Data for Multi-Party System Operation

Energy Data Taskforce Appendix 5

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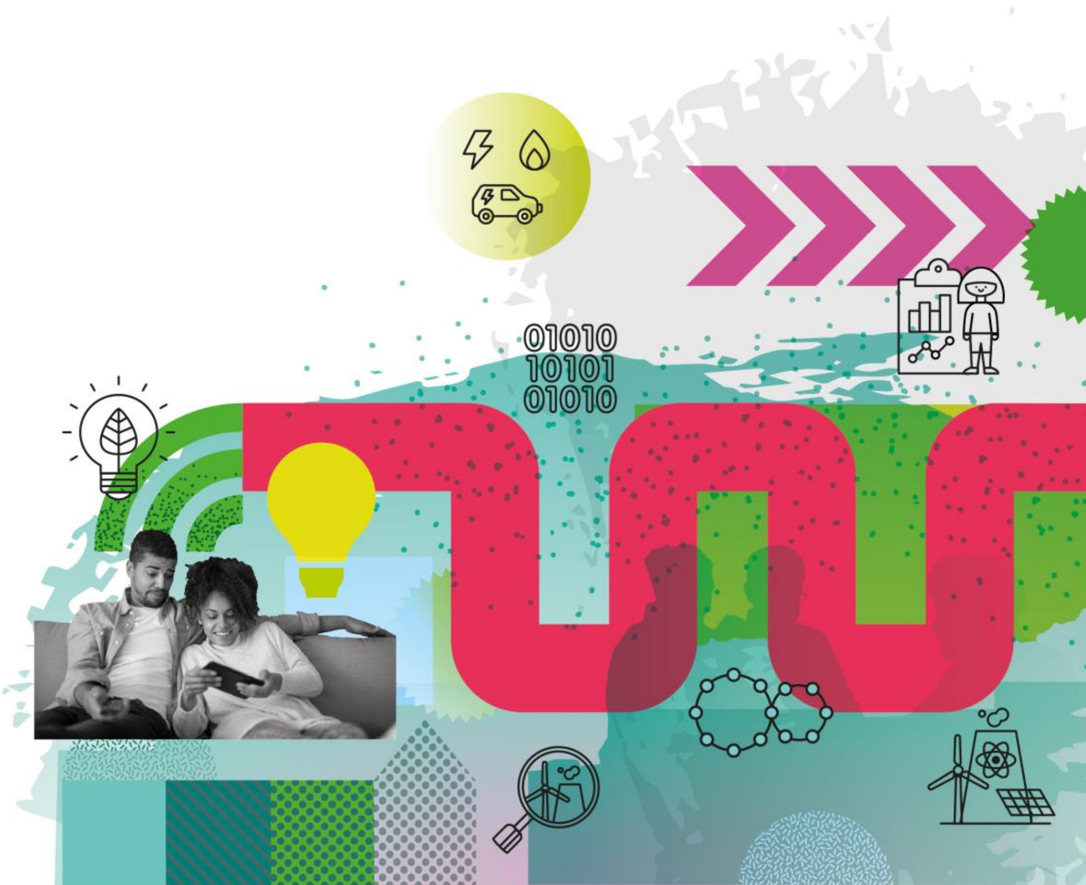

Contents

1. Executive summary

The digitalisation of the Energy System requires a much more sophisticated use of data.

Decarbonisation technology, particularly in solar energy, is driving the development of many smaller more distributed energy sources, and new dynamic low carbon demand technologies, including smart EV charging, smart multi-vector heat and storage technologies are emerging to make the system operation challenge ever more complex.

New IoT control systems are also emerging that enable the control of production and demand by customers and their service providers. Much of the demand control could develop 'behind-the-meter', increasing the ability for customers to choose to optimise locally or between peers. This will require coordination between systems, new control and data distribution systems, new customer interfaces and transaction systems as well as creating new opportunities for data analytics to support these interactions.

There are many possibilities for a multi-actor system but what is clear is that the future system operation will require collaboration between multiple parties. This annex considers the data needs of such a complex multi-actor system.

Considering this complexity, there is a strong argument to adopt a functional approach to system management, such as that developed by the Future Power Systems Architecture (FPSA) programme. The FPSA programme developed a group of functions to "Form and share a best view of state of system in each time scale".

For there to be coordination between multiple parties the likely actions of those involved in managing the system must be transparent, enabling a common view of how the system will operate to be shared by all. This annex explores in more detail the energy system data that might need to be shared to achieve this, as illustrated below.

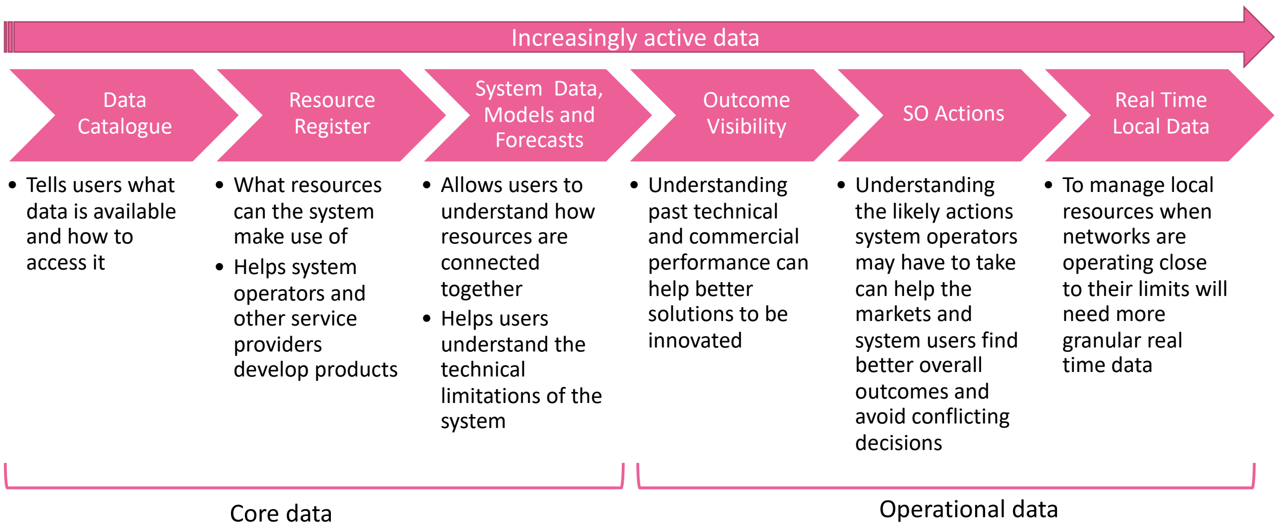

Figure 1 Data to share a common view of the system

We recognise that while much is already starting to happen, there remains a lot that needs to be in place to enable opening up of a shared view of the system. Much data already exists but needs to be made more readily accessible, and by less manual processes (e.g. APIs) so that third parties can bring the data together to create rich sources of new value, integrating across energy vectors and users, particularly transport.

The Taskforce recommendations for a Data Catalogue and an Asset Registration Strategy underpin this.

A potential road map, shown below, has been developed to stimulate debate about the way forward. The principles of Presumed Open are at the core of this roadmap, that is building structured, discoverable data and interfaces that enable the best view of the system to be shared.

