FLEXFORUM

HOW WILL DER & FLEXIBILITY PLAY ITS ROLE IN DELIVERING AFFORDABLE, RELIABLE AND ZERO CARBON ELECTRICITY

IDEAS FOR DISCUSSION

4 May 2022

The Flex Forum is a cross industry group formed to identify a set of actions to integrate distributed energy resources (DER) into the electricity system and markets to maximise the benefits for Aotearoa New Zealand

The FlexForum purpose is to:

- Deliver 3 objectives:
  1. Identify the minimum specifications of the services that DER can provide, to who, when, where, how and for how much
  2. Identify the practical, scalable, and no regrets steps to use the services that DER can provide
  3. Support ongoing learning and collaboration across the electricity sector on real world deployment of solutions to realise the benefits of DER, including identifying and resolving barriers
- Build a broad consensus across the electricity sector and others interests for the set of actions to integrate DER
- Build capacity and capability to implement the set of actions to integrate DER.

For more information: https://www.araake.co.nz/services-projects/flexforum/

To ask for a conversation or to send your thoughts and views, please contact us at info@flexforum.nz.

We are keen on any suggestions and feedback, but particularly on your thoughts and views on these questions:

Question 1	Are there any other reasons for acting or services required by a DER owner, transmission or distribution network owner, the system operator, retailer or generator to need to respond?
Question 2	What suggestions do you have for creating common terminology and descriptions of the service, the need or condition to be managed and the physical response?
Question 3	Does the list of planning and operational information requirements reflect what is used for making decisions about responding to network, system and market conditions?
Question 4	Does the list provide sufficient planning and technical information for flexibility providers to make decisions about when, where and how to supply flexibility?
Question 5	What suggestions do you have for creating common terminology and descriptions for each of the technical requirements?

Contents

Context: distributed energy resources and flexibility will have a role in the electricity system and markets

Electrification means households and businesses will be investing in millions of electric vehicle (EV) chargers, solar panels, battery storage, electric space and water heating, electric motors and smart devices – most of these will be DER[1].

DER will – if given the right opportunities – provide a range of benefits to households and businesses, distribution and transmission networks, and the electricity market.

- households and businesses can use DER to individually benefit by lowering their energy costs, by improving the reliability and resilience of their power supply, and potentially by earning some revenue supplying the flexibility of their DER
- distribution and transmission networks can use DER to benefit the households and businesses using their network by reducing network infrastructure costs, and by maintaining and improving quality, reliability and resilience of the network service
- the system operator can use DER to benefit consumers by reducing ancillary services market costs and resource adequacy capacity requirements
- electricity retailers and generators can use DER to benefit their customers by lowering the average wholesale power and network costs.

An overarching benefit of electrification and proliferation of DER will be the reduction to carbon emissions as households and businesses shift to more energy efficient consumption and to lower emission energy sources for power generation, transport, heating and cooling and other energy using activities.

DER is dual purpose

DER owners have resources – distributed generation (DG)[2], EV chargers, batteries, solar inverters, smart devices – which they have invested in to, for example, manage energy their costs, charge their vehicles or decarbonise.

DER can also supply flexibility to provide a defined service within the power system when it has the capability of modifying either generation injection and consumption patterns in response to an external signal.[3]

The key feature of a flexible resources is it is responsive if the owner chooses to respond.[4]

- solar systems can supply flexibility when the inverter has the capability to lower generation in response to a signal or instructions, eg about network voltage

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[1] **Distributed** – located with or near homes and businesses and connected to low and medium voltage distribution networks. **Energy** – electricity, stored heat such as hot water, or energy sources such as hydrogen. **Resources** – devices and equipment which generate and consume electricity, including solar PV, battery storage, hot water cylinders, air-conditioning units and other responsive devices.

[2] Distributed generation is connected to distribution networks. It ranges from kilowatt-sized household solar generators to megawatt-sized solar farms and hydro generators.

[3] This is the definition of flexibility developed in the European Union and United Kingdom and being used in Aotearoa New Zealand.

[4] Terminology is important. DER is often characterised as being controllable or uncontrollable. This perhaps reflects an electricity sector perspective. However, access by the electricity sector to flexibility fundamentally relies on the

- battery storage systems can supply flexibility by either discharging or charging in response to a signal or instruction, eg network charge
- electric vehicle charge points and electric vehicles can supply flexibility by either discharging or charging in response to a signal or instruction, eg spot price
- devices and equipment – space and water heating, ventilation and air-conditioning, machinery – can supply flexibility by switching on or off in response to a signal or instruction, eg an instruction.

Enough has been said about the importance of DER and flexibility

Enough has been said about the importance of DER and flexibility to the future of the electricity system and markets, and decarbonisation.

The role of DER and flexibility in a reliable, affordable and decarbonised power system and economy has been extensively considered in Aotearoa New Zealand. The work done to date includes:

- the Electricity Authority put more emphasis on DER and flexibility from 2016-17[5]
- the Productivity Commission made recommendations in its 2017-18 low emissions economy inquiry[6]
- the Innovation and participation advisory group (IPAG) provided advice to the Electricity Authority in 2019, 2020 and 2021[7]
- the Electricity Networks Association published a network transformation roadmap in 2019[8] (updated in 2022)
- the Ministry of Business Industry and Employment consulted in 2020 on accelerating renewable energy and energy efficiency[9]
- the Transpower Whakamana i te Mauri Hiko and series of think pieces on electrification impacts and opportunities.[10]

The question is not whether DER and flexibility will play a role in the electricity system and markets, but how. This means identifying the specific choices and actions which need to be taken to integrate and use flexibility and maximise the value of DER.[11]

owners of DER choosing to respond to signals and incentives. As such, DER is flexible or not flexible, with the flexibility resulting from its ability to respond to signals or instructions due to its connectivity, programming etc.

