Open Energy Networks Project

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Appendices

Executive summary

Energy Network Australia (ENA) and the Australian Energy Markey Operator (AEMO) launched the Open Energy Networks Project (OpEN-PRJ) in 2018 through a joint consultation paper[1] seeking stakeholder input on how best to integrate the increasing penetrations of Distributed Energy Resources (DER) into Australia's electricity system in order to bring both short and long-term benefits to customers, irrespective of whether they possess DER assets or not.

The project is seeking to understand what roles a future Distribution System Operator (DSO) and AEMO should play in the future energy system to ensure that value is returned to all customers; both those connected at transmission and distribution level. Specifically, the OpEN-PRJ is investigating four market and network frameworks that can facilitate market access for all stakeholders (DER owners, aggregators, network operators, etc) while ensuring that technical network limits are not breached and the integrity and security of the network is preserved, maintaining a safe and reliable power supply for all. These frameworks are interchangeably referred to as DER and DSO frameworks.

To achieve its goals, the OpEN-PRJ has commissioned EA Technology to investigate the high-level functionality required to bring about each of the four DER optimisation frameworks under consideration. As the four models each seek to optimise DER and bring value to customers in different ways it is necessary to develop a detailed understanding of these frameworks and the differences between them. For this purpose, industry workshops delivered by EA Technology were held with a wide cross-section of stakeholders in locations around Australia: Melbourne, Sydney, Perth and Brisbane. Within these workshops the four frameworks, each broken down into 13 key functions and associated activities required to deliver key DER optimisation principles, were examined in detail to answer three basic questions:

- Who is communicating with whom;
- What are they communicating; and
- How are they communicating and how often?

In this way stakeholders explored and fleshed out the requirements for DER optimisation, allowing EA Technology to gather and process stakeholder views in order to comprehensively characterise the full functional specification of each of the four frameworks. Full details of the four frameworks and the 13 functions that define them can be found in Section 3 of the report, while a brief summary of each is presented below:

- **Single Integrated Platform (SIP)** – A single central market comprised of wholesale and ancillary services markets is organised and operated by AEMO. The central market platform collects bids and offers from market participants, including DER via aggregators/retailers, and makes them available to AEMO for whole system optimisation.
- **Two Step Tiered (TST)** – A central market comprised of wholesale and ancillary services markets is organised and operated by AEMO, which has access to distribution network (D-network) connected energy resources only through a local platform facilitated by the DSO. The local market platform collects bids and offers from DER via aggregators/retailers which it may procure for network constraint management or pass to AEMO as part of an aggregated stack for use in whole system optimisation.
- **Independent Distribution System Operator (IDSO)** – Similar to the TST framework, except in that the local market platform is operated by an IDSO, a separate and unique entity independent from the DNSP (Distribution Network Service Provider)/DSO.

[1] "Open Energy Networks – Consultation on how best to transition to a two-way grid that allows better integration of DER for the benefit of all customers," AEMO and ENA, 2018.

- **Hybrid** – A conceptual cross between the SIP and TST frameworks, a two-sided marketplace comprised of wholesale and ancillary services is organised and operated by AEMO. The central market platform acts as the key data exchange platform between market participants (including network operators) and collects bids and offers from energy resources, such as DER via aggregators/retailers, and makes them available to AEMO and the DSO for whole system co-optimisation.

The realisation of the functional specification of each framework enhanced our understanding of them and allowed for the development of each into Smart Grid Architecture Models (SGAMs), a holistic method for describing a smart grid system (see Section 4). The SGAM outputs developed for this project provide a structured and coherent way to describe, visualise and interpret the DER frameworks by capturing the interactions between different actors from a high-level business context down to the detail of what information is exchanged, through the use of which communication methods. Through visual interaction with the SGAMs it is hoped stakeholders can explore the make-up of the four frameworks to enhance understanding and facilitate buy-in.

The SGAM methodology developed and implemented by EA Technology also allows for the like-for-like comparison and analysis of the frameworks which has been developed in a number of ways to begin exploring the optimal pathway forward in the DSO transition. Analysis has been carried out in three main areas which will be discussed in turn:

- Required capabilities and recommended actions (Section 5)
- Complexity analysis (Section 6)
- Pathways and indicators (Section 7)

Required capabilities and recommended actions

Investigation and consultation with stakeholders to date has drawn out key required capabilities which exist across all frameworks and act as enablers to the DSO transition. These required capabilities must be developed as a first priority in order to 'clear the way' for the wider DER optimisation, irrespective of the ultimate form that transition takes and the final framework which manifests. By laying the foundations of a framework that future work can build upon the industry will be well positioned to continue progressing towards a DER optimisation network-market model.

Three required capabilities key to the industry's transition from its current capacities to those of any future optimised DER world are as follows:

1. Determine network constraints
2. Define these constraints within an operating envelope
3. Communicate this operating envelope to customers, DER, aggregators, etc.

In order for network operators to achieve the required foundation in a manner conducive to optimising the impacts of DER for the whole grid, and delivering maximum benefit to customers, for each of the capabilities listed above a series of enabling actions have been identified, as shown in Figure 1.

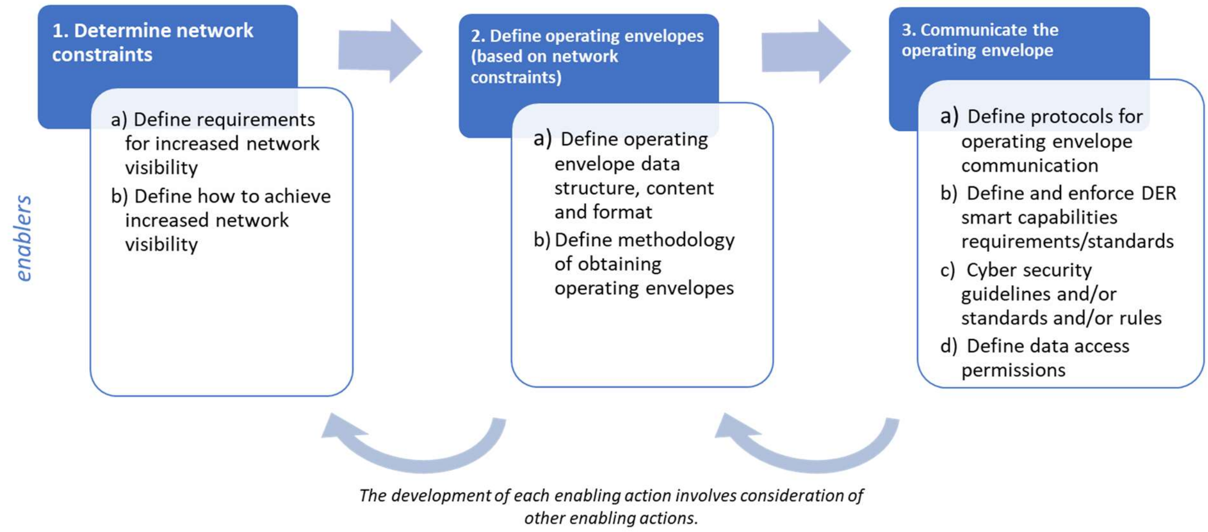

Figure 1 Required capabilities and enabling actions

The required capabilities and enabling actions are fully explored in Section 5, however it must be highlighted that underlying ENA's and AEMO's future vision for DER optimisation is the use of operating envelopes which indicate to customers the export and/or import limits that they must operate within for the safe and secure running of the network. At the foundational level, operating envelopes may be static and determined through an examination of the long-term constraints on the network. However, as network visibility is enhanced, operating envelopes may be calculated at shorter timescales and become dynamic.

Following the implementation of the required capabilities, recommended actions which exist at the convergence of four DSO frameworks can be prioritised. Recommended actions are drawn from the common key features present in all four frameworks and so can be undertaken without the need to choose an end-state framework, allowing the industry to further progress its DSO transition without regret (i.e. with minimal risk of additional work requirements, investments being sunk or value not being realised). This report does not suggest the timing in which these actions should be executed beyond recommending, that in order to reap maximum potential rewards for customers, actions are enacted in the short to medium-term.

While over 100 common key features are present across the four frameworks, to more readily engage with these least regret actions, they have been distilled down into ten recommended actions which are recommended as areas of work to engage with going forward. The derivation and exploration of these recommendations is fully explored in Section 5.2, while they are summarised in Table 2 below.

It is envisaged that these recommended actions will be undertaken in a staged manner, and so to assist this, recommendations have been grouped into priority areas where a high degree of synergy exists between then. Further, for each priority area we have suggested one of two ways in which it may be pursued:

1. Review and enact - An adjustment to business as usual practices, or current regulatory rules and frameworks, that can be reviewed and enacted across the system in a modest timeframe.

2. Trial - Trials are needed to explore best practice to achieve the functionality of the recommended action.

Table 2 Summary of recommended actions

Priority area	Recommended actions
	Recommendations to be reviewed and enacted
Aggregator development	R1. Define the aggregator role and required services • Clarification around the role the aggregator will play in DER optimisation and its relationship with the energy retailer • Further, there is a need to work across the industry to define the suite of products and services required by network operators as part of the energy system of the future
	R2. Aggregator and energy retailer coordinate to develop portfolios of customers • Aggregators and energy retailers can begin to further engage with active DER customers to acquire a range of services that it may offer the network or market operators
Collaboration for network forecasting and development	R3. Aggregators, energy retailers and transmission customers forecast the long-term and short-term load and generation profiles of their customers and portfolios • Aggregators and energy retailers have responsibility to provide to network and market operators granular load and generation profiles for their customers and portfolios, both long-term trends and projections and short-term forecasts based on network, market and customer status
	R4. D-network, T-network and joint system investment plans are created • An extension of business as usual investment planning with greater emphasis on joint planning and requiring cost-benefit analysis of the use of network services vs traditional investment routes
	Recommendations to be trialled
Wholesale market for DER integration	R5. Aggregator and energy retailer apply to participate in the wholesale and FCAS (Frequency Control Ancillary Services) markets • The wholesale electricity market is well established and so may be suitable for initial trials in integrating DER into the markets through aggregators and energy retailers
	R6. Aggregator and energy retailer dispatch customers in response to market signals or contractual arrangements • The creation of communication infrastructure and protocols between aggregators, energy retailers and the market platform to facilitate the use of real-time dispatch signals is needed to unlock DER value

Priority area	Recommended actions
Network services market for DER integration	R7. Adjust market rules to establish a network services market • A trial area for a distribution network services market could be established: to gauge the costs and benefits such a market would bring; to better understand the appetites of customers, aggregators, energy retailers and network operators to participate; and to determine best practice going forward
	R8. Rules or guidance are created on the use of bilateral network services contracts out with the market platforms • Bilateral contracts for network service must be coordinated with market operations and rules established setting out any exclusions on the use of bilateral contracts out with an optimised market platform
Network services market for transmission customers	R9. AEMO dispatches the T-NSCAS (Transmission Network Support and Control Ancillary Services), wholesale and FCAS markets AEMO may play a role in actively managing T-network constraints by trialling a network services market open to transmission customers
Pricing signals	R10. Pricing signals [to be developed] Local pricing signals can be developed to manage customer behaviour out with a market or contractual obligation. Signals can be market driven (i.e. based on the wholesale price of electricity), network driven (i.e. based on local constraints for import / export) or a combination of both. Trials may be undertaken to better understand customer response to pricing signals and their position in the DSO transition moving forward

By progressing these ten recommendations the transition to DER optimisation can be pursued without regrets, and thus begin to provide support to networks and benefits to customers at both the transmission and distribution level. As uncertainty over the future diminishes and a preference for a framework emerges, the industry will be in good standing to complete its journey to a system that efficiently integrates DER and facilitates its market access.

Complexity analysis

The implementation of the DSO transition represents a significant departure from current practice and represents an appreciable risk to the energy industry in terms of both the effort and cost necessary to bring it about. A measure of the risk affecting the successful implementation of a given framework can be established through an assessment of the complexity inherent in fully establishing DER optimisation in any of the frameworks. To determine this, EA Technology has developed a bespoke approach to determine the 'relative complexity' of the DSO frameworks against one another. That is, while we cannot empirically establish the level of effort necessary to complete the transition towards one of the four frameworks in a real-world sense, we can assess the SGAMs of the frameworks in a closed approach to approximate the relative difficulty of implementing each of them. The full methodology and application of this bespoke approach is presented in Section 6 while key results are presented below.

Figure 2 shows that the relative complexity of the four frameworks is relatively stable, with SIP showing marginally to be the least complex framework, and the IDSO framework the most complex. These findings are to be expected and can be explained by considering the underlying structure of each framework. The SIP framework remains closest to the status-quo and so represents the lowest complexity to implement. By contrast, the IDSO framework is the most distinct from current practice, requiring the creation of an entirely new regulated entity to function, adding a greater level of complexity to the DSO transition.

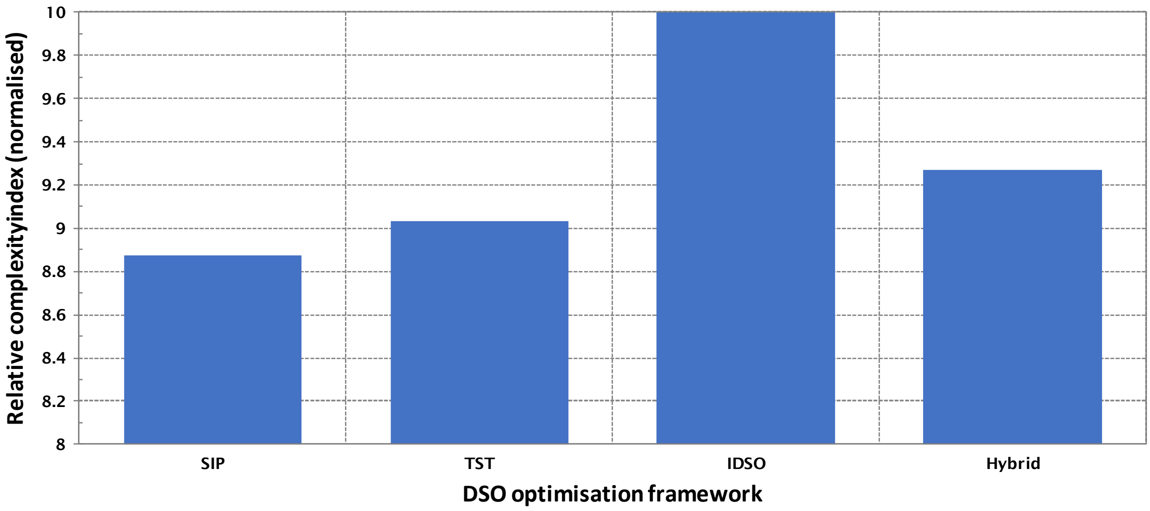

Figure 2 Relative complexity of the four DSO optimisation frameworks

The TST shows raised complexity in comparison to the SIP framework due to the required creation of a new market platform that operates in a complementary manner to AEMO's central optimisation. Similarly, the hybrid model makes use of a local platform to gather distribution level bids and offers, although in this case it is AEMO operated. To reconcile distribution network operation with AEMO's greater role at the distribution level, additional coordination between AEMO and DSO is present within the hybrid model, pushing the relative complexity slightly above that of the TST framework, where the DSO's greater authority and autonomy simplifies DSO-AEMO interaction.

Note that it must be made clear that a greater complexity to complete a given DSO transition pathway should not necessarily be regarded as a negative indicator of the merits of that framework. A more complex to implement framework may or may not bring additional benefit to customers, so to obtain a full picture the benefits as well as the complexity in implementation must be considered.

Further results from the complexity analysis synergise with those from the least regrets analysis. Contrasting the results of the two has revealed a misalignment between those areas which represent the greatest complexity (or the most effort to enact) and those areas which are common across the frameworks (or can be enacted in the short to medium-term).

This indicates that a significant amount of the work required to optimise DER and unlock value to customers is 'locked out' until a single transition pathway is selected. That is, while the required capabilities and secondary least-regret actions should still be implemented in the short to medium-term to allow the industry to progress DER optimisation, the actions which will have greatest impact on change (and potentially bring greatest value to customers) can only be taken once an end-state has been selected. Although a long-term consideration, it shows that progress towards a full transition cannot stall without incurring extra cost in the form of high opportunity loss for customers, clearly illustrating the need for industry direction to be established as early as possible.

Further work currently underway by CSIRO (Commonwealth Scientific and Industrial Research Organisation) is more fully investigating the value unlocked by customers through the DSO transition.

Pathways and indicators

Multiple factors will influence the transition pathway to DSO with technical, regulatory and commercial progress factors all in turn impacting the speed by which any change can occur:

- It can be difficult to predict the time taken to find and develop technical solutions to the appropriate technology readiness level for deployment as in the process of innovation not every investigation or trial leads to a greater understanding of what solutions work and what can be done.
- For regulatory changes, the current system requires between 40 working days and about 130 working days for a rule change to progress through the AEMC[2] from the point where a rule change request is made to when the final determination is published.
- Commercial changes need to come after the technical and regulatory foundations have been laid as the technical and regulatory requirements will form the structure for any new markets.

Work is already underway by certain organisations and projects looking at generating learning that can be applied to implement the requirements of DER optimisation. Table 3 highlights some of these key projects, whose outputs will provide indicators of progress towards the DSO transition, and relates them to the 13 DSO functions which enable the optimisation of DER.

Table 3 Example industry projects and related functions

Industry projects	Related DSO functions
• DEIP Framework Customer Insights Initiative • Distribution Transformer Low Voltage Circuit Monitoring by Energex	1. Distribution system monitoring and planning
• The ENOpEN project (looking at dynamic operating envelopes) by ANU, Energy Queensland	2. Distribution constraints development
• DEIP Framework Customer Insights Initiative • Impacts of PV, AC, and Other Technologies and Tariffs on Consumer Costs by the Australian PV Institute • Energy Used Data Model by CSIRO • Integrated System Plan by AEMO	3. Forecasting systems
• dEX Platform Development and Testing by Greensync	4 and 5. Aggregator and Retailer Bid and Dispatch
• FPDI: Demand Side Management Technology Testing by CEC	6. DSO optimisation at the distribution level
• AWEFS and ASEFS stakeholder consultation by AEMO	7. Wholesale – distribution optimisation
• Solar Energy Management System for Utilities (by CSIRO Ergon Energy GWA Group • VPP demonstrations by various parties	8. Distribution network services

[2] "A guide to the rule change process" AEMC, Jun. 2017. https://www.aemc.gov.au/sites/default/files/2018-09/A-guide-to-the-rule-change-process-200617.PDF

Industry projects	Related DSO functions
• A Distributed Energy Market: Consumer & Utility Interest, and the Regulatory Requirements by the Australian PV Institute • Modelling the impact of various tariff structures on distributed energy resource take-up and electricity pricing by SAPN	9 and 10. Data and settlement
• Energy Networks Australia Connection Guidelines Development • Work on inverter standards	11 and 12. Connecting DER and the DER Register
• Bruny Island project by TasNetworks • Hornsdale Power Reserve	13. Network and System Security with DER

Beyond the speed by which the transition is possible, the shape of the transition will vary locally to meet network and customer needs, as each DNSP is starting from a different position. To understand and track progress it is important to be aware of:

- The 'starting' position of the network
  - The current uptake level of DER
  - The network and asset characteristics and capabilities
- The 'end' point
  - The forecast point at which interventions in some form will be required in order to maintain reliable and safe network operation
- The factors that will influence the pace of change between these points, e.g. policies and incentives

Ultimately, each stakeholder's journey will be different and the direction of travel for each may change and in different ways. Being attuned to the evidence provided by the latest industry data is of paramount importance to the successful operation of the future electricity system.

Next steps

In the immediate future, it is important that stakeholders can feel confidence in the four frameworks, and so they are encouraged to explore the SGAMs developed to represent them. Alongside this, the work developed by CSIRO to explore the economic impacts and benefits of the DER optimisation process will also be available shortly. It is hoped that with a developed understanding of both the frameworks themselves and the impacts associated with them, the industry can begin the process of selecting its desired end-destination for DER optimisation. Once an end-destination for the system has been selected a transition strategy can be developed, at which point the SGAM can be enhanced to define the full physical system architecture necessary to achieve the functional specification currently modelled.

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Acronyms

AEMO	Australian Energy Market Operator
BUC	Business Use Case *(alternative term for DER optimisation framework)*
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D-network	Distributions network
DER	Distributed Energy Resources
DNSP	Distribution Network Service Provider
DSO	Distribution System Operator
ENA	Energy Networks Australia
FCAS	Frequency Control Ancillary Services
HLUC	High-Level Use Case *(alternative term for DER function)*
IDSO	Independent Distribution System Operator
NSCAS	Network Support and Control Ancillary Services
OpEN-PRJ	Open Energy Networks Project
PUC	Primary Use Case *(alternative term for DER activity)*
RERT	Reliability and Emergency Reserve Trader
SIP	Single Integrated Platform
SGAM	Smart Grid Architecture Model
T-network	Transmission network
TNSP	Transmission Network Service Provider
TSO	Transmission System Operator *(European term for AEMO equivalent)*
TST	Two Step Tiered

Glossary

Ancillary services	Refers to offerings made by energy resources to market and/or network operators which assist in the running of the networks and/or system. Includes frequency control, network support and control and system restart ancillary services.
Constraints	Referring to technical parameters or capabilities of the network assets (e.g. transformers and cables) that if exceeded would compromise the quality, and/or stability and/or reliability of the power supply.
DER optimisation function (see also for activity, process and step)	One of the 13 functions deemed necessary for developing the functional specification required to progress towards a distributed level optimisation framework. The 13 functions have been parsed into more granular activities which, in turn, are realised by a number of processes described by functional steps.
DNSP	Distribution Network Service Providers which do not transition to a DSO are responsible for the development and operation of the distribution network following an active network management approach in order to facilitate the secure, safe and reliable delivery of power flows between network connections. To overcome the challenges of increasing DER penetration on their networks DNSPs will engage with IDSOs to facilitate the consideration of distribution network constraints in the whole system dispatch process and, based on network and DER state, provide an operating envelope for all active DER.
DSO	To overcome the challenges of increasing DER penetration on their networks DNSPs may transition to Distribution System Operator business models responsible for the development and operation of the distribution network following an active network management approach in order to facilitate the secure, safe and reliable delivery of power flows between network connections. DSOs will engage with the NSCAS market to alleviate distribution network constraints while also supporting the optimised participation of DER assets in the electricity markets through the provision of an operating envelope for all active DER.
IDSO	In the 'IDSO optimises distribution level dispatch' platform an Independent Distribution System Operator is created as a separate entity for each DNSP. The IDSO is responsible for the transparent and unbiased aggregation of DER market bids, taking into account distribution network limits through close collaboration with the given DNSP, and will allocate dispatch to individual aggregators/retailers based on the exchange schedule across D-network boundary set by AEMO.
Key features	As part of the least regret analysis, the functional steps within the framework models were distilled down into a number of key features. Note: common key features are those key features which are strongly present across all three frameworks, these form the 'recommended actions'.
Recommended actions	The actions that may be taken in the short- to medium-term to progress the DSO transition once required capabilities are in

	place. These least regrets actions arise from analysis of feedback from stakeholder and the common elements.
Network services market	A market platform where DER and other energy assets may offer network operators network support and control ancillary services (NSCAS) in order to manage or mitigate network constraints.
Operating envelopes	Derived through understanding of network constraints and customer requirements, the operating envelope indicates the export or import limits that customers should operate between.
Optimisation	Referred to here as the aggregation and prioritisation of distribution level bids and offers; in other global markets also known as “orchestration”.
Required capabilities	The three key enabling capabilities required to facilitate the integration of increasing DER uptake rates while maintaining security and quality of power supply and avoiding excessive network augmentation.
System services	Refers to all offerings made by energy resources to market and/or network operators and will include wholesale and ancillary service offerings.

1. Introduction

We are witnessing considerable disruption in the power sector. A combination of political, technological and customer behavioural drivers are affecting a move towards a decarbonised, decentralised, democratised and digitalised system. An example of the changes underway can be seen in the actual and forecasted uptake rates of DER. Solar PV is already hitting 30% penetration in some Australian states causing reverse power flows, capacity constraints and voltage issues. The changes underway are profound and so a rethink of the energy industry’s business models, stakeholder roles and stakeholder interactions are imperative.

In 2018, Energy Networks Australia and AEMO launched the OpEN-PRJ, a joint consultation seeking stakeholder input on how best to integrate and optimise DER into Australia's electricity grid through the transition to a DSO framework in order to bring both short and long-term benefits to customers, irrespective of whether they possess DER assets or not. To achieve its goals, the OpEN-PRJ has commissioned EA Technology to investigating the high-level functionality required in a world with increasing levels of DER.

Four frameworks put forward by the OpEN-PRJ steering group in consultation with stakeholders, each exploring a different way of delivering the DSO transition and bringing value to customers, were considered with a cross-section of stakeholders at industry workshops conducted in Melbourne, Sydney, Perth and Brisbane. Within these workshops the four frameworks, each broken down into 13 key functions and associated activities required to deliver key DER optimisation principles, were examined in detail to answer three basic questions - in order to fulfil each of the functions and associated activities:

- Who is communicating with whom;
- What are they communicating; and
- How are they communicating and how often?

In this way. EA Technology has gathered stakeholder views on the four frameworks in order to develop SGAMs for each framework which provide a structured and coherent way to describe, visualise and interpret the DSO frameworks by capturing the interactions between different actors from a high-level business context down to the detail of what information is exchanged, using what communication methods.

The SGAM methodology developed and implemented by EA Technology also allows for the like-for-like comparison and analysis of the frameworks in order to draw out common themes and areas of similarity between them. This informs the presentation of the required capabilities that are necessary to bring about an environment suitable for the implementation of a DER framework, and the subsequent exploration of further actions that can progress the DSO transition in the short to medium-term without regret.

Further, EA Technology considered the complexity, as well as the associated risk this generates, necessary to bring about any of the four DSO frameworks. Finally, as the pathway to the implementation of any given framework will be highly dependent on localised issues, the indicators which will influence the DSO transition were explored.

In summary, this report contains:

- **Section 2** – Background into international best practice around the DSO transition
- **Section 3** – Summary of the four DSO frameworks, their functions and associated activities and the actors involved in the DSO transition

- **Section 4** – An overview of the SGAM methodology and implementation as well as practical guidance on navigating and interpreting the SGAMs developed for the OpEN-PRJ
- **Section 5** – Required capabilities and secondary actions to progress the DSO transition in the short to medium-term without regret
- **Section 6** – Assessment of the complexity of each framework, and associated risks and benefits of this
- **Section 7** – Exploration of the local issues and indicators which will impact the DSO transition pathway

A summary of our conclusions and recommendations is available in Section 8.

2. International review: The Distribution System Operator transition

Around the world there has been observed a continuing increase in both the demand for and the supply of energy from renewable energy resources. Three main drivers exist for this trend: the need for energy security through diversity of supply; the increasing cost and future scarcity of fossil fuels; and a growing global push for decarbonisation. Due to the sometimes competing objectives of these drivers, together the three are often referred to as the energy trilemma. The balance of these drivers and the scale and uptake rate of low carbon technologies, including renewable energy generation, varies from location to location. Irrespective of absolute volumes of DER, their incorporation into national electricity networks, and markets, brings new challenges.

This section of the report sets the scene around the international progress towards the transition to network and market models that facilitate elevated levels of DER. In the UK, and other areas around the world, this is often referred to as the transition to DSO. At the very highest-level, proposed approaches to the DSO transition may be considered according to which business actor (or actors) lead the procurement of D-network connected energy resources primarily, but not exclusively, for use in solving network constraints or congestion management.

Generally, DSO models can broadly be considered to fall into one of four groupings: DSO led; Transmission System Operator (TSO) led; independently led; and jointly procured. However, it must be stressed that within these categories there exists countless variation both in implementation and underlying design. Conversely, a great deal of overlap between these categories also exists, particularly where projects consider underlying enablers or mechanism to the DSO transition as opposed to specific market or network arrangements. As such, it is difficult and perhaps misleading to definitively place any of the projects discussed herein into a single categorisation, however these four philosophies to the DSO transition can be spotted throughout the industry.

Office of Gas and Electricity Markets (Ofgem)[3]

Ofgem does not endorse any particular path forward but does suggest certain ‘mechanisms’ that might be enacted in future TSO and DSO (or DER market) models. Ofgem encourages the use of competitive approaches wherever possible in order to deliver maximum benefit to customers.

- **DSO/SO procurement mechanism** – DSOs could collect bids and offers for flexibility services from distribution connected flexibility resources. These bids and offers would then be used to manage constraint and system requirements within the distribution network. At the same time, each local flexibility unit would be linked to the national balancing mechanism so that bids and offers from distributed providers could be accepted by the local DSO or the TSO to maximise their value to the system.

- **Changes to market signals and arrangements** – Market arrangements could evolve to respond to locational market signals. For example, if there were constraints on exporting energy from a particular area of the network, then this would mean the price in that local market would fall, creating a signal for flexible resource that could turn up demand to help match generation in that local area.

- **Changing roles and responsibilities in system operation** – Responsibility for network operation and managing system parameters could be further aligned within a single party. The TSO could gain involvement in distribution network operation. Alternatively, the DSO could enact enhanced management of system parameters, including transmission constraints and frequency management, within their licence area.

[3] “A Smart, Flexible Energy System – A Call for Evidence,” Ofgem and BEIS, Nov. 10, 2016. https://www.ofgem.gov.uk/system/files/docs/2016/12/smart_flexible_energy_system_a_call_for_evidence.pdf

SmartNet Project (European Commission, Horizon 2020 framework)[4]

SmartNet explores five basic schemes for TSO–DSO coordination and system service provision.

- **Centralised system services market model** – There is one central market for system services which the TSO utilises to procure resources connected both at transmission and distribution level. The DSO is protected from the TSO activating resources that may cause additional distribution network constraints through a system of qualification but the DSO does not procure DERs from the central market.

- **Local system services market model** – A local market is operated by the DSO. After the DSO has procured the DERs needed to solve local congestions, the remaining resources are aggregated and offered to the TSO through a central market. Distribution connected resources cannot participate in the central market directly, and only those resources which respect network constraints are transferred from the local to central market.

- **Shared balancing responsibility model** – A local market is operated and utilised by the DSO to solve local congestion and balance the distribution network. The TSO has no direct access to distribution connected resources.

- **Common TSO-DSO ancillary services market model** – The TSO and DSO are jointly responsible for the operation and organisation of a central market. Both TSO and DSO requirements are integrated in the market clearing process which is optimised to minimise whole system cost.

- **Integrated flexibility market model** – A neutral entity organises and operates a central market. The TSO and DSO may purchase and sell resources freely alongside other market participants. Resources are allocated to the party with the highest willingness to pay. DSO constraints are integrated in the market clearing process.

evolvDSO Project (European Commission, FP7 framework)[5]

evolvDSO suggests three possible DSO models:

- A model whereby the TSO and the DSO would be able to contract network services from DERs for their own needs through a common platform where all offers are available to all parties, while giving both system operators the right to check that actions undertaken by the other system operator do not jeopardise their own grid.

- A model according to which the TSO would have access to resources on the DSO network through the DSO. The DSO would aggregate the resources connected to their network and offer them to the TSO or use them to solve constraints on the distribution network.

- A model based on a ‘scheduled balancing program’ at the transmission-distribution interface. In this model, the DSO would be responsible for balancing the distribution network and the TSO would have no direct access to DER. Instead DER are effectively offered to the TSO indirectly through the negotiated balancing profile.

Eurelectric

Eurelectric[6,7] in collaboration with other entities such as ENTSO-E (the European Network of Transmission System Operators for Electricity) suggested possible options for coordinating the use of flexibility resources:

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[4] http://smartnet-project.eu/
[5] http://www.evolvdso.eu/
[6] “General Guidelines for Improving TSO-DSO Cooperation,” Eurelectric, Nov. 2015. https://www.entsoe.eu/Documents/Publications/Position%20papers%20and%20reports/entsoe_pp_TSO-DSO_web.pdf
[7] “Eurelectric Vision about the Role of DSO,” Eurelectric, Feb. 2016. http://www.eurelectric.org/media/258031/dso_vision_final_100216_web-2016-030-0092-01-e.pdf

- **Single marketplace** – The market is operated by the TSO in close coordination with the DSO and is utilised by both parties to bid for either balancing or congestion management services.

- **Local congestion markets** – The DSO operates a local market for congestion management with a high level of coordination with the TSO.

Council of European Energy Regulators (CEER)[8,9]

CEER explores how the relationship and regulatory arrangements between DSOs and TSOs may need to evolve to ensure efficient system solutions (either conventional or new) can be deployed to accommodate the needs of a sustainable energy system. CEER sets the principles it believes should set the trajectory of the future DSO-TSO relationship and related regulatory arrangements.

- **Overarching principles** – There is a need for DSOs and TSOs to build constructive and cooperative relationships which are focused on optimising the outcomes for the system as a whole rather than minimising the DSOs' and TSOs' costs in isolation.

- **Governance** – Regulatory arrangements will need to evolve to support the effective coordination of action between DSOs and TSOs. In particular, controls on revenue and appropriate incentives are essential to bring about holistic and optimised system operation.

- **Network planning** – Network transparency and shared forecasts will be crucial in allowing least cost solutions to be identified, and in creating the environment for innovation to be developed between DSOs and TSOs.

- **System operation** – Network transparency and enhanced cooperation between DSOs and TSOs will enable them to better maintain the overall system security of their networks.

The State of New York's Reforming the Energy Vision (REV)[10]

The electricity regulator within the state of New York launched the Reforming Energy Vision (REV) initiative which calls for the restructuring of the state's distribution utilities into Distributed System Platform Providers (DSPPs) with enhanced and changing responsibilities:

- DSPPs will promote the integration of a diverse range of electricity sources and services into the electricity network in order to meet customers' evolving needs and to reduce overall system costs.

- DSPPs will take on many of the roles currently undertaken by TSOs, particularly in regard to market functions. For example, REV mandates the creation and operation of local distribution markets for the provision of system services and local load management.

- Within their new remit of responsibility, DSPPs will be responsible for the daily scheduling of local generators and external electricity transactions in order to match supply and demand.

Energy Networks Association, Open Networks

A multi stakeholder group consisting of nine of UK and Ireland's electricity grid operators, academics, non-Government organisations, Government departments and the energy regulator Ofgem came together for this initiative looking to lay the foundations of the smart energy grid in the UK. The project came up with five market models as listed. A: DSO coordinates, B: Joint procurement and coordination C: Price driven flexibility, D: ESO coordinates and E: Flexibility coordinators. (Note: in this work ESO (Energy System Operator) refers to the organisation that is

[8] "CEER Position Paper on the Future DSO and TSO Relationship," CEER, Sep. 21, 2016. http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Cross-Sectoral/2016/C16-DS-26-04_DSO-TSO-relationship_PP_21-Sep-2016.pdf
[9] "The Future Role of DSOs," CEER, Jul. 13, 2015. http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Cross-Sectoral/Tab1/C15-DSO-16-03_DSO%20Conclusions_13%20July%202015.pdf
[10] "Reforming the Energy Vision (REV)," NYS Department of Public Service Staff Report and Proposal, Apr. 24, 2014.

traditionally known as the TSO). EA Technology was directly involved in this project and facilitated the creation of SGAMs for each of the five DSO worlds. The key characteristics for each are described below.

- **World A: DSO coordinates** – The DSO facilitates a regional market for D-network flexibility resources, directly procures them and also balances the D-system according to a pre-defined power exchange schedule agreed with the ESO. The ESO operates and procures resources from a central market for T-network flexibility resources.

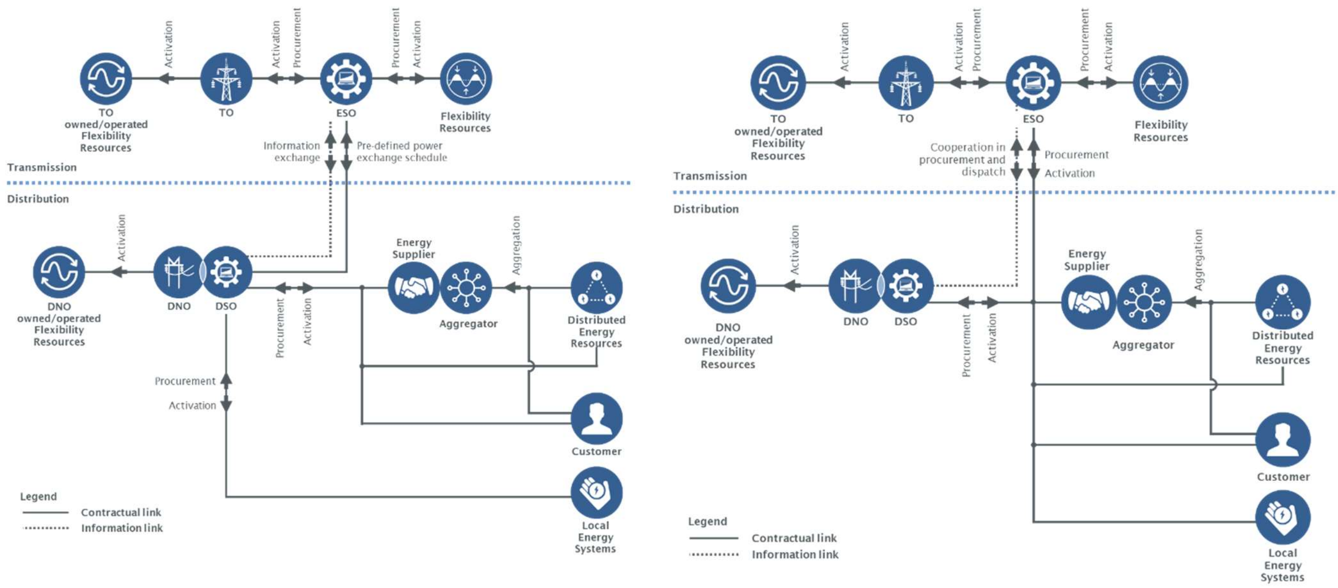


Figure 3 Actor-relationship diagrams for (left) World A: DSO Coordinates, (right) World B: Joint procurement and dispatch

- **World B: Joint procurement and coordination** – The ESO procures flexibility resources from both central and regional markets, while the DSO procures from the regional market. They both coordinate their procurement and dispatch to maximise synergy.