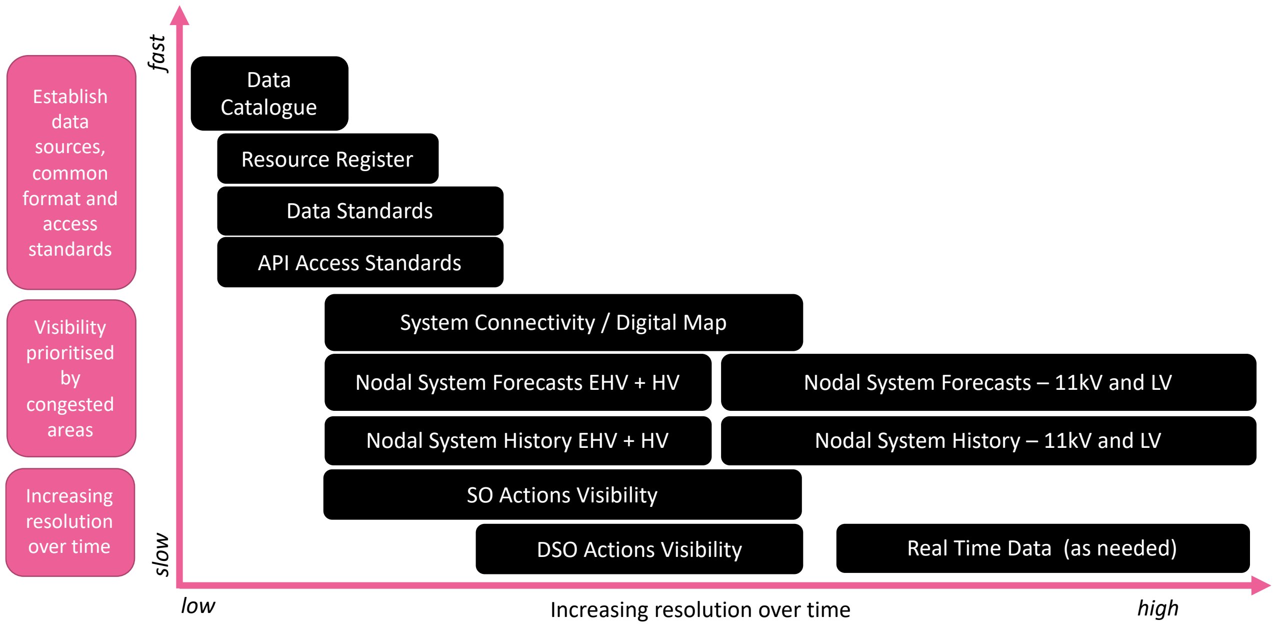

Figure 2: Data roadmap for multi-party system operations

The roadmap recognises that opening the data needs to be prioritised according to need, with some real-time data already being used to manage flexible generation. The roadmap is aligned with the recommendations of the main report, recognising the priority of need to develop a catalogue of the data and a register of system assets, without which forecasts and connectivity data are impaired.

Appropriate standards for data and access to it should be given consideration early on to support the innovation of data driven technologies.

A Digital System Map, based on open data standards, would drive the development of a cohesive data set covering geospatial, connectivity and potentially technical data. Enabling others to map emerging demands for LCT infrastructure such as EV charging to this data which will help to prioritise the data development needs.

A system map could also support the visualisation of the system operator's needs and likely interventions, creating the transparency been actors in the system to avoid conflicting instructions and to optimise actions between markets and real-time operations.

2. Data for Multi-Party System Operation

2.1. Introduction

The digitalisation of the Energy System requires a much more sophisticated use of data.

Decarbonisation technology, particularly in solar energy, is driving the development of many smaller more distributed energy sources. New dynamic, low carbon demand technologies, including smart EV charging, smart multi-vector heat and storage technologies, are emerging to make the system operation challenge ever more complex. New IoT control systems are emerging that enable the control of production and demand by customers and their service providers.

The old 'analogue' system built around a small number of highly specified, controllable generators could be managed by a single system operator, but the new 'digital' system that is developing needs coordination between national and local systems, energy services and behind-the-meter technology. There are many possibilities for a multi actor system but what is clear is that future system operation will require collaboration between multiple parties.

This annex considers the data needs of such a complex multi-actor system.

2.2. System Operations

System Operation is the process of:

- ensuring that supply and demand in the energy system remains balanced;
- the system provides a safe supply to customers within a given set of technical parameters (frequency and voltage);
- the system is resilient to an unexpected incident.

The System Operators' role is to ensure that consumer energy demand is met safely and reliably. This includes balancing real-time supply and demand within the constraints of the system, ensuring reserves are sufficient and the system delivers the power to meet statutory standards.

This annex concentrates on the electricity system.

The impetus to decarbonise the energy system has already driven change. Supply has moved away from central transmission connected generation towards low carbon distribution connected generation, which is weather dependent making the system more challenging to manage particularly at times of lower system demand. As widely distributed energy resources begin to dominate supply, combined with the adoption of electric vehicles and low carbon electric and hybrid heating systems, they will drive further changes to the way the system needs to be operated. This shows a growing need to manage many more distributed, active energy resources and smart loads to help balance the system locally and nationally[1,2] to avoid supply constraints[3].

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[1] https//www.westernpower.co.uk/anm-further-info
https://www.ukpowernetworks.co.uk/electricity/distribution-energy-resources/flexible-distributed-generation
https://www.ssen.co.uk/GenerationAvailabilityMap/?mapareaid=1

[2] https://picloflex.com

[3] http://www.electricnation.org.uk/wp-content/uploads/2017/11/14-How-will-the-growth-of-electric-vehicles-impact-the-grid.pdf

2.3. How does the system operate today?

Figure 3 below illustrates how the parties involved in the electricity system interact today.

Energy suppliers trade in the energy markets to achieve a commercial balance between the supply of energy they purchase and the demand of their customers. Their position can be refined up to an hour ahead of each 30-minute supply window. The system operator then ensures supply and demand are balanced throughout the 30-minute window.

Capacity markets have been developed to ensure that sufficient capacity is available for the markets to operate effectively.

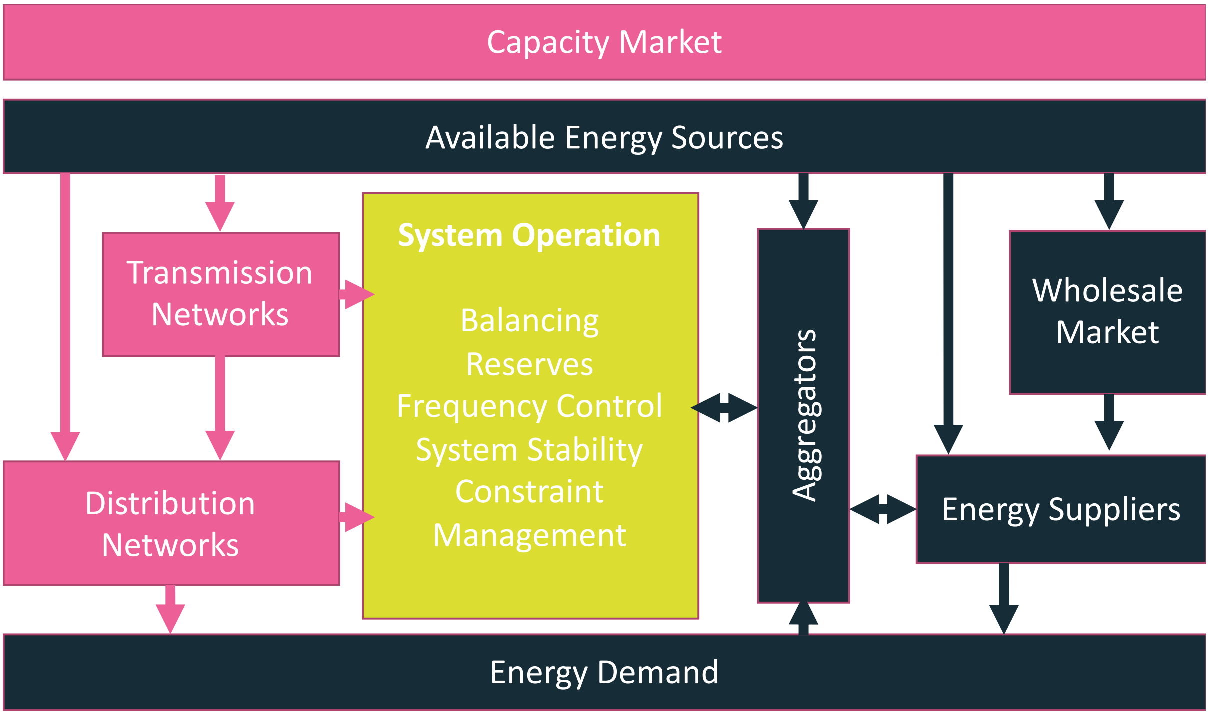

Figure 3 How system operation integrates markets and networks.

In the hour before the supply window, the Electricity System Operator (ESO) runs the Balancing Market where it receives bids and offers to increase production or reduce demand in order to maintain a balanced system, at all times.

The System Operator buys other services to allow it to:

- maintain frequency response (including inertia: the system's resistance to changes in frequency);
- have reserves available for potential system incidents (e.g. loss of a large generator); and
- maintain the technical (e.g. voltage management) performance of the transmission system.

As more resources are connected at lower voltages, distribution network operators are becoming increasingly involved with the transmission system processes as well as buying active services to support their own networks, and as such are being referred to as Distribution System Operators (DSO).

2.4. Potential Futures

The shape of the future system will be influenced by the development of IoT technologies, creating greater interconnectedness and controllability of the systems that we use and consume energy.

It is inevitable that the electricity system will see another phase of dramatic growth as hydrocarbons used in transport and heat are replaced, entirely or in part, by electric solutions. The major change at the heart of the system revolution is that consumption is likely to become more controllable than generation. IoT / ICT technology will be at the heart of matching smart demand to low carbon resources as efficiently as possible.