5 See https://www.ea.govt.nz/about-us/corporate-projects/201617-planning-and-reporting/implementation/work-programme-for-201617-published/

6 See https://www.productivity.govt.nz/inquiries/lowemissions/

7 See https://www.ea.govt.nz/development/advisory-technical-groups/ipag/final-advice/

8 See https://www.ena.org.nz/resources/electrification-of-nzs-energy-needs/

9 See https://www.mbie.govt.nz/have-your-say/accelerating-renewable-energy-and-energy-efficiency/

10 See https://www.transpower.co.nz/about-us/transmission-tomorrow

11 Integration of DER means considering the commercial (products and markets), service provider/customer (transactional) and network (technical and performance characteristics) dimensions of using DER for its primary purpose and any additional use supplying electricity-related services.

The FlexForum is looking at how DER and flexibility will play a role in the electricity system and markets

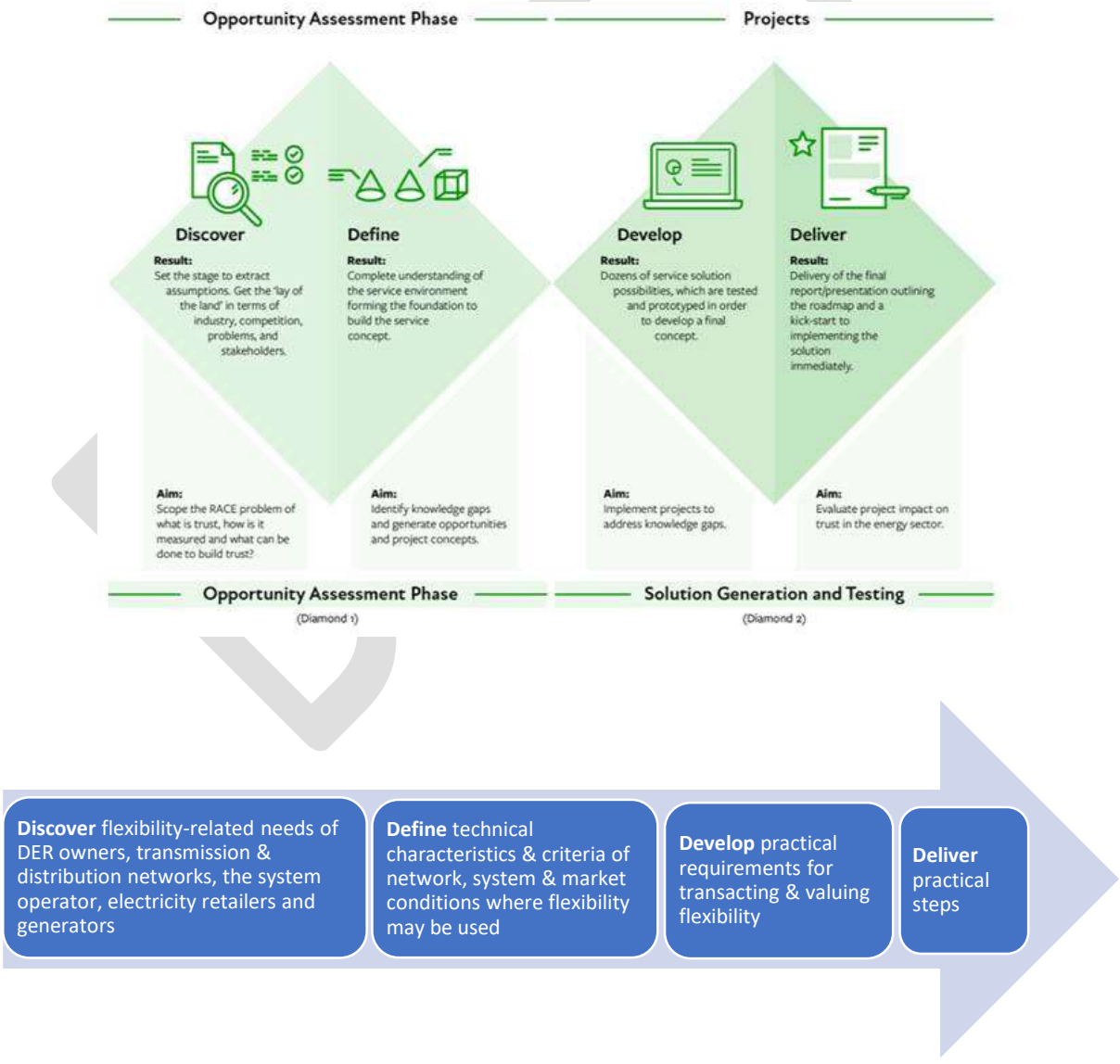
The FlexForum is looking at how DER and flexibility will play a role in the electricity system and markets by defining standard use cases, or service definitions, for the services which could be supplied by DER across the electricity supply chain, and the practical requirements for using flexibility to supply those services.

