REPORT

NTR: Grid Design, Operation, Platform & Telecoms

Prepared for: Energy Netwokrs Association

Project No: 110020
Document Version: Version 1.0
Date: 29 September 2016

Version History

Date	Version	Author(s)	Notes
29/09/16	Issue 1.0	Tim Butler, Mark Sprawson	Final report for issue.

Final Approval

Approval Type	Date	Version	EA Technology Issue Authority
Final Business	29/09/16	Version 1.0	Dave A Roberts

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Executive summary

Background to the Project

The Electricity Network Transformation Roadmap (NTR) project is being delivered through a partnership between the Energy Networks Association (ENA), the peak electricity network industry body, and Australia's national science agency CSIRO. The project has been informed by the plausible 2050 scenarios defined by the Future Grid Forum, and is seeking to collaboratively develop an integrated program of actions and measures to guide Australia's electricity transition over the critical 2017–27 decade.

This work forms part of Work Package 6. In particular, the focus of this piece of work is on the grid-side architecture, and systems required to enable implementation of highly distributed energy resources that unlock the maximum value for all actors.

It considers the key actions that are required and their associated timescales, identifying any particular challenges or barriers to implementation that exist. In concert with the pieces on innovation and standards, this will form part of the overall roadmap (stage 2) and will identify a prioritised action plan to move forward.

Approach

In order to determine the features and characteristics of the future grid and to assess how we transition from where we are today to this future grid, it is necessary to consider what the functionality of the grid could be and how this could be achieved.

In order to do this, we have positioned ourselves in each of the four future worlds as if we had stepped from a time-machine into these futures. From here we have considered the key actors who exist and the roles that they fulfil. The four future worlds we have considered align with those described in previous Network Transformation Roadmap work, namely: Set and forget; Rise of the prosumer; Leaving the grid; and Renewables thrive.

Within each world we have considered a number of functional use cases that were created by ENA and refined and tested with a wide group of stakeholders at a workshop in Brisbane. We mapped the use cases against the future worlds to determine the applicability and the functions observed and this then informed the detailed consideration of the scenarios. For each scenario, we have mapped the worlds against the Smart Grid Architecture Model (SGAM) framework which describes the various 'layers' of the grid that will need to exist to facilitate the worlds under consideration.

Having performed this detailed mapping exercise, it was then possible to distil the key attributes of the grid in each case and how it has changed from the grid we observe today. This then allows for key areas of similarity and difference to be defined and priorities for key actions to be determined.

Mapping Future Worlds to the Australian Networks

Analysis of data provided by CSIRO has demonstrated that different states will experience different challenges under the various scenarios. This has illustrated that while, for example, South Australia, could experience reverse power flows and becoming a significant net exporter of power within a ten-year time horizon under certain scenarios, others will see demand erosion as their biggest challenge.

The need to monitor customer behaviour and uptake of new technologies that will influence the direction of this demand curve, together with performing the more day-to-day network monitoring to gather information will become crucial in identifying the future world that is emerging and assisting network and system operators in responding in a timely and efficient manner.

Conclusions and Recommendations

The following lists the key actions that should be taken forward with appropriate timescales indicated. These actions constitute a way to progress along a least regrets pathway to ensure the grid of the future will be fit for purpose, irrespective of the precise details regarding the future world which emerges.

Recommendations

Immediate

Increased monitoring – Greater visibility of network data (lagging indicator) and of customer behaviour (leading indicator) are essential in identifying the scenario that is manifesting and informing the necessary timing for further action.

Development of network ready solutions / services – New technological and commercial solutions must be available in an 'off-the-shelf' manner when they are required, meaning that prioritised innovation in this area needs to be undertaken now, lasting for the next 5 years.

Together with this prioritised list, there needs to be a framework established to provide standardised methods of capturing learning associated with: skills, data, customer and system integration

Scenario planning – Investment planning decisions must take due regard of potential future scenarios allowing businesses the opportunities to manage uncertainty and 'flex' to meet changing requirements.

Develop a cross-sector engagement group – In order to address risks around pace of change, a cross-sector engagement group beyond network operators, involving the broader supply chain, regulator, government and new players such as EV manufacturers, aggregators etc. should be initiated, populated by senior individuals.

Agree the various roles of DSR – The use of DSR can be an efficient method to solve different network and system issues, but there are distinct use cases and these should be considered now, in preparation for suitable trials.

Within the next 5 years

The following needs to be started in the short term with an aim to be complete and embedded within 5 years.

Planning tools – Existing tools alone will not be fit for purpose and tools which allow the evaluation of cost-benefits of the range of technological and commercial solutions that will be deployed must be developed.

DNO – DSO business strategy – Each network business should formulate a strategy for how they see their company operating by 2026 and beyond to determine how much of an active role they wish to have in system operation which will in turn inform the market as to the level of gaps that can be filled by new entrants.

- This strategy should include the extent to which the DNO envisages transitioning to a DSO;
- These strategies can then be centrally assimilated by the ENA and communicated to the wider sector, thereby providing information regarding the common base for new participants in the market;
- In turn, this will allow the market to respond and offer those services of greatest value to the various network and system operators.

Trial systems for decentralised control – The need for a distributed control architecture to make decisions and take actions at a local level will be key and this does not exist today meaning it is essential that consideration be given to approaches to perform this function such that they are available in an off-the-shelf manner when required.

