to the market players that control the flexibility assets. In this case, an aggregator or other competitive agent would assume this function and operate the DERs according to the price signals. For example, DSOs could procure flexibility services from their network users, such as voltage support and congestion management, to defer network investment, or DSOs might provide reactive power support to TSOs (for more information see *Innovation landscape brief: Future role of Distribution System Operators* [IRENA, 2019b]).

IV. CURRENT CONTEXT AND ONGOING INITIATIVES

Policy makers and electricity market stakeholders across the world are taking the initiative to better integrate the growing number of DERs into the power system. Table 3 lists a range of initiatives to increase TSO-DSO co-operation in a European context. Initiatives that focus on increasing DER integration through better TSO-DSO co-operation are described in Table 3.

Table 3 Initiatives to increase TSO-DSO co-ordination in Europe

Description	Key facts
Regional or national plans for TSO-DSO co-operation	The European Union, as part of its Clean Energy Package for All Europeans legislative package, has issued Regulation (EU) 2019/943 on the internal market for electricity. It contains rules on co-operation between the European Network of Transmission System Operators for Electricity (ENTSO-E) and a European Entity of Distribution System Operators (EU DSO entity), which is to be established. The rules include close co-operation on the preparation, implementation and monitoring of network codes and providing guidance on the integration of distributed generation and energy storage into distribution networks or other areas that relate to the management of distribution networks.[1]
Companies participating in pilot projects for TSO-DSO co-operation	• **TSOs**: Elia, ELES, Transelectrica, APG, MAVIR, Energinet.dk, TERNA. • **DSOs**: ENDESA, SE, Edyna, EDP. • **Market design solution providers**: cyberGrid GmbH (demand-side response), N-Side (developing market design for procuring ancillary services as part of SmartNet project).[2]
Investments made in co-ordination projects	• **InteGrid**: EUR 14.53 million[3] • **SmartNet**: EUR 12.66 million[4] • **SINTEG**: EUR 500 million (including the digitalisation of the energy sector)[5] • **CoordiNet**: EUR 15 million[6]

Source: [1]EUR-Lex (2019); [2]N-Side (2018); [3]European Union (2016); [4]EC (2020); [5]BMWi (2016); [6]Coordinet Project (2019).

Collaborative procurement of flexibility services by DSO and TSO, Belgium

The TSOs in Belgium use DERs to balance generation and demand. The DSOs assess the quality and capability of DERs before qualifying it for providing balancing services to the TSO. The TSO and DSOs collaborated to develop a central shared IT platform for sharing all data related to procuring DERs for flexibility. It brings together all the data needed to economically assess the flexibility available, for example the consumption profiles of all grid users who opt to offer flexibility. The system calculates the quantity of energy "not consumed" or generated in a given period. This means the data hub is a critical data tool for ensuring the smooth operation of the market processes involved in providing flexibility.

The platform allows the TSO to contract flexibility, substituting the current bilateral agreements. Through this data hub, all users and generators connected to the distribution/transmission grid can provide flexibility services to TSO on a daily basis (Elia, 2018). Moreover, the TSO is given more visibility over the actions of DERs and contracting options.

SINTEG programme, Enera project, Germany

Germany's SINTEG programme, launched in 2017, aims to set up pilot or "showcase" projects demonstrating solutions to integrate high shares of energy from VRE sources, such as solar and wind, into the national grid. Under this programme, five showcase projects will be implemented at an investment of EUR 500 million. Enera, one of the five showcases, aims to develop solutions to enable DER participation in the wholesale market for ancillary services.

Enera focuses on three core areas: (a) grid management – using data to improve grid operations and create a "smart grid operator"; (b) market – improving the intraday markets to enable procurement of flexibility services from DERs to manage the distribution networks; and (c) data – building secure information and communication systems to gather and analyse data. As part of this project, EWE AG and the power market operator, EPEX SPOT, created a local market platform for system operators to procure flexibility services to manage congestion. The market platform was activated in 2018 and facilitated the first transaction in 2019 (EWE, 2018; Tix, 2019).

Energy Network Association's Open Networks Project, United Kingdom

The Open Networks Project aims to develop a smart, flexible energy system to accommodate a greater share of renewables. The key components of the project involve aiding DSOs to take up the role of a system operator and also implement mechanisms for better TSO-DSO co-ordination.