The intention is to identify the services that DER can provide, to who, when, where, how and for how much.

Doing this will assist to identify the practical, scalable and least-regrets steps needed to maximise the net benefit of DER and its flexibility for Aotearoa New Zealand.

The FlexForum is using a discover-define-develop-deliver approach.[12]

Figure 1 The discover-define-develop-deliver approach



[12] Image source: https://www.racefor2030.com.au/wp-content/uploads/2021/11/E1-Trust-building-for- 5 collaborative-win-win-customer-solutions.pdf

- Discover the flexibility-related needs of DER owners, transmission and distribution networks, the system operator, and electricity retailers and generators
- Define technical characteristics for the operational response of transmission and distribution networks, the system operator, and electricity retailers and generators to network, system and market conditions
- Develop practical requirements for transacting & valuing flexibility
- Deliver the output of the develop stage. The outputs are expected to provide a template or scope of work for demonstration projects and trials implementing the practical, scalable and least-regrets steps for integrating DER and transacting flexibility.

Discover stage – what are the flexibility needs of DER owners, network owners, operators, retailers and generators

The starting point for the FlexForum was to discover the current and future requirements, or needs, for DER owners – households and businesses – wanting to sell flexibility and the needs of network, owners, operators, retailers and generators which may want to buy flexibility.[13]

The FlexForum has identified two complementary flexibility-related 'needs':

- DER owners – the flexibility providers[14] – need information on when, where and how they could supply flexibility
- Network owners, operators, retailers and generators – the flexibility buyers – need flexibility to respond to physical and market conditions.

Flexibility providers need information on when, where and how they could supply flexibility

Flexibility providers need information on when, where and how they could supply flexibility, if they choose to do so.

DER may have the capability to supply a response to physical and price-related conditions in specific areas of the electricity system and across the electricity supply chain. However, this capability will not become routinely available or fully used unless the flexibility provider or their intermediary[15] knows what service to supply, when and how much they will get for supplying the service.

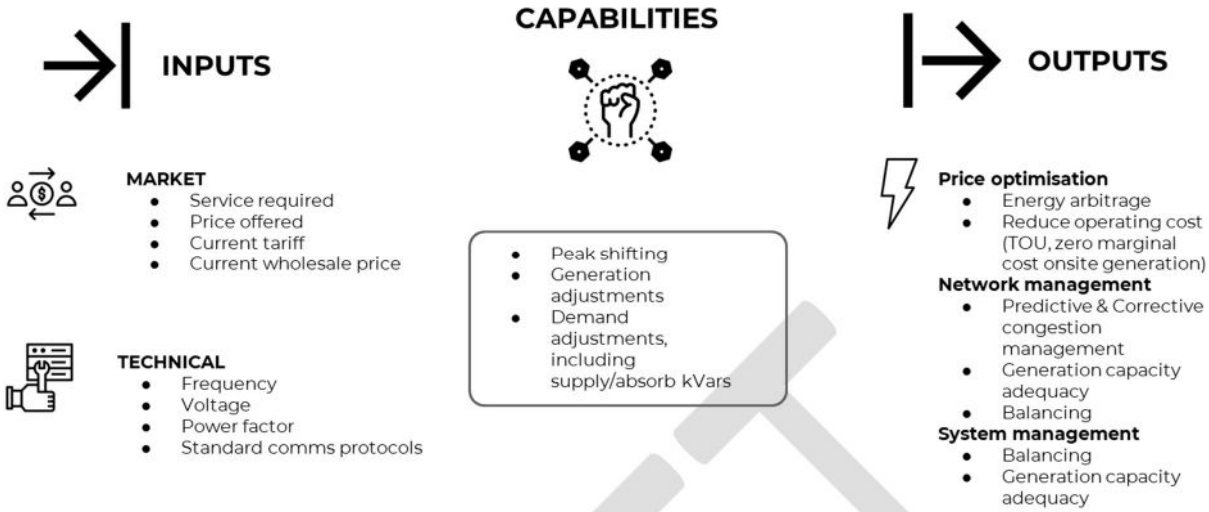
Flexibility providers 'need' market and technical information, plus upstream equipment manufacturers and service providers, to inform their decisions to invest in 'extra' DER capability, and to supply flexibility in addition to the owner needs (eg, charging their vehicle).

[13] Network owners, operators and market participants may also be DER owners.

[14] The FlexForum has mostly used the terminology for flexibility adopted by the Innovation Participation Advisory Group. Refer https://www.ea.govt.nz/assets/dms-assets/28/Transpower-DR-programme-review-slide-pack.pdf

[15] The working assumption adopted by the FlexForum is most DER owners will supply flexibility via intermediaries. For simplicity, the term DER owner means either DER owner or intermediary.

Figure 2 Matching inputs – capabilities – outputs to enable transactions between flexibility providers and flexibility buyers



DER owners wanting to supply flexibility need technical and market information to both invest in the necessary capability and to know when and where flexibility is required, and the value of providing flexibility.

Market information (or inputs) includes things like service definitions, compensation methods, terms of trade, and pricing data.

Technical information (or inputs) includes things like network voltage, communication protocols and network connection requirements, eg export limits.

Supplying flexibility is typically an optional extra, not the primary purpose of the DER. Households or businesses will supply flexibility when it is convenient and commercially worthwhile to them.

Service definitions and performance criteria

DER owners and equipment manufacturers and suppliers need to know what capability is required to supply a service.