- **World C: Price driven flexibility** – as in World B there is a central market for D- and T-network connected flexibility resources, however in this World this is supported by strengthened locational and time of use pricing signals which allow additional price flexibility arrangements to supplement any contracted flexibility arrangements.

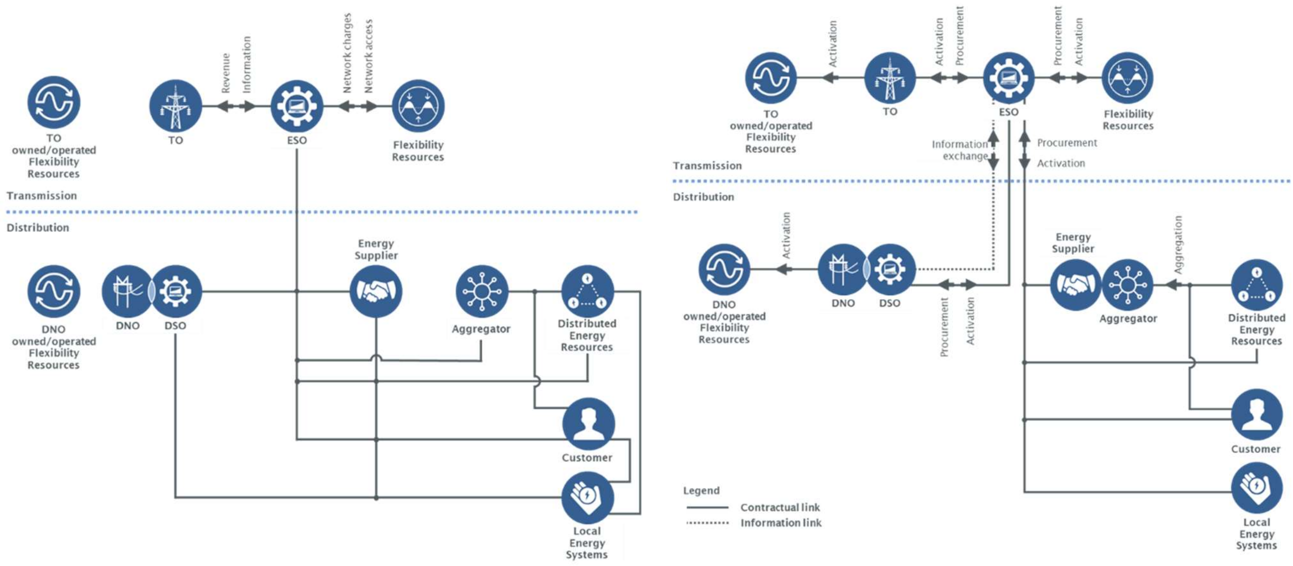


Figure 4 **Actor-relationship diagrams for (left) World C: Price Driven Flexibility, (right) World D: ESO Coordinates**

- **World D: ESO coordinates** – The ESO coordinates with the DSO to pre-qualify flexibility resources for dispatch by the ESO in order to prevent additional D-network constraints. The DSO procures flexibility services from ESO (both flexibility resources and smart grid networks solutions) and offers the ESO flexibility services (smart grid networks solutions only).

- **World E: Flexibility coordinators** – The flexibility coordinator (FC, a new role not currently present in the UK system) procures D-network flexibility resources on behalf of ESO and DSO through a whole system optimisation platform. The FC mitigates any conflicts between the DSO and ESO so that dispatch of flexibility resources does not cause additional D- and T-network constraints.

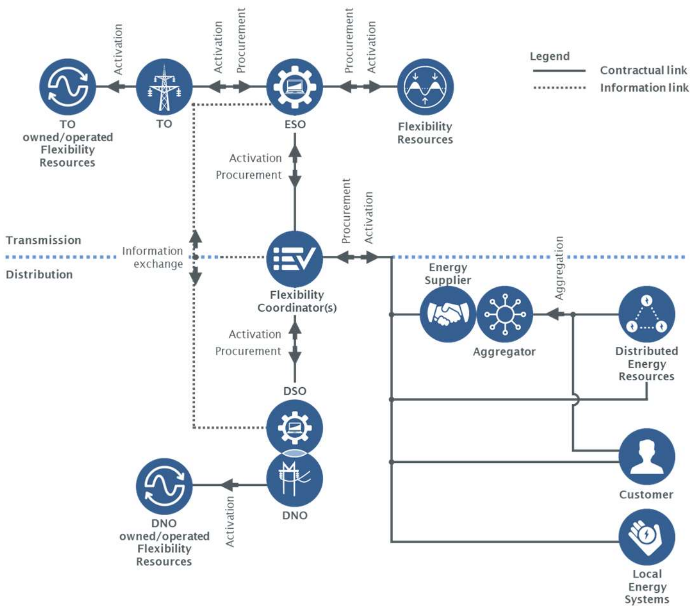


Figure 5 **Actor-relationship diagrams for World E: Flexibility Coordinators**

SPEN FUSION project trialling Universal Smart Energy Framework (USEF)

The USEF provides an internationally recognised standardised flexibility market framework designed for deployment alongside existing energy markets such as wholesale and capacity. By defining flexibility market players, their roles and the interactions between them it provides a blueprint to turn flexibility into a scalable and tradeable commodity for all market participants. An adapted SGAM representation of the USEF created by EA Technology allows for direct comparison of the USEF with each of the Open Networks models. This allows industry stakeholders to have focused discussions on the unique features of the USEF that could be of benefit to the wider industry and customers. Figure 6 presents the actor-relationship diagram for the USEF standard 'aggregator flexibility' model.

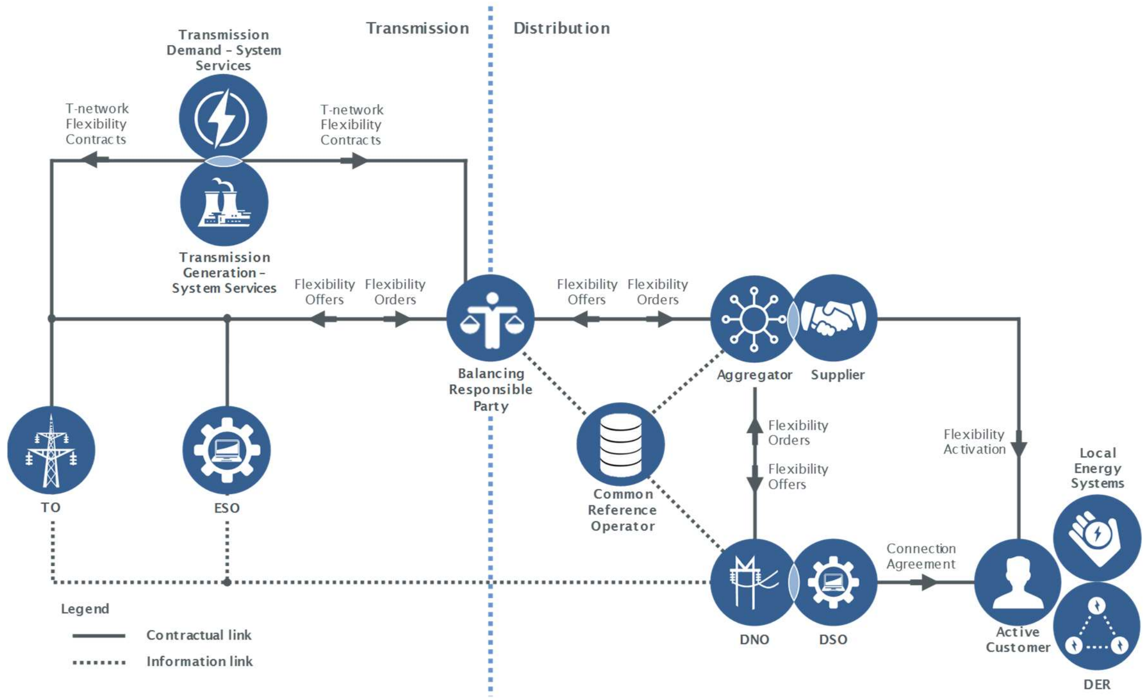


Figure 6 Actor-relationship diagram for the USEF 'standard aggregator' flexibility model

In the USEF flexibility market model:

- The aggregator enters into contracts with flexibility resources such as active customers and local energy systems for the use of their active supply and demand in order to create a portfolio of flexibility services which it offers to flexibility market parties, including DSOs, Balance Responsible Parties (BRPs) and the Electricity System Operator (ESO).

- The DSO procures distribution network connected flexibility services from aggregators for distribution network constraint management at identified congestion points through the exchange of flexibility offers and flexibility orders.

- The Balancing Responsible Parties (BRPs) is primarily an agent of an energy supplier/retailer and acts in the wholesale and flexibility energy markets to balance the supply and demand of the energy supplier's customer portfolio.

- The ESO procures transmission and distribution connected flexibility services from BRPs for transmission network constraint management and energy system balancing.

3. The DER optimisation frameworks

Three DER optimisation frameworks were first released in a joint consultation paper[1] by Energy Networks Australia and AEMO in 2018 which sought to enhance understanding of how DER participation in distribution networks might be optimised. The responses from the consultation paper and further engagement with stakeholders has resulted in refinement of the frameworks, and the creation of a fourth hybrid framework, the latest versions of which are shown and explained below in Section 3.1 which presents actor-relationship diagrams showing the key interactions between actors for each framework, supplemented with accompanying narrative.

These four frameworks have been explored and developed within industry workshops in order to produce a full functional specification for the implementation of SGAMs (see Section 4), however ultimately each framework is defined through 13 DER optimisation functions developed by the OpEN-PRJ and introduced in Section 3.2.

3.1 Frameworks

3.1.1 Actors

The actor-relationship diagrams discussed within this section were presented to stakeholders at the industry workshops in order to facilitate understanding of the four DER optimisation frameworks before a more detailed examination of the frameworks, within the context of the 13 DER optimisation functions (see Section 4.2), was undertaken. Key actors within the frameworks are introduced within the actor-relationship diagrams. Appendix II provides full definitions and goals of all actors within the frameworks, some of which were developed within the workshops themselves, while a summary of the actors considered to play a key role within the DER optimisation are summarised in Table 4 below. It is worth noting that the actors are largely considered to be organisation agnostic. That is, there is no reason a single company could not fulfil the role of multiple actors, notwithstanding regulatory limitations or where actors are unambiguously identified (as is the case for AEMO, AEMC etc.).

Table 4 **Summary of DSO framework actors**

Acronym	Description
A-DER	Active DER
Academia	Academia
ACCC	Australian Competition and Consumer Commission
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
Agg	Aggregator
BOM	Bureau of Meteorology
CEC	Clean Energy Council
CER	Clean Energy Regulator
COAG-EC	Council of Australian Governments Energy Council
DNSP	Distribution Network Service Provider
DSO	Distribution System Operator
E-Ombud	Energy Ombudsman

Acronym	Description
ECA	Energy Consumers Australia
EM	Equipment Manufacturer
ER	Energy Retailer
ESCO	Energy Service Company
Gas	Natural gas distributor
Heat	Heat network provider
IDSO	Independent Distribution System Operator
Installer	DER Installer
JB	Judiciary Bodies
LIN	Large Independent Network
MC	Metering Coordinator
P-DER	Passive DER
Reg	Energy Regulator
SA	Standards Australia
TC	Traditional Customer
TNSP	Transmission Network Service Provider
T-Gen	Transmission connected Generation
T-Load	Transmission connected Load

3.1.2 Single Integrated Platform

The Single Integrated Platform framework most closely resembles the current system with AEMO acting as the single market operator (see Figure 7).

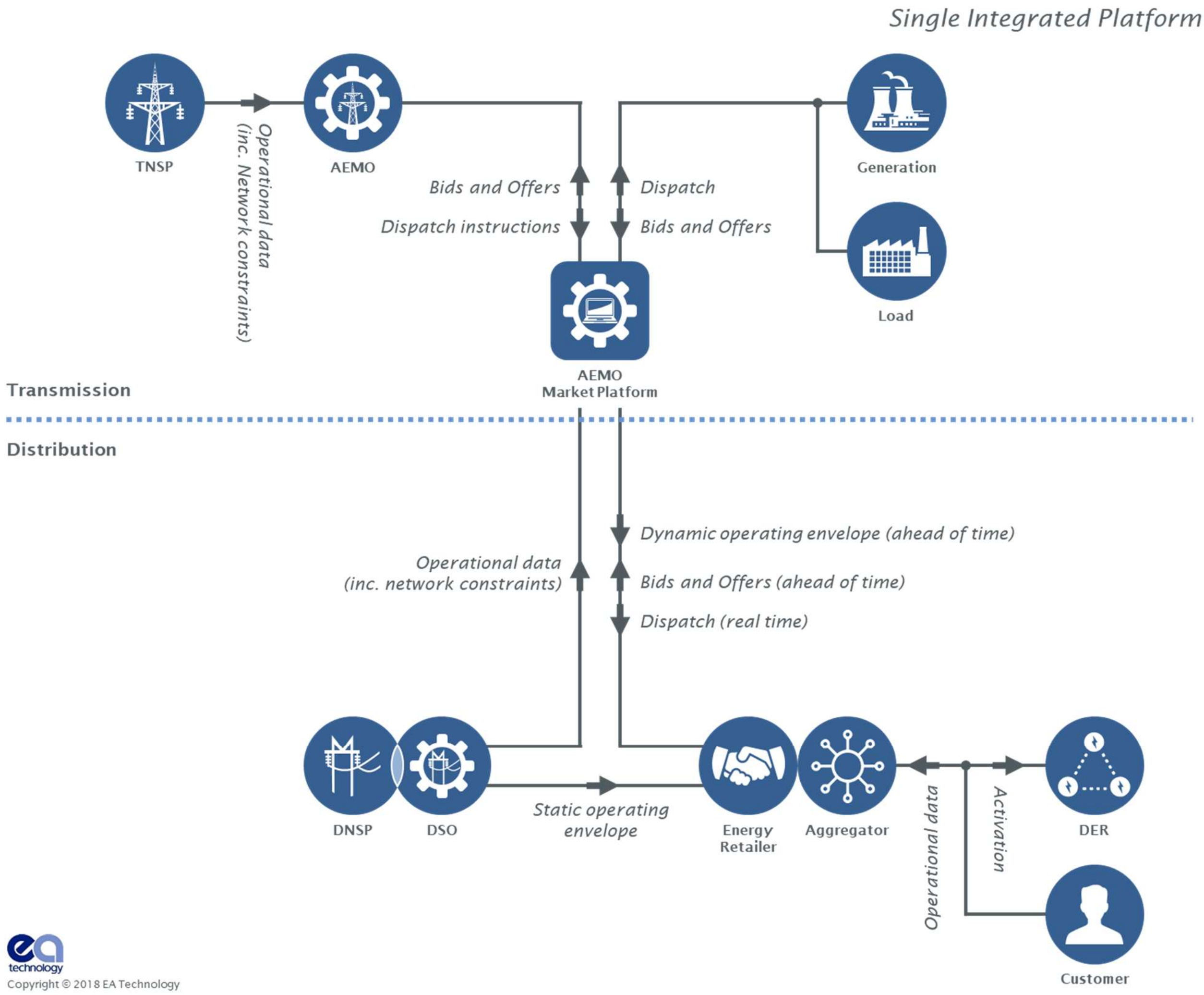


Figure 7 SIP actor-relationship diagram

Market design

In the SIP framework there is a single central market comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS) that is organised and operated by AEMO. The central market platform collects bids and offers from market participants, including DER via aggregators/retailers, and makes them available to AEMO for whole system optimisation. By allowing market participants direct access to the different energy markets simultaneously, energy resources can bid multiple services to AEMO in order to value stack, so long as they are able to meet their market commitments.

AEMO role

AEMO assesses forward market bids and dynamic distribution network constraints, provided by the DSO, as well as historic market and network data in order to generate dynamic operating envelopes for DER which aim to respect distribution network constraints and inform their technical and commercial offering to the markets. Subsequently, AEMO optimises the dispatch of energy resources within operating envelopes. Energy resources, including DER contracted by aggregators/retailers, activate based on dispatch instructions received from AEMO via the central market platform and through this means AEMO executes its responsibility for maintaining whole system security and reliability.

It follows that AEMO has the commercial relationship with DER via aggregators/retailers and is responsible for the financial settlement of market participants. However, where AEMO has unlocked market value through the use of distribution network support and control ancillary services, the DSO shall have responsibility for this cost as an alternative to traditional network investment.

DSO role

The DNSP/DSO is responsible for the development and operation of the electricity distribution network following an active network management approach and further supports the DER optimisation through:

- The provision of static operating envelopes to customers based on the long-term technical capability forecast of the distribution network to accommodate import/export; and
- The exchange of information with AEMO, such as network operational status and forecasts, to facilitate the consideration of distribution network constraints and the development of dynamic operating envelopes by AEMO in the whole system dispatch process

The DSO may use traditional network investment or rely on the use of D-NSCAS to provide customers with their entitlement to import/export. D-NSCAS may be procured bilaterally by the DSO in advance of need or procured by AEMO through the central market in order to unlock market value.

Aggregator/Retailer role

The aggregator/retailer combine different DER and offer their aggregated output as system services, within provided operating envelopes, either in bilateral arrangements or through the central market platform. Aggregators/Retailers must be prepared to adjust their market offerings in an iterative process as operating envelopes evolve dynamically to reflect live network constraints.

The aggregator/retailer may value stack by offering multiple service offerings simultaneously however they must balance this action against the risk and penalties of noncompliance if they fail to meet their commitments.

Advantages and disadvantages

Table 5 SIP advantages and disadvantages

Advantages	Disadvantages
• All market participants interact with a single entity (i.e. AEMO), via the central platform, that acts as an independent, neutral and transparent market facilitator • A central market allows for streamlined standardisation of processes and procedures • More moderate regulatory change is required (compared to other frameworks) as AEMO already performs this type of role and it can be seen as an extension of the existing wholesale and FCAS markets • Procurement, dispatch and settlement of DER for provision of system services is organised and operated by a single entity (i.e. AEMO)	• The expanded role for AEMO, requiring a wider range of resources, may have implications for AEMO's current funding model as it may need to be adapted • The DNSP/DSO does not have direct control over the DER connected at the distribution network because they are procured and dispatched by AEMO

3.1.3 Two Step Tiered Platform

In the Two Step Tiered framework there are two types of market platform, the central market platform operated by AEMO and a number of distribution level market platforms each operated by a DSO which has responsibility for the organisation and operation of the local market for DER and for the development and operation for the electricity distribution network (see Figure 8).

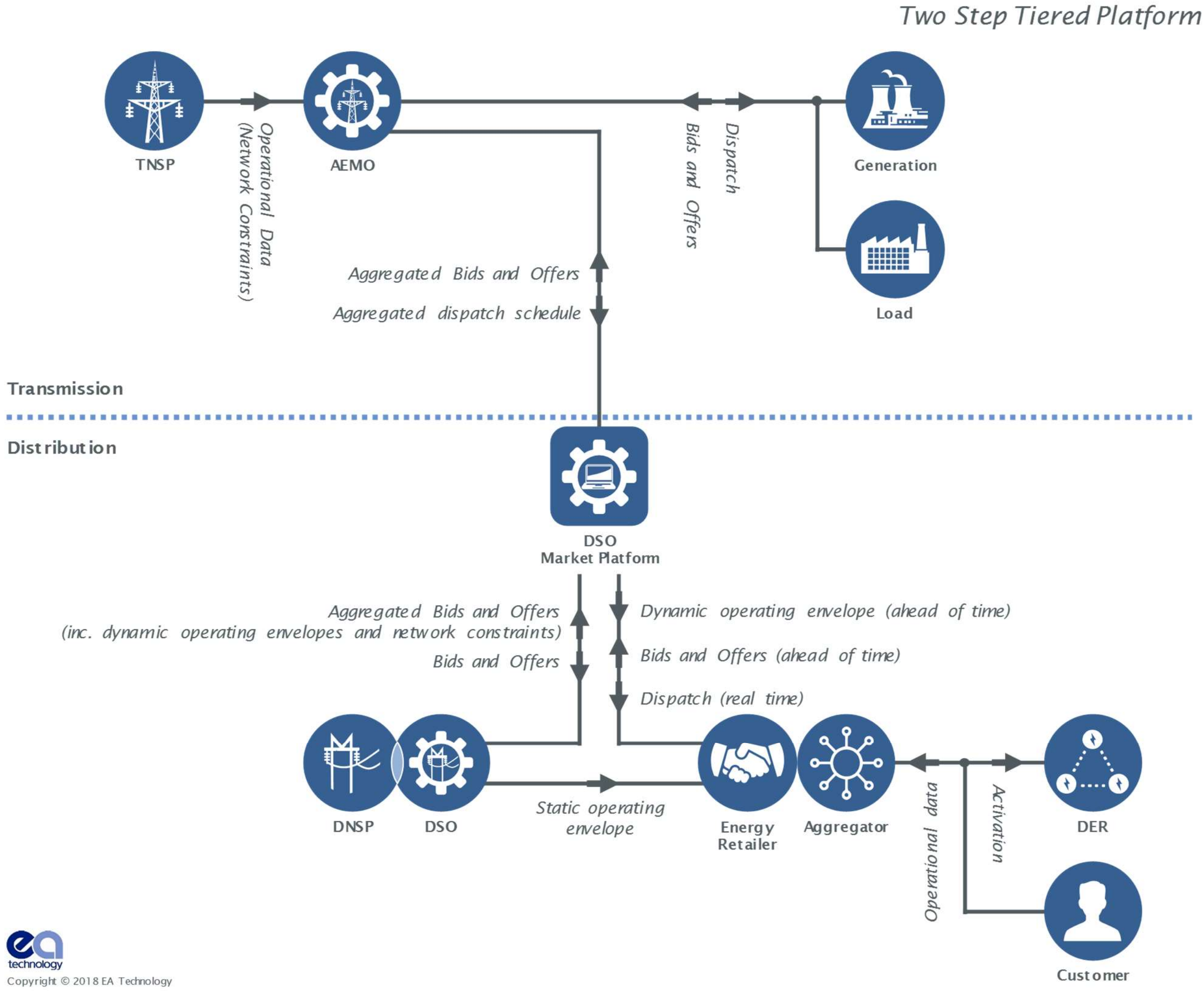


Figure 8 TST actor-relationship diagram

Market design

In this framework there is a central market comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS) for energy resources connected at the T-network that is organised and operated by AEMO. The central market collects bids and offers directly from T-network connected market participants and indirectly from D-network connected market participants via the DSOs, to facilitate AEMO's whole system optimisation process.

Simultaneously, there is a local market for DER that is facilitated by the DSO of the respective geographical region. The local market platform collects bids and offers from DER via aggregators/retailers for T- and D-networks constraint management and electricity transmission system balancing

Both the central and local markets facilitate the direct access of market participants to different markets enabling value stacking for energy resource owners, so long as they are able to meet their market commitments.

AEMO role

AEMO organises and operates the central market platform and is responsible for the optimal dispatch and settlement of the wholesale, frequency services and transmission network services markets. However, distribution connected energy resources do not submit market bids and offers directly with AEMO, which instead receives an aggregated bid stack from the DSO operated local platforms which has been pre-processed to respect distribution network constraints. Therefore, AEMO must optimises wholesale and FCAS dispatch across the distribution network boundary based on an aggregated dispatch schedule technically and commercially agreed with the DSO.

DSO role

The DNSP/DSO is responsible for the development and operation of the electricity distribution network following an active network management approach and further supports the DER optimisation through:

- The facilitation of a local market platform;
- The provision of static operating envelopes to customers based on the long-term technical capability forecast of the distribution network to accommodate import/export; and
- The assessment of forward market bids and dynamic distribution network constraints, as well as historic market and network data, in order to generate dynamic operating envelopes for DER which aim to respect distribution network constraints and inform their technical and commercial offering to the markets

Through the local market platform, the DSO collects bids and offers for system services which it converts into an aggregated bid stack tested against dynamic operating envelopes to ensure the activation of energy resources does not unduly constrain the distribution network. The DSO passes the aggregated bids to AEMO for whole system optimisation and later allocates dispatch to individual resources based on the dispatch schedule across D-network boundary resultant from AEMO's dispatch engine process. In this way the DSO acts as a non-commercial aggregator over a defined geographic area offering regional and national services to the central market.

Bids to supply D-NSCAS are not passed onto AEMO and instead are procured directly by the DSO as desired as an alternative to traditional network reinforcement, alongside bilateral arrangements made ahead of time, to meet customer import/export entitlements. Note that effort need only be taken to provide a customer's entitlement to import/export up to the level to which this entitlement will actually be utilised by the customer. For example, if a customer's wholesale market offering for generation falls outside of the merit dispatch order and therefore the asset will not be exporting power, then the DSO is under no obligation to provide the customer its pre-agreed entitlement to export.

Aggregator/Retailer role

The aggregator/retailer combine different DER and offer their aggregated output as system services, within provided operating envelopes, either in bilateral arrangements or through the local market platform. Aggregators/Retailers must be prepared to adjust their market offerings in an iterative process as operating envelopes evolve dynamically to reflect live network constraints.

The aggregator/retailer may value stack by offering multiple service offerings simultaneously however they must balance this action against the risk and penalties of non-compliance if they fail to meet their commitments.

Advantages and disadvantages

Table 6 TST advantages and disadvantages

Advantages	Disadvantages
• It allows DSOs to take full responsibility for management of DER in their own networks, facilitating a more decentralised and active operation and management of distribution networks • It allows DSOs to prequalify, procure, dispatch and settle DER from aggregators/retailers for D-network constraint management • The DSOs have priority over the procurement and dispatch of DERs from the distribution network • A local market may create less barriers to entry for DER	• DSOs do not have any existing experience with real-time dispatch processes, and would need to establish this capability • A streamlined interface between DSOs and AEMO around the communication of aggregated bids in real-time will need be designed to minimise complexity. This model may cause challenges in integrating a whole system dispatch optimisation with distribution network optimisation, since they will be separate processes operated by separate entities • It requires a seamless and coordinated dispatch process between DSOs and AEMO • DSOs may not be perceived as adequately independent and unbiased to fulfil this role. Models for managing any potential conflicts of interest with ring-fencing would have to be considered • DSOs will incur costs for the operation of a local market

3.1.4 Independent Distribution System Operator

The Independent Distribution System Operator framework is similar to that of the Two Step Tiered, except in that the distribution market platform is operated by an IDSO, a separate and unique entity independent from the DNSP (see Figure 9).

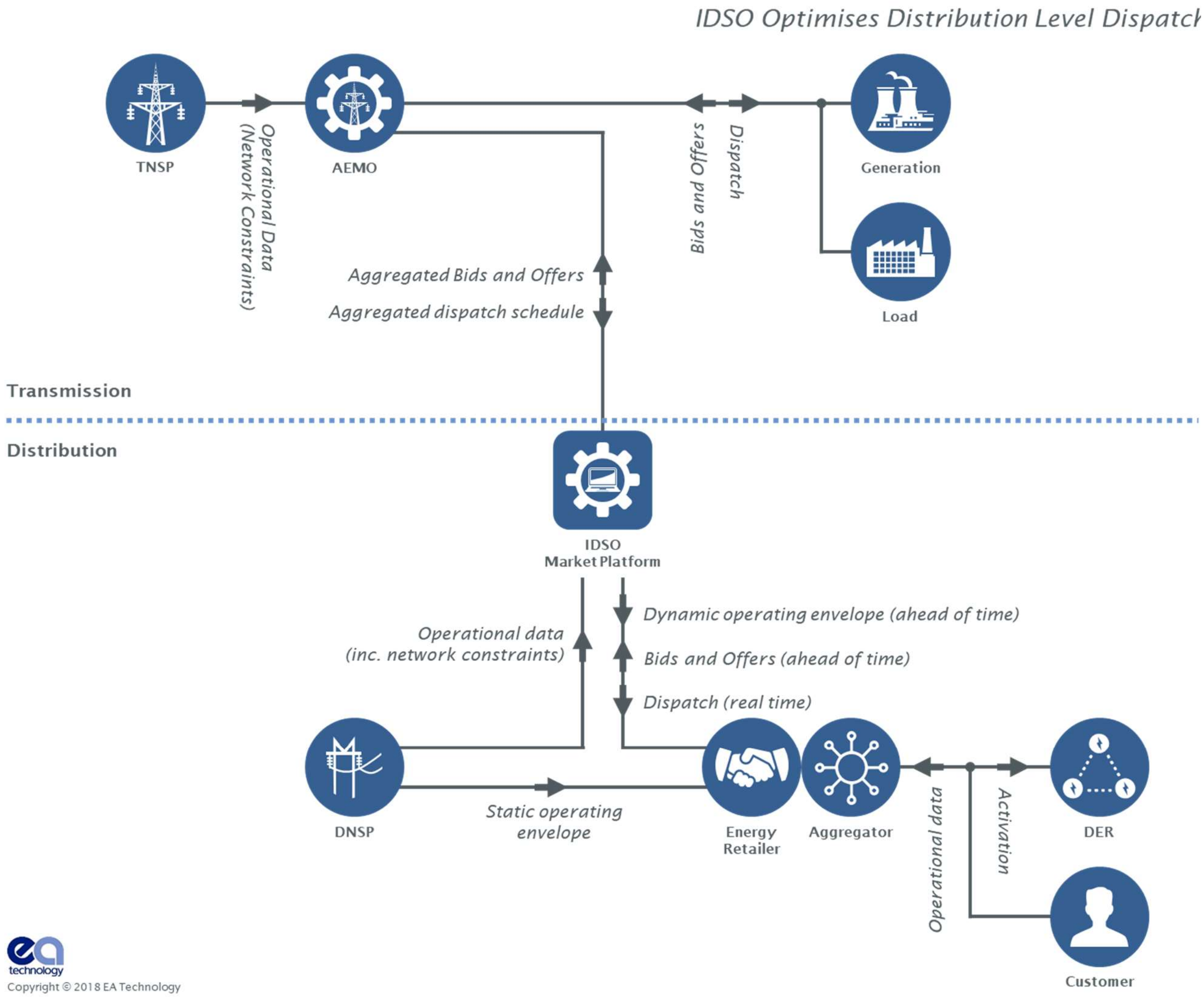


Figure 9 IDSO actor-relationship diagram

Market design

In this framework there is a central market comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS) for energy resources connected at the T-network that is organised and operated by AEMO. The central market collects bids and offers directly from T-network connected market participants and indirectly from D-network connected market participants via the IDSOs, to facilitate AEMO's whole system optimisation process.

Simultaneously, there is a local market for DER that is facilitated by the IDSO of the respective geographical region. The local market platform collects bids and offers from DER via aggregators/retailers for T- and D-networks constraint management and electricity transmission system balancing

Both the central and local markets facilitate the direct access of market participants to different markets enabling value stacking for energy resource owners, so long as they are able to meet their market commitments.

AEMO role

AEMO organises and operates the central market platform and is responsible for the optimal dispatch and settlement of the wholesale, frequency services and transmission network services markets. However, distribution connected energy resources do not submit market bids and offers directly with AEMO, which instead receives an aggregated bid stack from the IDSO operated local platforms which has been pre-processed to respect distribution network constraints. Therefore, AEMO must optimises wholesale and FCAS dispatch across the distribution network boundary based on an aggregated dispatch schedule technically and commercially agreed with the IDSO.

IDSO role

The IDSO supports the DER optimisation through:

- The facilitation of a local market platform; and
- The assessment of forward market bids and dynamic distribution network constraints, provided by the DNSP, as well as historic market and network data, in order to generate dynamic operating envelopes for DER which aim to respect distribution network constraints and inform their technical and commercial offering to the markets

Through the local market platform, the IDSO collects bids and offers for system services which it converts into an aggregated bid stack tested against dynamic operating envelopes to ensure the activation of energy resources does not unduly constrain the distribution network. The IDSO passes the aggregated bids to AEMO for whole system optimisation and later allocates dispatch to individual resources based on the dispatch schedule across the D-network boundary resultant from AEMO's dispatch engine process. In this way the IDSO acts as a non-commercial aggregator over a defined geographic area offering regional and national services to the central market.

Bids to supply D-NSCAS are not passed onto AEMO and instead are procured directly by the IDSO as desired as an alternative to traditional network reinforcement to meet customer import/export entitlements. Note that effort need only be taken to provide a customer's entitlement to import/export up to the level to which this entitlement will actually be utilised by the customer. For example, if a customer's wholesale market offering for generation falls outside of the merit dispatch order and therefore the asset will not be exporting power, then the IDSO is under no obligation to provide the customer its pre agreed entitlement to export.

DNSP role

The DNSP is responsible for the development and operation of the electricity distribution network following an active network management approach and further supports DER optimisation through:

- The provision of static operating envelopes to customers, based on the long-term technical capability forecast of the distribution network to accommodate import/export; and
- The exchange of information with the IDSO, such as network operational status and forecasts, to facilitate the consideration of distribution network constraints and the development of dynamic operating envelopes in market dispatch

The DNSP also must coordinate with the IDSO to make use of traditional network investment and bilateral arrangements, versus D-NSCAS, to deliver customer import/export entitlements.

Aggregator/Retailer role

The aggregator/retailer combine different DER and offer their aggregated output as system services, within provided operating envelopes, either in bilateral arrangements or through the local market platform. Aggregators/Retailers must be prepared to adjust their market offerings in an iterative process as operating envelopes evolve dynamically to reflect live network constraints.

The aggregator/retailer may value stack by offering multiple service offerings simultaneously however they must balance this action against the risk and penalties of non-compliance if they fail to meet their commitments.

Advantages and disadvantages

Table 7 IDSO advantages and disadvantages

Advantages	Disadvantages
• The IDSO (s) acts as an independent, neutral and transparent market facilitator removing concerns around conflicts of interest	• Seamless interfaces, between the IDSO and DNSP for exchanging real-time network status and distribution network constraints, and between the IDSO and AEMO for co-optimisation of resources in a multi-stage optimisation process, can be complex to achieve • New independent organisations would need to be established in each distribution network area to take on the role of IDSO • IDSO(s) would need to develop extensive capabilities on power networks and systems to deliver on their role and responsibilities

3.1.5 Hybrid

The Hybrid framework is conceptually a cross between the Single Integrated Platform and the Two-Step Tiered frameworks. It has been designed to allow both AEMO and the DSO to play to their respective strengths of operating markets and managing networks (see Figure 10).

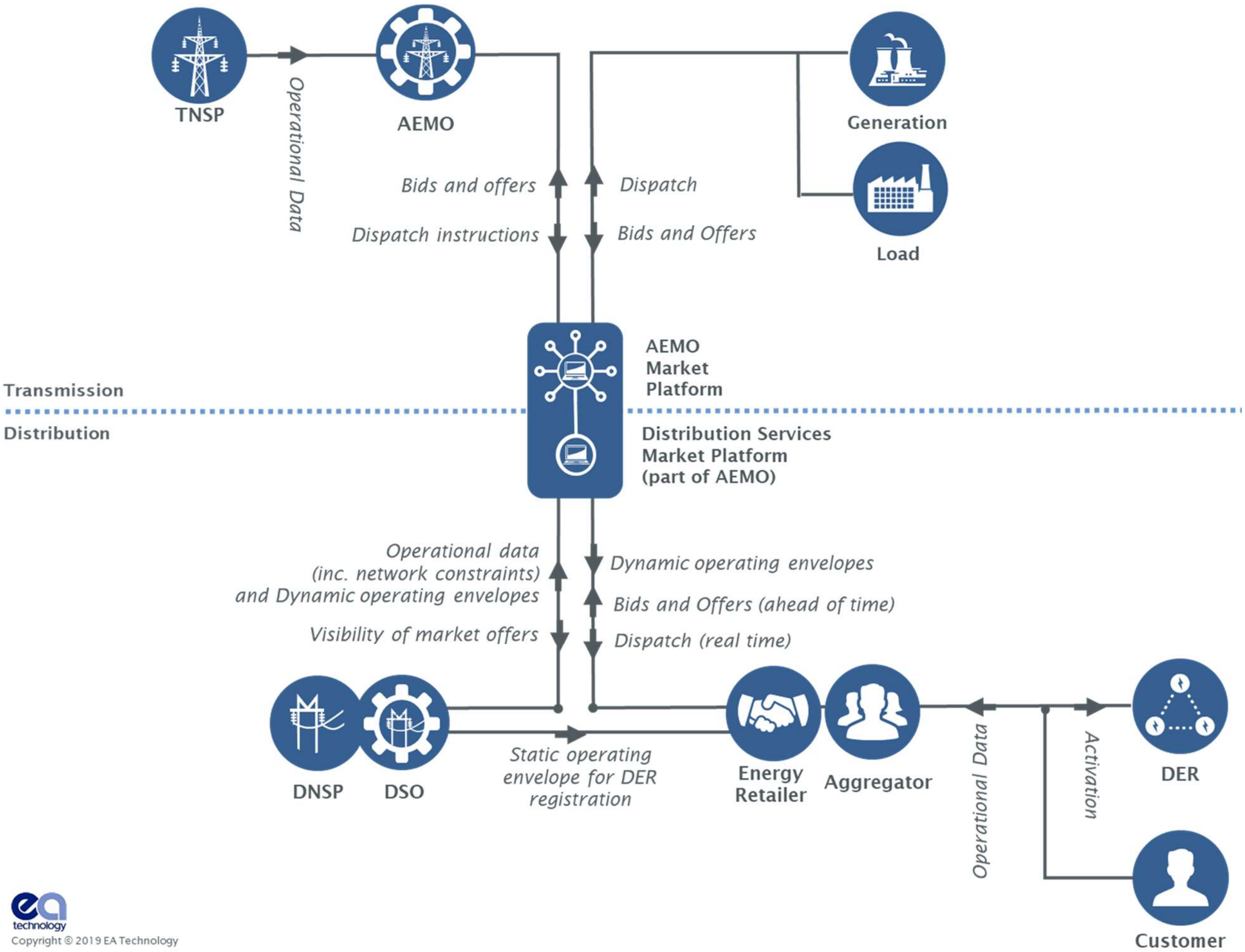


Figure 10 Hybrid actor-relationship diagram

Market design

In the hybrid framework there is a two-sided marketplace comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS, new services) that is organised and operated by AEMO. The central market platform acts as the key data exchange platform between market participants (including network operators) and collects bids and offers from energy resources, such as DER via aggregators/retailers, and makes them available to AEMO and the DSO for whole system co-optimisation. By allowing market participants direct access to the different energy markets simultaneously, energy resources can bid multiple services to AEMO in order to value stack, so long as they are able to meet their market commitments.