There are several future possibilities for how the system and markets will become more complex to operate. These futures could include:

- Local energy markets or communities could emerge that look to optimise the use of their local resources, requiring some level of local control and optimisation;
- Market players could take a more active role in managing behind the customer meter assets to influence the use of the resources they have contracted for and reduce their balancing costs;
- Real-time AI technology could allow customers' own resources e.g. EV's to respond automatically to real-time signals such as energy price, network use or local emissions;
- Rapid uptake of low carbon heat and transport technologies may be best met by actively shaping demand to maximise the use of low carbon resources and avoiding delivery network constraints.

In considering how these could affect the role of system operators, the ENA Open Networks project has proposed a number of future operational 'worlds'[4] based around the management of flexible energy sources and demands.

- World A: DSOs take the central role in coordinating distribution connected services
- World B: ESO and DSO work together to manage distribution connected resources
- World C: Price driven flexibility signals are used by both ESO and DSO
- World D: ESO takes a central role in managing all service needs
- World E: One or more independent third parties manage a market for flexibility services to both the ESO and DSOs

The ENAs transition paths and impact assessment foresee a development of World B[5], in the near future with either worlds potentially A or D developing thereafter, all supported by price driven flexibility.

This is a logical conclusion. There will almost certainly need to be some form of overall coordination of an interconnected system and its interactions with neighbouring systems through interconnections to continental Europe and Ireland. If complexity increases as anticipated, there will be an increasing need for local, automated, grid management to maintain safe, reliable supply and coordination between actors, which will be critical.

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[4] http://www.energynetworks.org/electricity/futures/open-networks-project/future-worlds/future-worlds-consultation.html

[5] http://www.energynetworks.org/assets/files/Future%20World%20Impact%20Assessment%20report%20v1.0_pdf.pdf

An important area for consideration is the developing interest in local area energy markets (LEM)[6,7,8,9]. Ofgem's definition is *"Energy arrangements led by (or for the benefit of) a local group and for the benefit of local consumers. A local group is a collection of people and organisations with shared interests in local energy outcomes within a common geographical area"*.

This concept inherently contains an aspect of local system operation, balancing local resources with local demand, to meet community objectives. LEMs also introduce the concept of local peer-to-peer 'trades', system operators may have to account for[10]. These trades could be both commercial and / or preferential (non-commercial i.e. given rights) as well as addressing other local drivers such as air quality (e.g. reduced gas or vehicle emissions at certain times of day) going beyond responding to electricity system prices.

Local markets could operate in two ways:

- Unconstrained, with a local DSO/coordinator then using flexibility offers to take actions to address constraints and imbalance and other system issues.
- Constrained by the requirements of the known network issues (Cornwall LEM[11] aimed to undertake such an approach, which can be enabled by price driven choices) and informed by the value of flexibility to other parts of the system.

There is considerable interest, innovation and investment in smart systems that can balance demand, embedded generation and storage behind the customer's meter to the benefits of local networks[12]. Examples such as the trial being undertaken by Evergreen Smart Power[13] which is looking to investigate how their virtual power plant systems can integrate with real-time data from the local distribution system.

Energy data is also being integrated with wider data to enhance operations, an example of which is the work Smarter Grid Solutions is undertaking as part of the EU Horizon 2020 OPTIMISED projects[14], looking at how data can be integrated to optimise energy in industrial and building systems.

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[6] http://www.cired.net/publications/workshop2018/pdfs/Submission%200272%20-%20Paper%20(ID-21042).pdf

[7] https://publications.parliament.uk/pa/cm201314/cmselect/cmenergy/180/180.pdf

[8] https://www.ofgem.gov.uk/news-blog/our-blog/exploring-local-energy-regulators-perspective

[9] https://www.ofgem.gov.uk/system/files/docs/2017/01/ofgem_future_insights_series_3_local_energy_final_300117.pdf

[10] https://www.current-news.co.uk/blogs/current-disruptors-vervs-peter-davies-on-expanding-peer-to-peer-energy-trading

[11] https://www.centrica.com/innovation/cornwall-local-energy-market

[12] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/783338/BEIS_innovative_domestic_demand-side_response-competition_phase_2.pdf

[13] https://evergreensmartpower.co.uk/what-we-do/domestic-dsr-fred-trial/

[14] https://www.optimised-h2020.eu

These smart systems, using multiple data sources from separate systems and markets, will be essential for managing flexibility across multiple vectors and finding whole system efficiencies that a DSO or the ESO is not able to directly influence or control. Creating standards for opening-up system data is essential to enable these technologies to develop in a way that can be integrated into system operations[15].

2.4.1. Summary of Potential Futures

Model	Description	likelihood
ESO Centric (ENA World D)	ESO run 'market' for all system operation resources – DSO specify their requirements to ESO. Market deals with unconstrained world - ESO manages constraints	**Possible** Key concern is the ability for a single SO to manage local level constraints – depends on the degree to which DSO activities can be automated. Likely only if DER uptake to manage local issues is limited.
DSO Centric (ENA World A)	DSO run 'market' for distribution connected resources for transmission and distribution – ESO specifies their requirements to DSOs Market deals with unconstrained world - ESO manages transmission constraints.	**High** There is a strong logic with many local constraints and highly embedded resources that DSOs may be best placed to optimise between local and ESO needs.
Coordinated SO (ENA World B)	Coordinated framework run by ESO and DSOs for specific services.	**High** Essentially a logical development of current arrangements
Local Markets (ENA World E – though LEMs are more than this and could include elements of ENA World C)	Local energy markets operate to optimise use of local resources. Embedded within DSO and included resources 'balanced' as a discrete exercise by DSO or separate operator.	**Probable** Engagement through: Peer to Peer sharing and trading + maximisation of local resources may be key part of developing flexible energy across vectors.
Markets using Price driven flexibility (ENA World C)	Markets manage constraint functions of ESO and DSO through price signals.	**Low** Purely price driven markets that can deal with local constraints and peer-to-peer will be challenging. Price signals will form a necessary part of all scenarios.

Table 1 Future options for system operation

[15] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/785547/unlocking_digital_competition_furman_review_web.pdf

2.5. Overview of roles in system operation

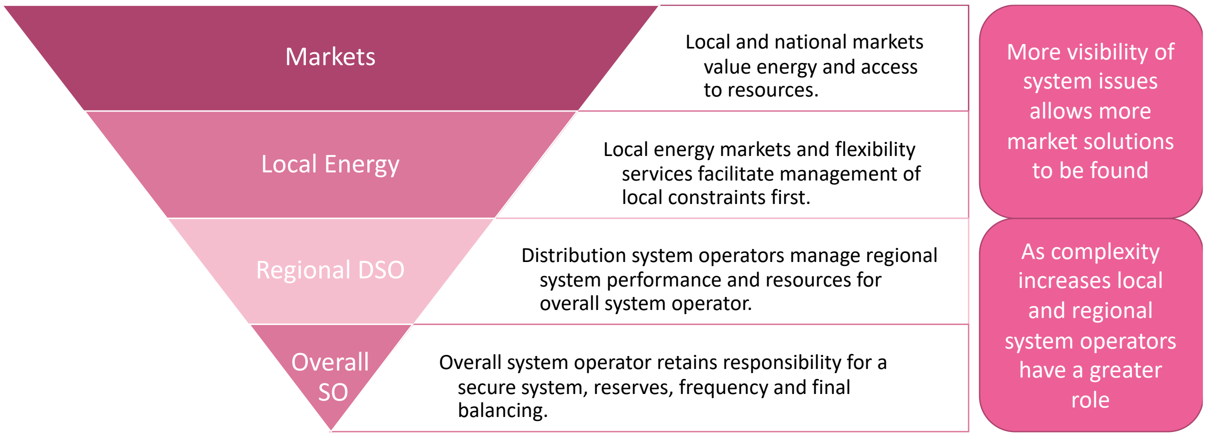

Figure 4 Roles in System Operations

2.5.1. System operations and energy markets

System operation is already underpinned by markets for balancing services and the commercial procurement of services for frequency response and other ancillary services. The price the SO pays for services and the cost of system operations is an important signal to users to find lower cost solutions – either as services to the system operators or as a means of avoiding the costs altogether.

In the first three futures set out in Table 1, the system operators identify and contract for the services or resources they need to manage the system in real-time.

Markets can operate unconstrained by the technical limits of the system, allowing for greater liquidity. If more constraints arise on the system, the system operator's costs will increase unless market actors can pre-empt the costs and adapt demand and production to reduce the operation costs.

In the more market driven options, the SOs signal the limitations of the system, and the costs of addressing system issues and markets take an active role in addressing constraints.

In either of these scenarios having a transparent view of the drivers of system operations costs, likely system operator actions and asset status will be important.; hence why the principle 'Presumed Open' has been recommended by the Taskforce.

Transparency of the impacts of asset status and the impacts on the overall system costs should also lead to better asset management decisions by the asset owners where these are separate from the system operators.