Explicit performance criteria enable the DER owner to assess the costs and potential trade-offs of supplying flexibility, eg, assessing the impact on a commercial operation or household of delivering a load reduction in one second.

Explicit performance criteria also need to include the approach to evaluating delivery of the service for DER owners to assess the costs and risks of supplying flexibility.

DER equipment manufacturers and suppliers will be more likely to invest in developing extra capability for DER, eg, built-in communications capability, when they are confident that doing so will deliver value to their customers.

DER equipment manufacturers will prefer cheaper (less capable) design options without awareness of or confidence in the potential benefits from providing capability to supply flexibility.

Payment and price mechanisms compensating the supply of the service

DER owners need information on the compensation mechanism[16], the potential compensation range, and duration of compensation to understand the pay-off of supplying the service relative to the costs of purchasing, configuring, or installing extra DER capability, eg, specific communications capability.

Digitalisation to enable automation and responsiveness

DER significantly extends the potential for optimisation of consumer, producer and network operation outcomes due to the capability to receive and respond to internal and external signals (eg, prices, temperature, network power quality thresholds).

Digitalisation across the electricity supply chain is needed to enable automated responses to network and market conditions by improving access to market and technical information, particularly event information (eg, price spikes, voltage excursions) which will underpin the need for and supply of flexibility. Digitalisation will improve visibility of the performance of low voltage networks for planning (ie, historical data can be used) and operation (ie, near real-time data may be necessary).

Digitalisation will also improve the capability for value-stacking, enabling the DER owner to access information on local needs to evaluate the value opportunities and which to respond to.

Common communication protocols, consistent with overseas standards used by technology manufacturers, will be needed.[17]

Network access and network use terms which reflect DER capability

Network access and network use requirements need to reflect the capability for DER to automatically respond to network conditions (eg, voltage or frequency excursions).

Network design and connection practices premised on quite predictable usage patterns of household and business power consumption may not be fit-for-purpose as DER alters traditional network use patterns.

Flexibility buyers will need flexibility to respond to physical and market conditions

The electricity supply chain – which includes network owners, operators and market participants – operates within physical and market parameters. Staying within these parameters requires operational responses to specific network, system and market conditions.

Network owners and operators need to ensure their networks operate within reliability and quality parameters, such as thermal and voltage limits. Generators need to ensure they generate taking account of fuel stocks, network conditions and price conditions. Retailers need to ensure they manage price conditions.

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[16] For example, flexibility could be compensated directly via a contract payment or indirectly via a price response.

[17] EECA and EEA are investigating the use of IEC 62746-10-3:2018 (OpenADR).

Network owners, operators and market participants – all potential flexibility buyers – need access to resources which can deliver a specific operational response to specific network, system and market conditions. Flexibility is an option.

The FlexForum has identified these flexibility needs of flexibility buyers:

- network owners and operators require new capability (ie, flexibility) to manage forecast electrification-related constraints and connection-related constraints, and associated implications for quality of supply, while maintaining or improving reliability and affordability for households and businesses
- market participants and the system operator require flexibility to manage risks associated with changing market and system conditions, eg, a changing generation mix will require more system balancing and increase price volatility.

Harnessing the flexibility of DER is a plausible new solution expected to complement, not replace, existing options for matching supply and demand for network capacity.

Electrification is expected to make flexibility a must have capability and resource, particularly for network owners.

A step change growth in demand for network capacity

Electrification will cause a step change increase in demand for network capacity as electrification of transport, water and space heating, and agricultural, commercial and industrial processes result in higher network use and higher maximum demand.

The challenge is network owners will not always be able to build extra network capacity fast enough. Flexibility provides an option to manage transient mismatches between supply of and demand for network capacity and maintain reliability and quality of supply.

Localised customer-driven increases in demand for network capacity

Electrification will not occur in an orderly and predictable way that results in a smooth demand growth curve. The leading edge of electrification is resulting in unpredictable, large and lumpy requests for extra network capacity by electrification of industrial processes, or clustering of EV chargers or solar PV.

The challenge is distributors will not always have sufficient capacity to meet the request for extra network capacity, but will not realistically be able to refuse the connection. Nor will distributors be able to dictate connection requirements which unnecessarily shift costs and risks to the customer, particularly as electrification becomes more urgent and as the (cost-saving) opportunities of DER become more known.

Flexibility provides an option to manage transient mismatches between supply of and demand for network capacity, meet customer preferences at lowest cost while maintaining reliability and quality of supply.

DER can support market and system operation

Flexibility from DER can do a similar as existing options available to market participants and the system operator for frequency-keeping, voltage management, spot price and fuel management.

The need or performance requirements for participation in markets for various market and system services – generation, reserves, frequency, voltage – have been formalised in regulation or are well known through experience. The potential for DER participation in these markets increases with smart devices able to respond to instructions or incentives.

Don't forget the human element – a social licence will be essential

Households and business will need to support the idea of the electricity sector reaching into their homes and businesses to access the flexibility of their DER.

A social licence will be essential to encourage DER owners to choose to respond to signals and incentives for the electricity sector to obtain access the flexibility of DER.

Trials undertaken so far suggest early adopters are comfortable with providing flexibility via a third party such as a retailer or flexibility trader who can manage the electricity consumption of their DER. Research in the United Kingdom suggests people place considerable value on the ability maintain control of their energy use such as electric vehicle charging (through an over-ride function), though this ability was rarely used[18].