Agree DSR arbitrage – As there are multiple roles for DSR that have been explored, it is possible that there will be times when multiple DSR types are called simultaneously by different actors and some form of arbitrage between these will be essential.

Establish DSR communications mechanisms – Set out the communications mechanisms by which the various players in the DSR market will be notified, communicated with and actuated.

Agree DSR requirements with market – Inform the market of the requirement for DSR and agree the commercial rates and mechanisms by which this will be governed.

Review fitness for purpose of charging (DUoS) mechanism – In light of the changes to customer demand that are anticipated, it will be necessary in advance of these changes fully manifesting themselves to explore alternative charging mechanisms looking at capacity and volumetric charging.

Develop a customer engagement strategy – The customer will play a much more active role in the future and in order to raise the profile of this issue as well as that of the DSO and TSO it will be necessary to define a strategy detailing how to communicate with customers along with what and when to communicate.

Develop a data strategy – The amount of data that will be available from the greater numbers of devices installed further into the network will be significant and a strategy regarding how to handle this data from a security, management and efficiency perspective should be developed.

In the next 5 – 10 years

The following needs to be started in the short term with an aim to be complete and embedded within 5 – 10 years.

Evolution of regulatory model – The current regulatory framework will need to be revised to accommodate the various new entrants to the industry, the transition from DNO to DSO and the need for network security to increasingly make use of third parties rather than asset redundancy.

- In each innovative trial that is carried out, establish and capture any regulatory barriers to implementation into business as usual;
- Use benchmarking techniques to learn from other global regulatory models and adopt best practice as and where appropriate.

Systems engineering approach – when considering the deployment of new technology, the holistic impact on the network needs to be considered to ensure that the various solutions are having complementary effects rather than competing with each other in their efforts to manage power flow and local system balancing issues.

- The wider impacts of any new technology deployed on the network needs to be captured. Hence innovative trials should be designed in such a way to ensure this is achieved;
- Replication of trials is essential to demonstrate how technology works in several environments, engaging with different parts of the eco-system, rather than an isolated trial in one area that fails to identify all the potential impacts of new technology interacting with older assets including communications systems, protection, actuators and customers;

- Control loops should be considered to ensure that the smaller loops (e.g. one for a local protection system, another for an automation system etc) interact in such a way so as to fit and coordinate within the overarching control of the broader system;

- Systems engineering is a discipline in its own right and therefore should be considered and addressed through the skills requirements identification process.

Training / education of staff – As new technologies are utilised on the network there is a need to ensure that all staff, particularly existing field staff who will encounter these devices, are fully aware of their operating regime.

- Review the outcomes of the Skills Assessment section of the Network Transformation Roadmap, ensuring that the skills identified in that document are aligned with the future needs set out here. For example, the need to coordinate big data systems management, increased communications requirements, commercial contract establishment, methods of engaging with customers etc;

- As innovative trials are completed, utilise a clear methodology to capture the skills required for successful implementation of the learning

The above recommendations constitute ‘least regrets’ across all potential future scenarios. If it is clear that a certain one of the future worlds is emerging, then the more detailed sections of this report relating to each specific future world should be considered.

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Appendices

1. Introduction

1.1 Background

The Electricity Network Transformation Roadmap (NTR) project is being delivered through a partnership between the Energy Networks Association (ENA), the peak electricity network industry body, and Australia's national science agency CSIRO. The project has been informed by the plausible 2050 scenarios defined by the Future Grid Forum, and is seeking to collaboratively develop an integrated program of actions and measures to guide Australia's electricity transition over the critical 2017–27 decade.

The Roadmap project recognises that modern electricity systems are a complex 'ecosystem' of technical, regulatory, economic and social sub-systems, all of which are experiencing varying degrees of change. The specific 'Work Packages' that develop new content within the Roadmap project broadly include the following within a strongly customer-oriented framework:

- Regulatory frameworks;
- Commercial networks and business models;
- Pricing and market structures;
- Customer-side technologies; and,
- Grid-side technologies.

This work forms part of Work Package 6 (the other components of which include work on innovation strategy and the need for standards development). In particular, the focus of this piece of work is on the grid-side architecture, and systems required to enable implementation of highly distributed energy resources that unlock the maximum value for all actors.

It considers the key actions that are required and their associated timescales, identifying any particular challenges or barriers to implementation that exist. In concert with the pieces on innovation and standards, this will form part of the overall roadmap (stage 2) and will identify a prioritised action plan to move forward.

1.2 Document structure

The document has been structured in the following way:

- Section 2 briefly explores the methodology adopted for this work.
- Section 3 gives a high level summary of today's grid (with more detail in Appendix I) to provide a base starting position from which we will examine the necessary changes over the coming decade.
- Section 4 outlines the four potential future worlds that are being considered in this work, describing their key characteristics and the functions that different actors need to fulfil within them. Greater detail on these future worlds and the various actors, interoperability and communication challenges are described in Appendix II – Appendix V. This section concludes with a summary of some of the key areas of commonality and difference across the future worlds with regard to the technical, commercial, regulatory and business process challenges and barriers that need to be overcome.
- Section 5 summarises the key points from a grid design and operation perspective and identifies key actions and timescales that should be taken in a least regrets manner.