2.6. A functional architecture for future systems

The Future Power System Architecture project[16] identified 35 functions that had to be delivered in a smart power system architecture. The key functions for system operation' data are focused in the group C of functions "Form and share a best view of state of the system in each time scale" [17], described below.

C1	**Forecast** all **demand**, **generation**, other **energy resources** and **ancillary services** across all voltage levels within the power system.
C2	Collate and distribute information throughout the power sector on the **availability** and **performance** of the **generation**, other **energy resources** and **ancillary services**, and any associated **operational restrictions**.
C3	Collect **outage information** from all parties of significance within the power sector, coordinate with affected parties, **identify clashes** and resolve, with assigned responsibility for security of supply.
C4	**Forecast and model** all **generation** and other **energy resources** and **ancillary services** with operational, cost, and security implications for the power sector.
C5	Identify **available generation**, other **dispatchable energy resources** and **ancillary services** and **associated operational restrictions** in **real-time**.

Table 2: FPSA functions relating to data visibility

The data requirements for system operations are defined in these functions. There is some overlap but essentially, they identify:

- Knowledge of all energy resources and where they are connected
- Forecast of demand on the system
- System ancillary service needs
- Operational restrictions such as network outages and constraints

The information describing what the system needs to undertake for the system operation functions is likely to remain the same in whichever future develops, the changes being in the granularity of data required and who processes and acts on the information.

2.7. Conclusions

It is clear that multiple actors will be involved in system operations in a multi-vector system. This will include a central system operator responsible for overall coordination and system security, most likely local DSOs as complexity emerges, but also automated systems managing cross vector assets behind-the-meter. It is not possible to determine the exact nature that these will take, nor would it seem sensible to do so given the possibilities from digital innovation.

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[16] https://es.catapult.org.uk/wp-content/uploads/2017/08/FPSA2-Synthesis-Report-WEB_Locked-ESC-version-1.pdf

[17] See Pages 19-20: https://es.catapult.org.uk/wp-content/uploads/2017/08/FPSA2-Synthesis-Report-WEB_Locked-ESC-version-1.pdf

Approaching system operations data needs from a functional perspective is the most appropriate approach that supports many futures.

The key functional requirement is to enable users of the system to share a common view of the system. The Taskforce's principle of Presumed Open is well aligned with creating a shared, common view of the system.

In the next section we will consider the data / information needed to achieve a common view of the system.

3. Data Needs for Multi-Actor System Operation

In order to explore the data needs for system operation we need to consider the management cycle, illustrated below.

Figure 5 System Operations Cycle

Supply and demand forecasts are fed into system models to assess possible system performance issues and constraints. This data informs the need for services for balancing, reactive power, frequency control etc.

As the system comes closer to real-time, the need to assess potential conflicts between market and System Operator (SO) actions grows so that the SO can develop the options that may be needed in real-time.

During real-time control the SO will take management actions to address potential issues on the system, maintain balance and ensure system security. These actions and the data about actual performance feed back into future system forecasts and models.

This cycle happens over several timescales as shown in Figure 6 below.

Data for Multi-party System Operation

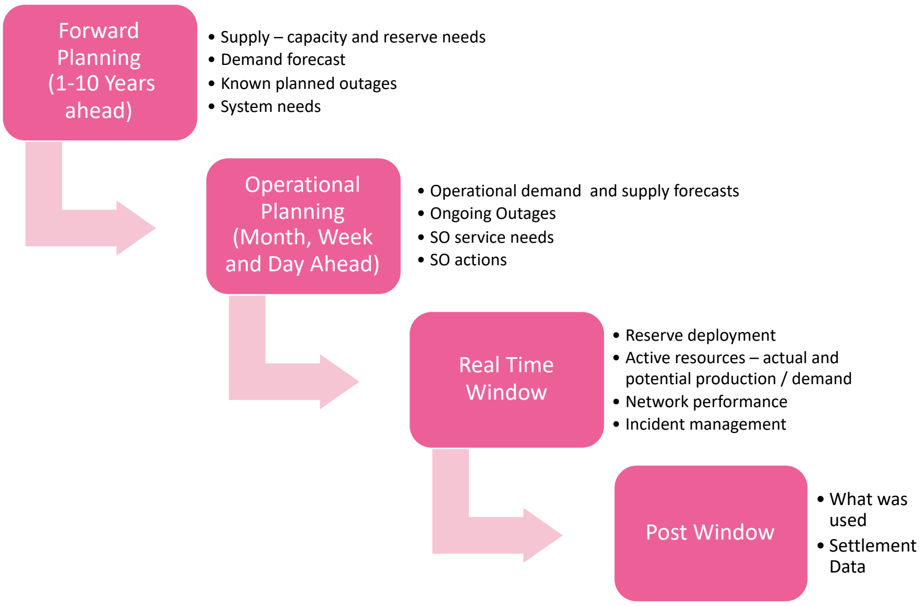

Figure 6 System Operation Timescales

Data will need to be made available at these different timescales in order that system needs can be signalled, suppliers can plan for their provision and effective markets develop for system services.

A recent ENA assessment of existing data[18] illustrated how data has evolved to meet specific needs and is not necessarily available in a consistent manner across organisations or in ways that facilitate automated access; data standards will be required to improve sharing of data between organisations. Examples include the different approaches to making constrained area information available[19] and how DSO long term development statements make network data available, but only through spreadsheets[20], that are not machine readable, (as opposed to API enabled data) and how that data is biased towards the higher voltages with 11kV and LV distribution network data availability being very limited. Efforts are required to fill the gaps in data

The diagrams below outline the data products we have identified to enable multi-party system operations. The granularity of data needed will increase over time, potentially down to street level low voltage supplies to support real-time control for services such as smart EV charging.

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[18] ENA survey of GBSO and DSO data: http://www.energynetworks.org/assets/files/WS1%20-%20P8%20-%20Survey%20Results%20-%20May%202018-DMacP%20(002).pdf

[19] Examples:
https://www.westernpower.co.uk/anm-further-info
https://www.ukpowernetworks.co.uk/electricity/distribution-energy-resources/flexible-distributed-generation
https://www.ssen.co.uk/GenerationAvailabilityMap/?mapareaid=1

[20] Example: https://www.ukpowernetworks.co.uk/internet/en/about-us/regulatory-information/long-term-development-statement.html