Experience in the United Kingdom suggests the key to engaging and winning trust of people is to make value accessible through simple and desirable customer propositions. Third parties play an important role in translating complex market signals into attractive customer propositions and ongoing collaboration across the electricity sector is required to ensure successful outcomes for the customer, consumers in general and the electricity system.

[18] See https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2021/10/21236_UKPN_Project-Shift_2021_Final-proof.pdf

Define stage – What can flexibility be used for?

The second step for the FlexForum was to attempt to define the characteristics and technical criteria for the services that flexibility buyers might want to use flexibility for.

Setting out the technical characteristics and criteria does two things:

- provides some of the information[19] needed by a flexibility provider to make decisions to invest in DER capability to supply flexibility to respond to network, system and market conditions
- provides a starting point for flexibility buyers to adopt a common language and common technical specifications when procuring solutions, including flexibility, to respond to network, system and market conditions.

Having common descriptions of the characteristics and technical criteria for each condition or 'need' provides clear and commonly understood specifications of the solutions available to respond to a condition – 'the what' flexibility might be used for.

Using common language and technical specifications is necessary to create a market in which sellers and buyers can easily transact flexibility.

What does the buyer want?

The FlexForum asked 'what does the buyer want?' to list the conditions which network owners, the system operator, market participants and DER owners respond to when doing what they do to deliver safe, reliable and affordable electricity to households and businesses (or themselves).

The list was developed by:

- defining the condition or need which provides the reason for network owners, the system operator, market participants and DER owners to do something
- specifying the planning and operational requirements of responses to the various conditions. Flexibility is one of several options for responding to a condition.

The list of conditions is summarised in Appendix A. The planning and operational requirements are described in Appendix B.

There are three types of response for five reasons

The FlexForum has identified five reasons[20] (or triggers or services) with three types of response available to transmission and distribution network owners, the system

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[19] The technical characteristics and criteria provide the service definitions and performance criteria information needed by DER owners.

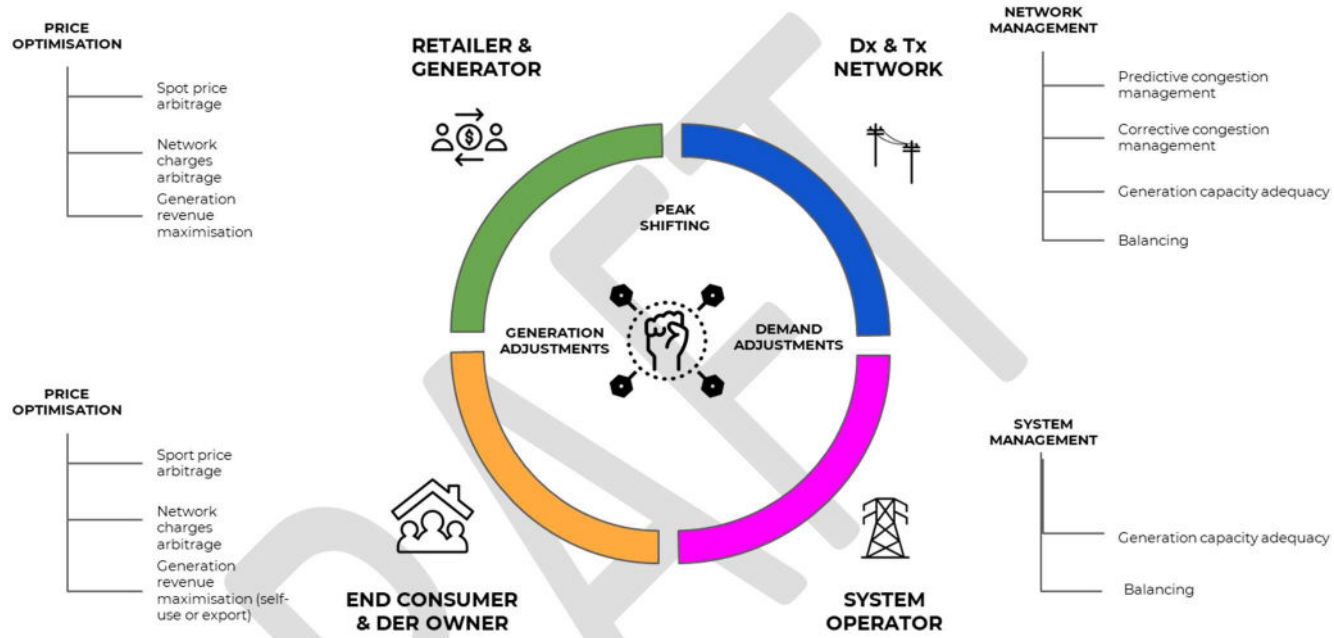
[20] Rather than reinvent the wheel, the categories and reasons identified through European research have been adopted.

See Flexible Energy Production, Demand and Storage-based Virtual Power Plants for Electricity Markets and Resilient DSO Operation (FEVER) project, D1.2 Function and operational requirements, September 2020, Figure 4, at https://www.fever-h2020.eu/data/deliverables/FEVER_D1.2_-_Functional_and_operational_requirements.pdf. Figure 4 was adapted from SWECO et al., Study on the effective integration of Distributed Energy Resources for providing flexibility to the electricity system – Final Report to the European Commission, April 2015.

operator, market participants and DER owners to, variously, reduce their costs, improve reliability of supply or improve quality of supply.