- Section 6 summarises the key points in terms of the successful operating platform for the grid of the future, identifying a number key actions and timescales that should be taken in a least regrets manner.

- Section 7 summarises the challenges around technical enablers and telecommunications, looking at the new links and enabling mechanisms that need to be established and those links that exist today, but require significant modification to enable the efficient operation of the future grid.

- Section 8 looks at the implications for Australia in the macro context, and also seeks to identify the differences that are likely to manifest on a regional (state-wide) level, identifying that different courses of action will be needed in different areas of the country over the decade.

Finally, conclusions and recommendations are presented in Section 9.

2. Methodology

In order to determine the features and characteristics of the future grid in terms of its operation and platform and to assess how we transition from where we are today to this future grid, it is first necessary to consider what the functionality of the grid could be and how this could be achieved.

To this end, a number of approaches have been taken to identify the key functions of the grid under different potential scenarios. From this, it is possible to distil the information relating to the nature of the grid in these potential future worlds and hence establish key areas of commonality that exist between the scenarios. Having identified these areas of commonality, it is then possible to prioritise the key decisions that need to be taken to ensure the grid progresses along the appropriate roadmap to meet the needs of all stakeholders in ten years' time and deliver the appropriate functionality.

In order to do this, we have positioned ourselves in each of the four future worlds as if it were the world of the 2030s and considered the key actors who exist and the roles that they fulfil. The four future worlds we have considered align with those described in previous Network Transformation Roadmap work: Set and forget; Rise of the prosumer; Leaving the grid; and Renewables thrive.

Within each world we have considered a number of functional use cases that were created by ENA and refined and tested with a wide group of stakeholders at a workshop in Brisbane. We mapped the use cases against the future worlds to determine the applicability and the functions observed and this then informed the detailed consideration of the scenarios.

For each scenario, we have created a Smart Grid Architecture Model (SGAM) framework which describes the various 'layers' of the grid that will need to exist to facilitate the worlds under consideration. Onto this framework we have mapped all of the key actors and illustrated their interdependencies and the links that exist between them. This mapping also indicates the 'zone' in which various actors and technologies reside; i.e. whether it is at individual customer level or is across the entire network.

Having performed this detailed mapping exercise it was then possible to distil the key attributes of the grid in each case and how it has changed from the grid we observe today. This then allows for key areas of similarity and difference to be defined and priorities for key actions to be determined.

As we move through time we can observe how the four potential future worlds move further apart, as shown in Figure 1below. For the purpose of this exercise, we are positioning ourselves in the 2030s where the divergence is clear and is accelerating.

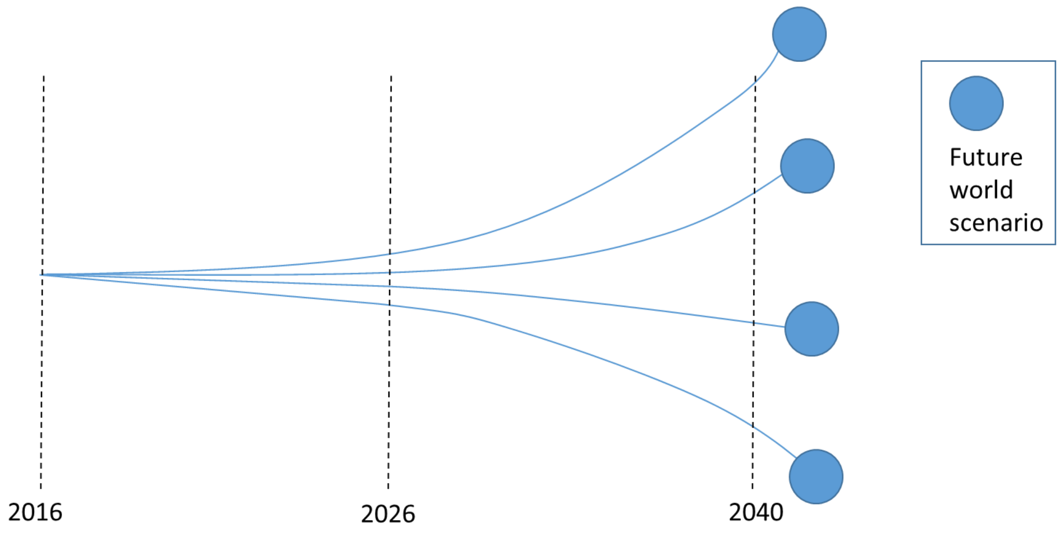


Figure 1 Fan diagram illustrating how each of the four scenarios diverge from each other with time

Each future world scenario is detailed in Appendices II to IV. These have been provided both as the source of material used to inform the thinking for the short-medium term actions, and as stand-alone reference guide for a network operator who may believe that they are more likely to have to accommodate a specific scenario.

3. The Grid Today

In order to effectively analyse future grid architecture, it is necessary to consider the grid of today. This allows for comparisons to be drawn between the today's relatively simple network structure, and the complexity of relationships and actors of the grid of the future. A diagrammatic representation of the key actors and relationships identified to have a crucial role in today's grid are shown in Figure 6 in Appendix 1.