AEMO role

AEMO organises and operates the two-sided market platform which collects all bids and offers for system services and is responsible for the optimal dispatch and settlement of energy resources within operating envelopes set by the DSO for distribution connected resources and while respecting network constraints on the T-network.

As AEMO provides the orchestration and communication platform for market participants and network operators, AEMO will provide distribution connected customers with operating envelopes, set by the DSO, to inform their technical and commercial offering to the markets. AEMO will provide the DSO with visibility of market processes to assist in the determination of these operating envelopes.

Subsequently, energy resources, including DER contracted by aggregators/retailers, will activate, following AEMO's market dispatch engine merit order, via dispatch instructions received from AEMO through the two-sided market platform, and by this means AEMO executes its responsibility for maintaining whole-system security and reliability.

It follows that AEMO has the commercial relationship with DER via aggregators/retailers and is responsible for the financial settlement of market participants. However, where AEMO has unlocked market value through the use of distribution network support and control ancillary services, the DSO shall have responsibility for this cost as an alternative to traditional network investment.

DSO role

The DNSP/DSO is responsible for the development and operation of the electricity distribution network following an active network management approach and further supports the DER optimisation through:

- The provision of static operating envelopes to customers based on the long-term technical capability forecast of the distribution network to accommodate import/export; and
- The assessment of forward market bids, provided by AEMO, and dynamic distribution network constraints, as well as historic market and network data, in order to generate dynamic operating envelopes for DER, communicated through the orchestration platform, which aim to respect distribution network constraints and inform their technical and commercial offering to the markets

The DSO may use traditional network investment or rely on the use of D-NSCAS to provide customers with their entitlement to import/export. D-NSCAS may be procured bilaterally by the DSO in advance of need or procured by AEMO through the central market in order to unlock market value.

Aggregator/Retailer role

The aggregator/retailer combine different DER and offer their aggregated output as system services within provided operating envelopes, either in bilateral arrangements or through the central market platform. Aggregators/Retailers must be prepared to adjust their market offerings in an iterative process as operating envelopes evolve dynamically to reflect live network constraints.

The aggregator/retailer may value stack by offering multiple service offerings simultaneously however they must balance this action against the risk and penalties of non-compliance if they fail to meet their commitments.

Advantages and disadvantages

Advantages	Disadvantages
• All market participants interact with a single entity (i.e. AEMO), via the two-sided platform, that acts as an independent, neutral and transparent market facilitator • Procurement, dispatch and settlement of DER for provision of system services is organised and operated by a single entity (i.e. AEMO) • DSO calculates the dynamic operating envelopes based on understanding and direct access to network operation data and constraints	• The expanded role for AEMO, requiring a wider range of resources, may have implications for AEMO's current funding model as it may need to be adapted • The DSO does not have direct control over the DER connected at the distribution network because they are procured and dispatched by AEMO • Seamless interface required between the DSO and AEMO for exchanging real-time network status and distribution network constraints and operating envelopes

3.2 Functions and activities

The OpEN-PRJ originally identified and defined 11 high-level functions deemed necessary for developing the key capabilities required to progress towards a distributed level optimisation. These functions were introduced within Energy Networks Australia and AEMO's joint consultation paper and, following stakeholder feedback, two additional functions were created. Within the industry workshops the four DSO frameworks were explored and defined within the context of the 13 functions. However, in order to achieve a greater level of granularity and to better guide stakeholder discussion, the functions were each further sub-divided into a number of associated activities. Table 8 summarises.

Table 8 **Summary of DER optimisation functions and associated activities**

Function	Activities
1. Distribution system monitoring and planning	Gather network data
	Network planning and investment
2. Distribution constraints development	DER engagement
3. Forecasting systems	Forecast short-term network state
4. Aggregator DER bid and dispatch	Engage with DER to create aggregator portfolio
	Aggregator bilateral reserve contracts
	Aggregator market engagement
5. Retailer DER bid and dispatch	Engage with DER to create retailer portfolio
	Retailer bilateral reserve contracts
	Retailer market engagement
	Optimise operating envelopes of distribution network end-customers

Function	Activities
6. DER optimisation at the distribution network level	Aggregation of wholesale and FCAS market bids
7. Wholesale - distributed optimisation	Update market dispatch engine
	Determine dispatch schedules for bilateral Reliability and Emergency Reserve Trading (RERT) contracts
	Receive transmission network requirements and market offers
	Receive distribution network market offers and run dispatch engine
8. Distribution network services	Smart grid network solutions
	Bilateral reserve contracts for D-network support and control ancillary services
	D-network market engagement for network support and control ancillary services
9. Data and settlement (network services)	Settlement of bilateral contracts for network services
	Settlement of NSCAS market
	Dispute resolution (network services)
10. Data and settlement (wholesale, RERT, FCAS and SRAS)	Settlement of bilateral contracts for Reliability and Emergency Reserve Trading (RERT)
	Settlement of wholesale, FCAS and SRAS markets
	Dispute resolution (wholesale, RERT, FCAS and SRAS)
11. DER register	Establish, maintain and publish or share DER register data
12. Connecting DER	Determine the regulatory framework for connections
	Connect DER assets
	Manage DER connections
	Contribute to DER register
13. Network and system security with DER	Asset security
	Distribution network security for high impact events
	Distribution network security under localised market failure
	Whole system security
	System restart

Full descriptions of the functions and their associated activities can be found in Appendix I while brief summaries of the 13 functions can be found below.

1. **Distribution system monitoring and planning** – Network monitoring and the assimilation of wider data (e.g. weather patterns) to inform long-term forecasts, including network constraints, for the creation of long-term investment plans

2. **Distribution constraints development** – Development of forecast network constraints into long-term static operating envelopes for network customers and, through engagement with DER, the determination of long-term requirements for network services

3. **Forecasting systems** – Network monitoring and the assimilation of wider data (e.g. weather patterns) to inform short-term forecasts, including network constraints, to inform market operation

4. **Aggregator DER bid and dispatch** – Aggregators engage with DER resources to develop portfolios of customers and services, and engage with network operators and markets to submit bids and offers

5. **Retailer DER bid and dispatch** – Retailers engage with DER resources to develop portfolios of customers and services, and engage with network operators and markets to submit bids and offers

6. **DER optimisation at the distribution network level** – Optimise operating envelopes in engagement with the markets to ensure DER bids and offers can feed into market dispatch optimisations while taking account of distribution network constraints

7. **Wholesale - distributed optimisation** – Receive market bids and offers and run market dispatch optimisation, integrating network constraints and/or operating envelopes into the market engine

8. **Distribution network services** – Procurement and use of distribution network services, such as power quality/voltage control, which can be provided by DER, either through bilateral contracts or through a market optimisation

9. **Data and settlement (network services)** – Financial settlement of network support and control ancillary services at distribution and transmission level

10. **Data and settlement (wholesale, RERT, FCAS and SRAS)** – Financial settlement of wholesale, RERT, FCAS and SRAS transactions at distribution and transmission level

11. **DER register** – Establish, maintain and publish or share DER register data

12. **Connecting DER** – Regulatory, technical and commercial arrangements around the connection, and active management of connections, to the distribution network

13. **Network and system security with DER** – DER contribution to, and influence on, system security as well as contingency planning for market or network failure events.

4. The Smart Grid Architecture Model

The four DER optimisation frameworks under consideration within the OpEN-PRJ have been rendered into SGAMs. These SGAMs will provide an intuitive and visual way for users throughout the energy industry to explore the differing functionality that is required of the various actors in the sector to fulfil the optimisation principles present across the different frameworks.

This section of the report initially introduces the fundamental principles and concepts that underpin the standard SGAM framework and provides extensive references for further exploration (see Section 4.1), before presenting the methodology developed for implementing the SGAM framework and demonstrating its step-by-step application to a 'use case' extracted from the OpEN-PRJ (see Section 4.2). Finally, Section 4.3 will assist users in the navigation of the SGAMs developed.

4.1 Introduction to the Smart Grid Architecture Model

The SGAM was developed by the Smart Grid Coordination Group[11]/Reference Architecture Working Group (SG-CG/RA) as part of the European Commission Mandate M/490[12]. The SGAM[13,14] is a holistic framework for describing smart grid systems, from their functional specification right through to their architectural design. The SGAM is represented by a three-dimensional framework that subsumes concepts from the GridWise Architecture Council (GWAC) Interoperability Stack[15], the National Institute of Standards and Technology (NIST) Conceptual Model[16] and the Automation Pyramid. The structure and composition of this three-dimensional framework is illustrated in Figure 11.

The SGAM framework is structured into five 'interoperability layers' derived from the GWAC Interoperability Stack. Each layer is represented by the 'smart grid plane' that is composed by 'domains' and 'zones' based on the NIST Domain Model and the Automation Pyramid respectively. The five interoperability layers represent: business objectives and processes; functions; information exchanges; communication protocols; and components. The domains reflect the electrical energy conversion chain. The zones characterise the hierarchy of power system management. Thus, the SGAM framework allows the representation of smart grid systems and their relationships through spatial positioning on the SGAM framework.

[11] Smart Grid Coordination Group:
https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx
[12] "Smart Grid Mandate, Standardization Mandate to European Standardisation Organisations (ESOs) to support European Smart Grid deployment," Mandate M/490 Smart Grids, European Commission, Brussels, Mar. 01, 2011.
https://ec.europa.eu/energy/sites/ener/files/documents/2011_03_01_mandate_m490_en.pdf
[13] "Smart Grid Reference Architecture," CEN-CENELEC-ETSI Smart Grid Coordination Group, Nov. 2012.
https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf
[14] "SG-CG/M490/F_Overview of SG-CG Methodologies," CEN-CENELEC-ETSI Smart Grid Coordination Group, Aug. 2014.
http://www.energynetworks.org/assets/files/electricity/engineering/Standards/SGCG%20Reports%20071014/SGCG_WGMethod_Sec0076_INF_ReportforComments(incl_annexes).pdf
[15] "GridWise Interoperability Context-Setting Framework," The GridWise Architecture Council, USA, Mar. 2008.
https://www.gridwiseac.org/pdfs/interopframework_v1_1.pdf
[16] "NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0," NIST Special Publication 1108r3, National Institute of Standards and Technology (NIST), U.S. Department of Commerce, USA, Sep. 2014.
https://www.nist.gov/sites/default/files/documents/smartgrid/NIST-SP-1108r3.pdf

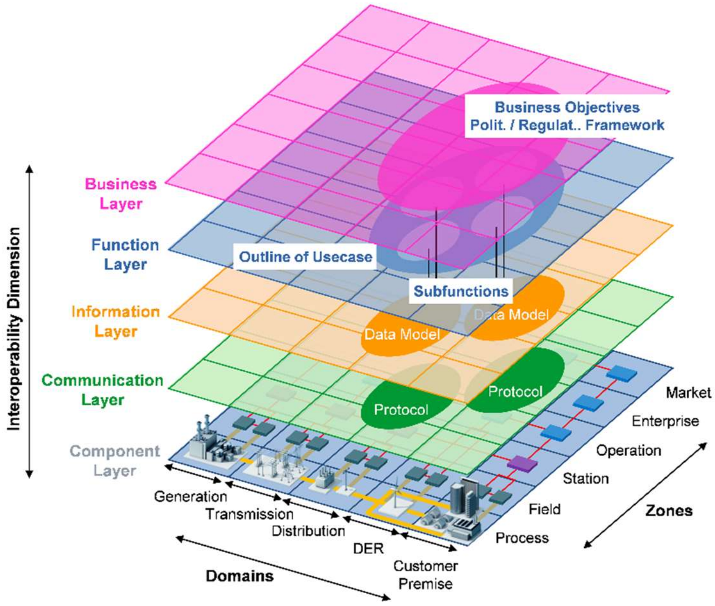


Figure 11 Smart Grid Architecture Model[13] (SGAM)

4.1.1 The interoperability layers

The five interoperability layers[13] describe the smart grid system in terms of interoperability requirements between its constituting elements. These SGAM layers are defined as follows:

- **Business layer**: represents the business-related aspects of the smart grid system such as business objectives, capabilities and processes, business models, business portfolios, organisational entities, policy and regulatory considerations.
- **Function layer**: describes the functions and services, including their relationships, that are required to exist to realise the defined business aspects.
- **Information layer**: describes the information exchanged between the functions and services that are realised by certain systems and components. The description of the information exchanges adheres to information objects and derived data models.
- **Communication layer**: consists of protocols and mechanisms for exchanging the information objects specified in the information layer.
- **Component layer**: comprises the physical components, such as power system equipment, ICT devices and software, which allocate the functions and communicate among themselves using the specified information objects and communication protocols.

The five layers represent a hierarchy from higher to lower levels of abstraction with each layer informing the development of the one below, from the business layer setting the most high-level objectives of the system, down to the component layer which represent the physical 'nuts and bolts'.

4.1.2 The smart grid plane

In the SGAM[13] each layer is represented by the smart grid plane that is composed of domains and zones. The domains reflect the electrical energy conversion chain (i.e. generation, transmission, distribution, distributed energy resources and customer premise) physically relating to the electrical power grid. The zones characterise the hierarchy of power system management (i.e. market, enterprise, operation, station, field, process) distinguishing between electrical process and information management viewpoints. Thus, every element on the 'smart grid plane' is aligned according to its position within the electrical power grid and its role within power system management. The smart grid plane is depicted in Figure 12.

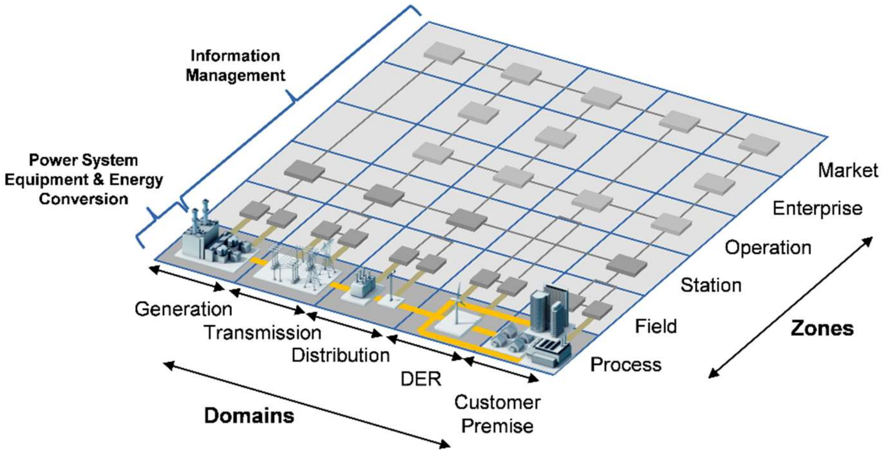


Figure 12 Smart grid plane[13]

Domains

The domains[13], described along one axis of the smart grid plane, cover the electrical energy conversion chain and are described in Table 9

Table 9 Domains

Domains	Description
Generation	Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale photovoltaic (PV) power – typically connected to the transmission system
Transmission	Representing the infrastructure and organization which transports electricity over long distances
Distribution	Representing the infrastructure and organization which distributes electricity to customers
DER	Representing distributed electrical resources, directly connected to the distribution grid, applying small-scale power generation technologies (typically in the range of 3kW to 10,000kW)
Customer premise	Hosting both end users and producers of electricity. The customer premise includes industrial, commercial and home facilities (e.g. chemical plants, airports, harbours, shopping centres, homes), as well as generation in the form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines, etc.
Non-electrical vectors	Represents a system that enables the transfer, in space and time, of a quantity of non-electrical energy. Thus, it may be a system that utilises, heat, natural gas, hydrogen or some other agent.

It should be noted that the non-electrical vectors domain is an extension of the standard SGAM smart grid plane to allow consideration of external impacts on the electricity system from vectors such as gas, heat and transport. This extension of the smart grid plane was first developed in the Open Networks project commissioned by the Energy Networks Association (UK)[17].

[17] “Modelling the DSO transition using the Smart Grid Architecture Model,” EA Technology, July 19, 2018. http://www.energynetworks.org/assets/files/Modelling-DSO-Transition-Using-SGAM_Issue2.1_PublicDomain.pdf

Zones

The zones[13] axis of the smart grid plane covers the hierarchical levels of power system management, distinguishing between electrical process and information management viewpoints. These hierarchical levels are based on the concepts of aggregation and functional separation in power system management. For example, data is typically aggregated at the station level to reduce the amount of data that is communicated and processed in the operation zone. The functional separation process assigns different functions to specific zones. For example, real-time functions are typically in the field and station zone (e.g. metering, protection) whereas functions that cover an area, multiple substations or plants, city districts are usually located in operation zone (e.g. wide area monitoring, generation scheduling). The zones are described in Table 10.

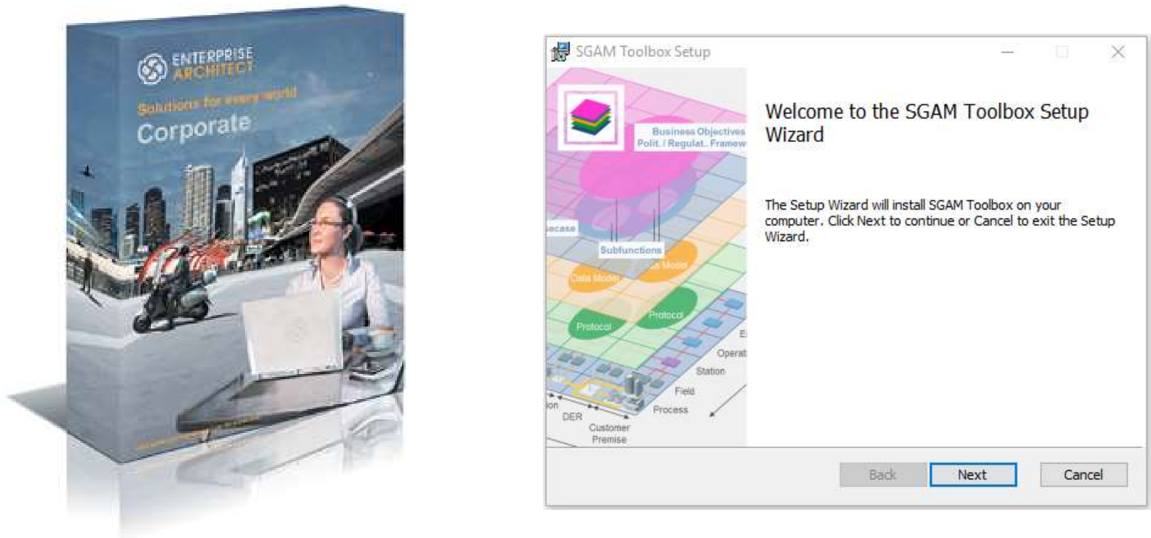
Table 10 Zones

Zones	Description
Process	Including both primary equipment of the power system (e.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads, etc.), as well as physical energy conversion (electricity, solar, heat, water, wind, etc.)
Field	Including equipment to protect, control and monitor the processes of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system
Station	Representing the aggregation level for fields, e.g. for data concentration, substation automation, etc.
Operation	Hosting power system control operation in the respective domain, e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems
Enterprise	Includes commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders, etc.), e.g. asset management, staff training, customer relation management, billing and procurement
Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, mass market, retail market, etc.

4.1.3 Software tools

EA Technology used the Enterprise Architect[18] and the SGAM Toolbox[19] software tools (see Figure 13) for the design and implementation of the different DSO frameworks.

[18] "Enterprise Architect," Sparx Systems. http://sparxsystems.com/
[19] "SGAM-Toolbox 2.0," Centre for Secure Energy Informatics, Salzburg University of Applied Sciences. https://sgam-toolbox.org/



(a) Enterprise Architect (Corporate Edition) **(b) SGAM-Toolbox (Version 2.0)**

Figure 13 **Software tools for the design and implementation of the SGAM**

Enterprise Architect is a visual modelling and design tool covering all aspects of organisational architecture such as the: modelling of business process; re-engineering of business process; design and implementation of new systems; changing or documenting of existing systems; etc. The SGAM-Toolbox is an add-on software utility that can be added to the Enterprise Architect to facilitate the usage of domain specific concepts, language and architecture relating to the SGAM method.

4.1.4 Key terms

Enterprise Architect makes use of terminology from the Unified Modelling Language (UML) standard by the Object Management Group (OMG) which does not fully align with SGAM or OpEN-PRJ terminology, therefore Table 11 provides a mapping of relevant terms.

Table 11 **Translation between OpEN-PRJ / SGAM terminology and Enterprise Architect**

Open Networks/DSO Terminology	Enterprise Architect Terminology
DSO framework	Business Use Case (BUC)
Function	High-Level Use Case (HLUC)
Activity	Primary Use Case (PUC)
Process (view showing information flows between business actors)	Sequence Diagram
Process (view showing communication protocols)	Activity Diagram

Other useful definitions of Enterprise Architect terms are provided below:

- **Package**: the name of a folder in Enterprise Architect
- **Root node**: top-level package for the model
- **Lifeline**: represents an individual business actor in an interaction on a sequence diagram
- **Stereotype**: used to classify UML elements. SGAM stereotypes include HLUC, PUC, Business Actor and Information Exchange

As this section of the report is intended to aid navigation through the Enterprise Architect generated models, the following subsections will focus on using such terminology.

4.2 Smart Grid Architecture Model Methodology

EA Technology developed a detailed methodology for the practical implementation of the SGAM in order to represent the four DSO optimisation frameworks under consideration within the OpEN-PRJ. The methodology comprehensively describes the 'use cases' within each framework by describing the business and functional specifications associated with it, and by visually representing the architecture of the smart grid system that underpins it. The methodology developed provides a structured and coherent way to describe, visualise and interpret the DSO frameworks by capturing the interactions between different actors from a high-level business context down to the detail of what information is exchanged, using what communication methods, between physical components / equipment. This approach also enables a like-for-like comparison between different models, as provided in Section 5.2. Figure 14 depicts a representation of the methodology for the development of the SGAM.

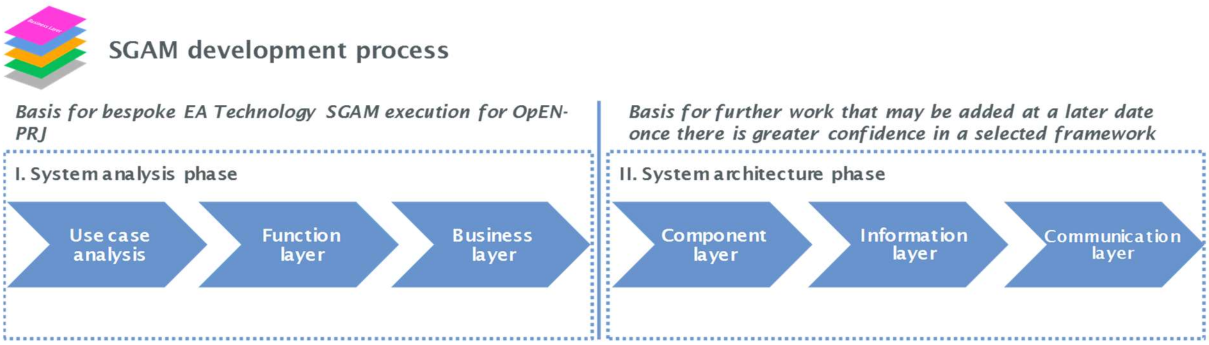


Figure 14 Methodology for the design and implementation of the standard SGAM

The design and implementation process of the standard SGAM is constituted by two distinct phases: system analysis and system architecture. The system analysis phase aims to define the system and its functional requirements. The focus is therefore on the required functional specification of a model rather than on technical or physical solutions. The system architecture phase aims to map the functional requirements of the system into a high-level architecture. This high-level architecture describes the main physical subsystems and their interactions without detailing their inner composition.

This section of the report will fully describe both phases of the SGAM development process, however the four DSO optimisation frameworks being investigated within the OpEN-PRJ have only been fully developed up to the completion of phase 1 (system analysis) and so the outputs described within phase 2 (system architecture) are not included within the SGAMs delivered. It is suggested that the system architecture may be developed at a later date when further details of the technology to be implemented are known and there is greater confidence as to which of the four DSO frameworks will develop.

4.2.1 Phase I: System analysis

Use case

The application of the methodology for the development of the SGAM is undertaken through 'use case analysis', whereby each of the DSO framework options is selected and analysed in detail. A use case from the OpEN-PRJ has been selected to demonstrate the step-by-step application of the methodology to the system analysis phase.

- Framework: Single Integrated Platform

- Function: 4. Aggregator DER bid and dispatch
- Activity: 3. Aggregator market engagement
- Process: 1. Market registration

This use case has been selected for its simplicity in isolation to other information so that it may be more readily understood, however to further aid in this some of the figures included within this section have been simplified with full figures available through the SGAM deliverables.

It is worth noting that the numbering of HLUCs and PUCs does not indicate an 'order of play'. They are used only to create an ID for easy reference across teams/personnel. e.g. the use case ID could be written as SIP.F4.A3.P1.

Use case analysis

In the system analysis phase, the model identifies and defines the business actors involved in the DSO framework for each use case, their individual business goals and their relationship with other business actors, in turn establishing the BUC that needs to exist for the business actors to realise their individual goals.

For each use case, the BUC invokes a HLUC and PUC that together describe the functional requirements necessary to fulfil the BUC, where HLUCs are defined from the framework functions and PUCs are defined from the framework activities. Together, these elements construe a use case diagram as portrayed in Figure 15 which shows a simplified diagram for the selected use case.

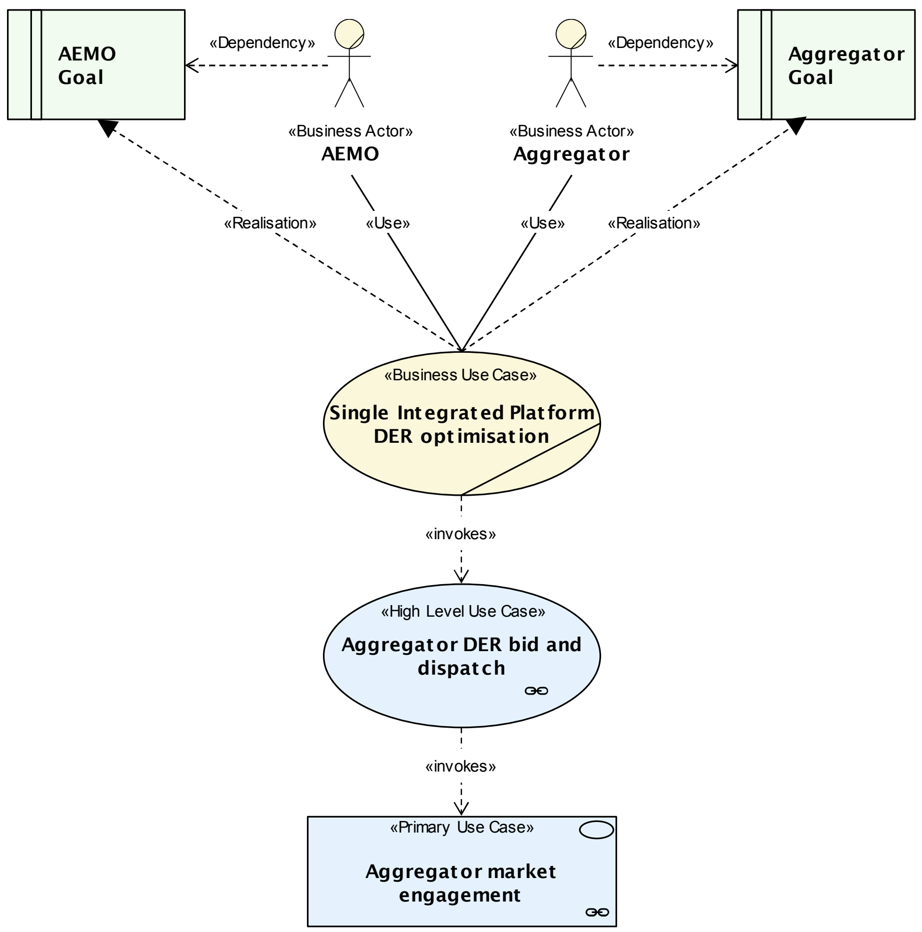


Figure 15 **Use case diagram**

Figure 15 has been produced as part of the SGAM development process using the Enterprise Architect software, consequently each element in the figure is a placeholder for further information that contains the detailed definition of the element. For example, selecting the aggregator element within the SGAM environment would provide the full description of that business actor. Within this report further information on the DSO frameworks, functions and actors can be found in Section 3.

The use case diagram also characterises the types of relationships between business actors, business goal and the BUC. The business actor has a ‘dependency’ relationship with its business goal as the physical specification and implementation of the business actor is dependent on the business goals it wants to achieve. The business actor has a ‘use’ relationship with the BUC as the business actor uses the BUC to physically implement its goals. The BUC has a ‘realisation’ relationship with the business goal as the physical implementation of BUC realises the business goals.

Function layer

Further developing each use case, the function layer defines the functional specification that is required to deliver the business objectives set out during the use case analysis. This is achieved through decomposing the BUCs into constituent HLUCs, which are made further granular through the exploration of PUCs, which describe the HLUCs in greater detail, to attain the full functional specification of the use cases within the OpEN-PRJ frameworks.

13 HLUC functions and 35 associated PUC activities considered necessary for developing the functional capabilities required by a DER optimisation framework were identified and defined within the OpEN-PRJ (see Section 3.2) through traditional stakeholder consultation. However, in order to develop a sufficient level of detail to allow for the full characterisation of the use cases under assessment, EA Technology facilitated and delivered live industry stakeholder workshops to develop suitable content. To achieve this, EA Technology asked participants three questions to consider whilst examining each framework element (BUC framework, HLUC function and PUC activity) in turn:

- **Q1.** Who is communicating with whom?
- **Q2.** What are they saying?
- **Q3.** How are they communicating (and how often)?

Figure 16 provides an insight on the approach adopted by EA Technology to facilitate the workshops and capture the stakeholders’ responses to the three questions expressed above.

In total, four workshops were held to generate content for the four DER optimisation frameworks. Workshops held in Melbourne, Sydney and Perth were held over two days and each explored in detail the SIP, TST and IDSO frameworks, while a later workshop in Brisbane explored the Hybrid framework. Note that the Brisbane workshop was undertaken in a different format than the original three and explored the SIP and TST frameworks to identify the areas of difference between these and the Hybrid framework in order to generate the required functional specification.

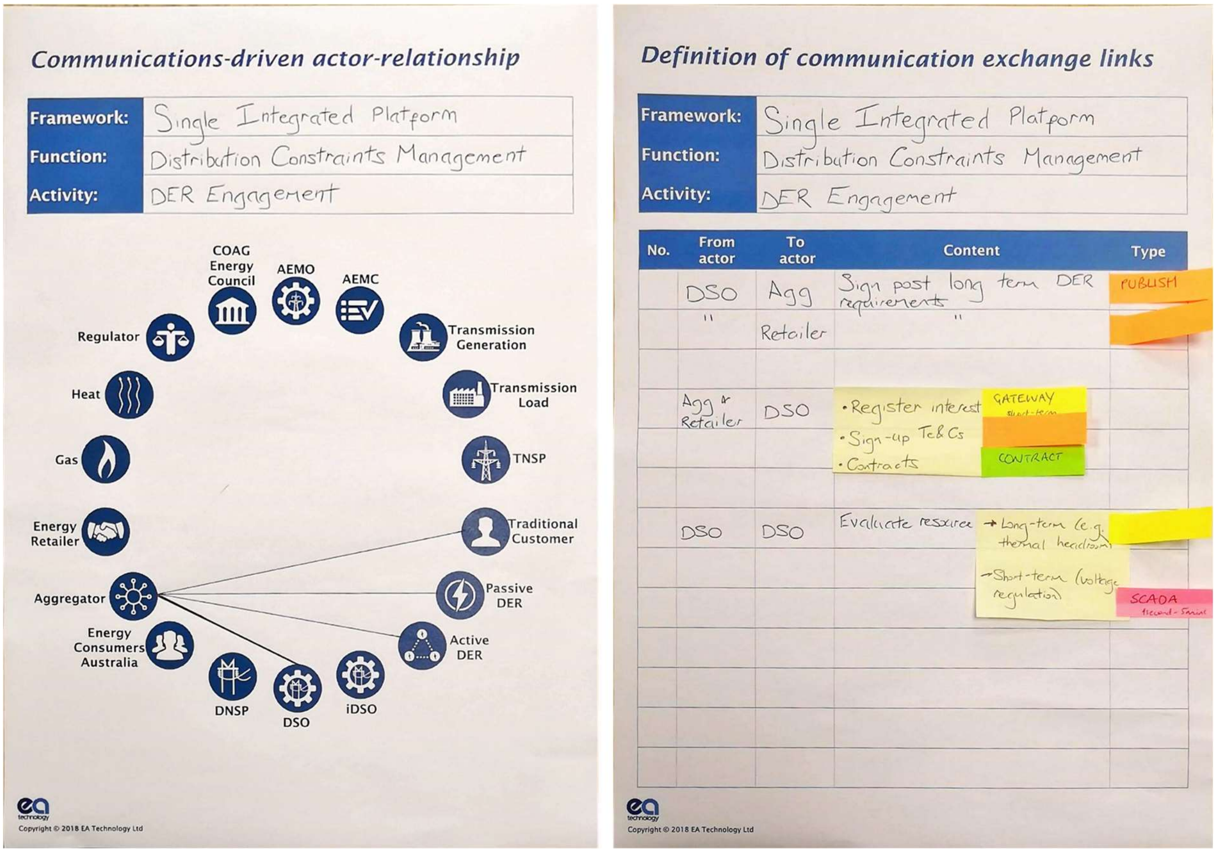


Figure 16 Example of content generated at industry workshops

Following the workshops, EA Technology processed the content generated by the industry stakeholders and translated it into bespoke Microsoft Excel templates, internally identified as the 'metamodel' templates, suitable for use with the Enterprise Architect software. As the industry stakeholder workshops were delivered in four different locations and with a varied number of participants and backgrounds, different workshop groups generated diverse content. As a result, during the processing stage of the workshop content, EA Technology unified the metamodels using a common modelling language to help achieve consistency in the language used between outputs and to benchmark the definition of processes, activities, functions and frameworks to a similar level of detail and standard, supporting the analysis and comparison of the frameworks (see Section 5.2). Where unity could not be found between stakeholder views this was raised as an issue with the project team and a decision taken as to which views to reflect in the metamodels (generally the majority view of stakeholders was taken).

Figure 17 displays an example of the metamodel template generated for our use case under analysis. It shows the 'aggregator market engagement' PUC activity which was presented to stakeholders who successfully generated the functional steps and content necessary to realise that activity through three distinct processes, the first of which is market registration.