The five main reasons or services required by a DER owner, transmission or distribution network owner, system operator, retailer or generator are shown here. The responses are peak shifting, demand adjustments and generation adjustments.

Figure 3 Five main services needed by transmission & distribution network owners, the system operator, retailers and generators and DER owners



Source: FlexForum and the FEVER project.

These reasons or triggers define what the buyer wants and the main services needed to respond to network, system and market conditions.

For example, a distributor would procure a ***corrective congestion management*** service (*the service*) to ***avoid an outage on a feeder during peak demand periods*** (*the need or condition to be managed*) from a flexibility supplier which would **use a combination of peak shifting, demand & generation adjustments** (*the physical response*).

The five reasons can be described as:

- **price optimisation** – optimising individual (eg, a DER owner) or aggregated (eg, a trader and retailer) generation and consumption profiles to maximise net benefits by minimising input costs (ie, spot, network and retail prices) or maximising generation revenue
- **generation adequacy** – the capability of the power system to reliably match generation to peak demand and the capability of the network owner to avoid or minimise the disconnection of consumers during planned and unplanned maintenance activities or following major asset failure, eg, due to earthquake or flood

Also see Silva, Ricardo, Everton Alves, Ricardo Ferreira, José Villar, and Clara Gouveia. 2021. "Characterization of TSO and DSO Grid System Services and TSO-DSO Basic Coordination Mechanisms in the Current Decarbonization Context" Energies 14, no. 15: 4451, at https://doi.org/10.3390/en14154451.

- **corrective congestion management** – avoiding, or addressing, excursions from physical network limits (ie, exceeding thermal limits) caused, for example, by high power consumption during peak hours, use of heat pumps or simultaneous charging of EVs or distributed power generation
- **predictive congestion management** - solving either current or forecast physical congestions related to reduced network capacity (overload or voltage violation), improve network reliability, or maximise asset utilisation to right-size connection and infrastructure costs.
- **balancing – system and network balancing**. At the system level, ancillary services procured by the System Operator are black start, over-frequency reserve, frequency-keeping reserve, instantaneous reserve and voltage support. At the network level, distributors undertake voltage and other power quality management activities.

The need cases or conditions of each buyer are listed in Appendix A.

Question 1	Are there any other reasons for acting or services required by a DER owner, transmission or distribution network owner, the system operator, retailer or generator to need to respond?
Question 2	What suggestions do you have for creating common terminology and descriptions of the service, the need or condition to be managed and the physical response?

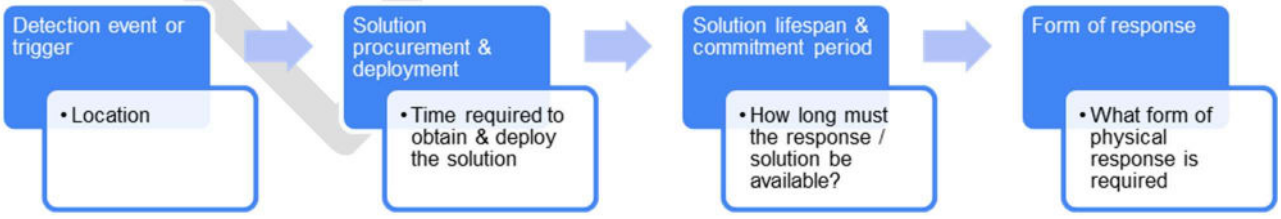
Planning and operational requirements for the five main services

The planning and operational requirements for the five main services are based on the critical decisions of the process from detecting a condition to physically responding to the condition.

The technical requirements outlined here are intended to be the key planning and operational information for responding to a network, system or market condition.

Figure 4 Summary of planning and operational information

Planning information



Operational information

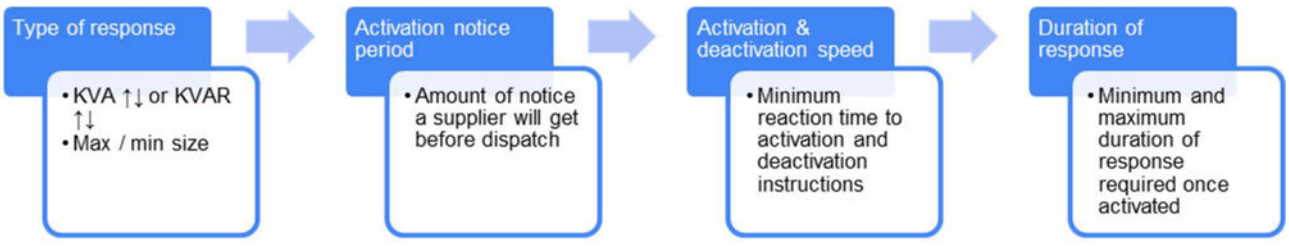


Table 1 sets out the planning and operational information for each service and associated outcome, giving examples of the information that would be available.

The intention is to try to identify the key information which flexibility buyers would make available when procuring services needed in the course of doing business.

Having a common list of key planning and operational information, and using common terminology and descriptions, is intended to provide the technical information needed by flexibility providers to make decisions about when, where and how to supply flexibility.

The requirements are described in more detail in Appendix B.