In today's world the role of the customer within the system is limited; their primary relationship is with a retailer who provide with their energy bills. The customer's electricity consumption behaviour is passive but somewhat influenced by their energy pricing structure. Today, high numbers of Australian customers are turning to rooftop solar PV installations to reduce their energy bill. Some also make use of load control systems for appliances such as pool pumps and hot water heaters. Although some customers will have relationships with their DNO, this is limited and mostly occurs during new connections or network faults.

A key role within the existing electricity system is that of the retailer. They act as an interface between the customer; the market operator (AEMO), metering providers and the DNO. Ensuring that the sale and purchase of energy is competitive and that customers' expectations are managed. AEMO manages Australia's National Electricity Market (NEM) and delivers a range of market and planning functions for the energy and power systems.

The role of the distribution network operator (DNO) is one of operation and maintenance of the existing infrastructure as well as restorative and new works. Although they monitor network conditions they cannot be said to act as 'system operators' in the same way as the transmission system operator (TSO). The TSO is responsible for the operation, maintenance and monitoring of the transmission system. They also provide real-time balancing services to the network and liaise directly with central generation and large customers to ensure nationwide network stability. Large (industrial) customers, central generators and storage are also involved in the electricity system although they have peripheral roles with the grid itself and are managed by the TSO, and in some cases the DNO. The majority of electricity is still provided by a few, large central generation facilities.

4. Future World Analysis – Overview

This work focusses on four future world scenarios for the electricity sector and how the grid is affected by the changes from today's world, both during transition and as an end destination. This section presents a brief overview of the key characteristics of the scenarios and the changes to the commercial and technical landscape of the grid. Also, the key similarities and differences are drawn out between the scenarios mainly to inform a view of which issues should be addressed with little uncertainty (i.e. they are prevalent across many scenarios) and those issues which are dependent on specific scenarios.

In the analysis of potential future worlds, we discuss the role of the TSO and the DSO. We acknowledge that, in reality, this role can be fulfilled by both a TSO and a TNSP (Transmission Network Service Provider) and likewise at distribution level by a DSO and DNSP (Distribution Network Service Provider). The extent to which these roles are separate, or delivered by the same body can vary across the future worlds and potentially as a result of individual business strategy and the importance of determining this functionality is referenced within this report.

This is an overview section of the report – additional detail on each of the scenarios and the impacts on the grid are contained in Appendices II to V. A succinct summary of all four scenarios is provided in Appendix VIII.

4.1 Set and Forget

In this scenario residential customers have installed energy storage and local generation, mainly solar PV, along with smart appliances that can alter/reschedule energy demands automatically. Customers set preferences for their use of technology and then contract with service providers to autonomously help them balance their daily requirements for energy with the costs of that energy. Technology will operate in co-ordination with real-time energy pricing, although the management of this will be in the hands of Customer Service Managers rather than customers making repetitive decisions on their energy use themselves.

The electricity market is heavily de-regulated to allow smaller new entities such as Customer Service Managers and/or community groups to trade with limited barriers. The TSO/DSO will form relationships either directly with these, where kWh volumes dictate, or with demand aggregators who aggregate the response from several smaller actors.

The TSO maintains responsibility for system balancing but demand aggregators play a more pivotal role such that there becomes a blurred responsibility between the TSO and aggregators.

A crucial aspect of maintaining the network is providing a high level of visibility through system monitoring and the communication pathways that facilitate demand response/balancing. Monitoring points will be dispersed across the network as demand aggregation will be both location independent for wide-scale balancing and location dependent for asset capability based grid constraints (e.g. thermal and voltage issues).

Overall, operation of the grid is similar to today but with much more emphasis on frequency control as system inertia is reduced and fault level management with increased levels of inverter coupled generation.

The role of the DSO will become more commercially focussed, contracting with various service providers for thermal support, voltage support and fault level services. Voltage and thermal support is a straightforward commercial relationship as demand response is in abundance, maintaining fault level however is a challenge with limited entities able to economically offer a service. The commercial activity between DSO and aggregators competes with energy trading price signals and is a regulatory challenge.

Economically, the TSO/DSO go to the market to assess the costs of addressing network constraints first before infrastructure solutions are considered.

Increasingly the DSO resorts to installing fault level devices across the network to maintain safe levels. The TSO contracts with various large industrial entities to ensure levels of inertia are acceptable. Where services are unavailable the TSO/DSO resorts to installing SVCs energy storage and even flywheels.

Protection schemes, commonly based on rate of change of frequency tripping (RoCoF) are unsuitable with lower levels of inertia. The DSO has rolled out alternative methods such as frequency-forcing or vector-shift. There are cases of permitted islanding where network topology makes this viable and syncrophasor protection is deployed to enable this.

Complex Active Network Management (ANM) solutions are deployed which have a comprehensive visibility of the network and also the contractual/cost position for deploying solutions through either TSO/DSO owned assets (e.g. energy storage) or through third parties. The software contains least-cost algorithms to minimise expenditure.

4.2 Rise of the Prosumer

In this scenario, the customer participates actively in the energy market, with wide-scale adoption of solar generation and installation of energy storage to cater for in-home needs. Customer owned interactive technology is used for energy trading, balancing the needs of the customer and the desire to maximise return on their investment in the technology.

Energy trading is peer-to-peer, based on individual household real-time demands. In this regard the role of the TSO becomes peripheral and largely exists to facilitate stability through increasing inertia. The role of the DSO becomes one to facilitate trading from node-to-node. System balancing is devolved from TSO to DSO in many cases as the demand market is more active at low-voltage nodes.