Framework: Single Integrated Platform
Function: Aggregator DER bid and dispatch
Activity: Aggregator market engagement

Version: 1.0
Modified by: Manuel Castro
Date modified: 09/11/2018

Process no.	Process name	From actor	To actor	Step no.	Information exchange	Information name	Information description	Communication type
1	Market registration	Agg	AEMO	1	Apply for participation in the D-NSCAS market	D-NSCAS market applicatior	Compliance with market rules; Technical capability to fulfil NSCAS; Indication of market offering (service and price)	Contract
		Agg	AEMO	2	Apply for participation in the wholesale, FCAS and SRAS markets	AEMO market application	Compliance with market rules; Technical capability to fulfil service requirements; Indication of market offering (service and price)	Contract
		AEMO	Agg	3	Approve application for participation in the D-NSCAS market	D-NSCAS market applicatior	Registration as D-NSCAS market participant; Access to market portals	Contract
		AEMO	Agg	4	Approve application for participation in the wholesale, FCAS and SRAS markets	AEMO market application ap	Registration as AEMO market participant; Access to market portals	Contract
2	Market intelligence	DSO	Agg	1	Communicate static operating envelope for D-network end-customers as determined by the long-term technical capabilities of the local D-network	Static operating envelope	Active Power; Reactive Power; Voltage; Current; Location (NMI); Other	Publish
		DSO	AEMO	2	Submit forecast short-term D-network constraint information	D-network constraints	Network constraints (current and forecast): thermal, voltage, harmonic, other; Time; Location; Forecast assumptions and sensitivity studies	Gateway
		AEMO	Agg	3	Identify short-term requirements for D-network support and control ancillary services	D-NSCAS requirements	Required services: type, capability, magnitude, location	Gateway
		AEMO	Agg	4	Identify long-term requirements for system restart ancillary services per DER area	SRAS requirements	Required services: type, capability, magnitude, location	Publish
		AEMO	Agg	5	Submit D-network dynamic operating envelope	Dynamic operating envelope	DER operating instruction sets; Network running arrangements; Network constraint points; Thermal headroom; Voltage legroom and headroom; Other	Gateway
		AEMO	Agg	6	Market intelligence and insight reporting	Market surveillance report	Supply and demand positions; Traded volumes; Prices; Balancing services needs and requirements; Other	Gateway
		Agg	Agg	7	Optimise market offers to maximise value to customers	Market offers	Type; Magnitude; Location (NMI); Price; Other	Gateway

Figure 17 Example of the common modelling language

Overall, the industry workshops generated over 2000 information objects to describe the functional specification of the four frameworks. In particular, the industry workshops allowed for the characterisation of the use case under analysis by inferring the processes that need to exist to deliver the practical realisation of the PUC activity: aggregator market engagement. Figure 18 displays the primary use case model constituted of three practical DER optimisation processes.

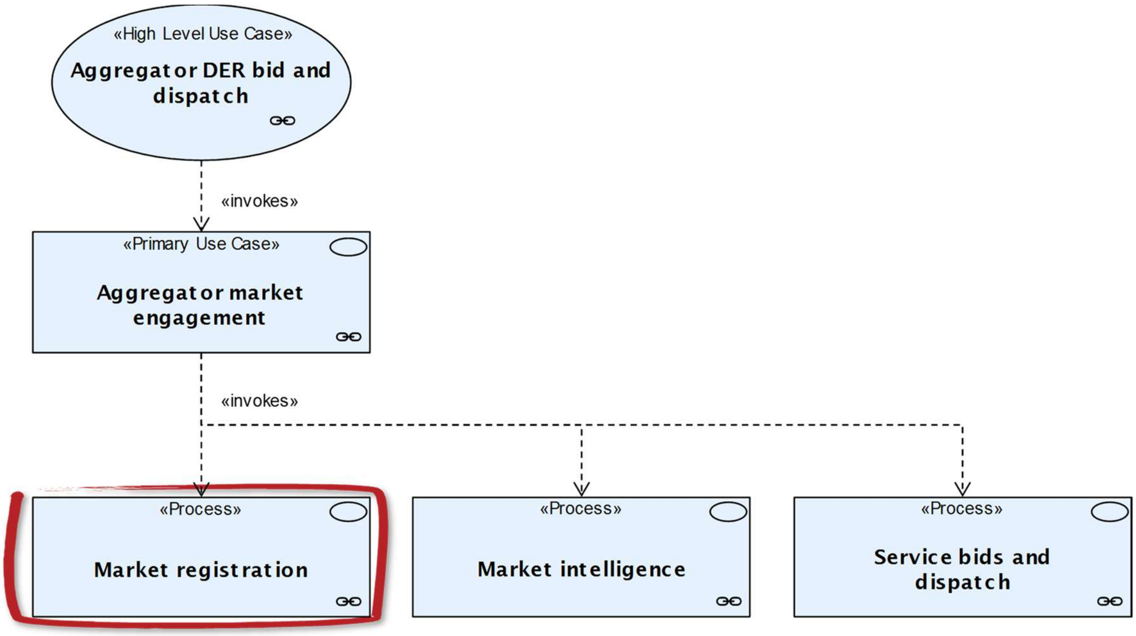


Figure 18 Primary use case model for aggregator market engagement

Of the three processes identified in Figure 18, the use case being analysed focusses on developing the functional specification of the market registration process. This specification was captured in the workshops, processed in the metamodel template, and is displayed in Figure 19 as the final SGAM output.

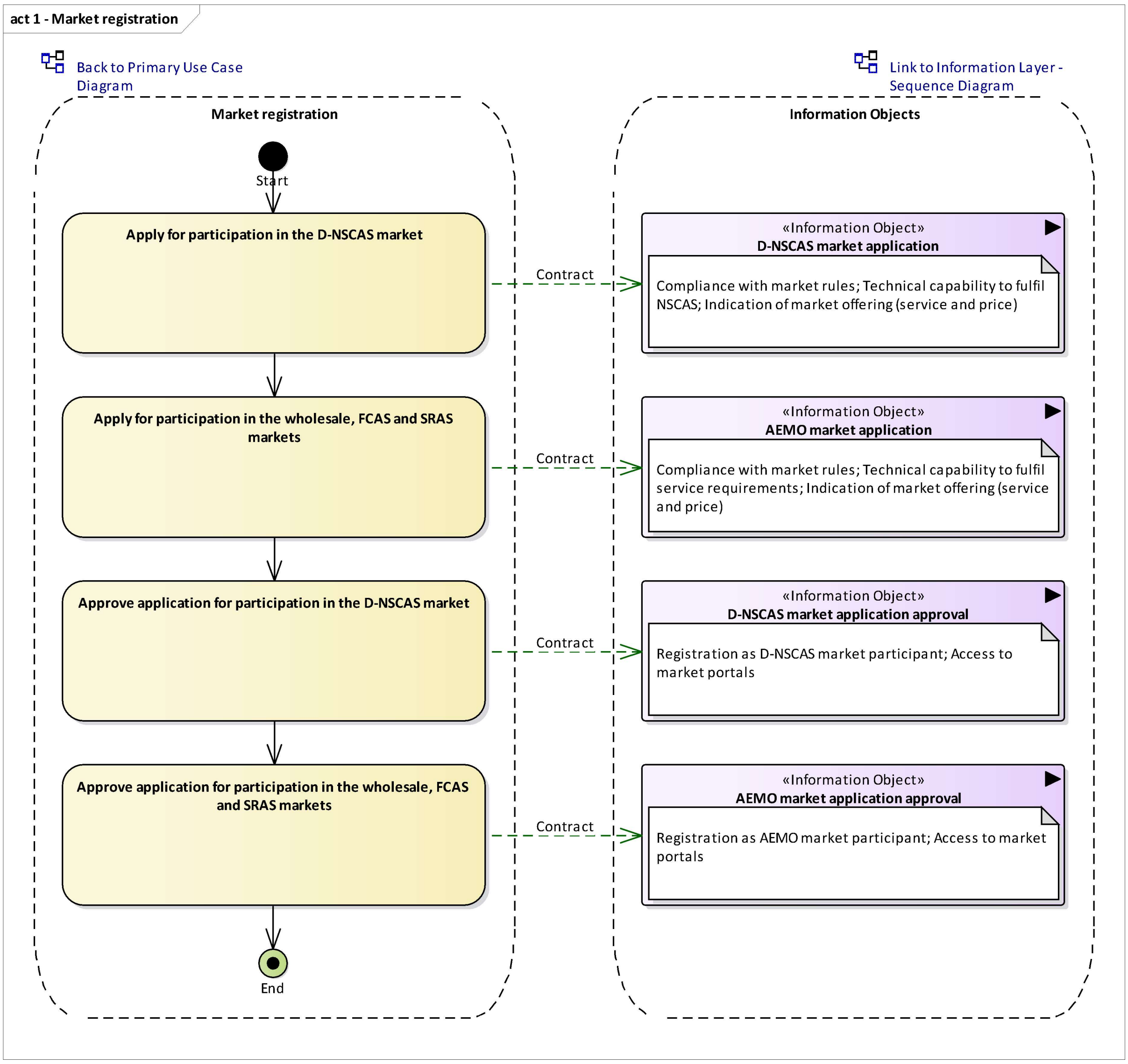


Figure 19 Activity diagram for market registration

Figure 19 uses an activity diagram to describe the functional steps required to realise the process for market registration. It also assigns 'information objects' to the functional steps to characterise the information that is being exchanged in each. The activity diagram is complemented with a sequence diagram detailing who is communicating with whom (i.e. business actors), what they are saying and in what sequence the activities and information are being realised. The sequence diagram is introduced in Figure 20.

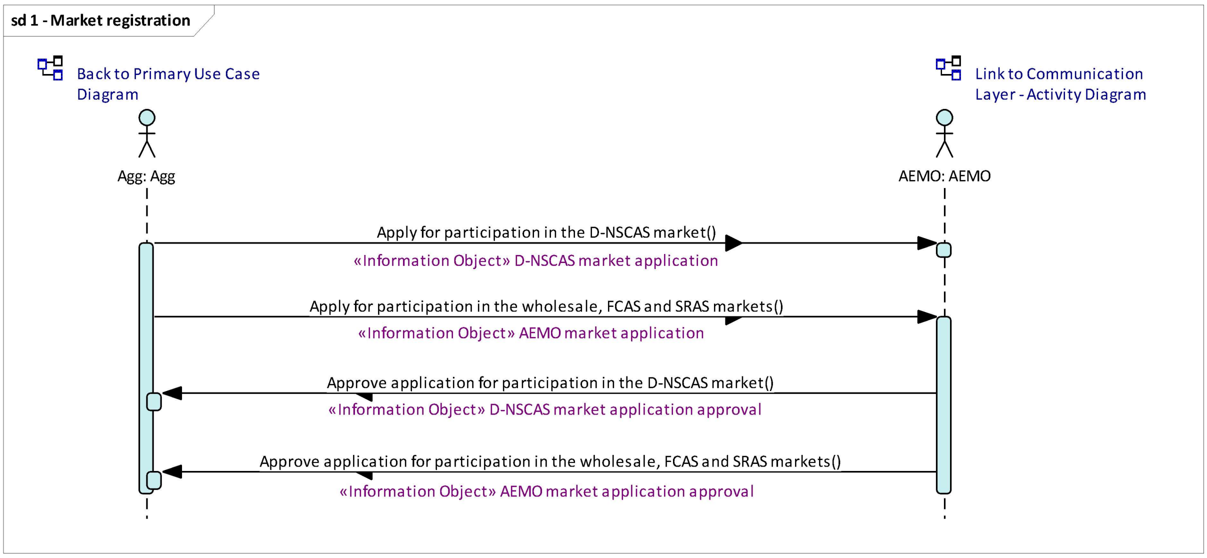


Figure 20 Sequence diagram for market registration

Finally, the last stage in the development of the SGAM function layer requires the mapping of the PUCs onto the function layer smart gird plane. This spatially distributes all PUCs involved in a HLUC across the domains of the electrical energy conversion chain and the zones of the information management hierarchy. In this way, the function layer is developed separately for each HLUC. Figure 21 shows the function layer for the ‘aggregator DER bid and dispatch’ HLUC within the SIP framework.

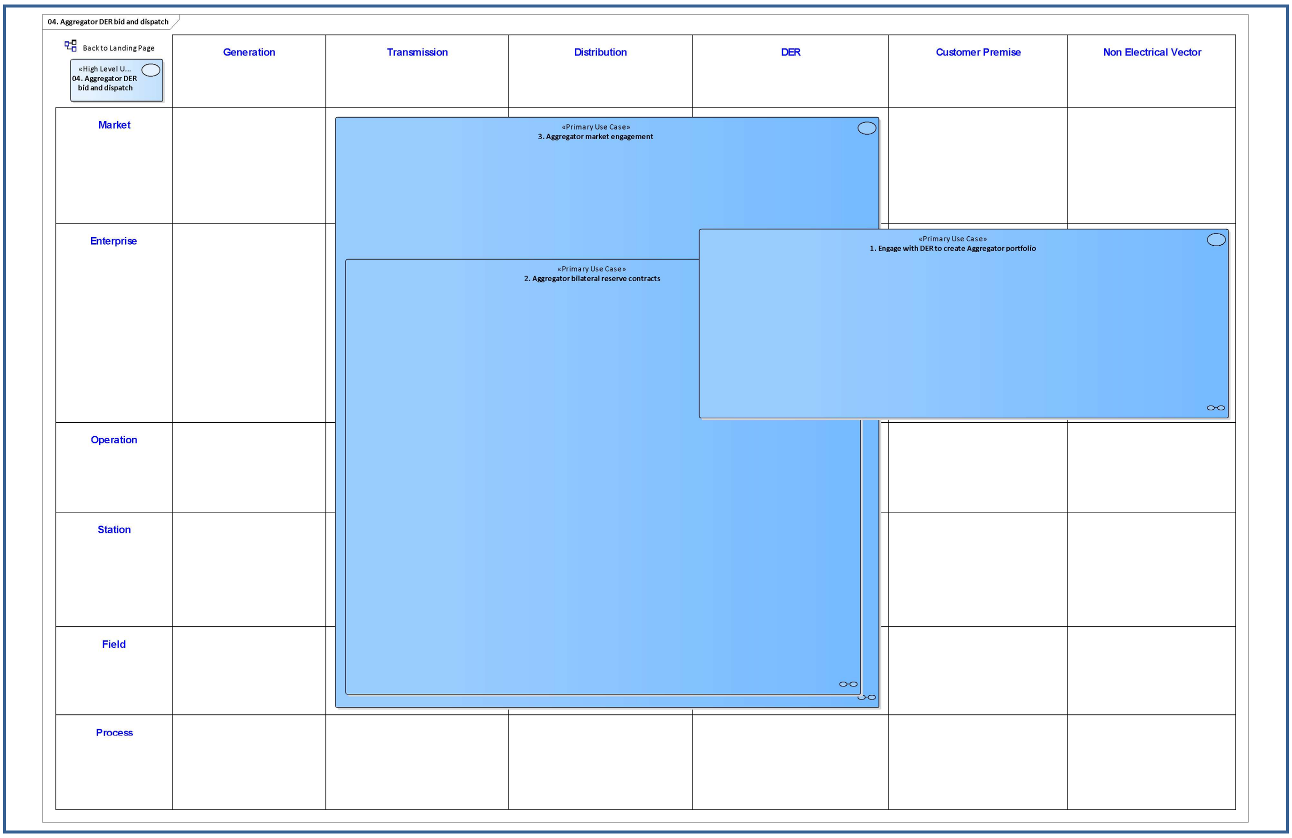


Figure 21 Function layer for the ‘aggregator DER bid and dispatch’ HLUC function

Business layer

The business layer spatially distributes all HLUC functions across the domains and zones of the smart grid plane for every BUC (i.e. DER optimisation framework). In this way, there will be a single business layer per DSO framework (see Figure 22).

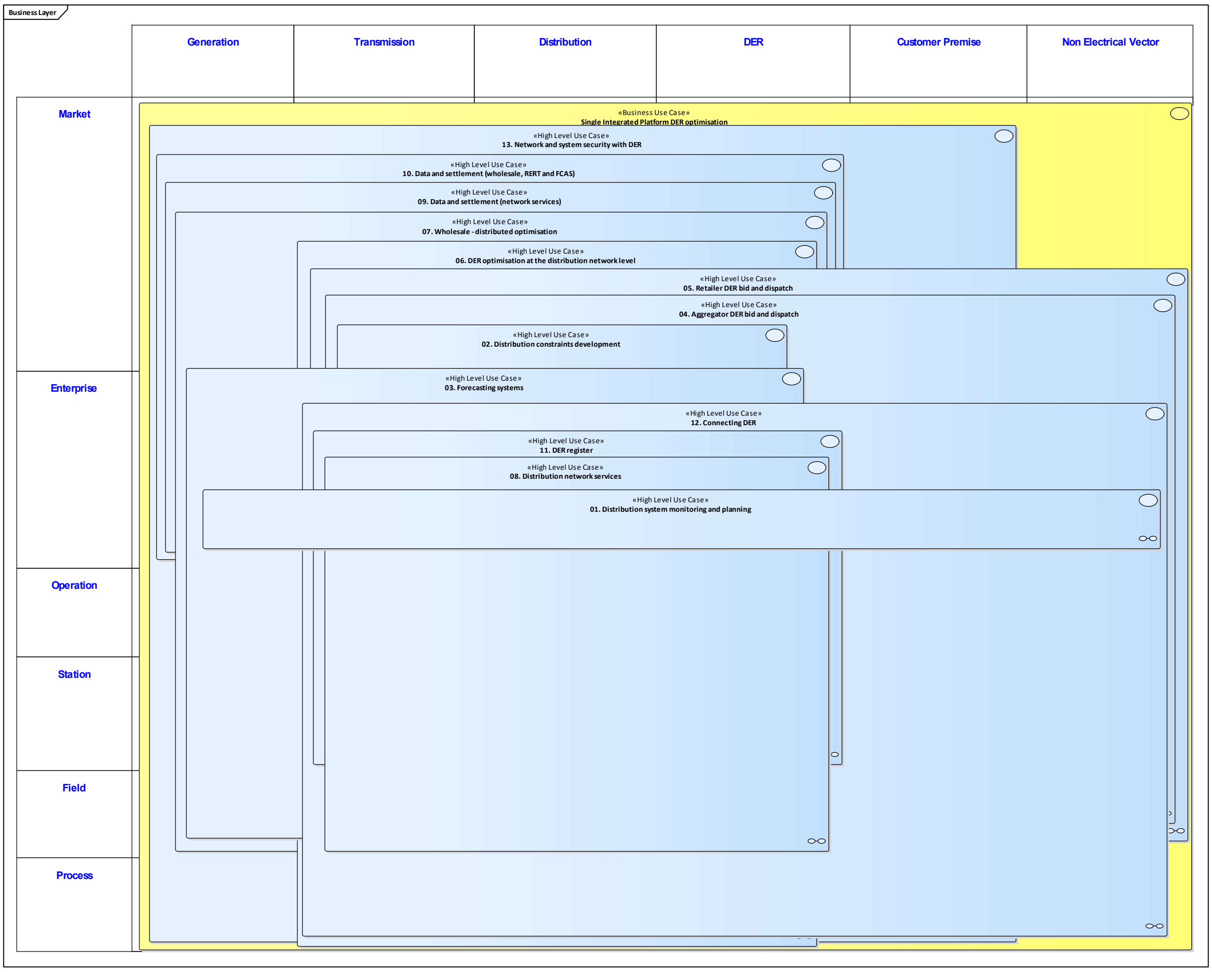


Figure 22 Business layer for SIP framework

4.2.2 Phase II: System architecture

The OpEN-PRJ has only fully developed the DSO frameworks up to the completion of phase 1 (system analysis) and so the outputs described within this section are not included within the SGAMs delivered. It is suggested that the system architecture may be developed at a later date when further details of the technology to be implemented are known and there is greater confidence as to which of the four DSO frameworks will develop. To this purpose, details of the system architecture methodology are included below.

The system architecture phase aims to map the functional requirements of the system into a high-level architecture. This high-level architecture describes the key functionality of the main subsystems / components and their interactions without detailing their inner composition. Thus, the system architecture can be interpreted as a black box model of all involved subsystems / components with the description of the interactions between them being the key difference and focus across the component, information and communication layers. Similarly, to the function layer, these three SGAM lower layers are developed for every HLUC function.

To achieve this, business actors are transformed into 'logical actors' as their physical architectural realisation involves: logical decisions and evaluations; processing commands; performing calculations; etc. Thus, business actors are converted into logical actors to realise the 'logical level' activities of the functional specification and to maintain independence from the 'business level' activities. Specifically, the transformation creates separation between business and functional activities from a modelling perspective rather than a physical one

Figure 23 demonstrates the transformation of business actors into logical actors. This is a model transformation of type 1:n as a business actor can have various logical actors while any logical actor can only originate from a single business actor.

Please note that figures within this section of the report are illustrative only as additional work with stakeholders would be necessary to accurately reflect the energy system architecture.

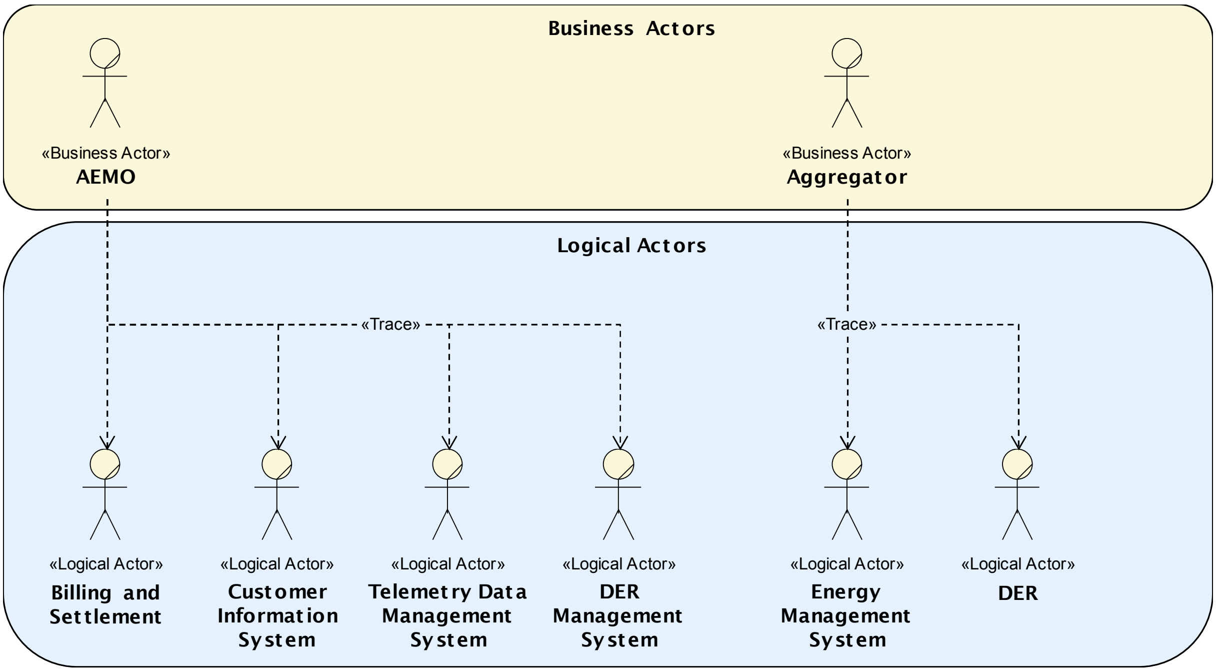


Figure 23 Transformation of business actors into logical actors (illustrative)

Component layer

The component layer directly maps the functional requirements of the system into a high-level architectural solution composed by subsystems / components. To this end, logical actors are converted into components. This is a model transformation of type n:n as different logical actors can be converted into the same physical component and vice versa. Figure 24 illustrates the transformation of logical actors into components.

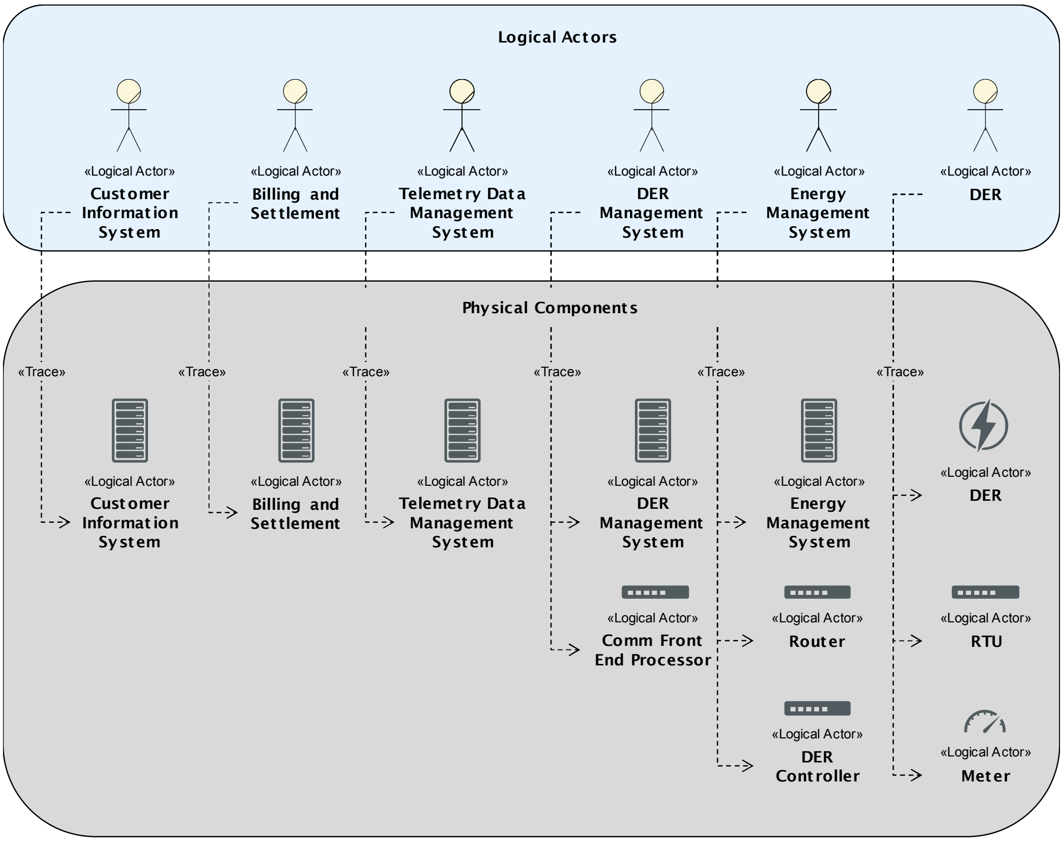


Figure 24 Transformation of logical actors into physical components (illustrative)

The physical components are now spatially distributed across the domains and zones of the smart grid plane to form the component layer. As previously indicated, the key focus of this layer lies on the physical connections between components, i.e. general network topology and ICT network architecture between components, rather than on the components themselves. Figure 25 introduces the component layer in an illustrative example.

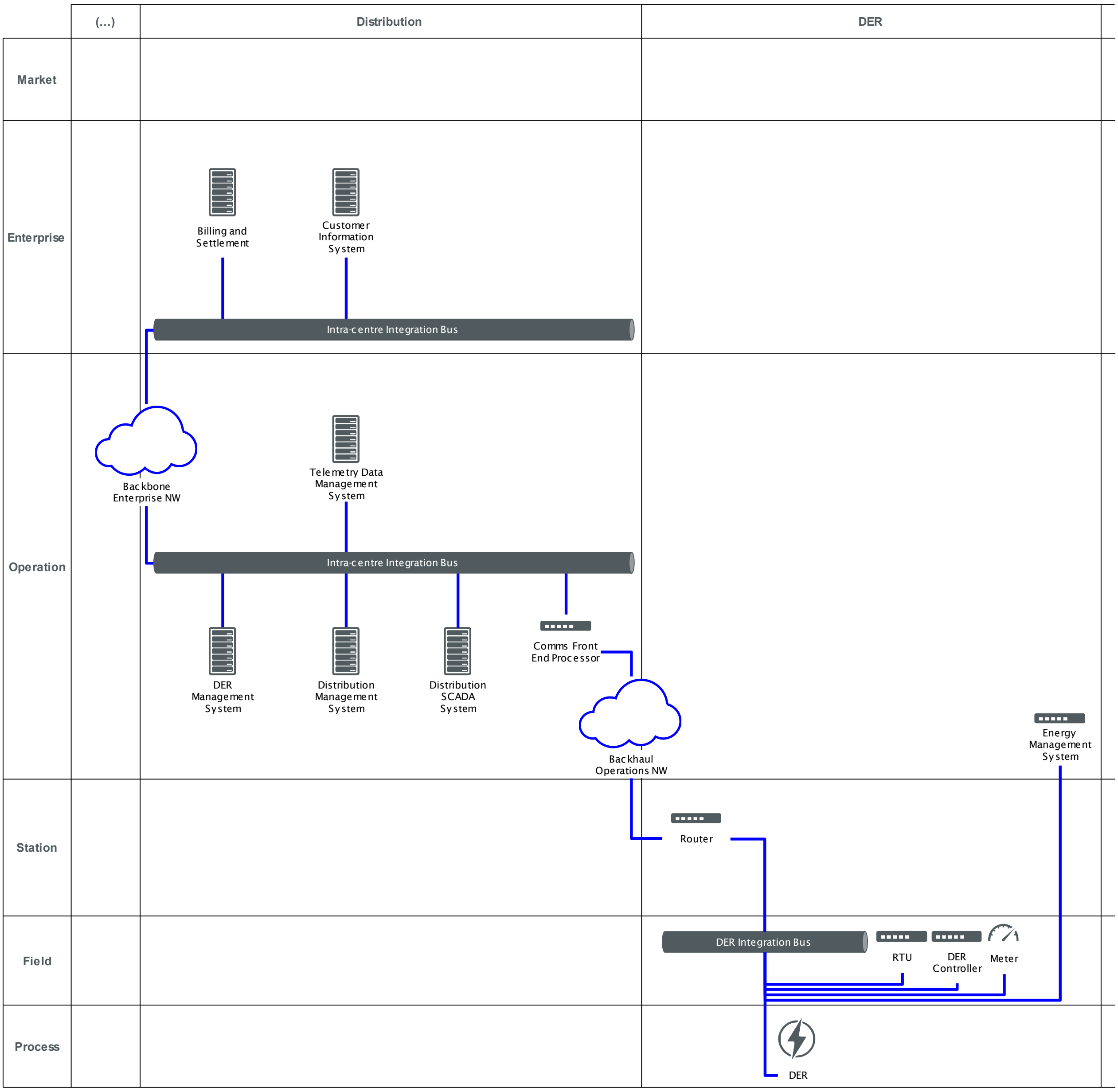


Figure 25 Component layer (illustrative)

Information layer

As part of the functional specification of the model captured within the system analysis phase, information objects are generated to represent and characterise the information exchanged between business actors. The information layer maps these information objects onto the information layer grid across the relevant physical components. Figure 26 displays the information layer in an illustrative example.

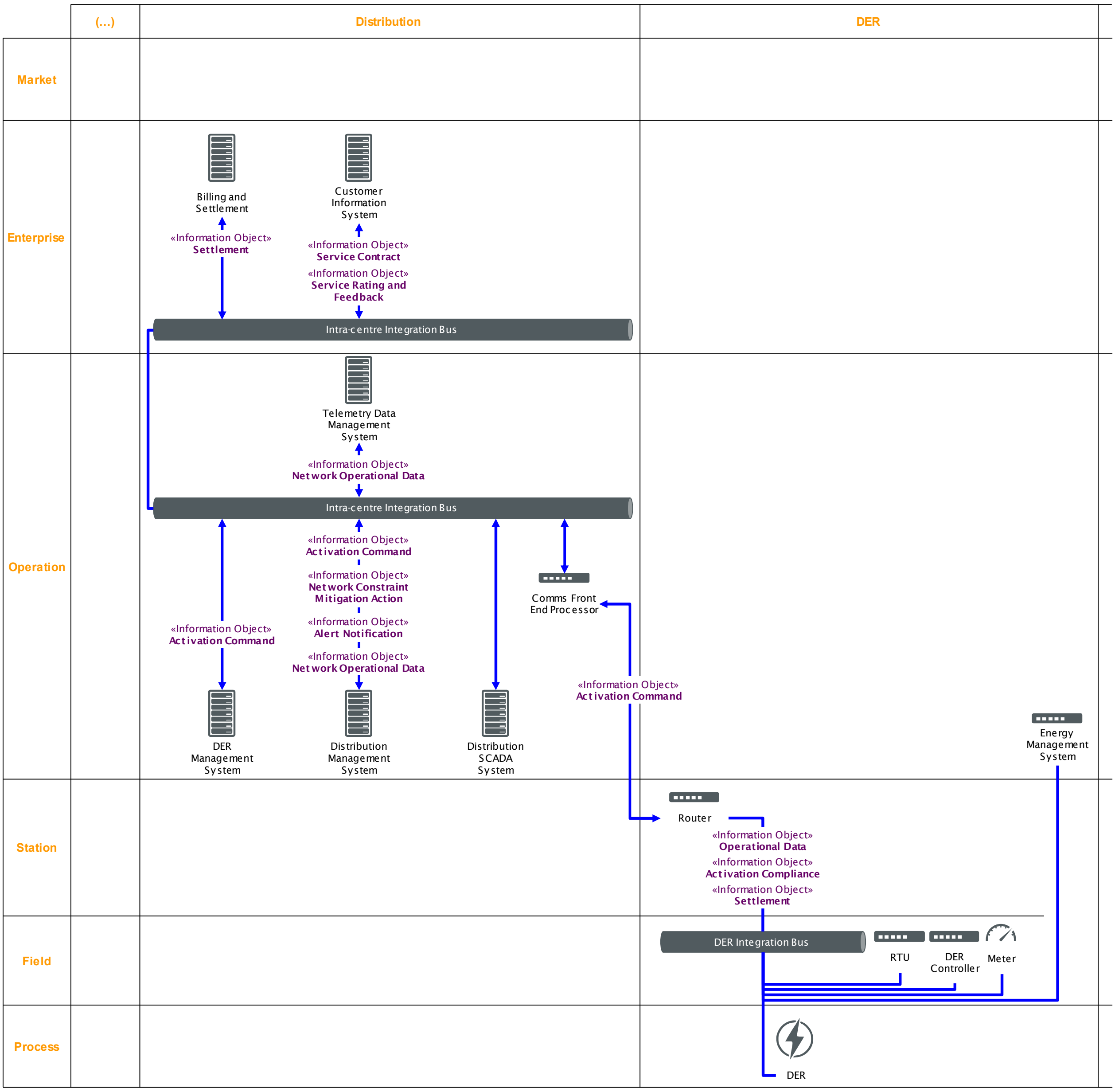


Figure 26 **Information layer (illustrative)**

Communication layer

As part of the functional specification of the model captured within the system analysis phase, the ways and means by which business actors communicate is determined. Within the OpEN-PRJ communication means were grouped into five generic communication types presented in Figure 27.

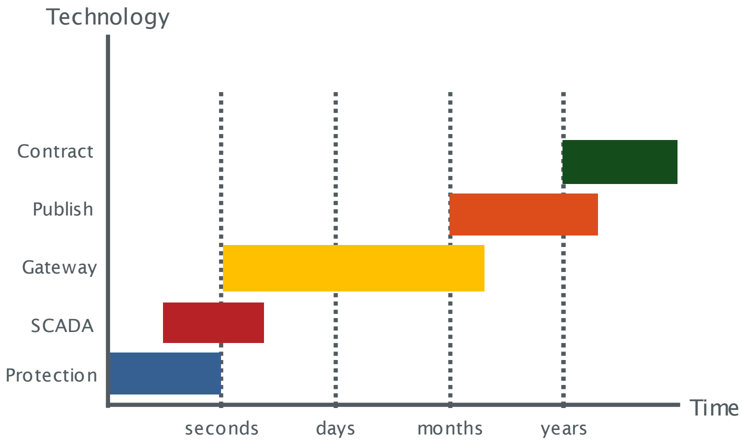


Figure 27 Generic communication types

Broadly, these five generic communication types are defined as follows:

- Protection: Hard wired communications; Timeframe: real-time (<1sec)
- SCADA: Electronic real-time communications within DSO; Timeframe: 1sec – 5mins
- Gateway: Electronic communications from / to outside world; Timeframe: real-time (sec), short-term (sec to days)
- Publish: Public statement; Timeframe: medium-term (months)
- Contract: Pre-defined / agreed / legally enforced communications; Timeframe: long-term (years)

The communication layer considers the communication types and maps them onto the communication layer grid across the relevant physical components. Figure 28 displays the communication layer in an illustrative example.