Question 3	Does the list of planning and operational information requirements reflect what is used for making decisions about responding to network, system and market conditions?
Question 4	Does the list provide sufficient planning and technical information for flexibility providers to make decisions about when, where and how to supply flexibility?
Question 5	What suggestions do you have for creating common terminology and descriptions for each of the technical requirements?

Table 1 Technical requirements (planning and operational information) for the five main services

Service	Need & outcome	Detection event or trigger	Location	Procurement & deployment timeframe	Response lifespan & commitment period	Form of response	Type of response	Activation notice period	Activation / deactivation speed[21]	Response duration
Service and desired outcome		**Planning information**					**Operational information**			
Portfolio optimisation	Managing spot prices to reduce energy costs / increase revenues	Spot price, actual or forecast Retail tariffs	GXP	12 months to hours ahead to instantaneous	By trading period	Shift Shed Shimmy	KVA ↑↓	Day ahead to hours ahead of trading period to instantaneous	Seconds to minutes	Trading period to hours
	Optimising network charges	Subject to charging basis, eg, peaks in measurement period	Network, subject to charging basis, eg, region	Over 12 months, depending on pricing structure changes	Ongoing	Shift Shed Shimmy Shape	KVA ↑↓ KVAR ↑↓	Months ahead to hours ahead	Seconds to minutes	Hours
	Managing fuel stocks	Fuel stocks, weather forecasts etc	Island HVDC GXP	Up to 12 months	By trading period	Shift Shed Shimmy	KVA ↑↓	Months ahead to hours ahead	Minutes to hours	Trading period to hours
Generation capacity adequacy	Power system – security of supply	System demand forecasts	Island HVDC GXP	Up to 12 months	Months to years	Shift Shed	KVA ↑↓	Months ahead to hours ahead	Minutes to hours	Hours to months, eg winter or summer
	Network reliability: avoid or minimise duration of planned & unplanned outages	Asset loading forecasts Monitoring Maintenance schedule Faults	GXP Zone substation Feeder	3-10 years Weeks ahead for planned outages	Months to years	Shift Shed	KVA ↑↓	Months ahead to instantaneous	Seconds to minutes	Hours
	Network resilience: avoid or minimise outages from major asset failure, eg, earthquake	Network configuration risk assessment Faults	GXP Zone substation Feeder	3-5 years	Months to years	Supply Shift Shed	KVA ↑↓	Instantaneous	Seconds	Hours to days

[21] Three activation/deactivation timeframes are proposed: 1. **seconds** for unplanned events protecting critical infrastructure; 2. **seconds to minutes** for unplanned events protecting non-critical infrastructure; and 3. **minutes to hours** for planned events protecting both critical and non-critical infrastructure

Service	Need & outcome	Detection event or trigger	Location	Procurement & deployment timeframe	Response lifespan & commitment period	Form of response	Type of response	Activation notice period	Activation / deactivation speed[21]	Response duration
Service and desired outcome		**Planning information**					**Operational information**			
Corrective congestion management	Network reliability: managing thermal limit excursions at peak periods • connection-related • growth-related	Faults Asset monitoring Asset loading forecasts Connection request	Connection LV / MV / HV network	1 year or less Connection timing	Months to years	Shift Shed	KVA ↑↓	Months ahead to instantaneous	Seconds to minutes	Hours
	Network reliability: managing voltage excursions / phase imbalances	Faults Monitoring Quality complaints Asset loading forecasts	LV / MV / HV network	Up to 3-5 years	Months to years	Shed Shimmy	KVA ↑↓	Months ahead to instantaneous	Seconds	Minutes to hours
Predictive congestion management	Network security: managing risk of thermal excursions • configuration • connection-related • growth-related	Outage, planned or unplanned Asset loading forecasts Connection request	Feeder or remote assets Connection LV / MV / HV network	Up to 3-5 years Connection timing	Months to years	Shift Shed	KVA ↑↓	Months ahead	Seconds to minutes	Hours
	Network planning: sizing of connection & network assets	Connection request	Connection LV / MV / HV / Tx network	Connection timing	Ongoing	Shift Shed Shape	KVA ↑↓	Months ahead	Seconds to minutes	Hours
Balancing	System and network quality • frequency keeping • frequency, FIR & SIR, AUFLS • voltage • black start	Monitoring Faults	LV / MV / HV / Tx network	Up to 3-5 years	Months to years	Shed Shimmy	KVA ↑↓ KVAR ↑↓	Months ahead to instantaneous	Seconds	Depending on the need: >60 seconds to 30 minutes

Appendix A: Need cases for network owners, system operator, market participants and DER owners

The conditions or need cases, and the characteristics of those cases, identified by the FlexForum are listed here. These are situations where flexibility may satisfy the need by resolving the condition.