The regulatory environment has evolved to support the mass-party trading arrangements and to protect customers to ensure affordability of essential energy needs. Many areas of regulation are similar to today’s landscape, with central generation providing base load.

The overall operating context for the TSO/DSO is similar to the Set and Forget scenario but power flows are more dynamic and de-centralised, mostly transferring energy from low voltage to other low voltage and high voltage nodes. The role of the TSO/DSO faces significant change, moving from a central control operating philosophy to a peripheral role as the market and customer behaviour dictate power flows.

The system will see significant generation connected through inverters, which give rise to fault level issues for the DSO. Mitigation will be through procuring fault level services from third parties and the installation of fault level devices where more economical.

A primary function of the TSO/DSO will be to manage and draw down on demand response contracts with aggregators. This will be a combination of location dependent response and regional. Similar to the Set and Forget scenario, the grid will need to become far more visible to the TSO/DSO and third parties.

ANM systems will be ubiquitous on the distribution network, which will take price signals as inputs and seek to find the least expensive solution, communicating with aggregators direct without DSO intervention. The distribution system in particular will be far more interconnected to allow autonomous reconfiguration, decided by ANMs.

RoCoF based protection is largely phased out due to reliability as the system frequency exhibits greater non-fault instability. New methods are rolled out such as frequency-forcing and vector-shift. Islanding is increasingly permitted, enabled through syncrophasor protection devices.

4.3 Leaving the Grid

As customers become more active in the energy system, owning and operating distributed generation, energy storage and energy 'smart' appliances, there becomes less reliance on the grid. As the expense of operating the system has to be met across less kWh import there becomes less justification for staying connected. Customers may choose to leave the grid completely and rely solely on their technology or they may stay connected purely to allow energy trading of spare generation or storage capacity. Overall this scenario leads to less load on the grid, and hence less revenues for the TSO/DSO whilst cost pressures are maintained to support those still connected. The role of the TSO/DSO is relegated to provision of backup services in case customer owned technology fails or to deal with abnormal generation intermittency.

Regulatory changes are developed to attempt to fairly distribute the costs between those reliant on the grid and those not, despite disparity of volumes of energy imported (e.g. ratio of standing charge and per unit charge). Customer protection is needed for those unable to off-grid and those in rural locations where they would face disproportionately high charges compared to city/dense environments.

The lower levels of system inertia lead to installation of SVCs and energy storage where commercial 'inertia services' are unavailable.

RoCoF based protection is largely phased out due to reliability as the system frequency exhibits greater non-fault instability. New methods are rolled out such as frequency-forcing and vector-shift. Islanding is increasingly permitted, enabled through syncrophasor protection devices.

Levels of investment are low due to lower revenues and a tough justification environment with reducing demand. This is partly alleviated through reduced reliability targets and planning standards. This leads to far less infrastructure investment to improve reliability, instead focussing on an operating model of using mobile generation whilst faults are addressed.

As grid defection deepens, maintaining system frequency becomes more challenging as there are less commercial entities with which to contract with for demand services and less revenues to invest in assets such as energy storage.

4.4 Renewables Thrive

This scenario involves the wide-scale deployment of renewable generation across the network from transmission connected large generation to small scale distributed generation such as rooftop PV. Electricity is generated from 96% renewable sources, from a diverse set of technologies (PV, wind, tidal, wave, etc) and a key issue is dealing with frequency variations due to intermittency.

The role of the TSO/DSO remains largely unchanged compared to today's world with the bulk of generation performed by central plants and low voltage connected demand is masked due to the wide-scale adoption of solar PV and within premises energy storage.

The TSO manages demand by engaging with large generators to alter load and generation demands on the network, also engaging with demand aggregators to entice responses from customers through control of their energy storage systems. The DSO accesses response where it is needed on local networks.

Protection systems based on RoCoF become unstable with a system dominated by renewables and other techniques have been deployed such as frequency-forcing and vector-shift. Energy storage is used to mitigate the impact. Islanding becomes beneficial in certain cases, enabled by syncrophasor protection schemes.

Much of the activity of the DSO is commercial management of a series of aggregators to help manage constraints on the distribution system. Where services are scant, infrastructure solutions such as grid-scale energy storage are deployed by the DSO but a more common model is ownership by a third party.

A key function of the DSO, compared to today's operating context, will be to implement and maintain complex Active Network Management systems and associated monitoring and communications systems to alleviate constraints on the network through generation curtailment and demand shifting.

4.5 Key Differences and Similarities between Scenarios

From a grid operation perspective, the four scenarios considered above contain key issues and opportunities that must be addressed to enable the future world. This section draws out some key differences and similarities in the scenarios to inform a future roadmap of innovation required to facilitate the transition.

4.5.1 Key Differences between scenarios

Table 1: Summary of differences seen between scenarios based on key attributes at 2040

	Degree of customer participation	Importance of TSO/DSO role	Degree of technical differences for TSO/DSO	Degree of regulatory changes for TSO/DSO	Volume / $ of TSO/DSO owned solutions	Level of system balancing challenge
Set and Forget	2/4	3/4	3/4	3/4	2/4	3/4
Rise of the Prosumer	3/4	2/4	3/4	4/4	3/4	2/4
Leaving the Grid	4/4	1/4	4/4	2/4	1/4	4/4
Renewables Thrive	1/4	4/4	1/4	1/4	4/4	1/4

An accompanying narrative to support the above graphic is provided below.