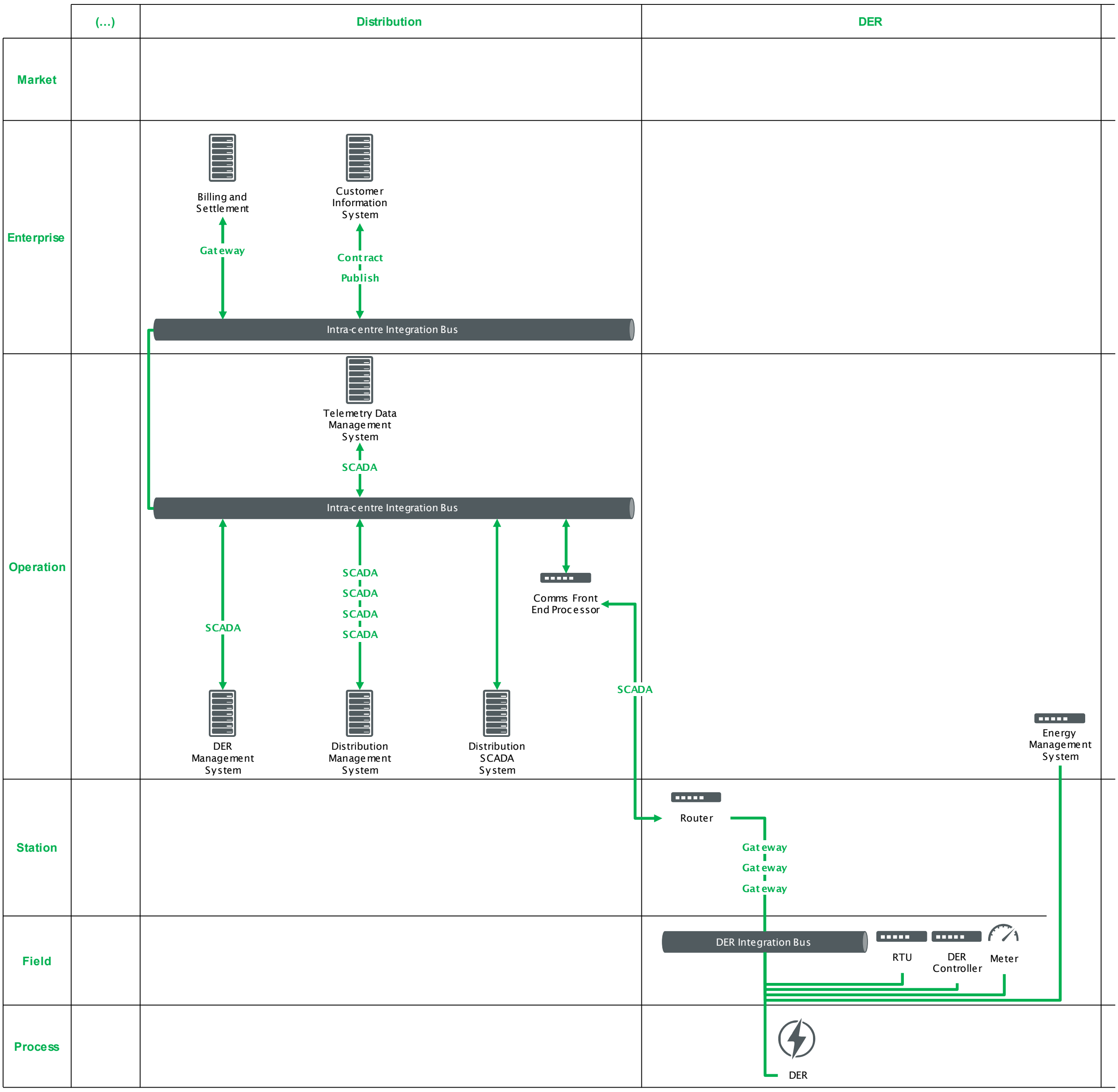


Figure 28 **Communication layer (illustrative)**

4.3 Navigating the Smart Grid Architecture Model

SGAMs of the four DSO frameworks, following the system analysis methodology laid out in Section 4.2.1, were developed alongside this report using Enterprise Architect software. These files have been made available as HTML publications, the use and navigation of which is set out in this section of the report.

4.3.1 The landing page

A landing page diagram is present as the home page for each SGAM and acts as a means to introduce the model and navigate within it. An example is shown in Figure 29 annotated with numbers corresponding to items in the below list:

1. The name of the model and high-level description of the framework

2. A useful tips document similar to that presented in Section 4.1.3

3. A link to the SGAM business layer diagram

4. A diagram showing the business actors in SGAM domain groupings and the contractual and information links between them. These actor icons are the starting point for ‘navigation by actor’ and will take you the corresponding actor view diagram (see Section 4.3.3)

5. The 13 HLUCs. These elements are the starting point for ‘navigation by function’ and will take you the corresponding HLUC diagram (see Section 4.3.4)

6. Links to other useful resources

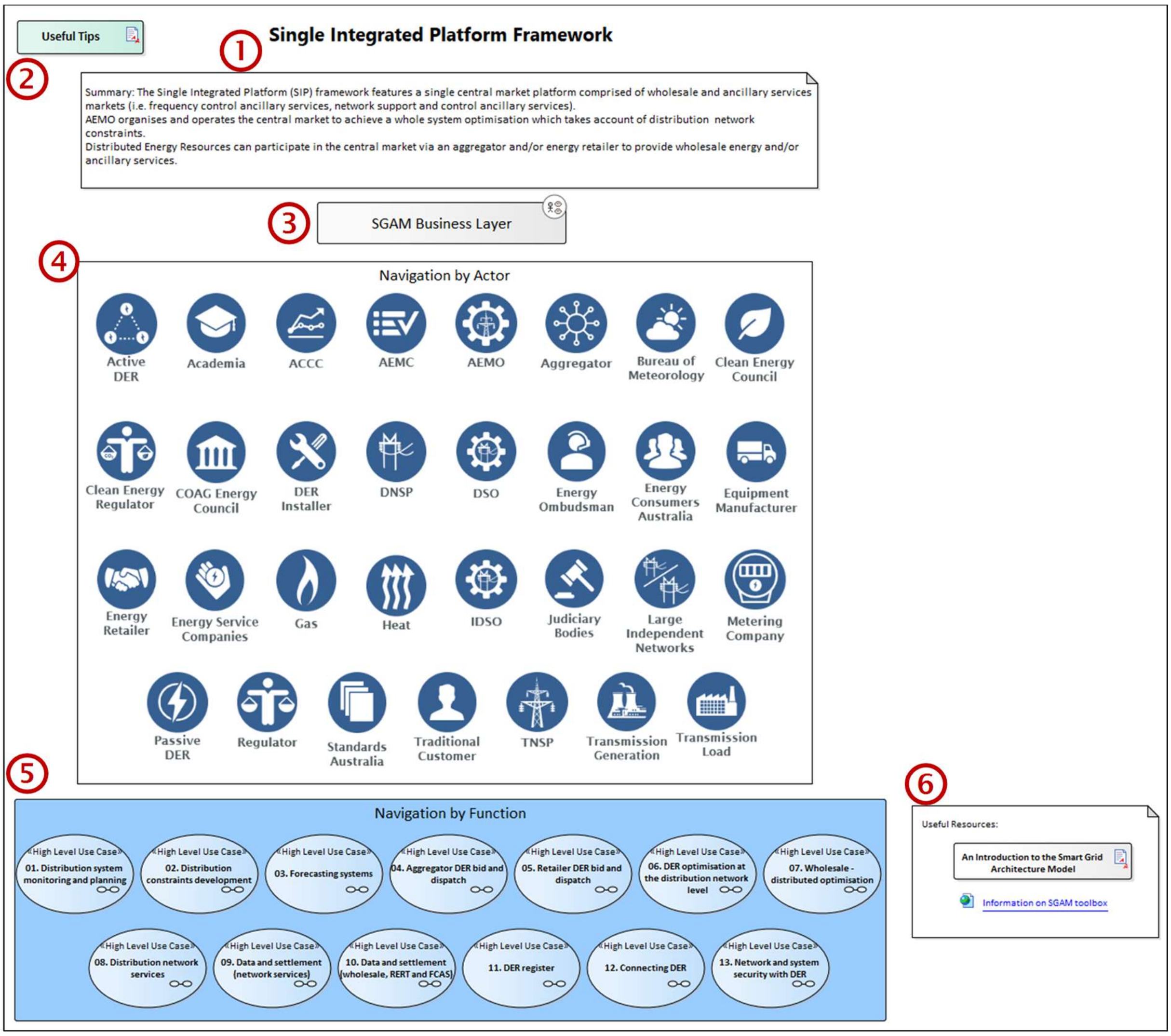


Figure 29 **Annotated model landing page diagram**

Links back to the landing page are located in the top left corner of many of the diagrams.

4.3.2 The business layer diagram

The SGAM business layer diagram (see Figure 30) links the business actors to their goals. These are realised by the central business use case which invokes the 13 HLUC functions at the bottom of the diagram. It also contains a very high-level description of the world.

Clicking on an actor will open the linked actor view diagram (see Section 4.3.3), clicking on a HLUC will open the linked HLUC diagram (see Section 4.3.4) and clicking on a goal will show the description of the goal.

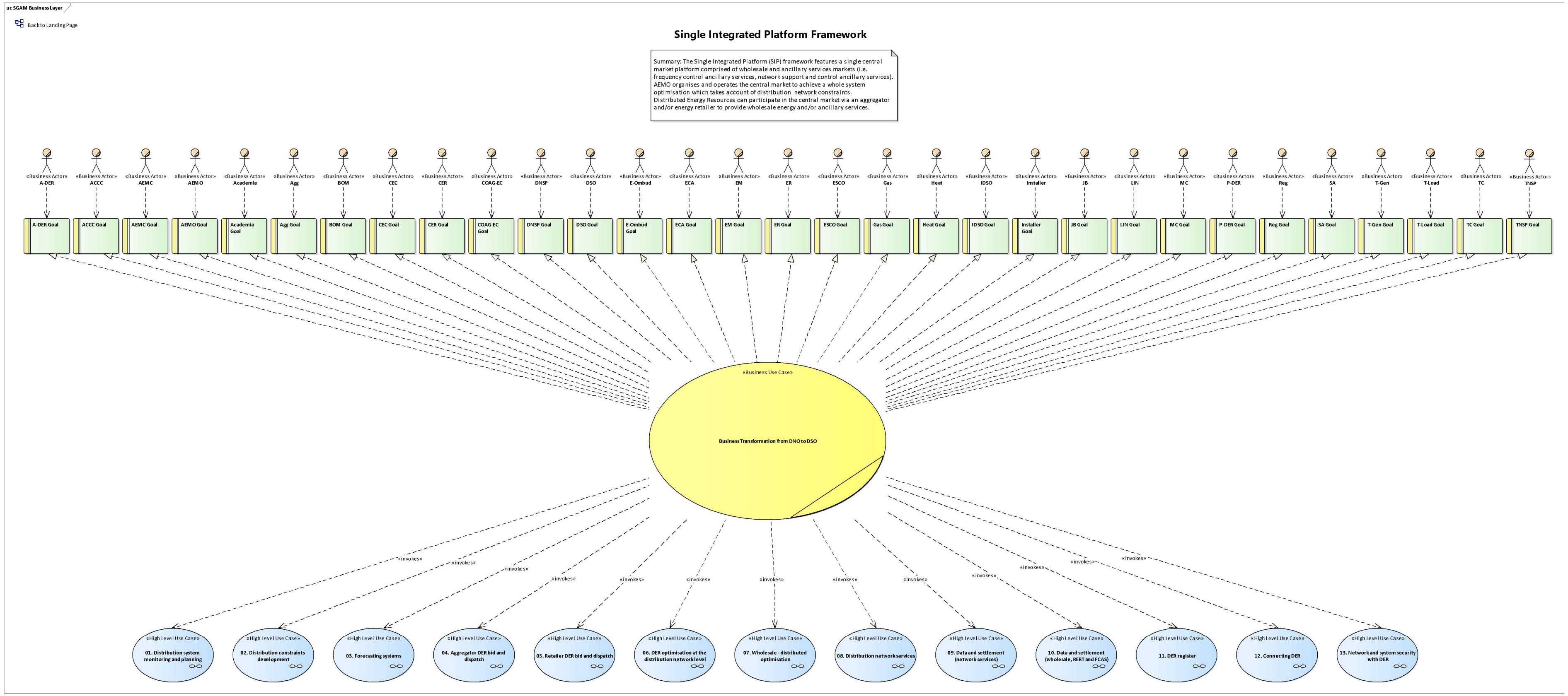


Figure 30 Business layer diagram

4.3.3 The actor view diagram

Clicking on an actor icon on the landing page diagram leads to the associated actor view diagram (example shown in Figure 31). This displays the actor in the centre of the page with the full name and description of the actor in the bottom right corner. The PUCs are present around the central actor, grouped by HLUC in titled boxes. Links exist between the central actor and PUCs in which it is present, this allows users of the model to quickly identify the functional requirements of each actor within the model simply by clicking upon the appropriate PUCs.

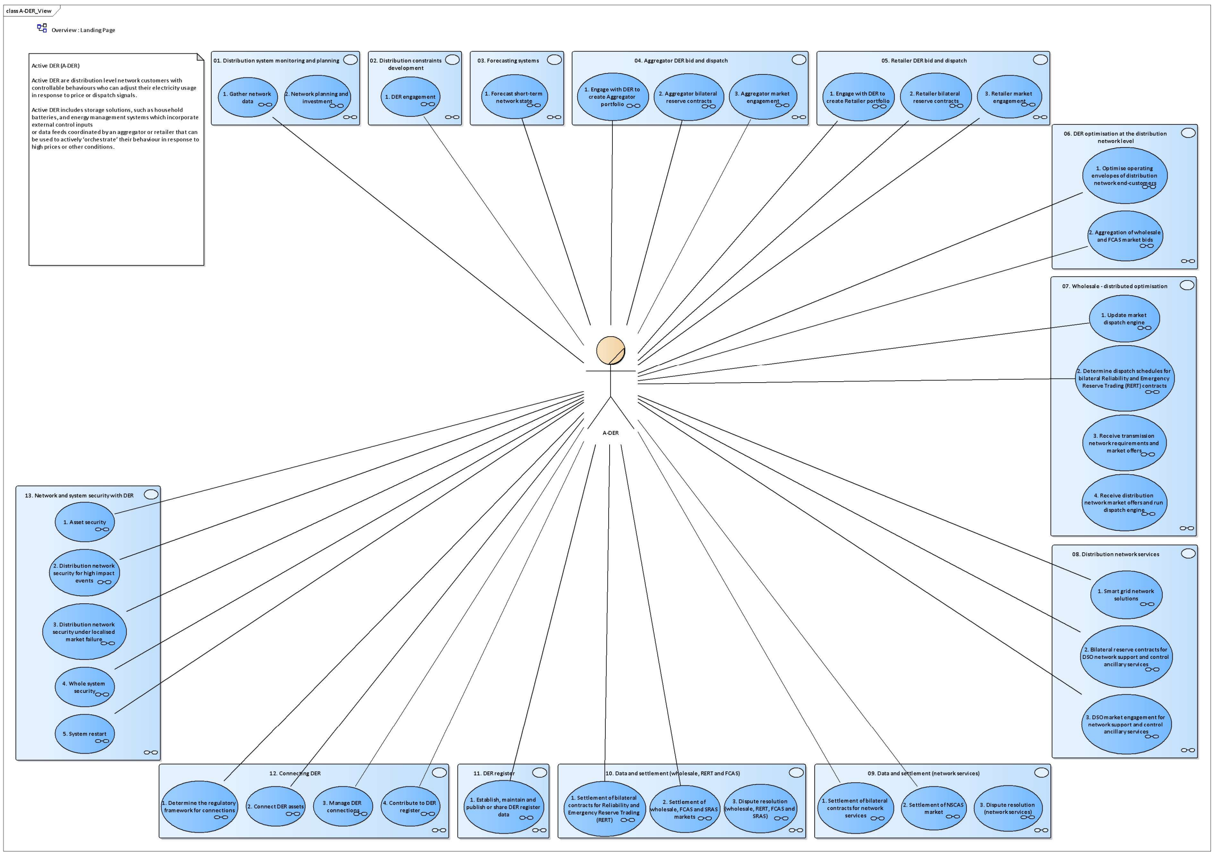


Figure 31 Actor view diagram

4.3.4 The high-level use case diagram

Each HLUC is made up of a number of PUCs. The HLUC diagram (see Figure 32) maps these PUCs onto the market agnostic SGAM plane. The width and height of the PUC rectangle on the swim lanes shows the coverage across the breadth of the energy conversion chain and the depth of the hierarchical levels of power system management covered respectively. In short, the width of the PUC tells you who is involved and the height tells you the level of detail involved. Each rectangular PUC object on this diagram can be used to navigate to its linked PUC diagram (see Section 4.3.5).

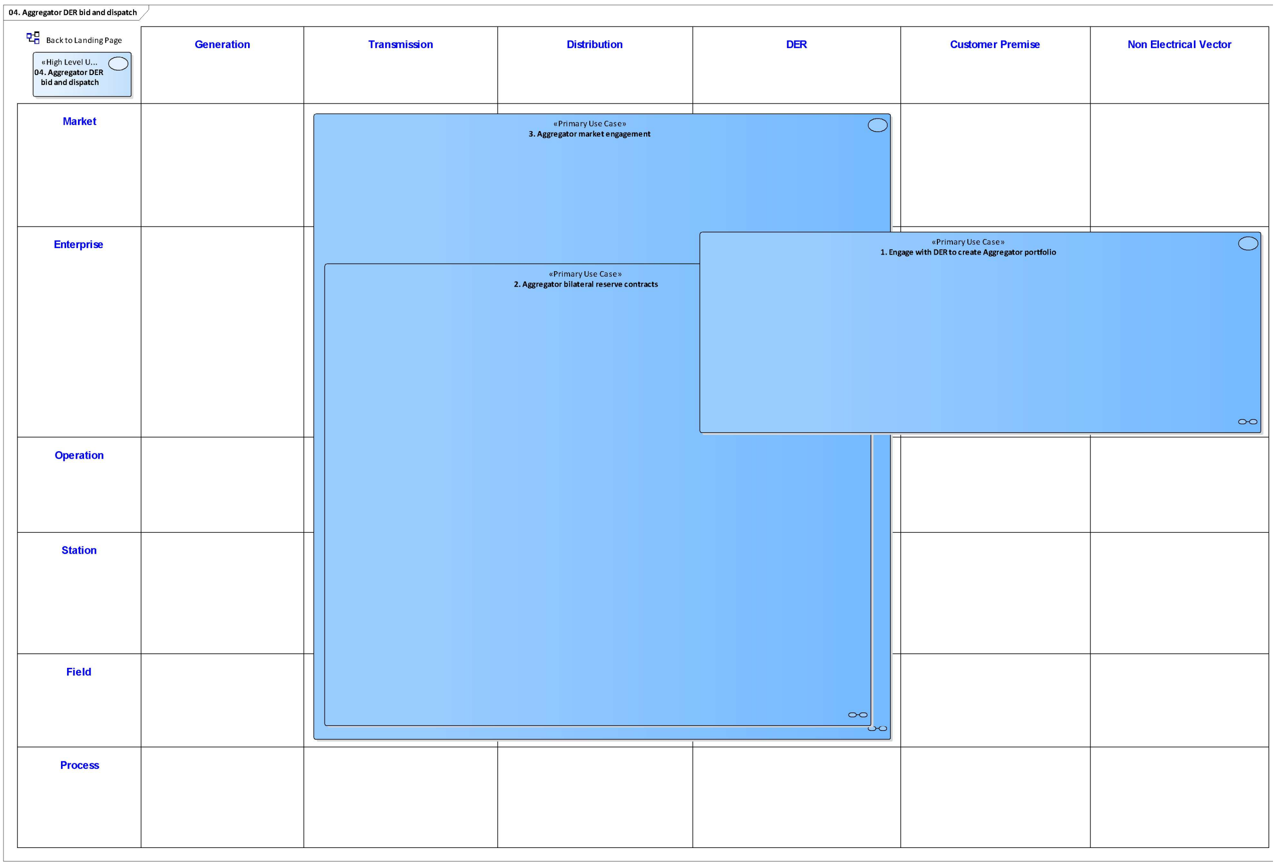


Figure 32 **HLUC diagram**

4.3.5 The primary use case diagram

The PUC diagram (see Figure 33 for example) sits below the HLUC diagram and contains:

- The PUC element which is placed centrally on the diagram.
- The HLUC element which invokes the PUC element at the top left of the diagram. Clicking on the HLUC element will navigate back to the HLUC diagram (see Section 4.3.4).
- Links to the process sequence and process activity diagrams, in boxes on the right-hand side, which fully describe the processes needed to fulfil the functionality of the PUC.
- The business actors which are present in the processes within the PUC are placed around the PUC element. Clicking on a business actor will navigate back to the linked actor view diagram (see Section 4.3.3). Note that the actors on this PUC diagram may not be present in all of the processes listed. The presence of an actor in a process can be gleaned by viewing the sequence diagrams which show all participating actors across the top of the page.

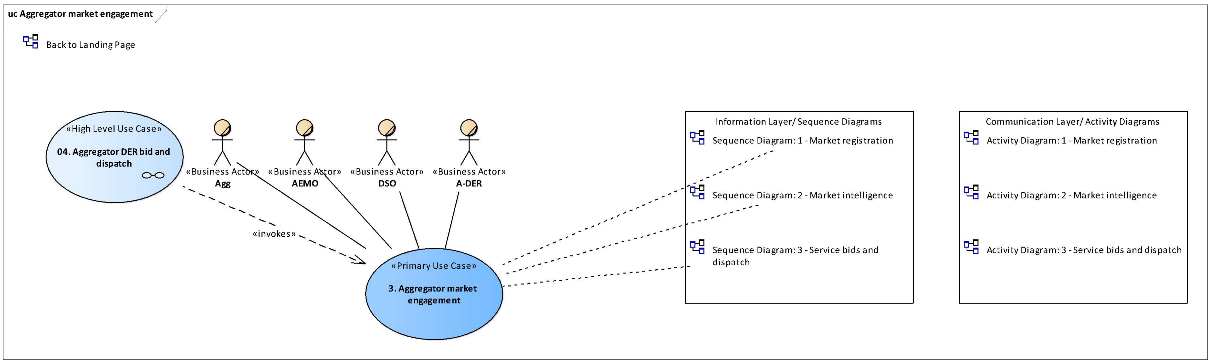


Figure 33 PUC diagram

4.3.6 The sequence diagram

Figure 34 shows a sequence diagram which are used primarily to show the interactions between actors in the sequential order that those interactions occur. Each sequence diagram contains:

- Lifelines of the business actors required to fulfil the process that the sequence diagram is describing
- Links between the actor lifelines which describe process steps and the information objects exchanged between actors to fulfil a given step.

Process steps follow a logical sequence of implementation from the top of the diagram to the bottom. The direction of the links in a sequence diagram may only indicate which actor leads a particular process step. For example, if the linked information object is an 'industry consultation' or 'service contract' a reverse flow of information is implied to complete the step.

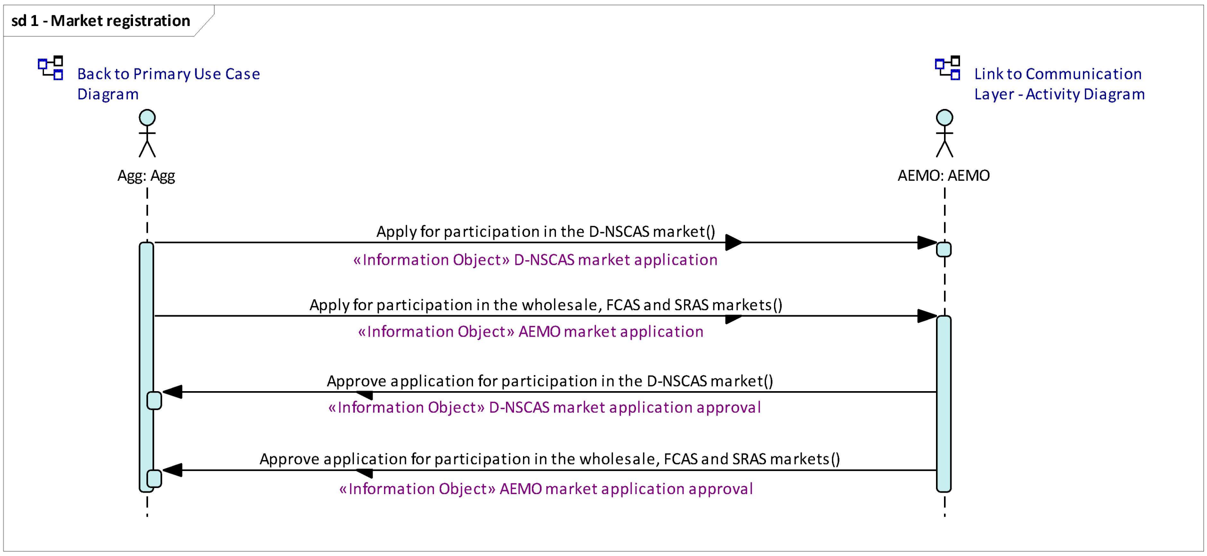


Figure 34 Sequence diagram

4.3.7 The activity diagram

The purpose of the activity diagram is to model the procedural flow of actions that are part of fulfilling the functionality of the larger PUC. Each activity diagram (see Figure 35 for an example) contains, in logical sequence of process implementation, from top to bottom:

- A description of the process step in the left region

- The information object required to enable the functionality of the process step and a description of the information that object represents in the right region
- And a link between the two with a high-level description of the communication protocol used in the information object exchange (e.g. SCADA, contract, etc.)

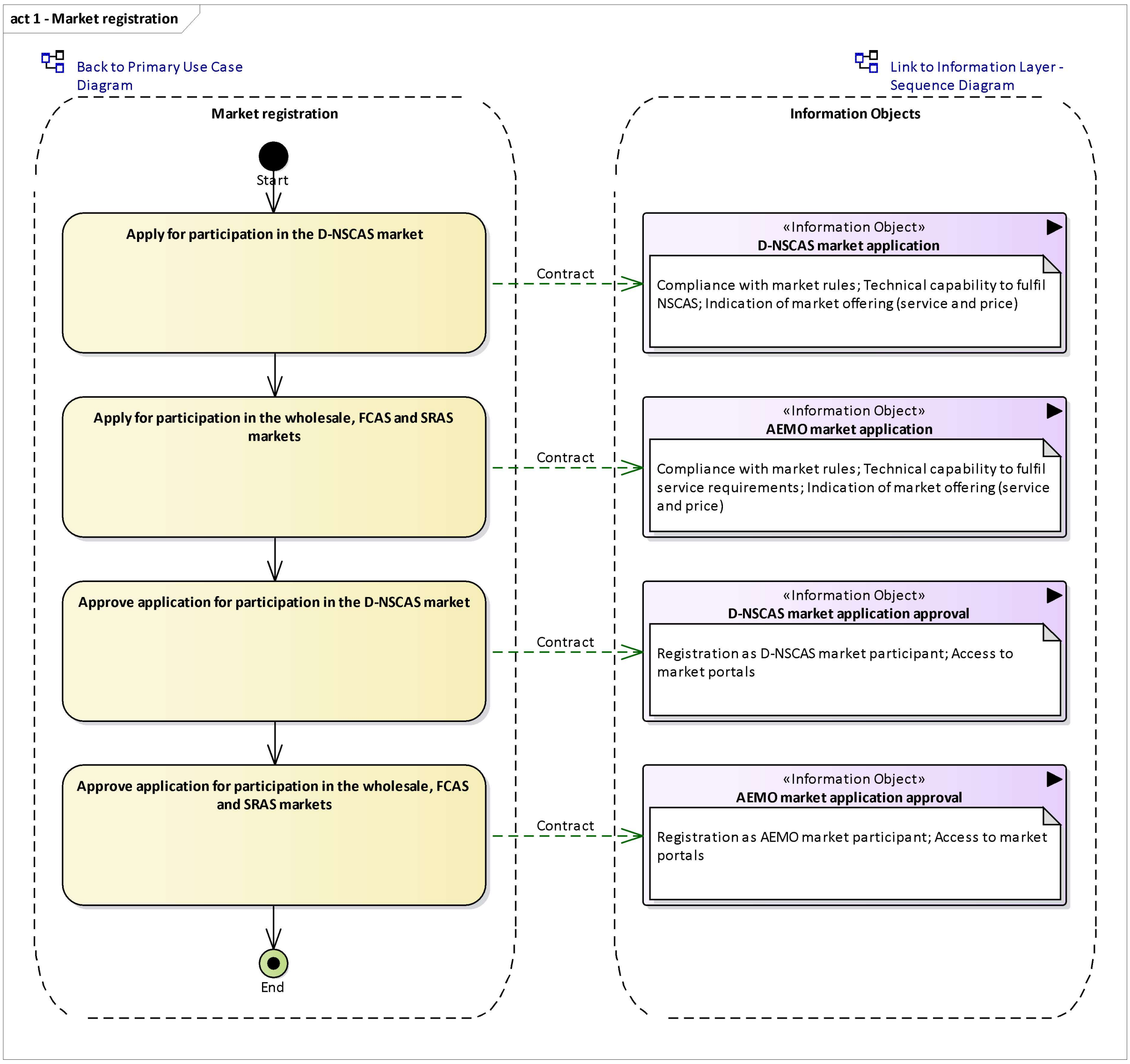


Figure 35 Activity diagram

5. Required capabilities and recommended actions

In order to explore the pathways and next steps that can be taken to progress the DSO transition, irrespective of the DSO framework ultimately adopted, this section of the report examines the areas of commonality that lie across all four of the frameworks. By identifying those elements which are common throughout the frameworks we are able to present a series of recommended actions or initiatives that can be begun in the short to medium-term without regret (i.e. with minimal risk of additional work requirements being created, additional investments being sunk, or value not being realised) to support DER optimisation and bring about an environment suitable for the advancement of energy decarbonisation, decentralisation, digitalisation and democratisation.

To achieve this, we will first set out in Section 5.1 the high-level required capabilities, drawn out through investigation and consultation with stakeholders, which act as enablers to the optimised integration of DER. These required capabilities are necessary irrespective of which framework evolves and represent the key competencies that should be developed now to prepare for the next steps on the journey towards an optimised distributed energy framework facilitating greater access to markets for DER.

Subsequently, Section 5.2 will focus on identifying recommended actions that can build upon and enhance the required capabilities so that industry can continue to progress along the DSO transition. The identification of recommended actions is undertaken through an examination of the technical, commercial and regulatory key features which exist across the 13 functions within the four frameworks, while also given consideration to wider stakeholder commentary captured with the workshops which could not be easily parsed into the 13 functions or was otherwise considered out of scope.

5.1 Required capabilities

Investigation and consultation with stakeholders to date has drawn out key required capabilities which act as enablers to the DSO transition and which must be developed as a first priority in order to 'clear the way' for the wider DER optimisation, irrespective of the ultimate form that transition takes and the final market model which manifests. By laying the foundations of a framework that future work can build upon, the industry will be well positioned to select a definitive future pathway for network and market development or continue in its framework-agnostic approach by pursuing the secondary least-regrets actions presented in Section 5.2.

In total three required capabilities that are key to the industry's transition from its current capacities to those of any future optimised DER world are as follows:

1. Determine network constraints
2. Define these constraints within an operating envelope
3. Communicate this operating envelope to customers, DER, aggregators, etc.

In order for network operators to achieve the required foundation in a manner conducive to optimising the impacts of DER for the whole grid, and delivering maximum benefit to customers, for each of the capabilities listed above a series of enabling actions have been identified, as shown in Figure 36.

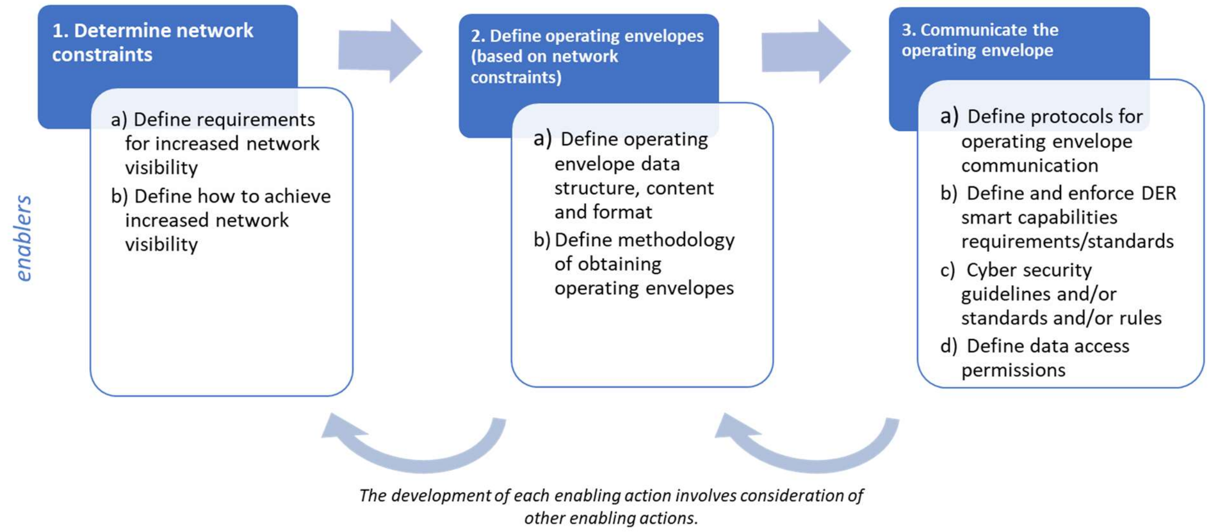


Figure 36 Required capabilities and enabling actions

In order to make progress towards the required capabilities and enablers, which are examined in further detail below, multi-stakeholder working groups targeted at addressing these enablers may be the best approach. Who will lead or has responsibility for the implementation of these elements may vary slightly between market models, depending on who is operating the market platforms for DER participation, but nonetheless these steps will still require development in a multi-stakeholder forum.

5.1.1 Determine network constraints

In all four frameworks there is a requirement to determine network constraints in a more dynamic, and granular manner than is currently possible. To achieve this, it is necessary to have greater visibility of the prevailing conditions on distribution networks than is currently the case, particularly at LV. This is currently the responsibility of DNSPs as these are the business entities with responsibility for the safe and secure operation of the distribution networks.

For this process it is important to understand and define the requirements for:

- What (network operating) information is needed to maintain network operation within parameters;
- How much data needs to be gathered (how many locations, how frequently); and
- Where on the network does the data need to be/can be collected?

Once the above parameters are decided then a set of technical system specifications can be written to cater to these requirements, giving consideration to: ICT infrastructure; monitoring technologies for different parameters; and modelling software and techniques.

Finally, to link to the next step, network operators need to have a method, whether that is a set of constraint equations, modelling or other means, that calculates the operating envelope from the network constraints data.

It is necessary to note that while the level of network visibility and network constraint data required is not prescribed, and approaches may vary between geographies or businesses, the gathered network constraint data must be sufficient to allow the development of transparent operating envelopes for customers. That is, whilst the approach employed to bring increased network visibility to network operators may vary, operating envelopes should be developed and presented in a consistent and unified manner to enable retailers or aggregators to offer the most value to customers who own distributed resources, in turn reducing costs for all consumers.

5.1.2 Define these constraints within an operating envelope

Following stakeholder consultation, underlying ENA's and AEMO's future vision for DER optimisation is the use of operating envelopes which indicate to customers the export and/or import limits that they must operate within for the safe and secure running of the network. At the foundational level, operating envelopes may be static and determined through an examination of the long-term constraints on the network. However, as network visibility is enhanced, operating envelopes may be calculated at shorter timescales and become dynamic.

To develop operating envelopes, network constraint data needs to be processed into an appropriate form to be issued to stakeholders (DER, aggregators, etc). The operating envelope definition should be determined based on an understanding of the information aggregators, energy retailers and other DER stakeholder will require to operate successfully in energy markets. A key enabler is therefore to develop a set of guidelines to define the structure, form and content of operating envelopes. It is vital that this is consistent across different geographic network areas, allowing various market participants to gain access to the local markets in a fair and transparent manner. The creation of these guidelines will need to be agreed with the appropriate stakeholders and hence this 'operating envelope definition' becomes a second key requirement that must be developed irrespective of the framework to ultimately be adopted.

The various methodologies that could be used to process network constraint information into operating envelopes need to be defined. It is important to recognise the need for a range of methodologies to suit a variety of network structures and DER uptake levels. In addition, in the innovation process of trialling operating envelopes it may become apparent that the original definition of the structure and format of the operating envelope may need to be adjusted, hence the emphasis on the need for an iterative and non-linear process.

5.1.3 Communicate this operating envelope

Operating envelopes must be communicated to stakeholders in a suitable manner and format to allow them to receive, understand and respond to them in a market timeframe. This third required capability of 'communicating the operating envelope' may be considered in four parts:

- Determine the method and format used to transmit operating envelope;
- Define and enforce DER smart capabilities requirements/standards (to receive the envelope);
- Ensure the data is transmitted securely; and
- Optimise access levels for different stakeholder groups.

It will be incumbent on network operators to provide operating envelopes either directly to market participants or to a platform operated by another party. While the precise parties involved in the communication is dependent on the final framework that is adopted, the need to communicate this information in a clear and consistent way is universally true across all potential market models. To enable this there is therefore a need to pursue a standardised form of communication of this information. A working group of relevant bodies may decide what data can and should be shared, at what frequency, by what means and how it will be stored, accessed and maintained. Appropriate regulatory and standards bodies can refer to these industry guidelines, which may need to be updated every few years as technologies change. Once agreed, this common approach can be adopted by all networks across Australia, ensuring that it is possible for market participants to engage in multiple markets without needing to engage with different systems and constructs. This is equally the case for generation (such as solar PV) and loads (such as electric vehicles or storage) as the operating envelopes will allow for both positive and negative values representing import and export entitlements.

However, effective communication is not only about the transmission of information. For the communication of operating envelopes to create value, the target audience (the market participants) needs to receive, understand and respond to the information being provided to them. Standards need to be defined and enforced for DER technologies to have these capabilities as it will add cost to customers to retrofit these capabilities at a later date.