Table 2 Need cases and the triggers for a response to network, system or market conditions

DER owners	Network owners	System operator	Market participants
Price risk management and minimising ongoing energy costs • managing spot price volatility and high spot prices • optimising network charges/costs	Congestion management due to thermal constraints from overloading asset capacity • short-term capacity shortfall at peak load due to new or larger connections • forecast capacity shortfall at peak load due to load growth	Instantaneous reserves[22] • fast instantaneous reserves (FIR) • sustained instantaneous reserves (SIR)	Price risk management • managing spot price volatility • managing high spot prices due to transmission constraints or fuel shortages • managing network chargers/costs
Connection design options which right-size connection & network infrastructure costs	Security of supply management and restoration time after a contingent event • ongoing security shortfall due to network configuration, eg, long feeders into remote areas • short-term security shortfall due to new or larger connections • forecast security shortfall due to load growth	Extended reserves[23] when the system frequency falls well below 50 Hertz and has not been corrected using instantaneous reserve services	Fuel management • optimising generation fuel stocks
Maximising ROI of DER investment by accessing all available revenue streams	Voltage management • voltage control • phase imbalances	Frequency keeping to keep the system frequency at 50 Hertz second-to-second	

[22] Instantaneous reserves are required in the event of a sudden failure of a generating or transmission facility to maintain system frequency at 50 Hertz. FIR must be available within one to six seconds and able to operate for one minute. SIR must be available within 60 seconds and be available for 15 minutes or until redispatched.

[23] Extended reserves are currently supplied by distributors and large users in the North Island and grid owner in the South Island through automatic under-frequency load shedding (AUFLS) which automatically disconnects blocks of load at specified frequency and time settings.

DER owners	Network owners	System operator	Market participants
Resilience & ability to maintain supply following major asset failure, eg, due to earthquake	Power quality management, harmonic imbalances etc	Voltage support to maintain voltage levels within a set band	
	Network resilience & ability to maintain supply following major asset failure, eg, due to earthquake	Black start to restore supply when the power system has no electrical input	
	Network design options which maximise feeder utilisation to right-size connection & infrastructure costs		

Source: FlexForum

Appendix B: Description of technical requirement categories

Each condition has specific requirements or technical criteria determining what needs to be done. The criteria appear to be common across conditions, even though the responses will differ according to the condition and circumstances.

These categories are the basis for the technical requirements set out in Table 2.

The criteria which a response to a condition needs to address are listed here.

Table 3 Key criteria for identifying a response to network, system or market conditions

Criterion	Description of criterion	Example
Planning and investment information		
Detection event or trigger	When would the need to respond to the condition be identified? When would the party needing to respond become aware of the impending condition? The amount of notice available and given about an impending condition will influence the availability of resources which can respond.	Notice of a condition can be years ahead to seconds after it occurs. • network owners will be aware of potential conditions 3-5 years in advance through annual updates to asset management plans • market participants will be aware of potential conditions up to 1 year in advance based on weather and fuel cost forecasts • the system operator will be aware of a frequency excursion seconds after it happens.
Location of condition	Where is the condition? Specify the geographic area or location on the network where the response to the condition will be required Relevant for understanding if and how resources can be aggregated	Location information identifies the point of delivery of the response, for example, Island, HVDC, GXP, Distribution Network (zone substation, suburb, feeder)
Procurement and deployment timeframe	What is the timeframe, following the detection event or trigger, for selecting, procuring and deploying a response? • operational (real-time) • short-term planning (D-1 to M-1) • long-term planning (>M-1 to Y-1, or more) The procurement timeframe will influence the availability of resources which can respond.	Procurement and deployment of a response can be years ahead to (potentially) seconds prior. For example, • network owners will contract for a response 3-5 years ahead due to procurement timelines and time required to deploy alternative solutions
Response lifespan and commitment period	What is the duration of the need and expected lifespan of the response? The commitment duration will influence trade-offs and decisions to make resources available to respond, contract length, value and compensation levels and structures.	The condition and the circumstances will determine the commitment duration.

Criterion	Description of criterion	Example
Form of response required	How is the response to the condition described? Common language should be adopted to assist in commoditising responses and reduce transaction costs	There are four forms of response. • Shift - moving demand sporadically in response to an external signal • Shed - switching off load • Shimmy - adjusting demand over very short timescales in response to an external signal • Shape - moving demand routinely according to a long-term pattern
Operational information		
Type of response	What physical response is needed? What is the minimum and maximum quantity of response required per offer? Relevant for understanding if and how resources can be aggregated.	There are four types of physical response. • KVA ↑↓ – raise or lower active power • KVAR ↑↓ – raise or lower reactive power
Response activation notice period	How far in advance of the use of a service would the request for action be sent (ie, instructions or event signals)? Is the response: • signalled ahead of time (ie, reserved)? • activated in real time? • both? The amount of notice prior to activation will influence trade-offs and decisions to make resources available to respond. The amount of notice given will also inform the mode of activation, whether manually, by request, or automated.	The condition and the circumstances will determine the notice available before activation of a response. For example, • instantaneous and extended resources are activated instantaneously (no notice)
Speed of response when activated and deactivated	How quickly does a response need to be activated after receiving the activation/deactivation instruction or event signal?	Period between instruction to activate or deactivate and full delivery or cessation of the physical response. For example, • FIR requires a response speed <6 seconds (NB interruptible load requires a response speed of <1 second)
Duration of response when activated	What is the minimum and maximum delivery period of the response once activated?	Duration the physical response needs to be delivered. For example, • a network congestion management response must be delivered for 1-4 hours, depending on the duration of the peak demand period • a spot price risk management response must be delivered for the 30-minute trading period

Source: FlexForum and Silva, Ricardo, Everton Alves, Ricardo Ferreira, José Villar, and Clara Gouveia. 2021. "Characterization of TSO and DSO Grid System Services and TSO-DSO Basic Coordination Mechanisms in the Current Decarbonization Context" *Energies* 14, no. 15: 4451, at https://doi.org/10.3390/en14154451