	Degree of customer activeness	**Importance of TSO/DSO role**	**Degree of technical differences for TSO/DSO**	**Degree of regulatory changes for TSO/DSO**	**Volume / $ of TSO/DSO solutions**	**Level of system balancing challenge**
Set and Forget	Customers own technology but play a passive role in day-to-day energy management	The distribution system carries most power-flows with less importance on the transmission system as the network becomes more locally balanced	Negotiating and maintained commercial contracts with third parties will form a major activity for the DSO	Some changes needed to protect customers and allow new entrants into the energy markets	DSO in particular will need to invest to achieve much greater visibility of the network. Infrastructure solutions will only be made where the market is more expensive	Balancing is primarily achieved by contracting with third party aggregators/service providers
Rise of the Prosumer	Customers invest in energy management devices and actively participate in markets to achieve better returns	The distribution system carries most power-flows with less importance on the transmission system as the network becomes more locally balanced	Negotiating and maintained commercial contracts with third parties will form a major activity for the DSO	Significant changes will be needed to protect customers and facilitate a very active and dynamic energy market	DSO in particular will need to invest to achieve much greater visibility of the network. Infrastructure solutions will only be made where the market is more expensive	Generation means that balancing is primarily achieved by contracting with many third party aggregators/service providers
Leaving the Grid	Customers adapt their behaviour and extensively use their own technology to balance demand and generation	Role is limited to providing a resilience service and a means to serve electricity to those who cannot generate their own	Little difference initially as power-flows begin to reduce. As the system becomes extensively deloaded, stability issues will occur	Little change, although asset management cost justification may become more complex on increasingly under-utilised assets	Little investment in solutions needed.	Balancing longer term becomes a larger issue as more reliance is placed on fewer participants, with likely less income to find solutions
Renewables Thrive	More energy delivered by larger high voltage connected generation plant	The high voltage grid continues to be the backbone of the electricity network	Little operating change but large scale energy storage will feature extensively to deal with renewables intermittency	Most changes will be centred around incentivising renewable generation that accounts for the benefit of stable generation	High value assets such as energy storage needed for balancing	Balancing largely achieved with demand/generation response contract with few large generators and demand aggregators. Little change

4.5.2 Key issues prevalent to all scenarios

Whilst there are a number of differences, there are areas of commonality. This common ground represents a rich seam of activity which needs be explored in order to ensure the grid and its supporting infrastructure is fit for purpose into the future.

Protection Methods - Today's methods for network protection are unsuitable for all the future scenarios. Protection based around sensing of RoCoF will become unstable as system inertia reduces and larger (non-fault) variations in frequency are commonplace. It will be necessary to investigate and trial alternative protection mechanisms that exhibit better stability, such as frequency-forcing, where grid parameters such as frequency variations and voltage dips are more commonplace.

Network Visibility - All scenarios involve third parties in a variety of roles interacting with the grid in real-time: to make decisions on device discrete operation to keep the grid in normal operation, to facilitate network-led price signals, or to allow groups of customers to change behaviour based on local grid constraints. All these require real-time access to monitoring data. This gives rise to the requirement for a cheap, reliable and open monitoring and communications platform.

Energy Storage - The levels of deployed energy storage will increase significantly across all scenarios. The will range from high volumes of very small (domestic level) installations through to much larger units which may be operated directly by the DSO/TSO or controlled by a third party who offers services to the networks for balancing and constraint management. In order to ensure the mechanism for storage to be used is consistent, there will need to be an appropriate market structure established and sufficient competition in place to keep the prices at a level where there is value to the grid. Some form of hierarchy to determine how the services will be called should be established to permit its use for balancing, energy supplier price hedging and local constraint management. In order for all this to happen, appropriate communications between all parties will need to be introduced, capable of operating with the reliability and latency necessary to make storage a fundamental part of the energy system of the future.

Active Network Management - Far greater levels of control and management within the distribution network in particular will be required. This will need to be dynamic and flexible to respond to conditions at different times of day in real time and will require the need for consistent, open and flexible systems to ensure the present needs along with those of the future can be met. There will therefore need to be suitable communications and open standards in place that will permit new entrants to the market to help offer this flexibility and provide solutions to networks that can be readily and cost-effectively deployed. All of this will also require greater levels of intelligence and decisions-making to be performed deeper into the network with a decentralised ort hierarchical control system in operation.

Prolific use of Aggregators - In all future worlds, the growing role of aggregators can be seen to be a key element of the overall system. They will offer services for balancing at a system level, but also for constraint management at a much more local network level. In order to fulfil these various roles, aggregators may be geography specific, customer specific (focusing on large commercial or small domestic customers etc.) or technology specific, whereby they offer services related to electric vehicle charging, heating and cooling demand, or indeed related to specific manufacturers (hooking into systems provided by large technology firms, such as Google with Nest, their home energy management system. For this market to succeed, there must be a common structure for parties to operate within, allowing sufficient competition to emerge and keep the costs at a level where value is offered to the network and system operators. Also standardised communications and operating interfaces will be necessary to ensure that the market remains open to new entrants.