Inseparable from the issue of data sharing is that of data security and, more broadly, cyber security. This is an area that will require ongoing work to keep up to date with the latest advancements and techniques. For there to be the best chance of success in cyber security, which can only be measured by the absence of security issues, there needs to be a whole system approach to cyber security. However, there may also be benefit and efficiencies in having separate working groups for different areas/aspects. For example, one working group for secure equipment design interfaces and one for secure operational procedures. Working groups should consist of a diverse set of professionals and have buy-in and engagement from advocates or ambassadors representing each network company and stakeholder in the supply chain. Responsibilities and obligations for cyber security and data protection need to be defined at the outset to mitigate and manage the associated risks.

It is also necessary to weigh the potential benefits and associated risks of sharing different information with stakeholders and consider whether there should be different communication methods and data security requirements for different levels of data access.

Without these required capabilities in place it will not be possible to ensure network integrity when DER market participants seek to offer network services for local or whole-system support, particularly as DER penetration rates increase. As such it is essential that these required capabilities are developed as a first order priority to continue the industry's pathway towards DSO and DER optimisation.

5.2 Recommended actions

The least regrets analysis explores the four currently available framework pathways the electricity system may travel down to progress towards a DSO optimisation to identify areas of commonality. The objective of this analysis is to determine common actions that can be implemented, following enaction of the required capabilities, in the short to medium-term without regret. These actions will assist in the DSO transition, irrespective of the ultimate scenario which manifests.

Currently, recommended actions exist at the convergence of four possible DSO frameworks, however as we move forward in time and confidence grows as to which frameworks are preferred, additional least regrets may arise from the areas of convergence between remaining frameworks (as illustrated in Figure 37).

A higher number of least regrets is advantageous as it allows for a more flexible decision-making process and lowers the risk of being locked into a specific pathway earlier in the transition process. Therefore, while it may be desirable to agree on a preferred DSO pathway (and hence identify the desired end-state) as early as possible, the pursuit and enablement of the required capabilities and recommended actions highlighted within this report do not preclude any of the potential end-states from emerging. Therefore, confidence can be taken that all of these actions will advance the overarching transition process. In other words, all actions described within this document fall into the 'region of least regrets' show in the figure and can be commenced with the full knowledge that they will be relevant irrespective of whichever framework emerges. Moving forward, subsequent actions that are not common across all frameworks and progress into areas of divergence will likely require an end state in mind to ensure progress is towards the desired end-goal.

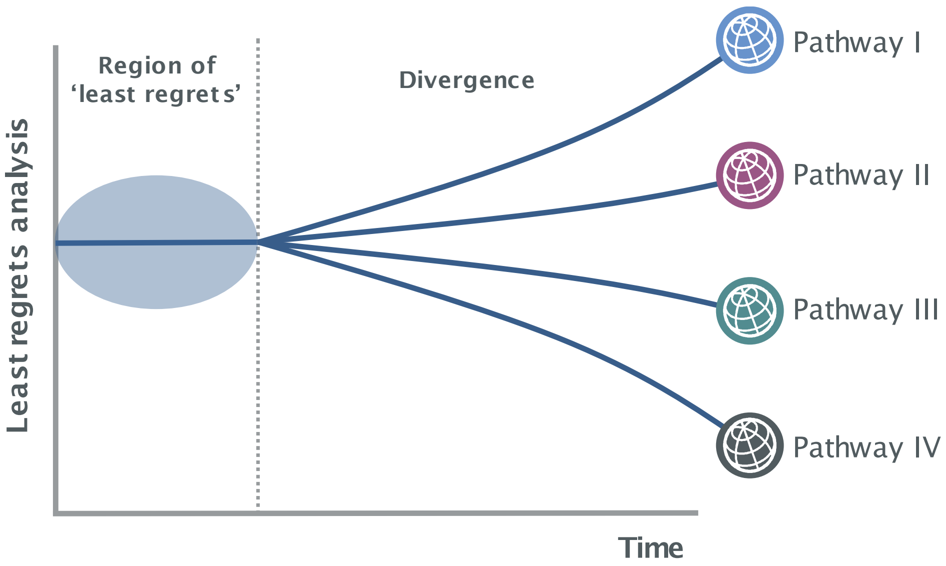


Figure 37 Illustrative example for least regrets analysis

Two distinct, but connected, approaches have been undertaken to identify the recommended actions to be prioritised whilst the four available transition pathways remain on a parallel route.

The initial approach examines the content of the 13 functions (see Section 5.2.1) represented in the SGAMs for each of the four frameworks. The functional steps within the SGAMs were categorised by functional area, those being technical, commercial and regulatory, and then further parsed to draw out the key features that are present within each framework-function. The key features were compared across frameworks, and those with a strong presence in all four were judged for importance to identify recommended actions.

Being aware of the, necessarily, closed scope of the 13 functions explored within workshops our second approach to the least regrets analysis considers wider least regrets actions that do not emerge from examination of the pre-set functions. Instead they draw from the stakeholder feedback and views compiled within the workshops and other OpEN-PRJ briefings. This approach is detailed in Section 5.2.2.

Furthermore, Section 5.2.3 will combine these findings in order to put forward the recommended actions that may be taken or begun following the establishment of the required capabilities in the near-term to progress the DSO transition process.

5.2.1 Analysis of the 13 functions

An assessment was carried out of the functional steps within the framework SGAMs in order to classify each step by functional area, these areas being: technical, commercial and regulatory. This categorisation is helpful in identifying the underlying theme, or focus, of the step being considered and serves as a useful parameter for grouping information to aid in understanding. It should be said that subjective overlap may exist within a process step between these three functional areas, however to prevent an overly elaborate delineation of categories a definitive and singular assignment has been made in each case based on the understanding of the functional areas presented within Figure 38.

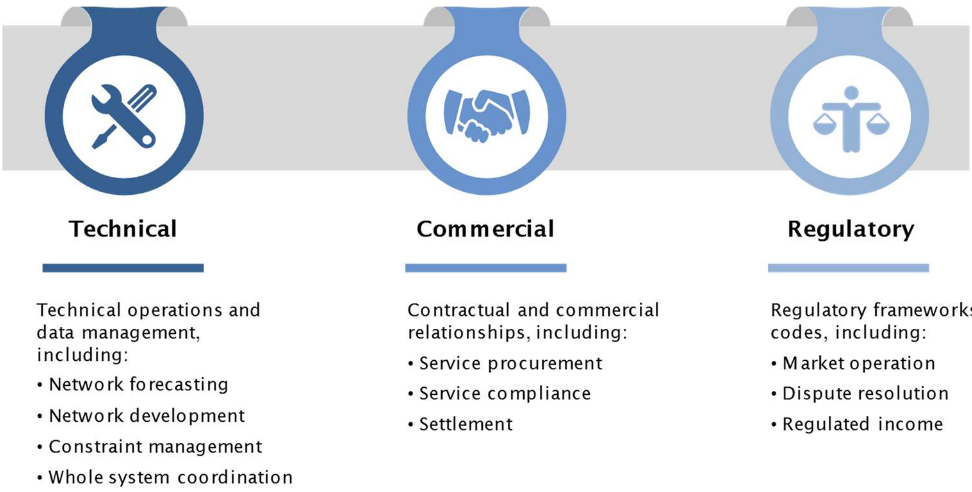


Figure 38 Examples of the components within each functional area

Once process steps were classified by functional area, framework functions could be more readily scrutinised to identify the key features which were present within each. This process distilled the detailed content of each function into the key functionalities which were being enacted within said function. As a result, the over 800 unique information exchanges required to realise the four DER optimisation frameworks, as generated within industry workshops, were successfully condensed to approximately 190 key features that may be enacted across the 13 functions to achieve transition. Examination of the functions' key features reveals that just under 110 of these are strongly present across all four frameworks. All of these common key features represent actions that can be begun without regret once the required capabilities described within Section 5.1 have been achieved, however for succinctness common key features have been judged for importance and the top 10 chosen as recommended actions, as presented in Section 5.2.3.

A breakdown of common key features by function will be presented within this section. However, in order to provide a more generalised and high-level overview of the results obtained by this analysis process, the report will first provide commentary on the levels of convergence present within the functions and across the four frameworks (see below).

Convergence across functions and frameworks

An inspection of Figure 39 below, which shows the percentage of key features which are common across functions classified by functional area, reveals that Functions 4, 5, 10 and 11 possess full (100%) convergence across the four DSO frameworks in regard to key features. This result is not unexpected.

- In respect of Functions 4 and 5, the high-level roles of the aggregator and energy retailer do not vary between frameworks. They engage with end consumers and generators of electricity in order to develop portfolios of services they may offer to interested parties through bilateral arrangements or via a market platform. While the aggregator and energy retailer may offer their services to different parties in different frameworks, this does not have an operational impact on their functionality, i.e. while who they engage with may vary slightly, the how and why remain fixed

- Functions 9 and 10 are also highly convergent as the settlement process is functionally similar between models

- It is also no surprise that the majority of the key features within Functions 4, 5, 9 and 10 are commercially focused due to their implicit focus on unlocking commercial customer value through the offering and settlement of services

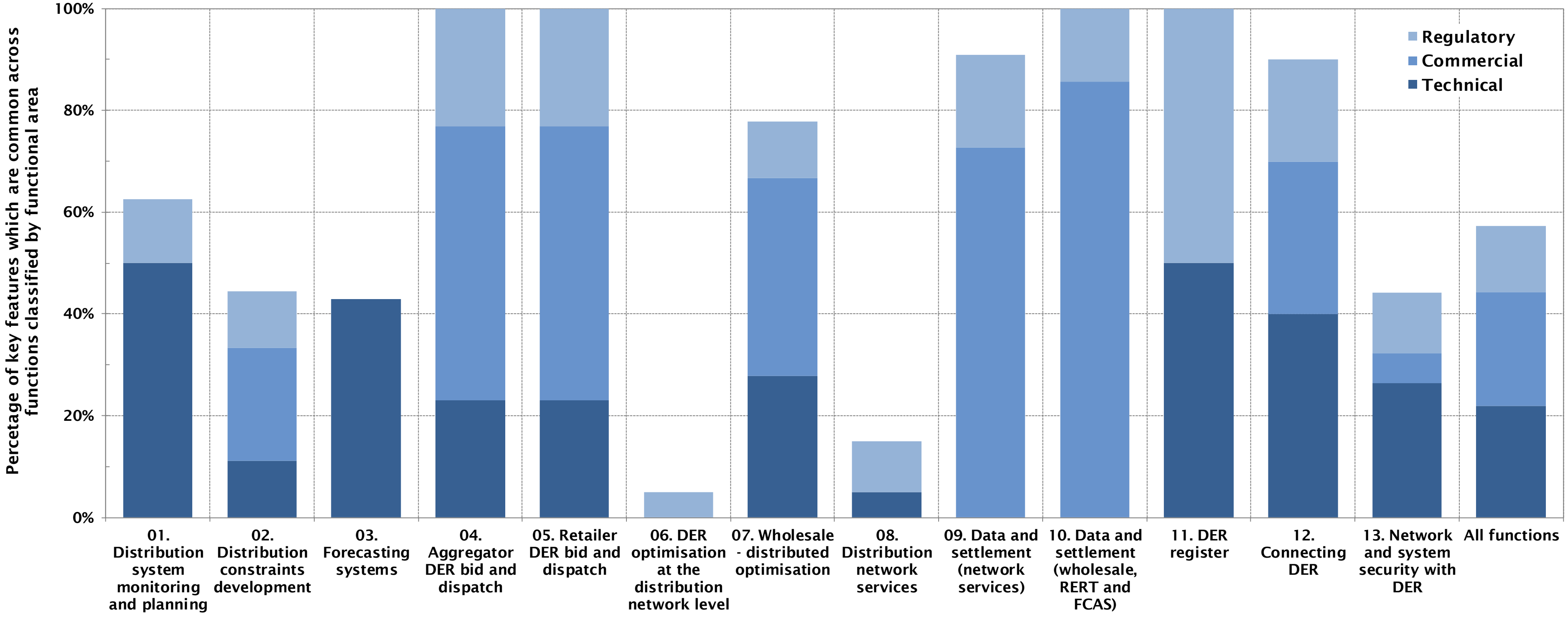


Figure 39 Level of common key features across functions

At the other extreme, Functions 6 and 8 possess the lowest levels of convergence. Across the four frameworks, the primary point of differentiation within the distribution system optimisation process lies in the operation of distribution level markets, particularly markets for distribution network services. Hence, the low commonality within Functions 6 and 8 comes about through the differing ways in which distribution network services are utilised to optimise DER operating envelopes.

In respect to informing the transition pathway to DSO, those functions with high convergence are suitable to begin implementing in the short to medium term. Nonetheless, common key features do exist within functions with low commonality, as will be further discussed in in the next sub-section.

Before moving on however, it is also of interest to examine how commonality or convergence is distributed across the four frameworks. Where a high correlation exists between pairs, we may conclude that there is a high degree of similarity between those frameworks. Table 12 quantifies this for inspection by showing what proportion of key features found in any given framework can also be found in any other given framework. An intuitive understanding of these results is difficult therefore the cells are colour coded to illustrate the amount of correlation that exists for each pair.

Table 12 Levels of convergence of key features between the DSO frameworks

Framework	SIP	TST	IDSO	Hybrid
SIP		92%	74%	99%
TST	91%		74%	91%
IDSO	78%	79%		78%
Hybrid	99%	93%	74%	

(a) All key features

Framework	SIP	TST	IDSO	Hybrid
SIP		83%	59%	99%
TST	82%		59%	84%
IDSO	61%	62%		61%
Hybrid	99%	85%	59%	

(b) Technical key features

Framework	SIP	TST	IDSO	Hybrid
SIP		100%	88%	100%
TST	98%		88%	98%
IDSO	89%	91%		89%
Hybrid	100%	100%	88%	

(c) Commercial key features

Framework	SIP	TST	IDSO	Hybrid
SIP		100%	86%	100%
TST	100%		86%	100%
IDSO	100%	100%		100%
Hybrid	100%	100%	86%	

(d) Regulatory key features

The tables presented are slightly asymmetric in nature. This arises due to the absolute number of key features differing between frameworks, resulting in slightly different proportions. For example, looking at '(d) Regulatory key features' and the SIP-IDSO figures, this table is telling us that 100% of the key features in the SIP transition appear in the IDSO transition, but only 86% of the key features in the IDSO are present within SIP. We can therefore deduce that additional regulatory steps must be taken to realise the IDSO transition as compared to the other frameworks.

Most noteworthy of the results shown in Table 12 is the outlying nature of the IDSO framework across all key features and all functional areas. This is not unexpected, given that the IDSO framework, uniquely, involves the creation of a new entity and is therefore by definition expected to show greater variation from other frameworks. Also of interest, a cursory examination of the colour coding reveals that the greatest divergence across the four frameworks is within those steps identified as lying within the technical functional area. Therefore, while the regulatory and commercial processes within the four frameworks may remain largely common across the four pathways, their technical implementation varies more significantly.

Common key features by function

This section provides visibility of the common key features that come about by identifying convergence across the four DER optimisation frameworks. The common key features, some of which inform the enabling required capabilities, and some of which are chosen as second order least regret recommendations, are summarised in Table 13 below.

Table 13 Summary of common key elements by function and functional area

Function	Common key features
1. Distribution system monitoring and planning	Technical • D-network, T-network and joint system investment plans are created • Aggregator, energy retailer and transmission customers forecast the long-term load and generation profiles of their customers • AEMO gathers data for, and performs, long-term system generation and demand forecasting Regulatory • Regulatory approval of network investment plans
2. Distribution constraints development	Technical • TNSP forecasts and communicates long-term network services requirements to T-network customers Commercial • Aggregator, energy retailer and transmission customers apply to participate in the network services markets Regulatory • Rules or guidance is created to standardise D-network constraint determination
3. Forecasting systems	Technical • Aggregator, energy retailer and transmission customers forecast the short-term load and generation profiles of their customers • TNSP forecasts short-term network state • AEMO forecasts and communicates short-term network services requirements to T-network customers
4 & 5. Aggregator and Retailer DER bid and dispatch	Technical • Aggregator and energy retailer gather data on their portfolios of customers • Aggregator and energy retailer dispatch customers in response to market signals or contractual arrangements Commercial • Aggregator and energy retailer coordinate to develop portfolios of customers • Aggregator and energy retailer apply to participate in the wholesale and FCAS services markets • Aggregator and energy retailer submit offers to the D-NSCAS, wholesale and FCAS services markets Regulatory • Determine aggregator and energy retailer portfolio response when acting as a virtual power plant • Determine process for aggregator and energy retailer customer dispute resolution

Function	Common key features
6. DER optimisation at the distribution network level	Regulatory • Rules or guidelines is created to develop customer operating envelopes within entitlements
7. Wholesale - distributed optimisation	Technical • AEMO forecasts RERT and reserve requirements and dispatches procured RERT as needed • TNSP dispatches bilateral contracts for T-network services • AEMO dispatches the T-NSCAS, wholesale and FCAS services markets Commercial • AEMO procures needed RERT services and reserve capacity • TNSP coordinates with AEMO to procure T-network services • Transmission customers submit offers to the T-NSCAS, wholesale and FCAS services markets • Network services market effectiveness is periodically reviewed Regulatory • Adjust market rules to establish a network services market • Provide guidance on the development and operation of Large Independent Networks (LINs)
8. Distribution network services	Technical • Aggregator and energy retailer demonstrate compliance with network service requirements Regulatory • Rules or guidelines are created on the use of smart grid network solutions • Rules or guidelines are created on the use of bilateral network services contracts out with the market platforms
9. Data and settlement (network services)	Commercial • Metering coordinator and transmission customer provide metering data • Baselining of customers for settlement purposes • Settlement of network services and associated aggregator and energy retailer customer portfolios Regulatory • Cost-recovery of network services expenditure • Determine process for network services dispute resolution

Function	Common key features
10. Data and settlement (wholesale, RERT and FCAS)	Commercial • Metering coordinator and transmission customer provide metering data • Settlement of: RERT, reserve contracts, and wholesale and FCAS services markets Regulatory • Determine process for wholesale and FCAS services market dispute resolution
11. DER register	Regulatory • Establish, maintain and provide access to DER register
12. Connecting DER	Technical • Apply for connection to the distribution network • Design and install DER systems that meet safety and protection standards Commercial • Review the costs of various connection sites and/or offers • Manage DER portfolios in compliance with licence conditions Regulatory • Develop regulatory approved connection offerings • Assess customer compliance with connection agreements and other obligations
13. Network and system security with DER	Technical • Establish thresholds for the emergency operation regime and/or market failure • AEMO establishes distribution network obligations to system security • AEMO procures and dispatches SRAS services • Automatic distribution network regime attempts to restore the system or prevent cascade failure • AEMO signals, oversees and coordinates the system restoration process • AEMO overrides all other network customer dispatch signals to manage whole system security when necessary Commercial • Define customer connection reliability requirements • Aggregator and energy retailer submit offers for the provision of SRAS Regulatory • Determine appropriate incentives for customers to assist with system security • Identify and support vulnerable customers • Review system security events

While Table 13 provides a comprehensive view of the common key features that may be undertaken within the 13 functions to progress towards a DER optimisation framework, some least regrets actions may be subjectively judged to be more important than others. Therefore, Section 5.2.3 of this report will provide succinct recommendations for actions to prioritise based upon the common key features presented within the table above, combined with further results provided in Section 5.2.2 below.

5.2.2 Analysis of wider issues

This section presents analysis of stakeholder feedback gathered thus far. The points described herein were gathered from stakeholders during the workshops and in briefings.

As the four DER optimisation frameworks were being explored during the industry workshops in Melbourne, Sydney, Perth and Brisbane in 2018/19, the stakeholders identified issues that arose that could not be addressed at the time within the 13 DSO functions. These were logged individually and amounted to almost 200 items. Many of these entries have since been addressed through: stated assumptions used in creating the framework metamodels; further discussion with the project steering group; and by identifying entries as concerning 'nice-to-have' features rather than essential elements necessary for DER integration. Further entries were relevant to only a single framework and so are not considered within the analysis of commonality presented in this section of the report.

This report has extracted only those entries that raise questions or reveal issues that require exploration and further work in order to realise *any* of the four future worlds. Less significant, non-urgent and non-framework agnostic issues that may resolve themselves once fundamentals have been established are not discussed.

The next three subsections show the most pertinent questions posed by the stakeholders into each of the three functional areas (technical, commercial and regulatory) of the models, along with some further commentary and exploration of what might need to happen in the areas identified to address these questions. It is important to note that each functional area explored in the subsections below does not constitute an issue that is solely technical, commercial or regulatory; there are always crossovers and overlaps.

A final subsection provides an even broader commentary encompassing the points raised at the briefings conducted in three cities where workshops did not take place.

Technical

Table 14 presents the technical questions posed by stakeholders within workshops that raise issues to be addressed, with further commentary below.

Table 14 Technical questions and issues raised by stakeholders in workshops and briefings

Key area	Questions and issues raised by stakeholders
Network losses	A new regime is needed for calculating and charging for network losses as DER penetrations increase. Stakeholders presented two options: • Calculate losses from more network points • Dynamically calculate loss factors based on local demand vs. generation
Latency of decision making	The time taken to approve bids will impact on both customers and market/network value. It is necessary to investigate the necessary speeds required for bid review and acceptance, as well as to design and test a system that guarantees these requirements can be met

Key area	Questions and issues raised by stakeholders
DER register	Several questions were raised around the DER register: • How to capture existing assets or non-active DER, especially passive DER • How would installers be policed to ensure they pass on information even if mandated as part of their licence? • Multiple pathways are needed for different customers to collect information on all DER connections Market bidding capability (e.g. associated Aggregator or Retailer if applicable) could be useful information to include in the register

- **Network losses** – The way in which network loss factors are calculated and contribute to market price needs to be reviewed because of the increasing penetrations of DER, and the fact that DER can be used to support the network and reduce losses if price signals are used in the right way, at the right place to incentivise their development. This even allows for the use of negative loss factors.
- **Latency of decision making** – The four frameworks place a lot of emphasis on the relatively novel concept of dynamic operating envelopes as well as other dynamic information exchanges. However, if data cannot be processed and decisions transmitted at a sufficient speed and with low enough latency to meet requirements, these dynamic exchanges designed to assist in DER optimisation could in fact prevent it.

Commercial

Table 15 presents the commercial questions posed by stakeholders within workshops that raise issues to be addressed, with further commentary below.

Table 15 Commercial questions and issues raised by stakeholders in workshops and briefings

Key area	Questions posed by stakeholders
Pricing signals	Local pricing signals can be developed to manage customer behaviour out with a market or contractual obligation. Signals can be market driven (i.e. based on the wholesale price of electricity), network driven (i.e. based on local constraints for import / export) or a combination of both
Alternatives to contestable markets	Further consideration is needed for areas where markets reliance may not be suitable (e.g. the WEM, edge of grid, isolated areas) and alternative solutions proposed for these areas
DER value	Further consideration is needed to quantify the value of DER to the network. For example, how much network services providers be compensated

Key area	Questions posed by stakeholders
Market bids	Several issues around the submission and processing of market bids merit further work: • An assessment of the standardised system services (e.g. wholesale energy, FCAS (raise/lower), contingency (fast raise, fast lower, slow raise, slow lower, delayed raise)) that can be provided by DER and under what terms and conditions would provide clarity to aggregators and energy retailers moving forward • It must be recognised that the market platforms may not be able to efficiently accepts bids from all network users. A trade-off exists between: the cost and complexity of the market, and its capability and economic efficiency
Autonomous dispatch	Stakeholders questioned the position of autonomous dispatch within the DER optimisation frameworks (i.e. assets that respond to network conditions such as a frequency deviation without instruction) particularly in regard to rewards for these services
Impacts on vulnerable customers	Understand and mitigate the impacts on vulnerable customers (e.g. those in economic hardship or reliant on electricity for their wellbeing and/or medical needs) in the DER optimisation

- **Pricing signals** – Pricing signals provide a way of externally controlling not only active DER customers, but also passive DER and even traditional customers who do not possess generation, storage, or automatic demand control. By influencing the amount customers must pay for their electricity, either through passing on the market price of electricity or by reflecting local network conditions in customer bills, end-users will be 'nudged' to shift their consumption to cheaper times when the system is able to better cope. However, it is important to ensure pricing signals to not overly conflict. For example, a high wholesale market electricity price may encourage customers to export into a constrained local network.

- **Alternatives to contestable markets** – On a macro scale there will be geographic areas where contestable markets are not suitable. There needs to be separate workstreams to define the characteristics and criteria for these areas and the applicable solutions.

- **DER value and market bids** – As more and more DER connect to the grid and wishes to generate income by providing different system services to the networks, the pricing, bidding and settlement processes become more complex, particularly with opportunities for DER to support both distribution and transmission networks. It is important to work out and understand all the possible routes and interactions associated with a DER's participation in multiple markets, and also the follow-on impacts of this.

- **Autonomous dispatch** – It was the view of some stakeholders that fast, autonomous response will be required to ensure network stability. Rewards for these autonomous solutions should be explored.

- **Impacts on vulnerable customers** – Though on the one hand there are rising numbers of traditional customers purchasing and installing DER, on the other hand there will be network customers who cannot afford these technologies or are otherwise limited. It is important that the network works for all of its customers and provides a fair and equitable solution.

Regulatory

Table 16 presents the commercial questions posed by stakeholders within workshops that raise issues to be addressed, with further commentary below.

Table 16 Regulatory questions and issues raised by stakeholders in workshops and briefings

Key area	Questions posed by stakeholders
Define the aggregator role	Clarification around the role the aggregator will play in the DER optimisation is required around several points: • What is the relationship between the aggregator and energy retailer? Is it necessary to separate or ring fence the operations of the aggregator and energy retailer? When an aggregator and energy retailer are both providing service to the same customer how will they coordinate? • What rules need to exist to ensure aggregators and energy retailers meet their dispatch requirements? Do they require reserve assets to hedge against the failure of an individual customers to comply? • When aggregators and energy retailers are acting as VPPs which rules need to exist on how they offer aggregated bids
Regulator-DNSP dialogue	Stakeholders felt that the current pace of discussion between DNSPs and the regulator is too slow compared to the pace of change in the industry. How can this be sped up?

- **Define the aggregator role** – The development of the aggregator role definition could be supported by examination of the common features across the functions and activities, as set out in Section 5.2.1, to enhance understanding of the role the aggregator is taking in the frameworks. The rules need to consider the different ways in which a DER owner may choose to interact with the aggregator.

- **Regulator-DNSP dialogue** – As the most significant impacts of the changes in the DER optimisation frameworks lie at distribution network level it is important for the regulator to keep in conversation with the DNSPs and related stakeholders about any regulatory changes that could support the integration of DER.

Broader commentary

Finally, it is worth mentioning two of the themes in conversation that have existed throughout the workshop process, and also in other stakeholder briefings.

First, there is a great desire to ensure that this transition process is undertaken in order to benefit the end-user and that before any final decisions are made in regard to which framework to pursue, an assessment of the impact of the four frameworks on the domestic user is undertaken to guarantee that the change is providing value.

Second, it is acknowledged that many of the changes that need to come about to complete the DSO transition require significant investment which will not bring immediate returns or savings. Instead any benefits will accumulate and appear in the medium to long-term. It is important to recognise enacting the recommended actions will not necessarily unlock value right away. Rather, these actions pave the way for the wider DSO transition which will transform the whole electricity sector and aims to bring long term benefits both to networks and customers. An investigation of the value unlocked by the recommendations contained within this report is being pursued by CSIRO and will further address this issue.

5.2.3 Recommended actions

In order to progress with the DSO transition in the near-term, following the completion of the required capabilities described in Section 5.1, the common key features and stakeholder questions gathered in this section have been judged for importance and significance to provide recommendations for the second order actions to prioritise. It is envisioned that actions will be undertaken in a staged manner, and so to assist this, recommendations have been grouped into priority areas where a high degree of synergy exists between the least regret actions. Further, for each priority area we have suggested one of two ways in which it may be pursued:

1. Review and enact - An adjustment to business as usual practices, or current regulatory rules and frameworks, that can be reviewed and enacted across the system in a modest timeframe.

2. Trial - Trials are undertaken to explore best practice to achieve the functionality of the common key features.

Review and enact

Aggregator development

The role of the aggregator must be developed within the electricity system in order to effectively unlock DER value both to customers and the networks. Although some forms of aggregator are beginning to emerge from the distribution networks in Australia today, this process must be accelerated and better controlled so that aggregators fulfil their obligations to the DER optimisation process, as set out within the four DSO frameworks.

Aggregator obligations to network and system security in particular require definition as, without control measures in place, aggregator operation can pose a high risk to network operation. For example, if operating a VPP control scheme, potentially hundreds to thousands of customers may react as a single entity, perhaps in response to a change in energy price. Without a set response profile this stepwise behaviour can introduce high instability to the system.

Initial work in this arena will include better defining the aggregator's role and its relationship with existing energy retailers as a great deal of uncertainty is currently perceived in this area.

Further to this there is a need to work across the industry to fully define the suite of products and services that would be required by network operators as part of the energy system of the future. This would enable aggregators to develop a portfolio of customers through which it can offer these system services.

Connecting customers to network and market platforms can create additional value for DER owners and also provide support to the network. The following recommendations are seen as enablers to this:

R1. Define the aggregator role and required services

R2. Aggregator and energy retailer coordinate to develop portfolios of customers

Collaboration for network forecasting and development

Aggregators have an obligation to assist network operators in forecasting and network development by providing granular long and short-term load and generation profiles of their portfolios based on network, market and customer status. For example: aggregators and retailers must now understand how their customers will respond to changes in market price; or how import / export profiles will alter based on updated customer settings, such as an increased desire for self-consumption for customers with generation assets. The integration of aggregator profiles in network forecasts can be enacted to better understand the impact DER has on the electricity network. This is a significant change from current obligations and is necessary to achieve the level of distribution network forecasting required to develop accurate network constraint models and, subsequently, provide customers with accurate operating envelopes.

Further, network development must also take greater account of DER impact by extending current business as usual investment planning activities (e.g. the transmission level integrated system plan) to place greater emphasis on joint planning between transmission and distribution. The impact of DER on the transmission network or wider system over time may be significant, particularly when considering raw generation export. Increasing levels of DER penetration at lower voltage levels must feature and be considered in the plans of network and market operators traditionally upstream of these resources to successfully manage the power exchange requirements at the transmission-distribution interface. Stakeholders have suggested that joint (transmission and distribution) system plans may be developed at annual joint planning sessions, though the exact means by which this DER planning is integrated across network operators may differ.

Conversely, joint investment planning (and investment planning in general) should remain cognisant that DER can offer alternatives to traditional investment. In the future investment planning should weigh the high cost of fixed assets against the potential risk of non-delivery offered by DER network services.

R3. Aggregators, energy retailers and transmission customers forecast the long-term and short-term load and generation profiles of their customers and portfolios

R4. D-network, T-network and joint system investment plans are created

Trial

Wholesale market trials for DER integration

The most fundamental changes being brought about by the DER optimisation process are in the inclusion of distribution customers in system services markets. As the wholesale electricity market is the most established in Australia it may be used for initial trials for integrating DER into the markets.

A trial approach is most suitable for enacting this component of the DSO transition as DER access to the wholesale market varies depending on the given framework that manifests. From the customer side, there is no functional impact arising through the market access point changing. That is, whether aggregators offer wholesale bids and offers to a central or local platform, the way they interact with the market will not change across frameworks.

Additionally, from the network point of view, communication infrastructure and protocols, and the processes for receiving and clearing market DER bids will be developed regardless of the final framework and these may be ported over at such stage as may be necessary. It is worth noting that the development of the necessary communications infrastructure needed to allow aggregators to respond to market signals in real-time may present a number of challenges and, ultimately, decide the minimum thresholds for participation in the energy markets either in terms of market fees or size of customer portfolio. A lower threshold to market participation is of course preferable (if costs are not prohibitive) as it will enable smaller and more numerous aggregators which will increase customer choice and competition,

Recommended actions to pursue are:

R5. Aggregator and energy retailer apply to participate in the wholesale and FCAS services markets

R6. Aggregator and energy retailer dispatch customers in response to market signals or contractual arrangements

Network services market trials for DER integration

Outside of the established wholesale and FCAS markets there is a strong incidence within the four framework metamodels of network services markets used to: optimise customer operating envelopes within entitlements; or alleviate network constrain as an alternative to traditional network investment. Any transition towards the four DER optimisation frameworks explored must include some consideration towards network services markets. A trial approach is most suitable to undertake this recommendation as in the future DSO world each distribution area may have its own local market for services.

Network services market trials can be established to: gauge the costs and benefits such a market would bring; to better understand the appetites of customers, aggregators, energy retailers, and network operators to participate in such markets; and to determine best practice going forward. However, as part of any market trial, it will be necessary to establish market rules. These are likely to differ per trial area but may be possibly integrated or merged at a later date to develop a final regulatory framework for a network services market. Market rules should at a minimum establish the services being sought and the renumeration process for service providers,

R7. Adjust market rules to establish a network services market

Recommendation 6, which requires the creation of communication infrastructure between aggregators, energy retailers and the market platform to facilitate the use of real-time dispatch signals, is also needed to unlock DER value in network services markets, hence revealing synergy between the recommendations.

One additional area of network services market operation which requires clarity going forward is the use of bilateral contracts. Network support and control ancillary services are currently contracted on a bespoke and bilateral basis. A market platform would aim to standardise this process and allow more dynamic participation A trade-off would ultimately exists between the size of the network services market and the use of bilateral contracts. A larger market allows more opportunity for optimisation and potentially reducing system cost while greater usage of bilateral contracts provide more certainty in managing network constraints. For each trial area a decision may be made as per the use of bilateral contracts and how these might be integrated into the market process.

R8. Rules or guidelines are created on the use of bilateral network services contracts out with the market platforms

Network services market trials for transmission customers

Although the DER optimisation will occur primarily at the distribution network level, stakeholders at industry workshops expressed the view that enhanced optimisation would also occur at the transmission network level. To this end it is recommended that a network services market for transmission customers is also trialled in the near-term, operated by AEMO. Such a market, as envisioned by stakeholders at industry workshops, would entail the TNSP providing AEMO with constraint information on its network in a similar manner to the relationship between DSO and AMEO in the SIP market framework. Transmission customers would likely engage with the AEMO run central market directly.

R9. AEMO dispatches the T-NSCAS, wholesale and FCAS services markets

The advantage of this market trial recommendation is irrespective of which framework manifests the communication links enabling this market will not require alteration. This trial will also bring benefits to transmission network customers, as opposed solely to distribution connected DER customers.

Pricing signals

Workshop stakeholders expressed the view that local control was necessary to unlock the value of DER and allow networks to cope with increasing levels of penetration. However, opinion was mixed as to whether control should be active, passive or a combination of the two.

Active control would place contractual obligations on customers to operate and behave in a prescribed way, either through bilateral contracts or market dispatch signals. Passive control would incentivise all customers (including those not engaged with aggregators) to contribute to system security. This would be achieved through local pricing signals.

Local pricing signals can be market driven (i.e. based on the wholesale price of electricity), network driven (i.e. based on local constraints for import / export) or a combination of both. Trials may be undertaken to better understand customer response to pricing signals and their position in the DSO transition moving forward.

R10. Pricing signals [to be developed]

5.2.4 Recommendations summary

Table 17 summarises the common key features that have been judged to be of high importance and significance and so are categorised as least regrets actions to be pursued in the near-term to build upon the implementation of the required capabilities and further progress the transition to DSO. The table groups recommendations by priority area and provides a suggestion as to whether each action should be enacted across-the-system or trialled in select areas.

Please note that the numbering of recommendations is for referencing only and that this report does not suggest the timing in which these actions should be executed beyond recommending, that in order to reap maximum potential rewards for customers, actions are enacted in the short to medium-term.

Table 17 Summary of least regrets recommendations

Priority area	Recommended actions
	Recommendations to be reviewed and enacted
Aggregator development	R1. Define the aggregator role and required services • Clarification around the role the aggregator will play in DER optimisation and its relationship with the energy retailer • Further, there is a need to work across the industry to define the suite of products and services required by network operators as part of the energy system of the future
	R2. Aggregator and energy retailer coordinate to develop portfolios of customers • Aggregators and energy retailers can begin to further engage with active DER customers to acquire a range of services that it may offer the network or market operators

Priority area	Recommended actions
Collaboration for network forecasting and development	R3. Aggregators, energy retailers and transmission customers forecast the long-term and short-term load and generation profiles of their customers and portfolios • Aggregators and energy retailers have responsibility to provide to network and market operators granular load and generation profiles for their customers and portfolios, both long-term trends and projections and short-term forecasts based on network, market and customer status
	R4. D-network, T-network and joint system investment plans are created • An extension of business as usual investment planning with greater emphasis on joint planning and requiring cost-benefit analysis of the use of network services vs traditional investment routes
Recommendations to be trialled	
Wholesale market for DER integration	R5. Aggregator and energy retailer apply to participate in the wholesale and FCAS services markets • The wholesale electricity market is well established and so may be suitable for initial trials in integrating DER into the markets through aggregators and energy retailers
	R6. Aggregator and energy retailer dispatch customers in response to market signals or contractual arrangements • The creation of communication infrastructure and protocols between aggregators, energy retailers and the market platform to facilitate the use of real-time dispatch signals is needed to unlock DER value
Network services market for DER integration	R7. Adjust market rules to establish a network services market • A trial area for a distribution network services market could be established: to gauge the costs and benefits such a market would bring; to better understand the appetites of customers, aggregators, energy retailers and network operators to participate; and to determine best practice going forward
	R8. Rules or guidance are created on the use of bilateral network services contracts out with the market platforms • Bilateral contracts for network service must be coordinated with market operations and rules established setting out any exclusions on the use of bilateral contracts out with an optimised market platform
Network services market for transmission customers	R9. AEMO dispatches the T-NSCAS, wholesale and FCAS services markets • AEMO may play a role in actively managing T-network constraints by trialling a network services market open to transmission customers

Priority area	Recommended actions
Pricing signals	R10. Pricing signals [to be developed] • Local pricing signals can be developed to manage customer behaviour out with a market or contractual obligation. Signals can be market driven (i.e. based on the wholesale price of electricity), network driven (i.e. based on local constraints for import / export) or a combination of both. Trials may be undertaken to better understand customer response to pricing signals and their position in the DSO transition moving forward

6. Complexity Analysis

The implementation of the DSO transition represents a significant departure from current practice and represents an appreciable risk to the energy industry in terms of both the effort and cost necessary to bring it about. Section 6.1 quantifies the effort required in to realise each of the four DSO frameworks through the application of EA Technology's approach to assessing relative complexity within SGAMs. Further, Section 1.1 will examine the cost drivers both pushing and hampering DER optimisation.