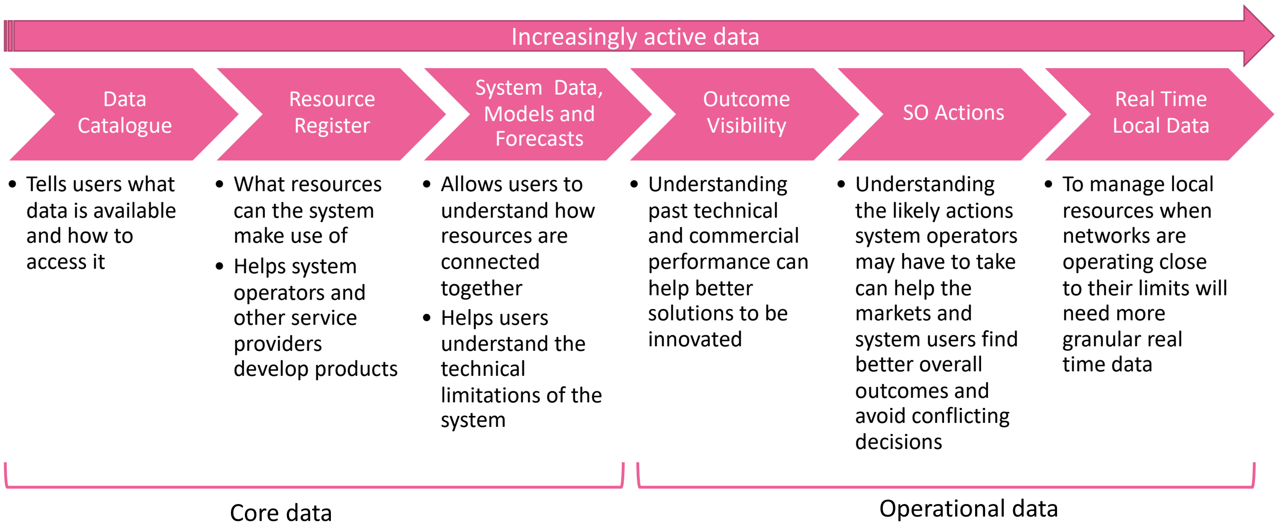

Figure 7 Data needs overview

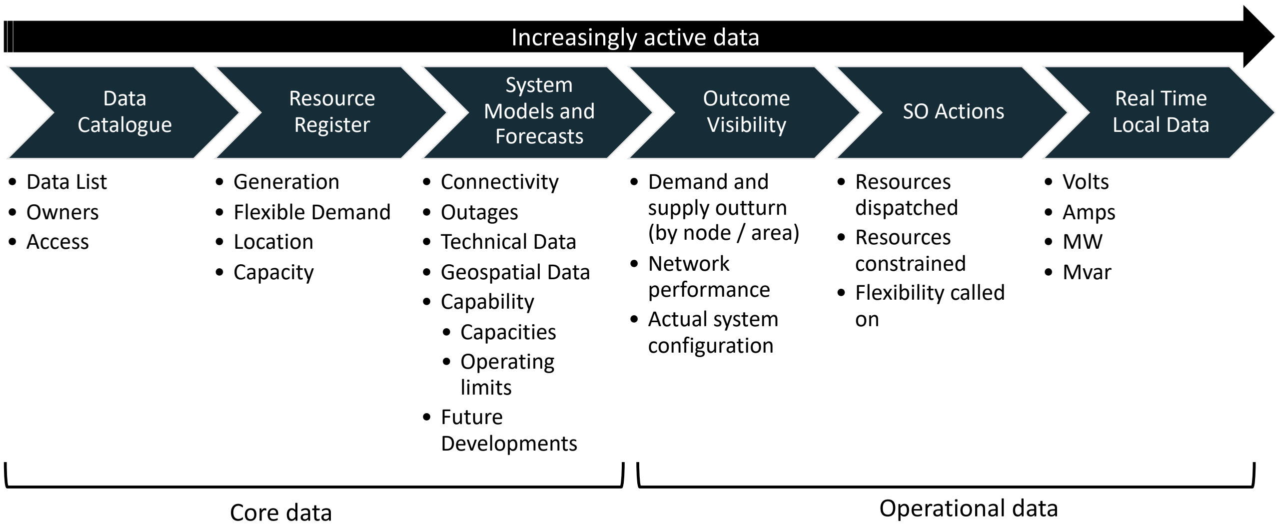

Figure 8 Data elements

Figure 7 describes the need for data to support Digitalising the Energy System. Core data describes the system and its expected development. Operational data provides information on actual events and how the system performed. Whist historic data is needed to inform future decisions, smart systems will increasingly use real-time data for active management. Figure 8 outlines the type of data associated with the suggested data products.

3.1. Asset Registration

A resource register is a prerequisite for the system operators to develop accurate system information. As is discussed in more detail below, a register of which resources are connected and their capability to match supply with demand must be at the heart of system and market operations. Such registers are already being implemented elsewhere, for example in Germany[21].

At its most basic, a register would detail production resources (PV, Wind, Thermal) and their capacities as well as the point of connection to the wider system. Any register should also include flexible resources such as storage or flexible demand.

The ENA system wide resource register proposals[22] also consider including the contracted status of the resources as a starting point for finding available resources. This information could also be vital for identifying potential conflicts, for example between supplier contracted flexibility and system contracted flexibility.

The resource register could also include the system technical data (resistance, reactance, ratings etc), though these may be better provided as part of a digital equivalent / model.

See **Appendix 3** for more information on the Taskforces recommendation.

3.2. System Data, Models and Forecasts

Providing system performance and constraint data requires a model of the system to exist so that the SO can assess how the system is expected to perform under the anticipated demand and supply forecasts. This requires:

- Data on the configuration and connectivity of the system: what is connected where and how the elements of the system connect to each other.
- Technical data on the components of the system: their electrical parameters (resistance, reactance etc), technical capabilities (thermal ratings, voltage ratings etc)

Appendix 4 outlines the Taskforce's recommendations for a Digital System Map to draw on open data sources.

3.2.1. Configuration and Connectivity

An understanding of how the system is structured and operationally configured, both technically and geospatially is important for users to understand how they can interact with the system and how it can affect them.

3.2.1.1. Geospatial Data

This helps users understand which areas are served by which parts of the system and the physical location of assets. This can be very helpful in understanding where resources can be best connected or where the system needs services to support it.

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21 https://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/CoreEnergyMarketDataRegister/CoreDataReg_node.html

22 http://www.energynetworks.org/assets/files/2018%2029th%20Nov%20ON-PRJ-WS1%20Product%208%20Report%20V2.pdf

Uses of geospatial data can include:

- Network service areas
- Constraint Zones (ENA heat maps, NGESO zones)
- Service need areas (Picloflex platform)
- Safety information for those working near live systems

3.2.1.2. Connectivity Data

This enables users to understand how the system is configured and how they are connected to it. It can be combined with geospatial data but can also be used on its own.

Published connectivity data may represent the normal running configuration (or normal running arrangement), but smart systems may have increasing need for real-time running arrangements accounting for planned and unplanned outages.

Understanding actual running arrangements can be essential to understanding system design limitations (e.g. worst-case operating conditions under outages) and interpreting historic system data.

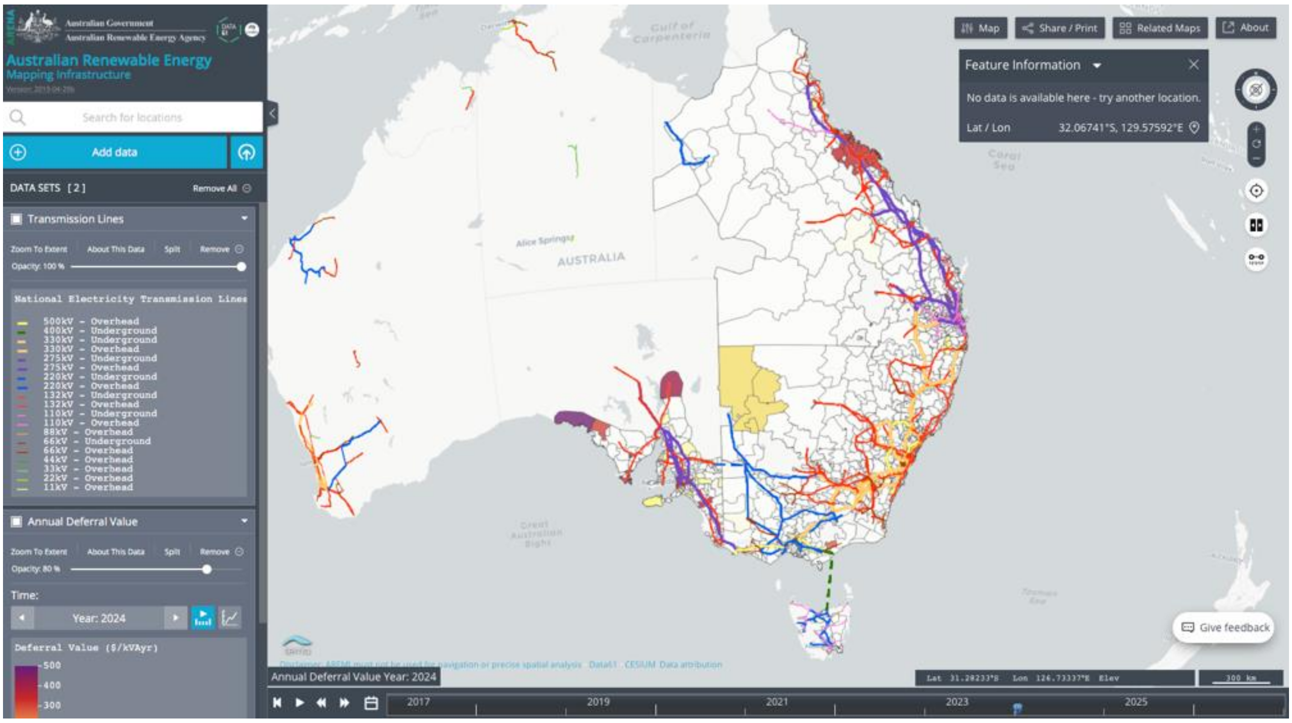

Figure 9 AREMI Distribution deferral value visualisation showing networks[23]

Providing accessible connectivity data for highlighting the system can also enable this data to be combined with other spatial data, to support wider development. This has been found to be useful as part of the GLA's FlexLondon programme[24] which looked to find synergies between existing and new flexible energy developments. The learning from FlexLondon is being integrated into wider

[23] https://nationalmap.gov.au/renewables/

[24] https://www.london.gov.uk/what-we-do/environment/energy/flexlondon

city planning and energy policy development with the aim of developing 1GWe of flexibility by 2050. Such tools can also help in the development of Local Area plans, helping to situate energy system resources spatially with other resources, like roads and buildings.