Field Operations Training and Awareness - The future electricity network will contain significant additional complexity for field staff primarily regarding increased automation and remote control, different protection methods being applied and the prospect of system islanding. Field operational staff are at the sharp end of these changes. The resources needed for training of staff is often hugely underestimated. It has been shown to be beneficial to heavily involve field staff during trial and demonstration stages of innovation projects to allow the departments to become aware of future drivers and adapt to change gradually and efficiently.

5. Summary: Grid Design and Operation

When compared with the grid today, irrespective of the future world that manifests itself, it is clear that the complexity of the sector in ten years' time and beyond will increase with a range of new entrants to the marketplace providing critical services. It is important to note that the network remains an essential service, although the precise nature of the functions it fulfils will vary from today and are likely to be different in different areas of Australia depending on the customer base.

The reason for this is that customer dependence on electricity is set to increase as it becomes more normal to use electricity not just for lighting, cooking and entertainment, but also for cooling, heating and for transport. The fact that customers are increasingly dependent on electricity does not, however, mean that they are necessarily more dependent on the electricity grid. The increased availability of generation and storage technologies has the effect of reducing the demand placed on the grid in the conventional sense, but brings with it different challenges that network and system operators will have to overcome.

While there will still be a need for the network to exist and there will still be some traditional roles fulfilled by distribution and transmission companies, there will also be some changes. The TSO is likely to retain ownership of system balancing and engagement with centrally dispatched generation. Over the time to 2026, it is likely that there will be some instances where the distribution network operator takes on a system operator role and begins to perform some local balancing. While this will only be in certain areas initially, it is expected to become more widespread in the 2030s. Indeed, the rate at which companies transition from being a DNO to a DSO does vary depending on the particular scenario that emerges, but this also depends on the appetite of the distribution businesses to take on this role. They could accelerate this transition if it aligned with their wider strategy, or alternatively they could be more passive choosing to procure services from other parties and essentially 'contract out' a large amount of the tasks required of a system operator function.

The DSO will need to be able to respond to the fact that customer behaviour is changing. It is important to acknowledge the pace of this change as customers have the ability to move much more quickly than the networks that serve them. If customers choose to install generation and a storage system and purchase an electric vehicle, they can do this in a matter of months. Networks on the other hand are designed with decades of intended use in mind. New assets that are installed are envisaged to operate in the same way for 40 – 50 years. A rapid change in customer demands and technologies is much more difficult for network businesses to rapidly respond to in an efficient manner.

Historically, network businesses have used previous trends in load growth to inform the likely future demands that the network will see, but these historic trends will not be accurate predictors of future load and nor will there be any indication form such measures of the likely pace of change. This will force network operators to re-evaluate the means by which they make network and investment planning decisions, and will also have significant repercussions for the regulatory landscape.

Network operators take decisions for investment based on the best available information at the time that the decision needs to be made. However, as a consequence of the level of uncertainty surrounding future load experienced by the network, there is a very real possibility that as the world changes, reactive action may be necessary. This might mean that assets installed only a few years ago are no longer delivering value to customers as the load levels that existed some years ago are no longer present to justify the need for such assets. Therefore, it may make sense to re-deploy some of these assets to other portions of the network where demand erosion is not occurring to the same degree as the customer base is different. Similarly, the approach to asset replacement, which may previously have been on a like-for-like basis, will now be much more on a case-by-case basis to determine whether the replacement is necessary or if the demand needs can be met by some alternative arrangements.

The regulatory structure needs to acknowledge these potential issues and make suitable allowance for them. Furthermore, as loads reduce, the need for current levels of redundancy in the network will, in some cases, be reduced. Rather than offering dual supplies to certain areas to allow for outages, it may make more economic sense to have a single supply, backed up by some generation or storage owned by the network operator or by a third party that can be called upon in the event of interruptions as an alternative to having greater volumes of very lightly utilised assets. Such approaches to providing capacity are more dependent on operational expenditure (such as contracts for services from a third party) rather than capital expenditure and an appropriate regulatory treatment would need to be in operation to allow such investment decisions to be balanced against the traditional methods of providing redundancy. The regulatory structure therefore needs to accommodate the new players in the market and provide sufficient opportunity and incentive for DSO and TSO to engage with these actors.

The changes in customer behaviour and adoption of new technologies result in a number of technical challenges with which networks need to resolve. At a macro level, the replacement of traditional centralised generation with increased intermittent renewable generation has the effect of significantly reducing the level of system inertia and also the fault levels across all of the future world scenarios.

This is exacerbated at a local level through the widespread uptake of small scale generation and increased levels of self-sufficiency through generation and storage, which has the effect of significantly reducing the demand levels seen at certain times of day and year. The challenge of trying to accommodate the much more significant swings in power flow that therefore occur (the difference between maximum and minimum demands at a local level increases) leads to balancing issues. The proliferation of generation also results in greater voltage variation as the voltage can be high at times of export, and then swing to a much lower level at times of maximum demand, giving rise to the need to have greater control of voltage further into the network. It is also likely that power quality issues will increase in certain portions of the network as a result of the lower fault levels (a less electrically stiff system therefore being present) and the increased connection of technologies at the customer-side which can increase harmonic levels and contribute to voltage flicker. Across the network, the management of frequency will be more of a challenge and RoCoF will not be fit-for-purpose. There is therefore a need to explore alternative protection arrangements such as the deployment of syncrophasor protection schemes or ‘frequency forcing’ measures (which involve setting the governor of generators to force tripping under certain conditions).