6.1 Relative complexity assessment

A measure of the risk affecting the successful implementation of a given framework can be established through an assessment of the complexity necessary to fully establish the DER optimisation. To determine this, EA Technology has developed a bespoke approach to determine the 'relative complexity' of the DSO frameworks against one another. That is, while we cannot empirically establish the level of effort necessary to complete the transition towards one of the four frameworks in a real-world sense, we can assess the SGAMs of the frameworks in a closed approach to approximate the relative difficulty of implementing each of them.

6.1.1 Method

The lowest-level data captured within the SGAMs are single steps, which together form functional specifications for processes, activities, functions and entire frameworks in turn. In order to assess the relative complexity of the four different frameworks, a measurement was derived by taking each of the steps captured during the workshops and assigning it two values which are summed together to establish the complexity of each step.

The first value (the linkage index) is concerned with the type of link between actors within a step and is designed to show the relative complexity in establishing such a link. For example, providing a SCADA link that facilitates the near-real-time exchange of data is inherently more complex than publishing a charging statement to several connected users.

Therefore, the following set of scores was established for linkage indices to attempt to capture the relative complexity between communication methods between actors:

- Publish = 1
- Contract = 2
- Gateway = 3
- Protection = 3
- SCADA = 5

The second scoring metric is concerned with the magnitude of the actors that are involved in each step: the replication index. This attempts to represent the fact that if the step establishes communication to the Regulator, for example, then this is only one entity with whom the communication is occurring. However, if the communication is with all customers connected to the network then this means there are hundreds of thousands or even millions of instances of it that are present. This scoring metric seeks to capture the complexity associated with having to replicate the communication depending on the actors involved. It should be noted that actors represent functional entities as opposed to discrete businesses, therefore for any given actor there may be a group of organisations or parties that fulfil that actor role.

Therefore, a set of scores shown in Table 18 was established for replication indices based upon the number of players or entities that exist that are serving within each business actor role:

Table 18 Replication index for OpEN-PRJ actors

Replication index	Number of players	Actors in this category
1	~1	ACCC, AEMC, AEMO, Bureau Of Meteorology, CEC, CER, Regulators, COAG-EC, Energy Ombudsman, ECA, Standards Australia
2	<50	Academia, DNSP, DSO, Gas, Heat, IDSO, Judiciary Bodies, Large Independent Networks, TNSP, Transmission connected Generation, Transmission connected Load
3	<150	Aggregator, Energy Service Company, Metering Coordinator
4	<1,000	DER Installer, Equipment Manufacturer, Energy Retailer
5	<1,000,000	Active DER
6	<3,000,000	Passive DER
7	>3,000,000	Traditional Customers

Using this scoring mechanism, every step that was captured within the SGAMs was assessed and scored by adding the linkage index to the replication index. The steps within a given framework or function could then be summed to discover the total complexity index.

6.1.2 Results

In running the complexity analysis for each step of each function the results can be grouped to assess the differences in relative complexity at macro and micro levels. This section compares: the full frameworks; the technical, commercial and regulatory functional areas established in Section 5.2; and finally, the 13 functions.

Frameworks comparison

Figure 40 shows that the relative complexity of the four frameworks is relatively stable, with SIP showing marginally to be the least complex framework, and the IDSO framework the most complex. These findings are to be expected and can be explained by referring back to the underlying structure of each framework as discussed in Section 3.1. The SIP framework has been presented as the most similar to the current market-network model, requiring the least change and complexity to transition towards. Whereas the IDSO framework is the most distinct from current practice, requiring the creation of an entirely new regulated entity to function, adding a greater complexity to the DSO transition.

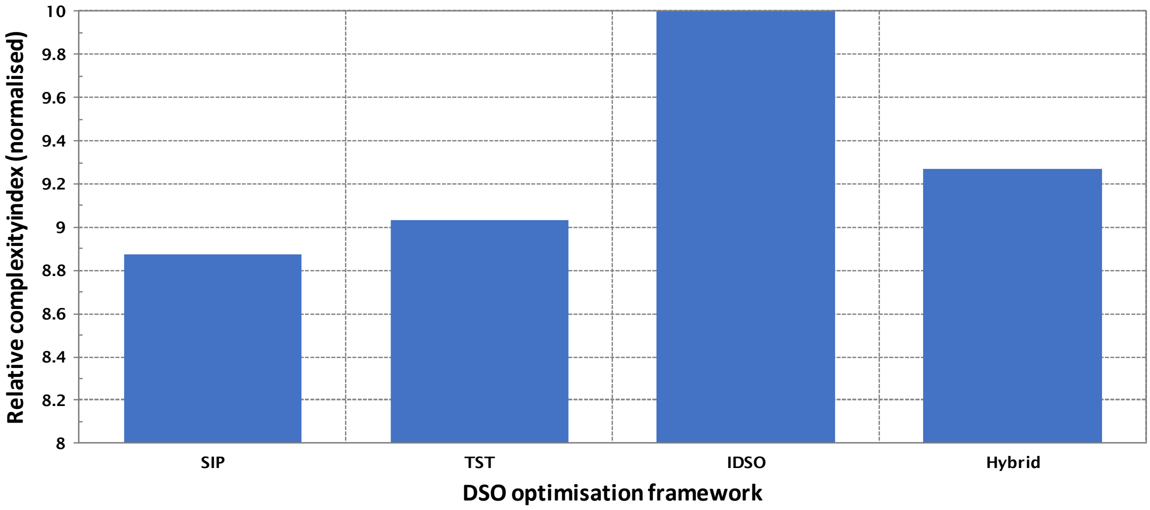


Figure 40 **Relative complexity of the four DSO optimisation frameworks**

The TST shows raised complexity in comparison to the SIP framework due to the required creation of a new market platform that operates in complement to AEMO's central optimisation. Similarly, the hybrid model makes use of a local platform to gather distribution level bids and offers, although in this case it is AEMO operated. To reconcile distribution network operation with AEMO's greater role at the distribution level, additional coordination between AEMO and DSO is present within the hybrid model, pushing the relative complexity slightly above that of the TST framework, where the DSO's greater authority simplifies DSO-AEMO interaction.

Also of interest is the complementary nature these results (and other results within this section of the report) have with those provided in Section 5.2.1, and Table 12 in particular. This is reassuring as it shows that the separate complexity index and common key feature methodologies have generated compatible and supporting results.

Finally, it must be made clear that a greater complexity to complete a given DSO transition pathway is not necessarily a negative indicator. A more complex to implement framework may or may not bring additional benefit to customers and these benefits must be considered together with the complexity in order to form an overall view as to the merits of each framework.

Functional areas comparison

Figure 41 was created to better illustrate the variation in relative complexity that exists between the different types of actions, or functional areas (as introduced in 5.2), that exist within the four frameworks.

The figure illustrates that greater implementation complexity arises from technical and regulatory actions as compared to commercial. The low complexity of the commercial functional area can be attributed to the bilateral nature of many of the commercially focused steps, as well as the slower communication mediums generally employed, e.g. commercial steps use primarily 'publish' or 'contract' communication mediums, whereas the technical steps include 'SCADA' communications which have higher linkage indices due to their more demanding system requirements.

In terms of the absolute number of steps in each category, regardless of the framework, the approximate ratio of steps is 2:3:5 for the regulatory, commercial and technical functional areas. The fact that the regulatory requirements of the frameworks are smallest in the absolute number of steps but introduce such high complexity reflects the difficulty in coordinating industry wide regulatory change amongst all energy sector stakeholders. That is, although the linkage indices (or the complexity of the communication mediums) in the regulatory space are low, many of these steps require consultation and collaboration across the sector, generating significant complexity.

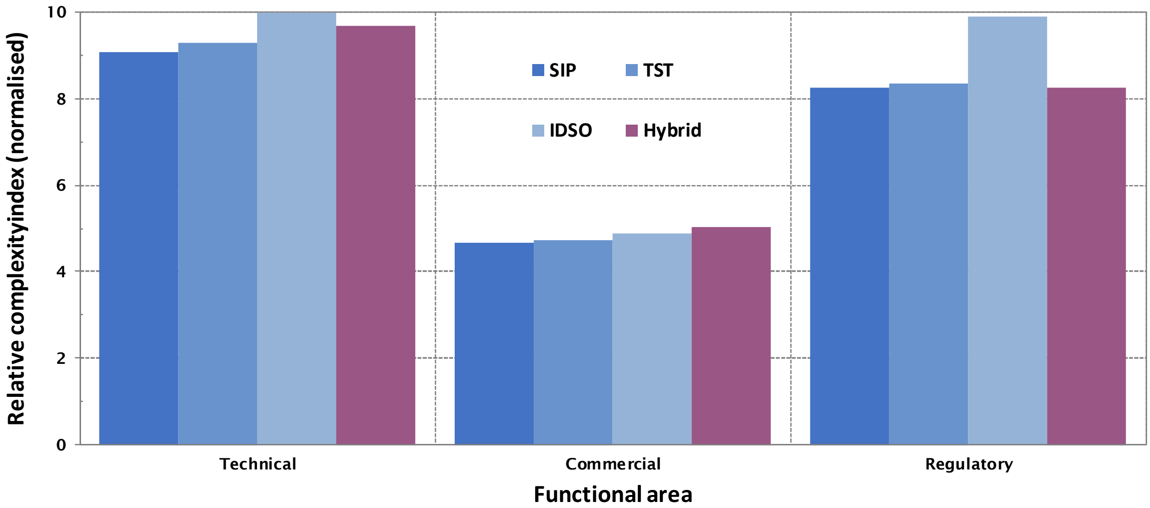


Figure 41 Relative complexity of the three DSO functional areas

Among the three functional areas, the level of technical change required to undertake the DSO transition is greatest. In contrast, Section 5.2 of the report shows that low similarity exists between the frameworks in the technical functional area. Although not a guaranteed result, this low technical similarity between frameworks paired with the high complexity exhibited in this area in Figure 39 allows us to infer that, until a final transition pathway is selected, a large proportion of the complexity required to fully unlock DER potential and bring benefit to customers is essentially 'locked out'. While the required capabilities and secondary least-regret actions we recommend for action in the short to medium-term will allow the industry to progress effectively without an end-point in mind (see Section 5), the utility of this strategy will have diminishing returns when significant levels of change are required in a pathway specific direction.

Frameworks comparison

Figure 42 shows the relative complexity of the 13 DSO functions, averaged and normalised across the four frameworks in order to give an, at a glance, impression of the complexity and effort required to implement.

It is interesting to compare Figure 42 with Figure 39 in Section 5.2.1. There is a misalignment between the functions with a high-level of commonality between frameworks (as shown in Figure 39) and the functions that represent the highest levels of complexity to complete the DSO transition. This further supports the argument made in the function areas comparison presented in the previous subsection in that, these results indicate that a significant amount of the work required to optimise DER and unlock value to customers is 'locked out' until a single transition pathway is selected.

As before, the required capabilities and secondary least-regret action presented in Section 5 will allow industry to begin the necessary changes, but only through selecting, and beginning to implement, an end-destination can the full objectives of the OpEN-PRJ be realised.

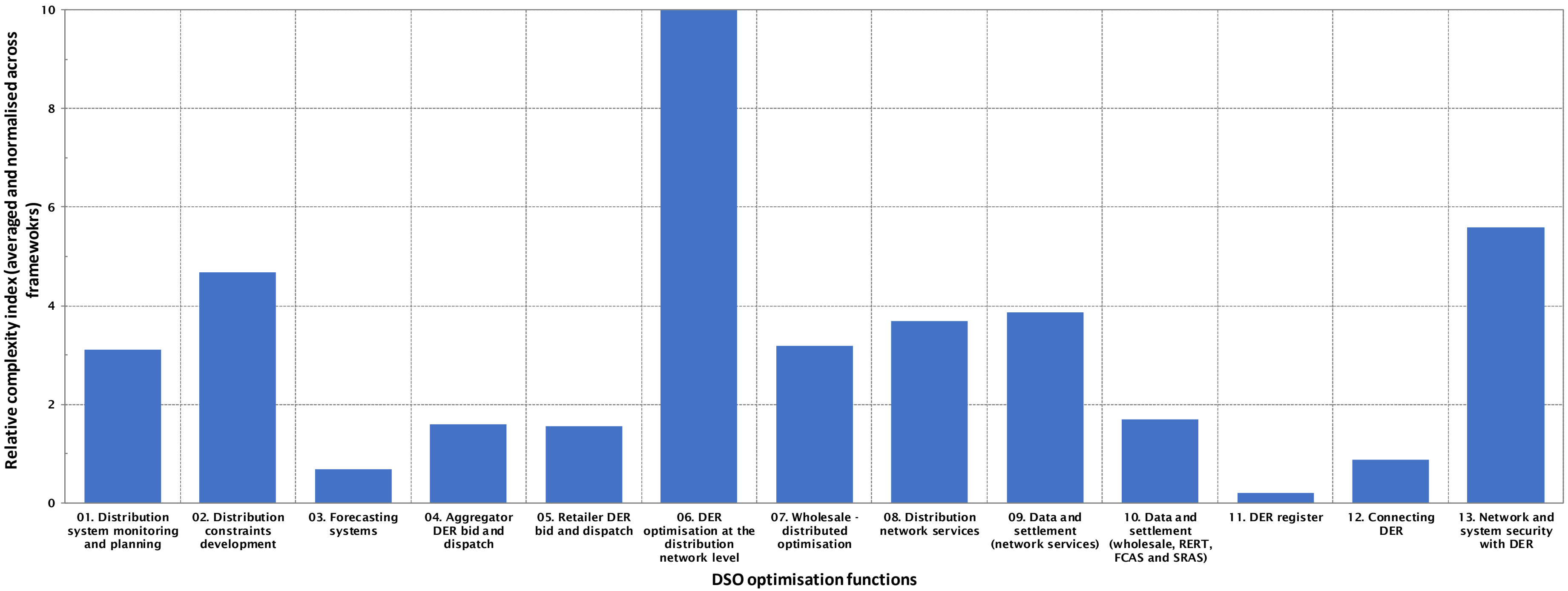


Figure 42 **Relative complexity of the 13 DSO functions (averaged and normalised across the four frameworks)**

1.1 Cost Drivers

The energy system transformation will take time and therefore money to prepare and execute the smooth DSO transition. Several cost drivers exist that will determine the total cost to customers, and this must be weighed against the benefits they will receive through participation in a more decarbonised, decentralised, democratised and digitalised system.

One of the significant and immediate cost drivers for all future models, as indicated by the required capabilities in Section 5.1, is network visibility. There are a number of different ways to achieve LV network visibility, however the most common method will require additional sensors on the distribution network, at substations and on feeders, as well as an adjustment to central IT software systems to allow data processing for the new nodes. There are also ongoing operational costs associated with the required network communications and data flows in the DER optimised world. Nevertheless, network monitoring is a key enabler to active network management systems including demand side management and other DER services.

Additional funding will also need to be procured for customer engagement in the form of dissemination or education, and potentially even specific incentives for participation in an active network management approach, perhaps in the form of tariffs. The size and form of customer incentives will be dependent on a number of factors, including: the energy assets customer possess (e.g. PV, EV or storage); the state of the local network and any requirement for network services; the price of alternative electricity; and the cost of network augmentation or other solutions.

Ultimately, work currently underway by CSIRO will investigate the value unlocked by customers through the DSO transition. This is necessary to allow industry to continue with confidence along the pathway to DER optimisation and will allow the prioritisation of actions that bring most value to customers both in the short and long-term.

7. Pathways and indicators analysis

The Network Transformation Roadmap[20] released in 2017 describes key actions and outlines a series of milestones which provide markers of progress to a decarbonised, decentralised, democratised and digitalised system over the coming years. This report and the accompanying SGAMs describe in more detail what capabilities are needed to be developed, and who is required to be involved, in order to meet the network objective of effectively integrating DER.

In Section 5 of this report we discussed the recommended required capabilities and recommended actions that should be pursued. This also gives an indication of the factors that have the most significant impact on progress in a short to medium-term time scale. We can consider technical, regulatory and commercial progress factors in turn (see Figure 43):

- It can be difficult to predict the time taken to find and develop technical solutions to the appropriate technology readiness level for deployment. In the process of innovation not every investigation or trial leads to a greater understanding of what solutions work and what can be done. Unfortunately, some trials demonstrate what doesn't work.

- For regulatory changes, the current system requires between 40 working days and about 130 working days for a rule change to progress through the AEMC[21] from the point where a rule change request is made to when the final determination is published. National standards, e.g. on communication protocols, can be adopted (with adaptations if necessary) from international standards to support the perpetuation of industry best practice and as a quicker solution than rule changes guidelines.

- Commercial changes need to come after the technical and regulatory foundations have been laid as the technical and regulatory requirements will form the structure for any new markets. The format and operation of the market can follow the pattern of other network services markets making these steps relatively quick to enact compared to some of the technical and regulatory changes. One of the main changes that would have to be made is the establishment of new interfaces either with existing market players into new markets or with new market players on existing markets.

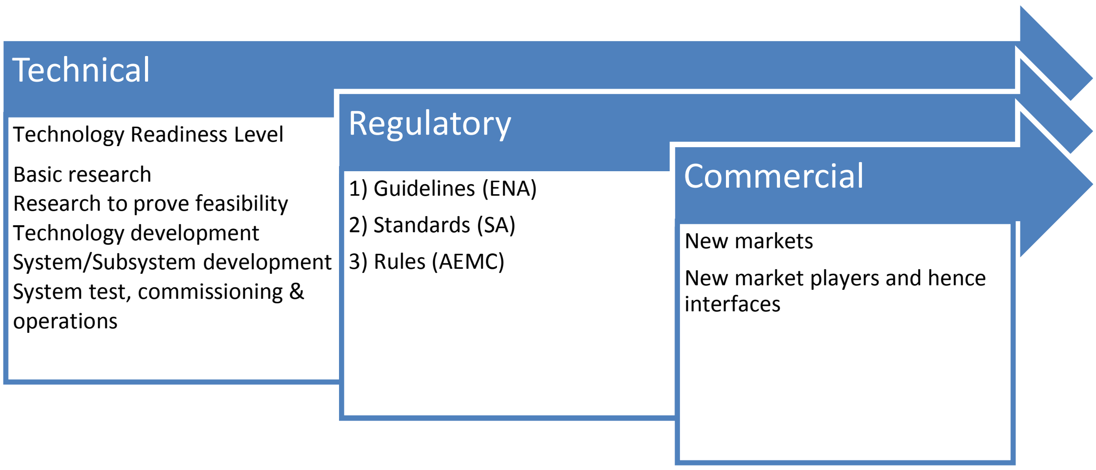


Figure 43 Technical, regulatory and commercial progress factors

[20] "Electricity Network Transformation Roadmap," CSIRO and ENA, Apr. 2017. https://www.energynetworks.com.au/sites/default/files/entr_final_report_web.pdf

[21] "A guide to the rule change process" AEMC, Jun. 2017. https://www.aemc.gov.au/sites/default/files/2018-09/A-guide-to-the-rule-change-process-200617.PDF

When heading into mostly unchartered territory it is sometimes more useful to focus on the positive changes that can be made now as these will provide a better view of what is to come and what needs to happen to keep heading in the correct direction. However, this raises the question of what proxies can be used to assess progress: the breakdown of the SGAMs, the definition of the DSO capabilities (see Figure 44), or some other criteria focusing on the desired outcomes?

- The DSO will take advantage of the opportunities brought by smart grid technologies and an active approach to distribution network management to provide network customers with a safe, secure and reliable network ensuring they receive high-quality network services at value for money
- The realisation of these opportunities will create value by:
  - The **improvement of network planning and operation processes** in order to optimise network investments
  - The **possibility to contract and activate flexibilities** at different timeframes to solve specific network constraints
  - The **ability to facilitate and enable** electricity **markets** in a neutral and transparent way
  - The possibility to provide **regulated services based on data management and provision**, in order to enable network customers' empowerment and to facilitate energy policy development and implementation
  - The **reinforced cooperation between TSOs and DSOs**

Figure 44 DSO opportunities

It is extremely difficult to quantitatively define progress in the transition from today to a future in which the transition to DSO has been made as it is not a linear one-dimensional path. The 'path' resembles the world wide web in structure more than it does the electricity networks. For each new change or solution to work effectively it needs to consider its connections with others both existing and new: changing technologies, emerging actors, updated commercial and regulatory frameworks, etc. The content of each of the linked articles may also need iterative updates for them to work effectively together. A good example of this is the creation of the dynamic operating envelopes and the link between this and the development of: LV network visibility equipment, calculation methodologies, connection guidelines, DER standards and so on.

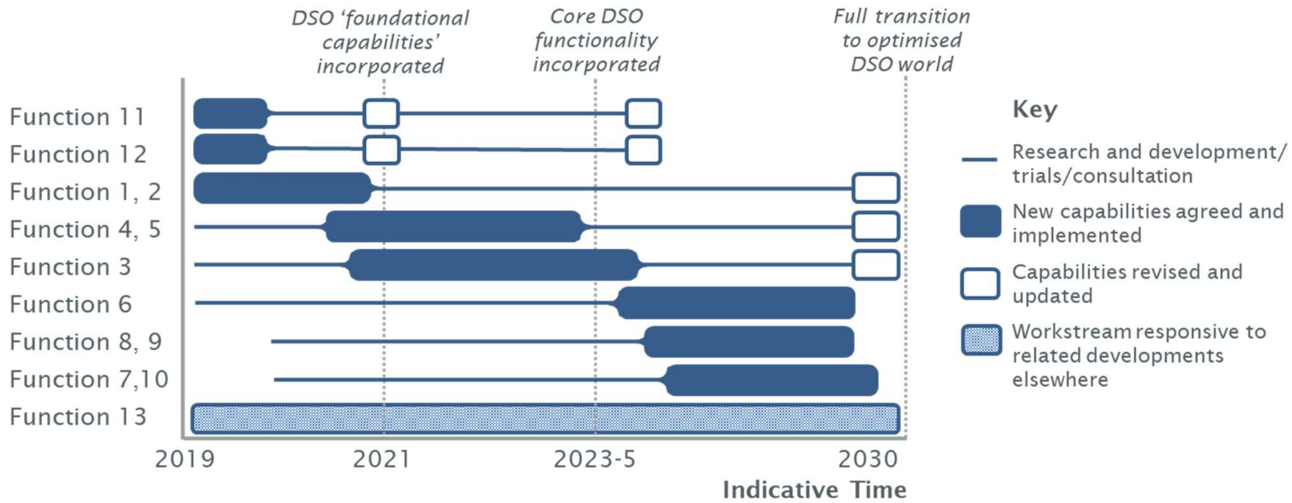
There are organisations and projects looking at generating learning that can be applied to implement the requirements set out by each of the DSO functions. Table 19 highlights some of these key projects whose outputs will provide indicators of progress towards the end goal. Though each of the projects are only listed against one function in Table 19 many of them provide learning that will help the development of a number of functions.

Table 19 Example industry projects and related functions

Industry projects	Related DSO functions
• DEIP Framework Customer Insights Initiative • Distribution Transformer Low Voltage Circuit Monitoring by Energex	1. Distribution system monitoring and planning
• The Evolve project (looking at dynamic operating envelopes) by ANU, Energy Queensland et al.	2. Distribution constraints development
• DEIP Framework Customer Insights Initiative • Impacts of PV, AC, and Other Technologies and Tariffs on Consumer Costs by the Australian PV Institute • Energy Used Data Model by CSIRO • Integrated System Plan by AEMO	3. Forecasting systems
• dEX Platform Development and Testing by Greensync	4 and 5. Aggregator and Retailer Bid and Dispatch
• FPDI: Demand Side Management Technology Testing by CEC	6. DSO optimisation at the distribution level
• AWEFS and ASEFS stakeholder consultation by AEMO	7. Wholesale – distribution optimisation
• Solar Energy Management System for Utilities (by CSIRO Ergon Energy GWA Group • VPP demonstrations by various parties	8. Distribution network services
• A Distributed Energy Market: Consumer & Utility Interest, and the Regulatory Requirements by the Australian PV Institute • Modelling the impact of various tariff structures on distributed energy resource take-up and electricity pricing by SAPN	9 and 10. Data and settlement
• Energy Networks Australia Connection Guidelines Development • Inverter standards development	11 and 12. Connecting DER and the DER Register
• Bruny Island project by TasNetworks • Hornsdale Power Reserve	13. Network and System Security with DER

Figure 45 gives an indication of the order and relative size of the work packages associated with the OpEN functions. Although this diagram represents one possible representation of a transition pathway the order shown needs to be largely upheld, as, for example, it will not be possible to optimise DER without the appropriate DER visibility and network constraint information.

The years shown on the graph are indicative, the incorporation of the 'required capabilities' is predicted to happen shortly after the comprehensive two-year Operating Envelopes project (Evolve). Other years are an estimate and represent average the timelines for the nation. (Some states may get there quicker and some perhaps a little slower depending on the local demands).



Function
11: DER Register
12: Connecting DER
1, 2: Distribution system monitoring and planning / Distribution constraints development
4, 5: Aggregator DER bid and dispatch / Retailer DER bid and dispatch
3: Forecasting systems
6: DER optimisation at the distribution network level
8, 9: Distribution network services / Data and settlement (network services)
7,10: Wholesale – distributed optimisation / Data and settlement (wholesale, RERT, FCAS and SRAS)
13: Network and system security with DER

Figure 45 Pathway diagram: indicative sequence of implementation of functional capabilities.

The solid blue bars in Figure 45 give an indication of when the key changes associated with the function will be decided and implement. There will likely (almost definitely) be work done prior and even post the blue bars. The bars with a blue outline represent a 'round two' refinement of the capability based on knowledge gained from the development of other functions.

Function 13 is represented by a bar across the breadth of the timeline in Figure 45, the intensity of work in this functional area will not be constant over the duration, but members of working groups in this area need to remain vigilant of developments that could have an impact.

7.1 Localised issues analysis

As will become apparent by the evidence provided in this section, although the frameworks have been developed nationally, the progression pathways to their implementation will be highly dependent on localised issues.

Each DNSP is starting from a different position. To understand and track progress it is important to be aware of:

- The 'starting' position
  - The current uptake level of DER (see Figure 46)
  - The network and asset characteristics and capabilities
  - Solutions trialled for applicability and cost-benefit (see Table 19 above)
- The 'end' point
  - The forecast point prior to which interventions in some form will be required in order to maintain reliable and safe supply (see Figure 48 below)
- The factors that will influence the pace of change between these points, e.g. policies and incentives (see Table 20 below)

The starting position

There are many considerations when assessing each DNSPs readiness to transition along the DSO pathway. The current uptake level of DER is an important first consideration (see Figure 46).

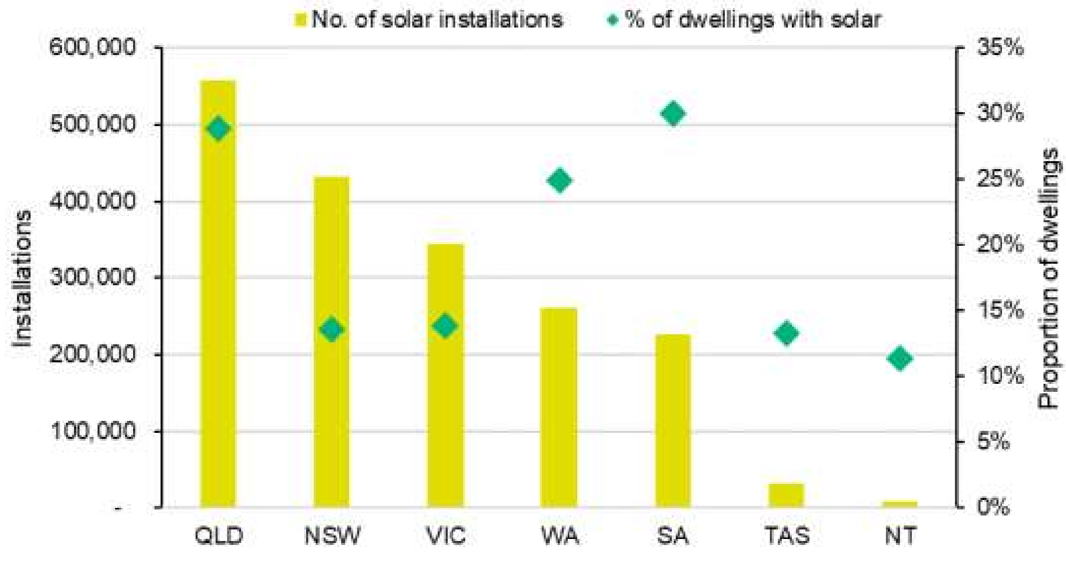


Figure 46 Solar installation by state

Network and asset characteristics and capabilities must also be considered.

- Ageing assets with poorer health are more susceptible to wear and tear from the changing demands placed by DER.
- PV generation causes voltage issues as evidenced by SAPN's increased number of customer enquiries.

- EV charging leads to thermal issues as shown by findings from international projects such as My Electric Avenue.
- Different transformers have different capabilities to be uprated and to accommodate more modern tap-changing mechanisms.

Network topology also has an impact on which solutions are most appropriate. Western Australia for example has many more rural circuits on long, stringy feeders than ACT and the optimum solution in these cases may be to operate these as micro-grids. TasNetwork's Bruny Island project has already found evidence of the savings presented by distributed but coordinated control of multiple, customer-owned battery systems (a virtual power plant) particularly compared to the alternative of maintaining the undersea cable.

The end point

Figure 47 illustrates the potential change in the anticipated demands between 2017 and 2027 for a range of states. In this scale '1' means there is no difference observed, while '2' indicates a doubling in demand and '0.5' a halving in demand. In this scenario of 'Renewables Thrive' (as set out in the Network Transformation Roadmap), it can be observed that there is a level of demand erosion in the middle of the day, with all states seeing different but material reductions. South Australia is the only state which is becoming a net exporter of power by 2027 and this chart illustrates the significant levels of change in the demand profile from those experienced today.

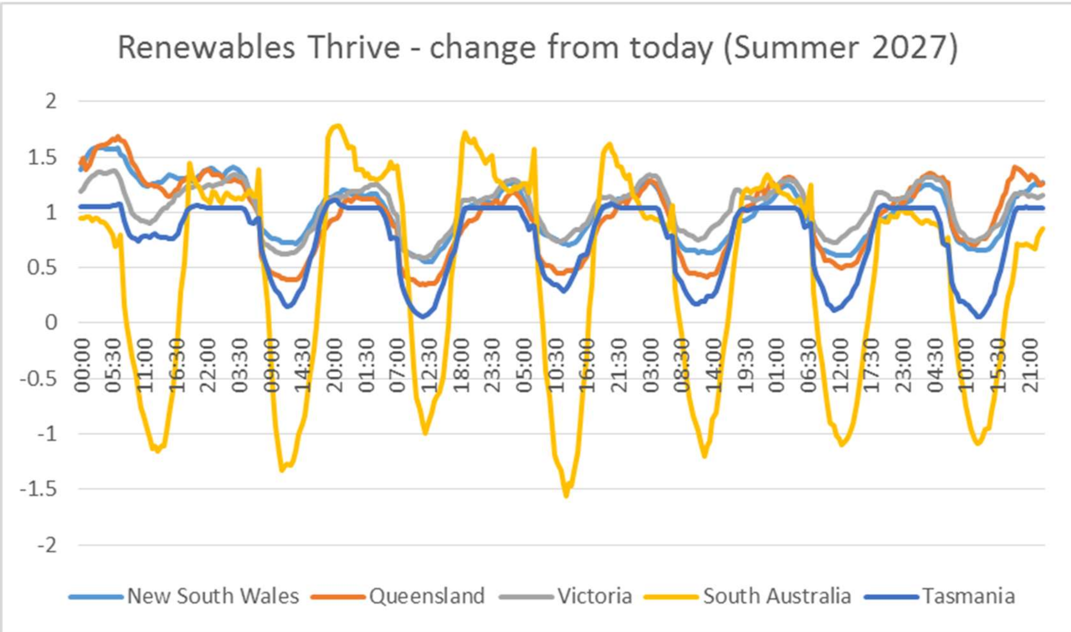


Figure 47 Expected demand by state in 2027 under the Renewables Thrive scenario (source: CSIRO)

Figure 47 presents a forecast that may under or overrepresent what happens in reality, so what means do DNSPs have to track the changes on the LV network? In Victoria the existence of smart meters across the state provides a capability to develop a better understanding of customer profiles. Meanwhile, DNSPs in South Australia and Queensland experiencing the highest penetrations of solar are trialling and using various different solutions to measure and manage the associated challenge. For example, SAPN carried out a project to look at the DER hosting capacity on their networks and extrapolated the findings from this using the Transform Model to understand the network-wide impacts and determine an appropriate strategy for management of the LV network.

The pace with which different states (and hence different DNSPs) will experience sufficiently high penetration of DER to pose material challenges to network operation will vary. Some are already witnessing this, while there will be large portions of the network that will not be affected for some years. Figure 48 illustrates the likely timescale for different zone substations to exhibit reverse power flow owing to local DER, highlighting the variation that exists across the country.

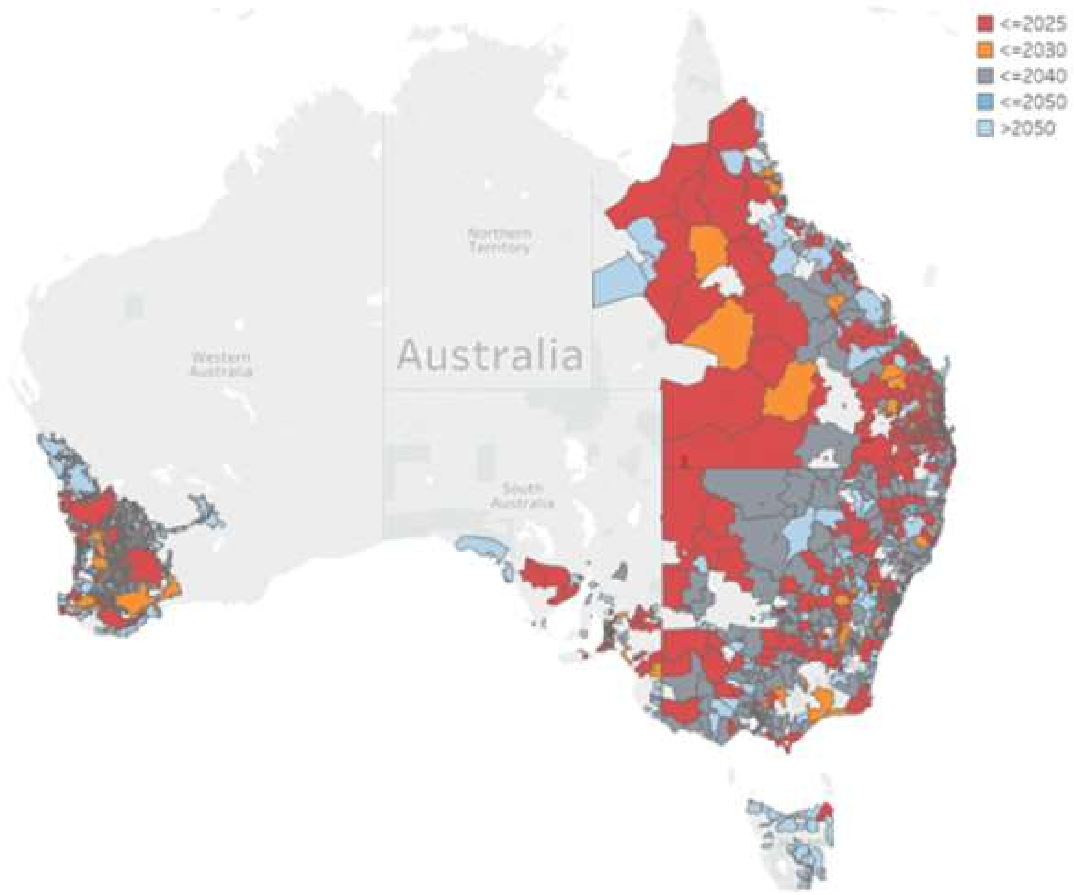


Figure 48 Projected decade in which each zone substation will reach a threshold penetration of rooftop solar adoption (40%) indicative of reverse power flow under the ESOO Neutral DER uptake scenario (forecasts from 2019).