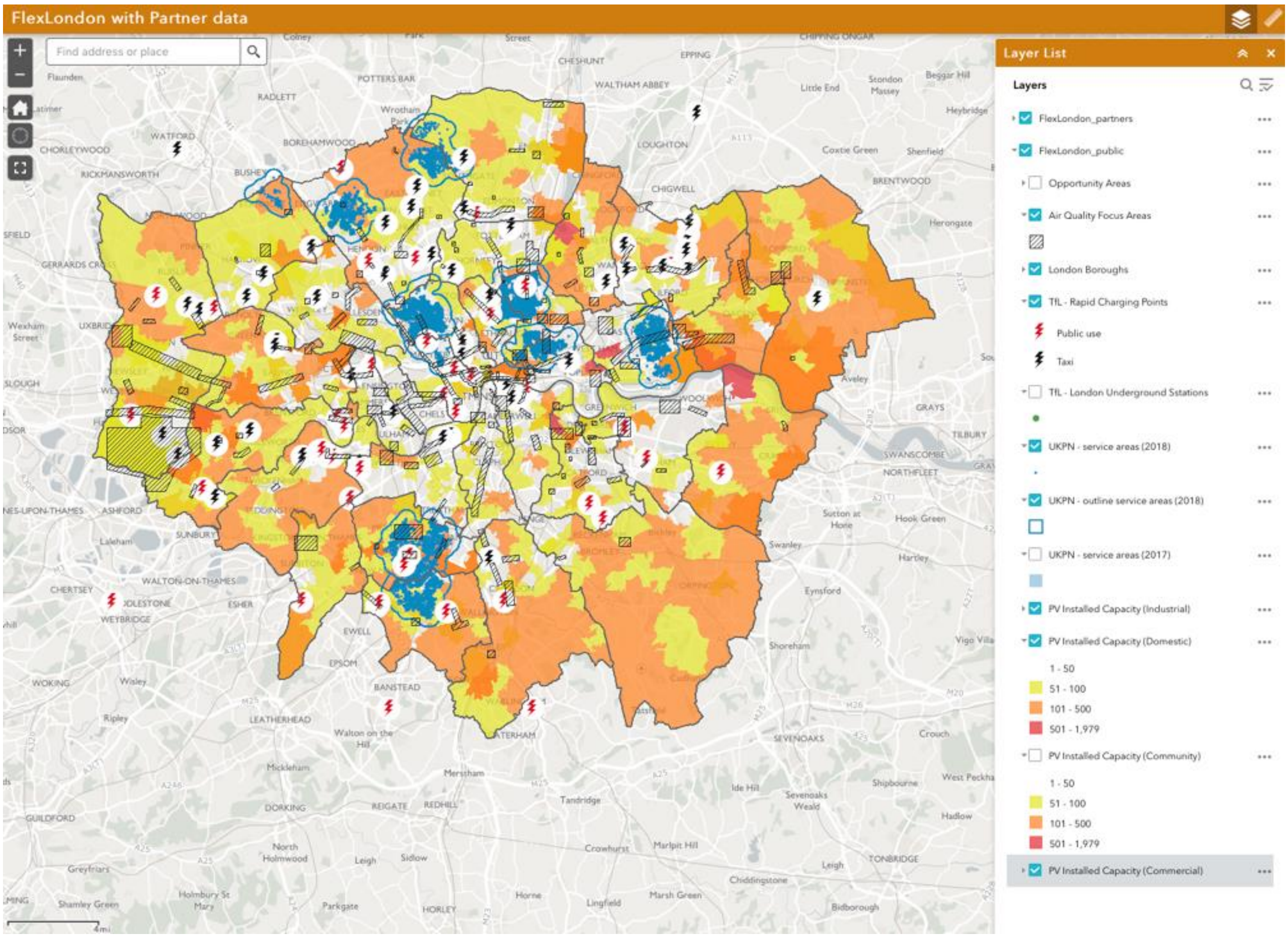

Figure 10 FlexLondon Data Visualisation, showing network constraint areas (blue), PV (orange and yellow), EV Charging (symbols) and air quality areas (grey hatched shaded areas)

3.2.2. Technical Data

This data describes the technical characteristics of the components of the system that are needed to model how the system will perform.

Technical data can be classified as

- Static rating data describing the technical limits of the components of the system
- Static impedance data (resistance, reactance, capacitance) for each component for load flows, basic fault studies
- Dynamic data (for generation and other sources) describing how devices respond to rapid changes in demand or faults on the system for stability studies

3.2.3. Modelled System Performance Data

System performance data communicates the outcome of the system operators' studies using the forecast demand and supply and the technical network data.

The studies identify:

- The operational limits of each part of the system, i.e. the maximum and minimum loading conditions of components that enable the system to operate within its technical parameters. For example, the maximum load on a circuit to maintain acceptable voltages might be significantly less than its thermal rating.
- The constraints this imposes on both import and export at each point in the system.
- The systems need for support from demand side and connected flexible resources.

System performance data should describe the expected operating conditions given the forecast data under foreseeable operating conditions so that service providers can understand the system needs.

3.3. Demand and Supply Forecasts

System operators produce forecasts to assist both planning and operations. Forecasts are important for identifying system limitations, service needs and future investment options.

Market data is not generally used by system operators to forecast demand or supply. Market positions are not considered to accurately reflect the demand likely to be seen on the system. This is for a number of reasons including:

- different forecasting capabilities of market participants;
- different levels of risk (a small supplier is likely to be exposed to more variability as a result of having less diversity and less data); and
- different approaches to managing their financial exposure.

In discussions with stakeholders it was felt that the system operators should develop their own forecasts as market data will continue to be insufficiently accurate to rely on unless new local markets are developed. Open historic data on system supply and demand outcomes therefore takes on an extremely important role in supporting market actors and the system operator in forecasting future system conditions.

3.3.1. Demand

The data used to forecast demand is that observed by the system operators, combined with economic data on trends that could lead to changes. Increasing amounts of small generation installed, particularly small PV, does not have export metering hence the forecasts are inherently of net demand. The moves away from deemed consumption profiles to smart metering or both import and export, should begin to improve the data available to develop better forecasts. Details of where resources are connected behind-the-meter would enable better forecasts of the inherent gross demand to be established.

3.3.2. Supply

Forecasts of supply are increasingly important as renewable energy supply will remain weather dependent.

Large generation production (and some large wind data outputs) are notified to the system operator as part of the balancing process and regarded as being accurate and valuable.

National Grid ESO are also incentivised to produce a wind forecast which has reasonable accuracy. Wind generation can often be constrained at times of low demand (when balancing inertia or providing generation with solar). One area that is less well understood is the dynamic capability or wind in real-time, i.e. the difference between actual output and potential output (which is not necessarily the same as rated output). This may also become an issue where storage and generation are integrated

There is very little if any visibility of small distributed generation. Solar generation output forecasts are currently provided by the Sheffield Solar Project[25] and are therefore reliant on academic support.

As distributed resources already provide most of the generation during times of system minimum demand, improving the ability to forecast performance is paramount to making maximum use of renewable output and the investment that has been made in it.

Clearly having visibility of the installed capacity, its capabilities and its historic performance would allow both the system operator and others to produce improved forecasts and enable better market pricing.

3.3.3. Flexibility

Flexibility could include several capabilities such as:

- Battery storage
- Responsive demand
- Flexible EV charging
- Cross-vector flexibility (e.g. with heat)
- Generation turn up/down

Flexibility will inherently form part of demand and supply forecasts based on observed demand. There may be a need for both forecasts, as there is today for forecasts with and without the effect of expected triad charges.

- Forecasts without flexibility assumptions identify any underlying demand / supply imbalance signalling the system needs for flexibility and the opportunities that presents.
- Forecasts with flexibility reflect expected response to the potential signals (e.g. time of use tariffs, surplus production), both national or local.

As with all other system resources the visibility of flexibility potential as well as that being offered or used may also be necessary:

- to allow both SOs and other market participants to identify those who can offer value as well as relying on market offers;
- to ensure that flexibility actions instructed by one party do not conflict with actions instructed by another.

This would be especially important if flexibility actions were to become automated by non-SO systems e.g. to match demand and renewable generation output.

[25] https://www.solar.sheffield.ac.uk

3.4. Outcome Visibility

The ability to understand actual outcomes has been identified as being as important as any forecast information. It is therefore an important outcome for data to be published so that

- forecast and actual supply and demand positions can be analysed, and participant response to actual conditions understood;
- the actual constraints that arose can be understood and any trends that are emerging identified and fed into future forecasts;
- the actions SOs took to manage the system are visible, both market actions and ancillary service instructions.

Outcome visibility is evidently connected to the settlement process. The impact an SOs actions has on the positions of participants in settlement has to be reconciled and so actions are made available today. Making the actions taken in real-time more understandable is challenging but important if all parties active in coordinating the system are to understand each other.

Nodal supply and demand data should not prove too challenging, at least at the higher voltage levels of the system.