The project will detail processes, roles and responsibilities to enable co-ordination between TSO and DSOs, and will address the increasing amount of energy flowing back into the distribution grid and being exported to the transmission network. The project will also focus on improving transparency between market participants, network operators and customers, and also work on setting up a fair market framework that focuses on benefitting the entire system (Smith, 2017; Energy Network Association, 2018).

SmartNet project, Denmark, Italy and Spain

The SmartNet project is funded by the European Union's Horizon 2020 programme, with a budget of over EUR 12 million to identify models for interaction between TSOs and DSOs. The overall objective of the project is to enable data exchange between TSOs and DSOs for monitoring and acquiring DERs to provide ancillary services. The project includes designing co-operation schemes and building a simulation platform (which includes a representation of the physical network, market and information and communication systems) to enable interaction between the system operators on a pilot scale in Italy, Denmark and Spain. Beyond developing the simulation platform and three national scenarios, pilot projects are also being carried out, as follows:

- **Denmark**: The objective of this pilot is to provide data from smart meters to TSOs, DSOs and aggregators, and enable system operators to monitor and control consumption to facilitate balancing and congestion management. In this pilot, smart meter data from 30 summer houses with electrically heated indoor swimming pools is aggregated and shared with the local system operator, Syd Energi, and with the TSO, Energinet.dk.

  The system operators use price signals to remotely control the electricity consumption of the swimming pools. The pools' heating schedule can be modified to solve balancing or congestion management issues faced by the system operator. The plan is to implement the model in such a way that aggregators can profitably participate in the data exchange platform. Also, the IT system is to be built so that it can obtain data from various smart meters and control a variety of thermostats.

- **Italy**: The objective of the pilot project in Italy is to aggregate real-time data on the total load and the amount of energy generated from different DER sources at the interface between TSO and DSO. This will facilitate providing ancillary services such as voltage and frequency regulation. Terna, the local TSO in Italy, is collaborating with Edyna, the DSO of the Südtyrol region, on this pilot project together with the two manufacturers, SELTA and SIEMENS, to monitor and control DERs connected to the distribution grid in real time (Engerati, 2017).

  In this pilot, the DSO grid is monitored in real time and information is passed on to the TSO, which manages the system in a centralised way.

The TSO is therefore informed about any limitations faced by distribution branches and can take the necessary action.

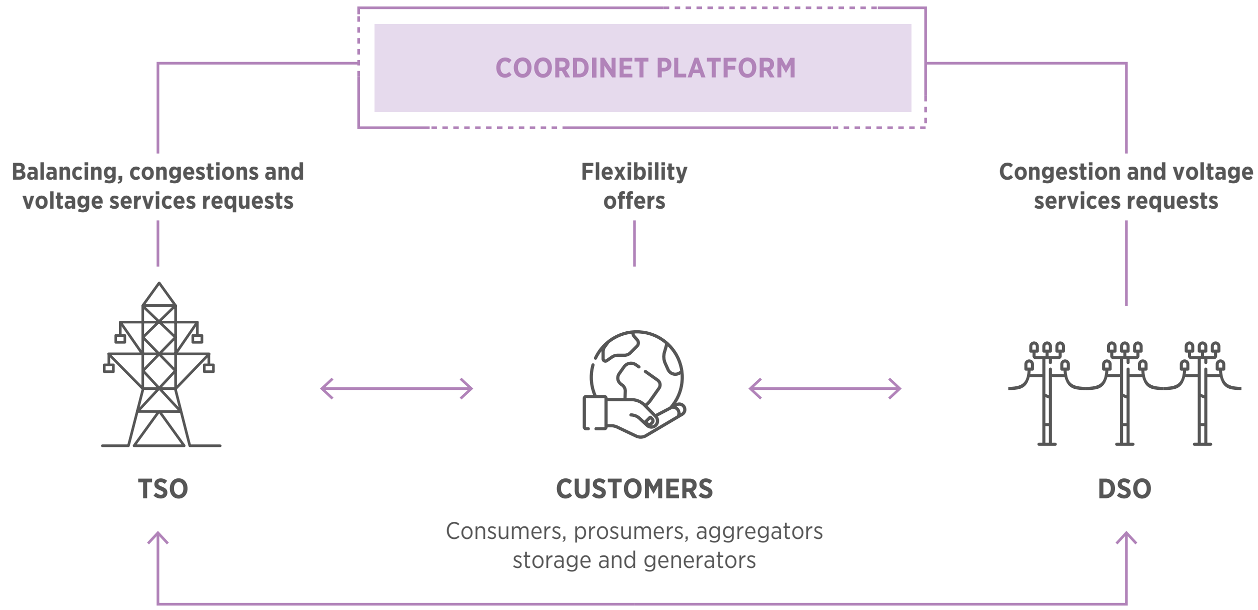
CoordiNet project, Greece, Spain and Sweden