Factors and influences

With forecasts it is important to consider the assumption made in their development and to adjust these as drivers change. The following are some of the matters that will affect the pace of change:

- National and global economic developments
- DER technology costs and availability influenced by research and development activity
  - Technology adoption curves, for example in electric vehicles often show a hockey stick, exponential uptake. However, if incentives for research and development or purchase of new technologies are removed prematurely, they may not have the momentum for this type of growth.
- Government incentives e.g. targets, loans/grants, feed-in tariffs
  - Incentives, such as feed-in tariffs, vary by geographic area. Table 20 shows incentives for battery storage which vary geographically.

Political changes may lead to changes in governmental policies and incentives so it is important to keep up-to-date and consider the impact of political influencers as a change in government policy can drive a rapid change in customer uptake and can lead to issues manifesting more quickly (or slowly) on networks. It has been observed from other sectors and internationally that customers can also change their habits and behaviours relatively quickly (within only a few years), which poses a challenge when considering investments on networks that are designed to cater for the longer term (a few decades).

Table 20 Government incentives for battery energy storage uptake by state.

State/ Territory	Program name	Policy/Incentive	Renewable energy target
ACT	Next Generation Energy Storage	$25 million fund aims to provide subsidised battery storage for 5,000 Canberra homes and businesses by 2020.	100% by 2020
NSW	Smart Energy for Homes & Businesses Smart Batteries for Key Government Buildings	$50 million for up to 200MW (home & business - $1,000 incentive per home). $20 million for up to 13MW (gov buildings).	Supports national Renewable Energy Target
SA	Hornsdale Power Reserve Home Battery Scheme SA Virtual Power Plant	100 MW/129 MWh lithium-ion battery operational. Proposed $100m grants program to facilitate batteries in 40,000 homes. Solar & Batteries for up to 50,000 homes (mix of public housing and privately owned).	Supports national Renewable Energy Target
VIC	Battery Storage Incentive Solar Homes Package	$40 million for up to $5,000 off as many as 10,000 battery systems (on homes with pre-existing solar). $1.34 billion for up to $2,225 off as many as 650,000 solar systems.	25% by 2020 40% by 2025
QLD	Interest – free loans for solar & storage	Loans up to $4,500 for up to 3,500 home solar systems. Loans up to $6,000 and grants up to $3,000 for as many as 500 battery systems. Loans up to $10,000 and grants up to $3,000 for as many as 1,000 solar + battery systems.	50% by 2030
NT		Home Improvement Scheme previously offered up to $4,000 vouchers for purchases including solar and batteries. Participants were required to fund at least 50%.	50% by 2030
TAS		Battery of the Nation pumped hydro feasibility study.	100% by 2022

		Proposed $200,000 micro-grid pilot.	
WA	No specific policy		Supports a national target
Federal	No name yet	$200 million for up to $2,000 off as many as 100,000 home battery systems (max size 4kWh). Further support to bring Australia to one million home battery installations by 2025.	Proposed-dependant on election results

The development of the DSO framework on a national level already suggests that, for example, there may be new national markets developed (by AEMO), while local factors will determine a local actor's choice to participate in those markets.

Although at the start of this section we talk about a 'start' and 'end' position the network transformation is a continuing and interactive process. Each stakeholder's journey will be different and the direction of travel for each may change and in different ways. Being attuned to the evidence provided by the latest industry data is of paramount importance to the successful operation of the future electricity system.

8. Conclusions

8.1 Summary

The primary work developed by EA Technology in the execution of work commissioned by the OpEN-PRJ can be summarised as follows:

- Industry workshops with stakeholders were organised, facilitated and delivered to comprehensively characterise the four DSO frameworks presented within Energy Networks Australia and AEMO's joint consultation paper, allowing for the full functional specification of DER optimisation to be detailed within the 13 DSO functions and associated activities developed within the OpEN-PRJ.

- Content generated within workshops was processed and developed into SGAMs, which provide a structured and coherent way to describe, visualise and interpret the DSO frameworks by capturing the interactions between different actors from a high-level business context down to the detail of what information is exchanged, using what communication methods.

- The overarching required capabilities of the system were identified in recognition of the gap between today's enabling capabilities and those required in any of the future worlds. In addition, comparison across the frameworks allowed the development of recommended actions that can be undertaken following the implementation of the required capabilities to advance the DSO transition in the short to medium-term without regret.

- An assessment of the complexity required to bring about the DSO transition revealed the extent to which unlocking customer value is 'locked out' at present without a clear end-destination in mind for the DSO. Only once a single pathway forward has been decided amongst stakeholders can full DER value be unlocked in the long-term.

- Although the frameworks have been developed nationally, the progression pathways to their implementation will be highly dependent on localised issues and so the indicators which will influence the DSO transition were explored.

8.2 Next steps

The four pathways available within the OpEN-PRJ display similar but not identical levels of relative complexity to implement (as shown in Figure 49) with the IDSO revealed as the most difficult framework to transition to. However, it must be made clear that a greater level of complexity to complete a given DSO transition pathway is not necessarily a negative indicator. A more complex to implement framework may or may not bring additional benefit to customers and these benefits must be considered together with the complexity in order to form an overall view as to the merits of each framework.

While the complexity analysis undertaken in Section 6.1 cannot recommend the correct pathway to pursue it has shown that to progress significantly towards DER optimisation and provide a high-level of value to customers, a single pathway must be selected to unlock full DER potential. Although a long-term consideration, it shows that progress towards a full transition cannot stall without incurring extra cost in the form of high opportunity loss for customers, clearly illustrating the need for industry direction to be established as early as possible.

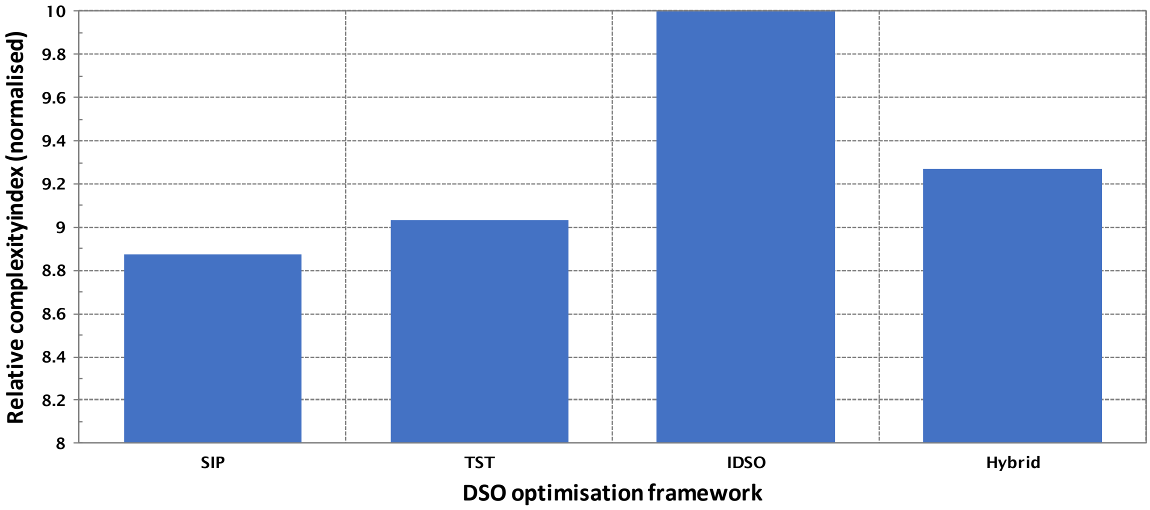


Figure 49 Relative complexity of the four DSO optimisation frameworks

Until confidence grows as to which framework to pursue in the long-term, the required capabilities and recommended actions identified in Section 5 remain valid for progression in the short to medium-term. Figure 50 below summarises the required capabilities and their enabling actions.

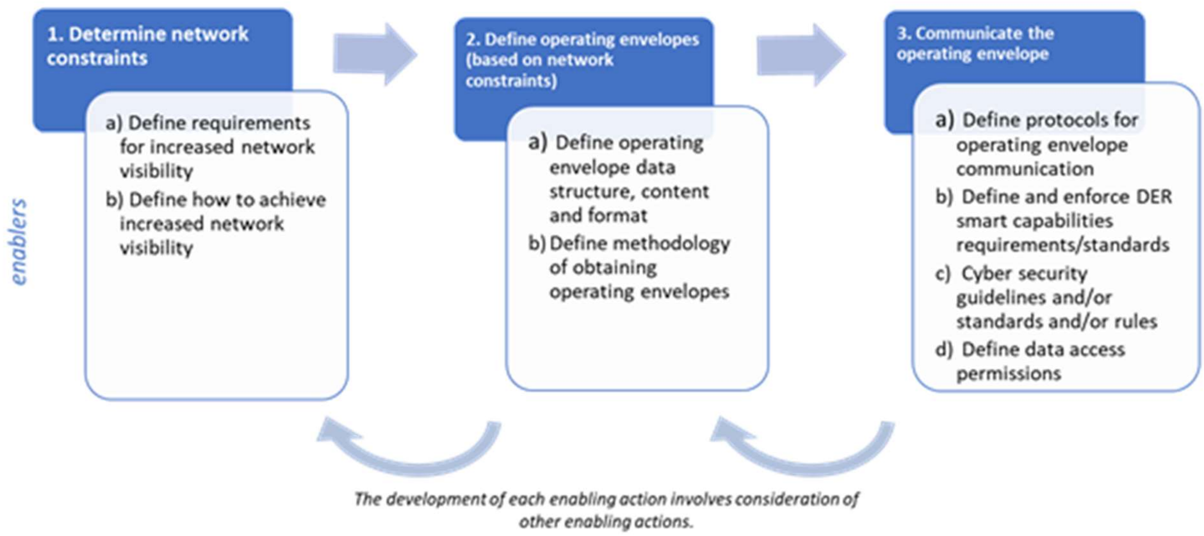


Figure 50 Summary of required capabilities and enabling actions

Regardless which of the four DSO frameworks or hybrid model eventually manifests, ten priority recommended actions have been identified to support the journey towards achieving the transition to an optimised integration of DER in the short to medium-term. As it is envisioned that actions will be undertaken in a staged manner, the recommendations shown have been split into priority areas, and a suggested approach that may be taken to pursue each change towards DSO has been indicated. They are presented in Table 21 below.

Table 21 Summary of recommended actions

Priority area	Recommended actions
	Recommendations to be reviewed and enacted
Aggregator development	R1. Define the aggregator role and required services • Clarification around the role the aggregator will play in DER optimisation and its relationship with the energy retailer • Further, there is a need to work across the industry to define the suite of products and services required by network operators as part of the energy system of the future
	R2. Aggregator and energy retailer coordinate to develop portfolios of customers • Aggregators and energy retailers can begin to further engage with active DER customers to acquire a range of services that it may offer the network or market operators
Collaboration for network forecasting and development	R3. Aggregators, energy retailers and transmission customers forecast the long-term and short-term load and generation profiles of their customers and portfolios • Aggregators and energy retailers have responsibility to provide to network and market operators granular load and generation profiles for their customers and portfolios, both long-term trends and projections and short-term forecasts based on network, market and customer status
	R4. D-network, T-network and joint system investment plans are created • An extension of business as usual investment planning with greater emphasis on joint planning and requiring cost-benefit analysis of the use of network services vs traditional investment routes
	Recommendations to be trialled
Wholesale market for DER integration	R5. Aggregator and energy retailer apply to participate in the wholesale and FCAS services markets • The wholesale electricity market is well established and so may be suitable for initial trials in integrating DER into the markets through aggregators and energy retailers
	R6. Aggregator and energy retailer dispatch customers in response to market signals or contractual arrangements • The creation of communication infrastructure and protocols between aggregators, energy retailers and the market platform to facilitate the use of real-time dispatch signals is needed to unlock DER value

Priority area	Recommended actions
Network services market for DER integration	R7. Adjust market rules to establish a network services market • A trial area for a distribution network services market could be established: to gauge the costs and benefits such a market would bring; to better understand the appetites of customers, aggregators, energy retailers and network operators to participate; and to determine best practice going forward
	R8. Rules or guidance are created on the use of bilateral network services contracts out with the market platforms • Bilateral contracts for network service must be coordinated with market operations and rules established setting out any exclusions on the use of bilateral contracts out with an optimised market platform
Network services market for transmission customers	R9. AEMO dispatches the T-NSCAS, wholesale and FCAS services markets • AEMO may play a role in actively managing T-network constraints by trialling a network services market open to transmission customers
Pricing signals	R10. Pricing signals [to be developed] • Local pricing signals can be developed to manage customer behaviour out with a market or contractual obligation. Signals can be market driven (i.e. based on the wholesale price of electricity), network driven (i.e. based on local constraints for import / export) or a combination of both. Trials may be undertaken to better understand customer response to pricing signals and their position in the DSO transition moving forward

In the immediate future, it is important that stakeholders can feel confidence in the four frameworks, and so they are encouraged to explore the SGAMs developed to represent them. Alongside this, the work developed by CSIRO to explore the economic impacts and benefits of the DER optimisation process will also be available shortly. It is hoped that with a developed understanding of both the frameworks themselves and the impacts associated with them, the industry can begin the process of selecting its desired end-destination for DER optimisation. Once an end-destination for the system has been selected a transition strategy can be developed, at which point the SGAM can be enhanced to define the full physical system architecture necessary to achieve the functional specification currently modelled.

Appendix I DER optimisation functions and activities

1.Distribution system monitoring and planning

No.	Function	Description	Activities	Description
1	Distribution system monitoring and planning	Enhanced function: distribution network monitoring to inform distribution network constraint development.	Gather network data	Gather distribution network data to facilitate distribution network forecasting in collaboration with AEMO and TNSPs.
			Network planning and investment	Plan distribution network design in collaboration with AEMO and TNSPs in order to make traditional and non-traditional investment decisions to satisfy distribution network requirements.

2. Distribution constraints development

No.	Function	Description	Activities	Description
2	Distribution constraints development	New function: to develop distribution network constraints in the form of long-term operating envelopes that will be a key input into the distribution level optimisation.	DER engagement	Identify long-term requirements for DER services to alleviate distribution network constraints and engage with DER to understand the availability and capability of resources to provide services.

3. Forecasting systems

No.	Function	Description	Activities	Description
3	Forecasting systems	New function: provide key forecasting information to allow for distribution level optimisation - may be available to market participants	Forecast short-term network state	Evaluate upcoming short-term network state, giving consideration to end-user response, and determine short-term DER requirements to alleviate distribution network constraints in order to deliver optimised operating envelopes to end-customers.

4. Aggregator DER bid and dispatch

No.	Function	Description	Activities	Description
4	Aggregator DER bid and dispatch	New function: aggregates local DER installation to provide bids into the markets (within provided operating envelopes).	Engage with DER to create Aggregator portfolio	Aggregator engages with and enters into commercial contracts with DER in order to create a portfolio of resources it may offer to other market participants.
			Aggregator bilateral reserve contracts	Aggregator enters into bilateral reserve contracts (short or long-term) to maintain network security and reliability. AEMO and/or the (i)DSO monitors market conditions and if necessary triggers the activation of reserves.
			Aggregator market engagement	Aggregator bids into the wholesale, FCAS, NSCAS and SRAS markets within its provided operating envelope and responds to dispatch instructions.

5. Retailer DER bid and dispatch

No.	Function	Description	Activities	Description
5	Retailer DER bid and dispatch	Enhanced function: retailer aggregates customer DER installations to provide bids into the markets (within provided operating envelope).	Engage with DER to create Retailer portfolio	Retailer engages with and enters into commercial contracts with DER in order to create a portfolio of resources it may offer to other market participants.
			Retailer bilateral contracts	Retailer enters into bilateral reserve contracts (short or long-term) to maintain network security and reliability. AEMO and/or the (i)DSO monitors market conditions and if necessary triggers the activation of reserves.
			Retailer market engagement	Retailer bids into the wholesale, FCAS, NSCAS and SRAS markets within its provided operating envelope and responds to dispatch instructions.

6. DER optimisation at the distribution network level

No.	Function	Description	Activities	Description
6	DER optimisation at the distribution network level	New function: optimise operating envelopes to ensure aggregated bid stacks for DER per area can feed into wholesale optimisation taking account of distribution network constraints.	Optimise operating envelopes of distribution network end-customers	Provide distribution network end-customers with optimised operating envelopes taking account of distribution network constraints.
			Aggregation of wholesale and FCAS market bids	Submit aggregated bid stacks for DER per area that can feed into wholesale optimisation within distribution network operating envelopes.

7. Wholesale - distributed optimisation

No.	Function	Description	Activities	Description
7	Wholesale - distributed optimisation	Enhanced function: integrate distribution level optimisation results into existing wholesale market optimisation.	Update market dispatch engine	Determine and implement a transparent regulatory framework to create an updated network dispatch engine and market processes.
			Determine dispatch schedules for bilateral Reliability and Emergency Reserve Trading (RERT) contracts	Collaborate with market/network operators to determine dispatch schedules and triggers for the activation of RERT contracts.
			Receive transmission network requirements and market offers	Receive TNSP network requirements for constraint management and market offers from transmission network end-customers.
			Receive distribution network market offers and run dispatch engine	Receive market offers from distribution network end-customers and run the dispatch engine for wholesale market optimisation.

8. Distribution network services

No.	Function	Description	Activities	Description
8	Distribution network services	Enhanced function: distribution network services, such as power quality/voltage control, which can be provided by aggregated DER, either through bilateral contract or through an optimisation.	Smart grid network solutions	Collaborate with AEMO to determine a dispatch schedule for DNSP/DSO smart grid network solutions and resolve conflicts.
			Bilateral reserve contracts for D-network support and control ancillary services	DNSP/(i)DSO enters into bilateral reserve contracts (short or long-term) and calls on these reserves to resolve distribution network constraints (non-network solutions).
			D-network market engagement for network support and control ancillary services	DNSP/(i)DSO sends requirements for network support and control ancillary services to the market to resolve distribution network constraints.

9. Data and settlement (network services)

No.	Function	Description	Activities	Description
9	Data and settlement (network services)	Enhanced function: financial settlement of network support and control ancillary services at distribution and transmission level,	Settlement of bilateral contracts for network services	Gather metering data and make agreed availability and activation payments.
			Settlement of NSCAS market	Determine NSCAS market clearing and settlement prices, gather metering data and facilitate payments.
			Dispute resolution (network services)	Resolve disputes between end-customers and network/market operators for network services.

10. Data and settlement (wholesale, RERT, FCAS and SRAS)

No.	Function	Description	Activities	Description
10	Data and settlement (wholesale, RERT, FCAS and SRAS)	Enhanced function: AEMO settles wholesale, FCAS and SRAS transactions at distribution and transmission level. AEMO already settles the existing market to the NMI.	Settlement of bilateral contracts for Reliability and Emergency Reserve Trading (RERT)	Gather metering data and make agreed availability and activation payments.
			Settlement of wholesale, FCAS and SRAS markets	Determine market clearing and settlement prices, gather metering data and facilitate payments.
			Dispute resolution (wholesale, RERT, FCAS and SRAS)	Resolve disputes between end-customers and network/market operators for wholesale, RERT, FCAS and SRAS operation.

11. DER register

No.	Function	Description	Activities	Description
11	DER register	New function: AEMO to provide DER register based on AEMC rule requirements.	Establish, maintain and publish or share DER register data	Periodically gather up-to-date DER information from market participants. Share disaggregated data and publish aggregated locational and technical data of DER with relevant market participants.

12. Connecting DER

No.	Function	Description	Activities	Description
12	Connecting DER	Enhanced function: regulatory, technical and commercial arrangements around the connection of DER to the distribution network.	Determine the regulatory framework for connections	Determine regulatory frameworks and arrangements for the connection of distribution network assets giving consideration to connection types, access rights and queue managements. Includes regulation around the access or sharing of data e.g. from the DER register.
			Connect DER assets	Assess network capacity and requirements for connection within a network area and offer appropriate connection point and connection agreement.
			Manage DER connections	Manage arrangements for the commercial and technical control of connections - as allowed by the signed connection agreement and regulatory frameworks.
			Contribute to DER register	Gather and provide information on DER to AEMO for the purposes of establishing, maintaining and updating a DER register.

13. Network and system security with DER

No.	Function	Description	Activities	Description
13	Network and system security with DER	New function: DER contribution to, and influence on, system security.	Asset security	Determine operational protocols and asset management practices for ensuring DER provide resilience and response to system disturbances (Inc. protection requirements).
			Distribution network security for high impact events	Determine regulatory framework and arrangements for DER to contribute to distribution network security during localised high impact events (e.g. extreme weather, fire, asset damaging accidents and incidents) giving consideration to emergency operating instruction sets and additional emergency DNSP/(i)DSO powers.
			Distribution network security under localised market failure	Determine regulatory framework and arrangements for DER to contribute to distribution network security during localised market failure giving consideration to emergency operating instruction sets and additional emergency DNSP/(i)DSO powers.
			Whole system security	Determine regulatory framework and arrangements for DER to contribute to whole system network security during widespread market failure and/or system emergency giving consideration to emergency operating instruction sets and additional emergency AEMO powers.
			System Restart	Determine arrangements for and actions during system restart with DER for system restart ancillary services.

Appendix II Actor definitions and goals

Active DER

Actor	Definition	Goals
A-DER	Active DER are distribution level network customers with controllable behaviours who can adjust their electricity usage in response to price or dispatch signals. Active DER includes storage solutions, such as household batteries, and energy management systems which incorporate external control inputs or data feeds coordinated by an aggregator or retailer that can be used to actively 'orchestrate' their behaviour in response to high prices or other conditions.	• To be supplied with safe, secure and reliable electricity with high quality of service and at value for money. • Establish commercial relationship with energy suppliers and/or aggregators to maximise revenue from their energy assets through the provision of system services to network / market operators.

Academia

Actor	Definition	Goals
Academia	Academia represents a combination of research centres and resources both domestic and international, such as: universities; colleges; private or publicly funded research councils and institutions; government publications; industry reports; research journals, articles and other publications.	• To provide subject matter expertise on issues facing the energy industry.

Australian Competition and Consumer Commission

Actor	Definition	Goals
ACCC	The Australian Competition and Consumer Commission promotes competition and fair trading in markets to benefit consumers, businesses and the community.	• Ensure that individuals and business comply with Australian competition, fair trading and consumer protection laws – in particular the *Competition and Consumer Act 2010.*

Australian Energy Market Commission

Actor	Definition	Goals
AEMC	The Australian Energy Market Commission creates and amends the National Electricity Rules, National Gas Rules and National Energy Retail Rules. They also act as expert energy policy advisor to the COAG Electricity Council.	• Develop new energy rules as required by legislature. • Review and enact requests for amendments to energy rules. • Provide expert energy policy advice to government.

Australian Energy Market Operator

Actor	Definition	Goals.
AEMO	The Australian Energy Market Operator has responsibility for the management of the National Electricity Market and the Wholesale Electricity Market. AEMO sets the clearing and settlement prices of these markets, determines optimised dispatch schedules, sends out dispatch instructions and facilities market settlement. AEMO is tasked with maintaining the frequency balance, system security and reliability of the electricity network across the five interconnected states through the use of T- and D-network connected energy resources and works with the TNSPs to develop transmission investment plans.	• Facilitate, dispatch and settle the NEW and WEM electricity markets. • Balance the electricity system and maintain frequency. • Coordinate whole system security through defence and restoration plans. • Coordinate with TNSPs to develop transmission investment plants. • Coordinate with (I)DSOs to access D-network connected energy resources.

Aggregator

Actor	Definition	Goals
Agg	An aggregator facilitates the grouping of DER in order to act as a single entity when engaging in power system markets (wholesale, FCAS, NSCAS and SRAS). This grouping cancels out the uncertainties of non-delivery that would exist if only a single small asset was engaging with the markets. Aggregators will enter into commercial arrangements with DER in order to exercise control over their behaviour and adjust their electricity usage.	• To manage its portfolio of DER to maximise benefit to its customers. • To maximise revenue from its portfolio by bidding services into the electricity market and/or establishing bilateral contracts for services.

Bureau of Meteorology

Actor	Definition	Goals
BOM	The Bureau of Meteorology provides national and regional weather forecasts, observations and warnings to the public and industry.	• To provide accurate long and short-term weather forecasts to the public and industry. • To provide accurate and up-to-date information on weather conditions across Australia. • To undertaking meteorological research to better understand and predict Australian weather patterns and trends.

Clean Energy Council

Actor	Definition	Goals
CEC	The Clean Energy Council is an incorporated not-for-profit national association which advocates effective policy to accelerate the development and deployment of all clean energy technologies to transform Australia's energy system to one that is smarter and cleaner. The CEC provides accreditation and approval to organisations and professionals within the solar industry.	• Run the CEC approved retailer list, based on participants signed up to the Solar Retailer Code of Conduct, a way of businesses to show their commitment to responsible sales and marketing activities and solar industry best practice. • Provide access to CPD, technical support and qualification for solar professionals via the CEC Solar Accreditation scheme which grants systems installed by those professionals eligibility for government incentives and rebates. • Advocate for an effective policy and market framework for clean energy while promoting the industry and its achievements.

Clean Energy Regulator

Actor	Definition	Goals
CER	The Clean Energy Regulator administers schemes legislated by the Australian Government for measuring, managing, reducing or offsetting Australia's carbon emissions.	• Provide education and information on the administered schemes. • Collect, analyse, assess, provide and publish information and data on each scheme • Accredit auditors for the administered schemes • Monitor, facilitate and enforce compliance with each scheme. • Work with other law enforcement and regulatory bodies.

Council of Australian Governments Energy Council

Actor	Definition	Goals
COAG-EC	The Council of Australian Governments Energy Council represents federal, state, territorial and local government which work together to develop energy policy that delivers secure, clean, efficient and affordable energy supplies to consumers.	• To deliver a secure and resilient national energy system. • To deliver secure low-carbon energy at the least cost to consumers, taxpayers and the economy. • To reduce carbon emissions cost-effectively. • To secure ambitious international action on climate change. • To manage the nation's energy legacy safely and responsibly.

Distribution Network Service Provider

Actor	Definition	Goals
DNSP	In the 'IDSO optimises distribution level dispatch world' the DNSP will not transition to a DSO business model. Distribution Network Service Providers are responsible for the development and operation of the distribution network following an active network management approach in order to facilitate the secure, safe and reliable delivery of power flows between network connections. To overcome the challenges of increasing DER penetration on their networks DNSPs will engage with IDSOs to facilitate the consideration of distribution network constraints in the whole system dispatch process and, based on network and DER state, provide an operating envelope for all active DER.	• Invest, build, maintain and operate the electricity distribution network to maintain a safe and secure system. • Provide fair and cost-effective distribution network access that meets customer requirements and system needs efficiently. • Provide data / information to facilitate markets and service provision. • Develop smart grid technologies to control distribution network constraints and derive revenue from the electricity markets. • Actively exchanges information with the IDSO to facilitate the consideration of distribution network constraints in the whole system dispatch process. • Facilitate the delivery of a dynamic operating envelope to all aggregators/retailers for all active DER at NMI level.

Distribution System Operator

Actor	Definition	Goals
DSO	To overcome the challenges of increasing DER penetration on their networks DNSPs will transition to Distribution System Operator business models responsible for the development and operation of the distribution network following an active network management approach in order to facilitate the secure, safe and reliable delivery of power flows between network connections. DSOs will engage with the NSCAS market to alleviate distribution network constraints while also supporting the optimised participation of DER assets in the electricity markets through the provision of an operating envelope for all active DER.	• Invest, build, maintain and operate the electricity distribution network to maintain a safe and secure system. • Provide fair and cost-effective distribution network access that meets customer requirements and system needs efficiently. • Provide data / information to facilitate markets and service provision. • Develop smart grid technologies to control distribution network constraints and derive revenue from the electricity markets. • Engage with the NSCAS market to alleviate distribution network constraints. • Facilitate the delivery of a dynamic operating envelope to all aggregators/retailers for all active DER at NMI level.

Energy Ombudsman

Actor	Definition	Goals
E-Ombud	The energy ombudsman resolves and mediates disputes between two sets of parties. End-customers may lodge a complaint with the energy ombudsman against their retailer and/or aggregator. Alternatively, retailers / aggregators may lodge a complaint against a market or network operator. To resolve complaints the energy ombudsman will interpret: bilateral service contracts between parties; market rules; consumer law; and government legislature. It will make a final recommendation for dispute resolution. Subject to jurisdiction, the energy ombudsman may be a government service or an independent not-for-profit NGO.	• To fairly, consistently and transparently resolve disputes between end-customers, retailers, aggregators and market / network operators.

Energy Consumers Australia

Actor	Definition	Goals
ECA	Energy Consumers Australia is an independent organisation created to promote the long-term interests of consumers with respect to the price, quality, safety, reliability and security of supply of energy, and to give residential and small business energy consumers a voice and advocate in the energy market.	• Ensure the consumer impact is considered through the industry change process. • Promote consumer value in industry discussions. • Provide consumer advice and support to other actors. • Ensure appropriate consumer protection arrangements are in place.

Equipment Manufacturer

Actor	Definition	Goals
EM	Equipment manufacturer refers to a technology provider that designs, manufactures and supplies equipment and devices for the electricity network.	• To design, construct and supply products that comply with legal requirements when placed on the market or put into service and that can be used safely and without harm.

Energy Retailer

Actor	Definition	Goals
ER	An energy retailer is a company that primarily acts within the wholesale electricity market in order to buy and sell electricity from/to end-use electricity users. The retailer sets the prices that consumers pay for the electricity that they use and works in a competitive market where customers can choose any energy supplier to provide them with electricity. An energy retailer may enter into commercial arrangements with their DER customers to gain control over their behaviour and adjust their electricity use so that they may engage with the FCAS, NSCAS and SRAS power system markets.	• Buy and sell electricity on the wholesale market to derive revenue from the supply of electricity to customers at value for money. • Establish and mange a portfolio of DER to derive revenue through bidding services into the electricity market and/or establishing bilateral contracts for services.

Energy Service Company

Actor	Definition	Goals
ESCO	Energy service companies provide a broad range of energy solutions to domestic or industrial end-users. These solutions may include any combination of electricity system design, implementation, upgrade, financing and management. ESCO may engage with or take on an aggregator role to derive revenue from its portfolio of customers through the offering of market and/or network services.	• Derive revenue by provide one-off or ongoing energy solutions to domestic or industrial end-users. • Engage with aggregators to derive revenue for itself and its portfolio of customers through the offering o market and/or network services.

Gas

Actor	Definition	Goals
Gas	Gas represents an energy system from which useful gas energy resources can be extracted or recovered either directly or by means of a conversion or transformation process (e.g. conversion of natural gas and derivatives into chemical energy). The gas energy vector makes this energy available for use away (time and space) from its source.	• To meet the gas needs of Australian consumers at value for money.

Heat

Actor	Definition	Goals
Heat	Heat represents an energy system from which useful heat energy resources can be extracted or recovered either directly or by means of a conversion or transformation process (e.g. conversion of heat exchanging fluids into thermal energy). The heat energy vector makes this energy available for use away (time and space) from its source.	• To meet the heat needs of Australian consumers at value for money.

Independent Distribution System Operator

Actor	Definition	Goals
IDSO	In the 'IDSO optimises distribution level dispatch' platform an Independent Distribution System Operator is created as a separate entity for each DNSP. The IDSO is responsible for the transparent and unbiased aggregation of DER market bids, taking into account distribution network limits through close collaboration with the given DNSP, and will allocate dispatch to individual aggregators/retailers based on the exchange schedule across D-network boundary set by AEMO.	• Aggregate DER bids per D-network boundary area to prevent dispatch which will worsen distribution network constraints. • Pass aggregated bids to AEMO to include in the central dispatch process. • Allocates dispatch to individual aggregators/retailers based on the exchange schedule across D-network boundary resultant from AEMO's whole system optimisation process • Collaborate with the DNSP to identify and understand distribution network constraints.

DER Installer

Actor	Definition	Goals
Installer	A DER installer designs a DER system for a customer, selecting the equipment and components necessary for their installation; carries out the installation; and, normally, completes the documentation associated with registering the system for renewable energy certificates.	• Maintain best practice in installation. • Provide customers with peace of mind by maintaining accreditation as installers. • Use accredited, standard compliant equipment and components. • Register DER system for renewable energy certificates.

Judiciary Bodies

Actor	Definition	Goals
JB	Judiciary bodies interpret and apply federal and national legislature and directives at the state and local level to best meet the unique needs and requirements of its citizens. Judiciary bodies may provide state or local level legislature, directives or advice in alignment with national objectives and will facilitate a mechanism and system of courts to resolve disputes between federal and state governments.	• Review federal and national laws, legislature and directives and provide state and local level direction as to their interpretation and implementation as appropriate. • Review and resolve disputes between federal and state or state and local government as they arise.

Large Independent Network

Actor	Definition	Goals
LIN	Large independent networks represent electricity networks which operate out with the National and Western Electricity Markets, most often in remote areas. LINs hold a monopoly position as network provider over a range of end-customers which must be regulated to protect consumers.	• Invest, build, maintain and operate the electricity network to maintain a safe and secure system. • Provide fair and cost-effective network access that meets customer requirements and system needs efficiently. • To derive sufficient regulated income to be profitable.

Metering Coordinator

Actor	Definition	Goals
MC	A metering coordinator will be appointed by an end-customer's retailer and/or aggregator to engage metering service providers in order to perform metering functions for the electricity markets. The MC has responsibility to allow appropriate market or network operators as well as retailers or aggregators visibility of end-user metering information, primarily for settlement purposes.	• To gather end-user metering data and provide it upon request to authorised parties within the electricity markets.

Passive DER

Actor	Definition	Goals
P-DER	Passive DER are distribution level network customers with energy assets such as rooftop PV or batteries, and/or internal energy management systems which operate under local algorithms and are not controllable by third parties through external price or dispatch signals.	• To be supplied with safe, secure and reliable electricity with high quality of service and at value for money. • To derive revenue from their energy assets.

Energy Regulator

Actor	Definition	Goals
Reg	The energy regulator is responsible for regulating the electricity industry. The energy regulator carries out functions to protect the interests of current and future consumers of electricity wherever appropriate by promoting effective competition between persons or entities engaged in the generation, transmission, distribution or supply of electricity.	• Investigate and enforce compliance with national energy legislation and rules. • Monitor market operations including: bidding, prices, forecasts and dispatch. • Drive effective market competition. • Approve standardised offers for connection services. • Hear and determine access disputes regarding access to electricity networks.

Standards Australia

Actor	Definition	Goals
SA	Standards Australia are Australia's representatives of the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC). They develop and adopt internationally-aligned technical standards and related products and services for Australia, though they are not responsible for enforcing, regulating or certifying compliance with those standards.	• Participate in the development and adoption of a wide range of international standards. • Assess and approve other organisations to develop Australian Standards. • Collaborate with Standards New Zealand to develop joint standards where appropriate.

Traditional Customer

Actor	Definition	Goals
TC	Traditional customers are network customers without DER assets or energy management systems and are instead load only customers. They do not respond to dynamic pricing signals or dispatch instructions and they are not engaged with the power system markets. Traditional customers will include end-users from low economic backgrounds without access to financial capital for DER or energy management system engagement.	• To be supplied with safe, secure and reliable electricity with high quality of service and at value for money.

Transmission Network Service Provider

Actor	Definition	Goals
TNSP	Transmission Network Service Providers develop and operate the transmission network areas to facilitate the secure, safe and reliable delivery of power flows between network connections. TNSPs will engage with the NSCAS market to alleviate transmission network constraints and collaborate with AEMO to determine a long term asset investment plan.	• Invest, build, maintain and operate the electricity transmission network in collaboration with AEMO. • Provide fair and cost-effective transmission network access that meets customer requirements and system needs efficiently. • Provide data / information to facilitate markets and service provision. • Engage with the NSCAS market to alleviate transmission network constraints.

Transmission connected Generation

Actor	Definition	Goals
T-Gen	Transmission connected generators (e.g. nuclear, gas powered or coal fired power stations, etc.) are dispatchable assets which can operate in the wholesale and FCAS electricity markets to support the system operator in the matching of supply and demand and in responding to unbalance. Transmission connected generators can also operate in the NSCAS market to offer network services through the increase or reduction of electricity volume being generated.	• Establish a commercial relationship with AEMO and/or the TNSP to derive revenue from the provision of services to the wholesale, FCAS and NSCAS electricity markets.

Transmission connected Load

Actor	Definition	Goals
T-Load	Transmission connected load (e.g. industrial demand such as steelworks, refineries, etc.) are dispatchable assets which can operate in the wholesale and FCAS electricity markets to support the system operator in the matching of supply and demand and in responding to unbalance. Transmission connected generators can also operate in the NSCAS market to offer network services through the increase or reduction of electricity volume being demanded.	• Establish a commercial relationship with AEMO and/or the TNSP to derive revenue from the provision of services to the wholesale, FCAS and NSCAS electricity markets.

Footprint

We provide products, services and support for customers in 90 countries, through our offices in Australia, China, Europe, Singapore, UAE and USA, together with more than 40 distribution partners.

Our Expertise

We provide world-leading asset management solutions for power plant and networks.

Our customers include electricity generation, transmission and distribution companies, together with major power plant operators in the private and public sectors.

- Our products, services, management systems and knowledge enable customers to:
- Prevent outages
- Assess the condition of assets
- Understand why assets fail
- Optimise network operations
- Make smarter investment decisions
- Build smarter grids
- Achieve the latest standards
- Develop their power skills

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