3.4.1. Value Data

Inherent in making decisions is the concept of value. Price signals can be used to drive behaviours in system operations and in markets such as California and PJM in the US, marginal price approaches have been adopted into which constraint values have been built in[26]. Whilst very different from UK markets, this illustrates how interregional data can be made accessible.

3.5. System Operator Actions

System operators have to balance multiple issues in real-time and dispatch/constrain resources to maintain a system of parameters (frequency, voltage, capacity) under reasonable sets of planning contingencies. They attempt to do this using the best combination of resources available to them through balancing markets and ancillary service contracts. It is therefore understandably challenging to capture the decisions made in real-time.

Understanding system operator actions is integral to understanding historic system outcomes. Market participants and analysts find it difficult to understand system operator actions and therefore how they might have responded differently to reduce their costs.

It would be well worth considering how more information about likely and actual system operator actions could be made available in order for participants in the system to better plan their actions.

There may be concerns that publishing detailed service information could reveal system vulnerabilities, but if the SOs are to make more constraint data available then publishing the actions likely to be taken to address them and the likely cost of such actions could allow markets to find lower cost solutions. Progress is potentially being made in this direction through a Grid Code modification that is looking to ensure that all parties have access to the same information at the

[26] https://www.pjm.com/markets-and-operations.aspx

same time[27], although this looks primarily at emergency notifications, consideration should be given to making a wider range of likely actions visible.

3.5.1. Potential Service Conflicts

In identifying needs in specific areas the system operators and market participants should be able to identify possible conflicts, for example a system operator could identify the need for demand turn up to release constrained solar output in response to a falling wind generation output, whereas a supplier could be looking for demand turn down to offset the same issue.

Whilst the process for addressing such conflicts are outside the scope of the taskforce, transparency of actions and underlying assumptions maximises the opportunity for conflicts to be identified through the cycles leading up to real-time operations.

3.5.2. Real Time Options

As the real-time operating window approaches there should be transparency about the likely actions the system operators may have to take and the resources they have secured to use.

An example of this could be the approach being used by Western Power Distribution for their flexibility contracts where they have three status levels:

- Available – contracted for the service but not committed
- Enabled – committed to be available for a specific period
- Utilisation – paid when the service is used.

3.6. Real Time Local Data

If and when smart systems become more active in managing a profusion of local constraints, for example to manage smart EV charging within system capacity, or matching PV export with EV needs, real-time data will be needed about local system usage and performance.

DSOs already have the technology to do this (where the instrumentation and SCADA systems are in place) as is demonstrated in current actively managed generation areas[28].

3.7. Data Challenges

3.7.1. System data and models

[27] https://www.nationalgrideso.com/codes/grid-code/modifications/gc0109-open-transparent-non-discriminatory-and-timely-publication
[28] https://www.westernpower.co.uk/anm-further-info
https://www.ssen.co.uk/ANMGeneration/
https://www.ukpowernetworks.co.uk/electricity/distribution-energy-resources/flexible-distributed-generation

3.7.1.1. Connectivity

Much system information is already made available in the NGESO Ten-year statement[29] and DSO Long term development statements[30]. In certain areas, geospatial, network connectivity and system performance data can reveal system risks that might be considered sensitive or commercially sensitive data such as planned export levels.

At an overall system level, studies are unlikely to reveal personal information about individual users' information, but sensitivities may emerge as the information becomes more granular and local, for example revealing critical national infrastructure load information either directly or indirectly.

The Taskforce has proposed a triage process should be able to manage such risks, using approaches such as obfuscation of names.

3.7.1.2. Geospatial data

Network data, particularly at lower voltages, may need to be improved in some areas to populate geospatial data systems. Basic map-based data (essentially just drawings) has been sufficient for identifying cables for safe working or designing connections. Fully digitalising all the data is time consuming and expensive and has been done in part but needs to be completed to fully realise the benefits of digital data.

3.7.1.3. Technical Data

Significant amounts of technical data relating to network components can be based on typical or assumed data (e.g. standard per km reactance). Many developers and their consultants often use such data when developing their own models.

Network models often only exist in full at 33kV and above, with 11kV distribution networks being modelled as required, because of their scale and the resulting challenge to maintain across separate control, asset management and GIS systems. Standards supporting geospatial data, connectivity and technical data would enable these models to be established and maintained.

3.7.1.4. Forecasts

Anonymity and aggregation of data appear straightforward where operation decisions are being taken at higher voltage levels where aggregated demand is sufficient to ensure anonymity.

If the system develops with more local markets, with actions potentially being taken using residential flexibility, greater transparency and understanding of customer types and potentially individual capabilities and needs may be required by both markets and system operators.

The management of localised constraints could create situations where anonymity of individual consumption profiles becomes more challenging if post event data is published by the SO (or other local market operator).

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[29] https://www.nationalgrideso.com/insights/electricity-ten-year-statement-etys

[30] https://www.enwl.co.uk/get-connected/network-information/long-term-development-statement/introduction-to-ltds/

It will remain to be seen if active systems need prior indication of consumers energy needs, for example kWh EV charging needs, in order to operate effectively.

A key element of well-informed decisions will be good information about what actually took place compared to forecasts, so that modelling can be refined, especially where the number of actors (demand and supply) is small.

3.7.2. System Operator Actions

Improving the understanding of the likely actions system operators may take, and why they took specific actions may be one of the most challenging set of data to develop.

The decisions taken by automated systems should be self-explanatory as these are expert systems acting on specific criteria. As AI based systems develop this may become more challenging, and a form of decision validation or reporting should always be available so that actions can be understood.

We recognise that capturing real-time control engineer decisions where judgement is employed to balance multiple risks is difficult. This needs to be considered further as it is seen as important in stakeholder interviews to understand future outcomes. Enhanced data on how the system was performing either side of decisions and more reporting of potential system outcomes that are expected to lead to system operator interventions could also be of value.

3.7.3. Service conflicts

Unless market contracts for flexibility between suppliers and flexible energy resources are visible to system operators, the identification of potential service conflicts (for example simultaneous turn up to manage local high voltage and turn down instructions to manage supplier balancing to separate DSR resources in the same network) remains. This is an example of where behind-the-meter control and markets interact with system operations. Ensuring visibility of such contracts may require regulatory change, but a register of flexible resources and transparent historic data could improve visibility.

3.8. Conclusions

We have described the data needs and highlighted the main challenges.

Establishing all the data does not need a 'big bang' approach but a structured, open, standards driven roadmap is required to support a digitally enabled, distributed energy system. A proposed roadmap is described in the next section.

4. A Roadmap to open up a shared view of the system

A recent ENA assessment of existing data[31] illustrated how the data has evolved to meet specific needs and is not necessarily available in a consistent manner across organisations nor in ways that facilitate automated access.

Examples include different approaches to making constrained area information available[32] and how DSO long term development statements make network data available, but only through spreadsheets[33] and how that data is biased towards the higher voltages with 11kV and LV distribution network data availability being very limited.

The roadmap below is concerned with producing standardised data and supporting the expansion of the data that is needed to develop a smart energy system. It draws on the Taskforce recommendations:

- **Digitalisation of the Energy System:** new legislative and regulatory measures to drive the capture of new data, improving existing data and developing 'Digitalisation Strategies'
- **Maximising the Value of Data**: new legislative and regulatory measures to ensure data is Presumed Open, promoting the development of 'Structures, Interfaces and Standards'
- **Visibility of Data:** developing a Data Catalogue to improve data visibility
- **Coordination of Asset Registration:** developing a new asset registration strategy
- **Visibility of Infrastructure and Assets:** developing a Digital System Map to increase visibility of assets and promote investment and new markets