The CoordiNet project, also funded by European Union's Horizon 2020 programme, is developing standardised co-ordination schemes for efficient TSO-DSO co-operation to allow renewables to provide electricity grid services (Figure 5). The main objectives of the CoordiNet project are:

- Demonstrating the activation and provision of services through a TSO-DSO co-ordination platform.
- Defining and testing standard products that provide services to the network operators.
- Developing a TSO-DSO-consumer collaboration platform in demonstration areas to pave the way for the development of an interoperable pan-European market.

The project has been implemented simultaneously in Greece, Spain and Sweden starting in January 2019. It is expected to identify modifications needed to grid codes and further increase co-operation between TSOs and DSOs. The project also explores how the Internet of Things, artificial intelligence and big data, peer-to-peer energy trading platforms and blockchain technologies can facilitate the market participation of prosumers. Overall, 23 companies and institutions from 10 countries are participating in the project between 2019 and 2022 (CoordiNet Project, 2019).

Figure 5 TSO-DSO co-operation model proposed by the CoordiNet project



Source: CoordiNet Project (2019)

Energy transition project in Colombia

The Colombian Ministry of Energy and Mines is pursuing a project called "Mission for the Transformation and Modernisation of the Electricity Sector", which includes adapting regulations to digitalisation, DERs and demand response. In view of the increasing DERs in the country, the project acknowledges the importance of closer co-operation between DSO and TSO for the optimal operation of the entire system.

Considering that distributed resources can provide services to both DSO and TSO, fluid co-ordination between both network operators is required – a new scenario that significantly increases the complexity of system operation. In addition to short-term co-ordination, there is also a need to co-ordinate network planning and operational functions in the long term. All this will lead to greater efficiency both in the use of networks and in the use of electricity generation and demand (MINENERGIA, 2019).

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS

Hardware:

- Smart meters and smart network devices, enabling advanced metering with bi-directional communication between metering points and aggregators/system operators.
- Widespread adoption of distributed generation sources and energy storage technologies.

Software:

- Information technology systems that enable real-time or near to real-time data collection and exchange between different stakeholders.
- Communication systems that enable price signals for frequency/voltage services between system operators and individual DERs or via aggregators.

Communication protocols:

- Common interoperable standards (at physical and information and communication technology level) to enable TSO-DSO co-ordination, as well as interaction with DER asset owners/operators.

POLICIES NEEDED

- Polices to implement advanced metering infrastructure that will enable two-way communication between DERs and system operators.
- Policies that define the role of system operators and their ability to access DERs for providing flexibility.
- Policies focused on creating functioning markets (wholesale electricity and ancillary services markets), deploying innovative technologies and reducing system operation costs.

REGULATORY REQUIREMENTS

- Clear regulations that ensure DSOs and TSOs act in a neutral and transparent manner in procuring services from DERs.
- Regulations that turn DSOs into active and neutral market facilitators.
- Regulations to share data from the hub with other market stakeholders while ensuring protection of consumer data.
- Regulations to ensure data integrity and security of the data hub or data sharing platform.
- Regulations that allow DSOs and/or TSOs to procure ancillary services from DERs.
- Regulations that allow aggregation of DERs to enable their participation in markets or reduction of minimum bid sizes to allow individual DERs to participate.

STAKEHOLDER ROLES AND RESPONSIBILITIES

ADSOs and TSOs: collaborate with each other and with other stakeholders, including electricity retailers, DER owners/operators and aggregators, to gain visibility on the types and capabilities of DERs to provide ancillary services.

TSOs and/or DSO: procure ancillary services from DER owners/operators (potentially via aggregators).

IT solutions providers: develop ICT infrastructure; ensure data protection and system security.

Policy makers and regulators: invest in pilot-scale projects to implement co-ordination schemes between DSOs and TSOs and ensure dissemination of results; define a vision for DER deployment and market integration, where applicable.

ABBREVIATIONS

DER	Distributed energy resource
DSO	Distribution system operator
EV	Electric vehicle
ICT	Information and communications technology
PV	Photovoltaic
TSO	Transmission system operator
VRE	Variable renewable energy

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CO-OPERATION BETWEEN TRANSMISSION AND DISTRIBUTION SYSTEM OPERATORS

INNOVATION LANDSCAPE BRIEF

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