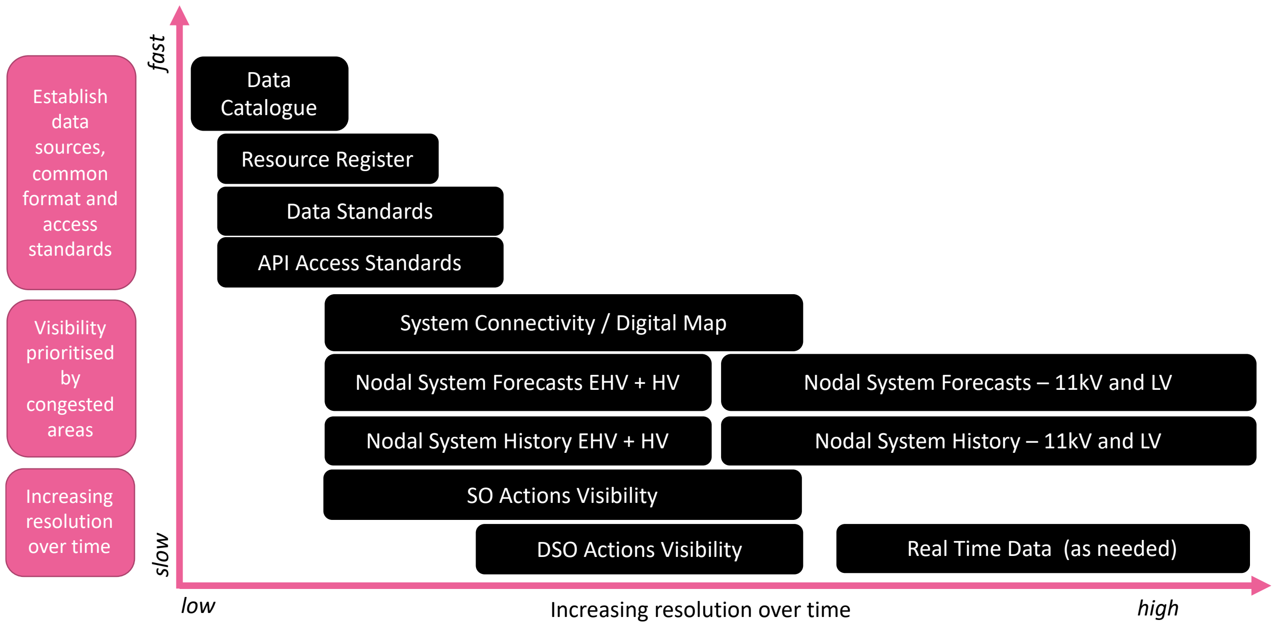

Figure 11 Roadmap for SO data

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[31]ENA survey of GBSO and DSO data: http://www.energynetworks.org/assets/files/WS1%20-%20P8%20-%20Survey%20Results%20-%20May%202018-DMacP%20(002).pdf

[32] Examples:
https://www.westernpower.co.uk/anm-further-info
https://www.ukpowernetworks.co.uk/electricity/distribution-energy-resources/flexible-distributed-generation
https://www.ssen.co.uk/GenerationAvailabilityMap/?mapareaid=1

[33] Example: https://www.ukpowernetworks.co.uk/internet/en/about-us/regulatory-information/long-term-development-statement.html

4.1. Establishing standards

The first priority should be to establish the data standards and access standards to improve consistency and interoperability ensuring that as data is opened up and systems are aligned across the industry.

Establishing standards for access protocols, in line with EU and worldwide standards, will also support innovators to develop more adaptable and futureproof systems.

Given the amount of data involved in forming a common view of the system, we would not expect data to be opened up in a 'big bang' release. Establishing standards as the first action will enable the progressive opening of lower voltage data as the need arises.

4.2. Nodal Data

Nodal data reflects the capacity and performance at key points of access to the system.

The NGESO Ten-year statements and DSO Long term development statements contain much nodal data already and some circuit data. The most important nodal data at present is that down to the large substations that supply the 11kV/6.6kV distribution networks, is already published. We anticipate that 11kV and below network data would be opened up progressively as DNOs identify areas where they expect needs to emerge and lower voltage telemetry expands.

Circuits provide the connectivity between nodes on the network and for the purposes of the roadmap would be combined with the connectivity data.

4.3. System Connectivity and Circuit Data

We expect some connectivity data will be developed in parallel, particularly given efforts to improve information for connections that are ongoing.

The most important consideration here is that standards, possibly based around the CIM data model trialled by WPD, will drive a common set of system data, accessible in a consistent approach across industry.

Connectivity data already exists in several places including control systems, system models, GIS systems, customer service systems (customer-network connectivity models to support customer service and reporting of interruptions performance). Creating a core data set should be the basis for the longer-term development of the system.

System connectivity data needs to be integrated with geospatial data to ensure that it provides useful information to aid understanding of the areas constraints affect, and where resources may be best developed to support the system. The geospatial approach taken by AREMI in Australia provides evidence of what is already possible[34].

[34] https://nationalmap.gov.au/renewables/

4.4. SO and DSO Actions

The SOs control room staff have a challenging real-time role in making decisions about dispatching resources in real-time to try to securely operate the system and minimise the costs of doing so. Documenting these decisions is particularly challenging but stakeholders reported that more information is needed to understand why actions were taken.

Work is starting in the ENA Open Networks programme to enhance visibility between system operators[35] and should be enhanced to consider wider visibility of SO actions. The SO could build upon the emergency notification system to indicate more about the actions it may have to take as part of existing code modifications[36].

4.5. Real Time data

NGESO currently make some real-time data for the overall system visible[37] but more detailed information will be needed on inter-regional flows, such as showing where areas are exporting and where voltages are getting close to operating limits. Similar detail has been developed in other places, for example in PJM[38] illustrates inter-regional flows, with real-time data made available to market participants.

Real-time data has already been made available to active management systems for the control of generation export on DSO networks and stakeholders involved in these schemes indicated that they saw few issues in making such data available for control purposes. These are 'closed' systems with secure connections to DSO SCADA data.

For the active management of local issues, similar data will need to be made available and innovation projects are looking at how to do this[39]. The timing for the need for low voltage data is uncertain, depending on the nature and speed of LCT uptake. The widescale roll out of LV SCADA data is a significant challenge and will need to be targeted at areas with more likely need. It is also not evident whether the right solution would be through centralised or local access architectures and this may depend on other infrastructures (e.g. communications systems) as well as the number of and growth in instances where this is needed.

The principle of the roadmap, to establish data standards and access protocols that could be local or centralised, applies equally here. The urgency in establishing standard is needed to ensure that the roll out of LV data gathering systems is done with robust technology that can meet the need for real-time data feeds in future.

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[35] http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/ON-PRJ-Phase%203%20PID-v1.2%20Final%20(Published).pdf
[36] https://www.nationalgrideso.com/codes/grid-code/modifications/gc0109-open-transparent-non-discriminatory-and-timely-publication
[37] https://extranet.nationalgrid.com/RealTime

[38] https://www.pjm.com/markets-and-operations/interregional-map.aspx
[39] https://evergreensmartpower.co.uk/what-we-do/domestic-dsr-fred-trial/

4.6. Next Steps

The roadmap is focused on ensuring the standards are in place to support the expansion of system operations data ahead of the expected growth in EVs expected from the mid 2020's.

The priority is to establish the standards for making data visible. There seems little point in pushing for investment to open-up more data before these have been developed and such standards should underpin the data required to co-ordinate between SO and their service providers. The Taskforce recommendation to develop metadata standards to support the implementation of the Data Catalogue is one step on the journey for achieving this.

Once the standards are in place the priority should be to open-up the data to provide the common view of the system at progressively lower voltages, helping to 'Fill the Gaps' in existing data through 'Continuous Improvement'.

Information to inform the development of services from embedded resources should underpin the opening-up of data, as is already the case; which can be supported by the development of an Asset Registration Strategy.

Nodal data showing system needs and constraints mapped to geospatial connectivity information to allow users to relate to it are key elements to enabling flexibility to be developed.

5. Conclusions

Energy System operations data will become increasingly essential as part of a data enabled and optimised world[40] where the energy system is more complex. It is essential that common data standards and interfaces are developed to support this. This is embedded in the **Presumed Open** recommendation to **Maximise the Value of Data.**

The old 'analogue' system built around a small number of highly specified, controllable generators could be managed by a single system operator, but in the new 'digital' system multiple parties will be involved in the operation of the system even if this is through automated processes. Coordination will be essential and as such the likely actions of those involved in managing the system must be transparent, enabling a common view of the how the system will operate to be shared by all. The recommendation to develop **Digitalisation Strategies** to support the **Digitalisation of the Energy System** encourages such a coordinated approach.

Much data already exists but needs to be made more readily accessible, and by less manual processes (APIs) so that third parties can bring data together to create rich sources of new value, integrating across energy vectors and users particularly transport. The Taskforce recommendations for a **Data Catalogue** underpins this.

Investment by users in flexible energy technology requires long term transparency of need to support business cases and access to products today. System operators need confidence and visibility of the availability and capability of flexible energy resources in order to develop such products. The Taskforce recommendation for an **Asset Registration Strategy** supports the transparency of system resources needed for multi-actor coordination.

The data needs will not arise uniformly, so we have proposed a roadmap that establishes standards and interfaces for all data and allows data to be developed and published as it becomes available and users increasingly demand access and transparency.

A **Digital System Map**, based on open data standards, would drive the development of a cohesive data set covering geospatial, connectivity and potentially technical data. Enabling others to map emerging demands for LCT infrastructure such as EV charging to this data will help prioritise data development needs.

A system map could also support the visualisation of system operator needs and likely interventions, creating the transparency been actors in the system needed to avoid conflicting instructions and to optimise actions between markets and real-time operations.

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[40] https://www.optimised-h2020.eu
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/783338/BEIS_innovative_domestic_demand-side_response-competition_phase_2.pdf

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