In order to cope with these challenges, the network needs to evolve from its current position of behaving in a passive manner at the lower voltages to a much more actively managed system with far greater reach and control of voltage and power flow through increased numbers of switching points and regulation devices at the lower voltages that need to be managed and controlled throughout the day to reflect the changing needs. In order to maintain local balancing, we will begin to see some delegated authority for frequency control from the TSO to the DSO in certain areas by 2026 and this will become much more commonplace as we progress through the 2030s. Network operators will engage in a much more proactive manner with aggregators and service providers to ensure system balancing is maintained and the levels of storage that are prevalent on the network and can be called upon from a range of sources (either owned by the network, service providers or procured via aggregators of numerous small-scale customer installations, will increase significantly.

The far greater variety of technological solutions that will be deployed on the network necessitate a more holistic approach to network planning and design. It is not sufficient to consider issues and devices in isolation, but instead the impacts of greater voltage regulation within the network, for example, must be considered along with the impact this has on the network both upstream and downstream. In short, a systems engineering approach will be required whereby the management of the wider system needs to be considered at all times and appropriate distributed or hierarchical control structures will be in place to report back on network conditions to a central hub while managing the local network in a semi-autonomous manner.

5.1 Actions

5.1.1 Immediate

Increased monitoring – Greater visibility of network data and of customer behaviour are essential in identifying the scenario that is manifesting and informing the necessary timing for further action. This 'monitoring' must include both network and customer indicators as network monitoring alone will be an inefficient measure, given that it is always a lagging indicator which can assists with reactive decision making. If networks rely on lagging indicators alone, the pace of change will overtake them. Understanding customer uptake of new technologies and macro-economic effects will act as leading indicators, assisting in the identification of load trends and hence inform the investment planning process.

Development of network ready solutions / services – In order to be ready to meet the challenges that will be imposed on the network, it is essential that the new technological and commercial solutions be available in an 'off-the-shelf' manner when they are required. For this to be the case, these solutions must be trialled, fully tested, standardised and integrated into business-as-usual and this process can take anything from 1 – 5 years. It is therefore essential that a programme of innovation activities be prioritised and commenced immediately such that the necessary solutions are available for use as soon as they are required thereby minimising costs and maximising benefits. These activities include methods for managing voltage swings, finding alternatives to RoCoF, actively managing networks and making use of more decentralised control structures.

Scenario planning – Investment planning decisions must take due regard of potential future scenarios. Each network business needs to consider likely future worlds and use scenario-driven investment tools to examine the key differences that could emerge and understand how best to manage the uncertainty associated with the various scenarios. This will allow the businesses to plan for the future in a way that ensures they can 'flex' between different potential outcomes in the most efficient way possible.

5.1.2 Within the next 5 years

Planning tools – Existing tools that are used for network planning are likely to be unfit for purpose when considering the various new techniques available for managing network security and designing networks in the future, such as procuring services from aggregators or other third parties. There is, therefore, a need to develop a toolkit that can inform investment decisions for what technologies or commercial contracts to use and when and to enable investment planners to understand the cost-benefit of the various approaches.

DNO to DSO transition strategy – Each network business should formulate a strategy for how they see their company operating by 2026 and beyond. This is essential in determining how much of an active role they wish to have in terms of being a system operator rather than a network operator. They may wish to take on a full role, or instead minimise their level of involvement and outsource activities to other parties. This in turn will inform the need for the market / other actors to respond.

5.1.3 In the next 5 – 10 years

Evolution of regulatory model – The current regulatory framework will need to be revised to accommodate the various new entrants to the industry that are anticipated to appear. It will also need to allow for the transition from a DNO to a DSO and make provision for local balancing and delegated frequency control. Furthermore, in a world where network security of supply and reinforcement actions may take the form of having services available to call upon rather than having physical assets providing redundancy, the regulatory treatment of such solutions, which are opex intensive rather than capex intensive will need to be re-examined to ensure that the regulated environment incentivises and encourages businesses to deliver solutions which represent best value to all stakeholders. Changes to regulation need to be appropriately timed to strike the right balance between meeting customer needs, providing confidence to markets, and giving sufficient time for network companies to adapt. Whilst we suggest 5-10 years for implementation, thought needs to start now on this.

Systems engineering approach – when considering network developments and the deployment of new technology, the holistic impact on the network needs to be considered to ensure that the various solutions are having complementary effects rather than competing with each other in their efforts to manage power flow and local system balancing issues. This requires a wider 'systems engineering' view which may represent a culture change compared to current practice.

Training / education of staff – As new technologies are utilised on the network there is a need to ensure that all staff, particularly existing field staff who will encounter these devices, are fully aware of their operating regime. This task is likely to be significant as the new technologies deployed are likely to be significant and the time and cost of ensuring all staff are fully briefed to allow safe and reliable operation should not be overlooked.

6. Summary: Operating Platform

In all the future scenarios that have been considered, customer dependence on electricity increases so reliability and security of supply is critical. However, customers will have greater choice as to how this is provided (by the network operator, services from elsewhere, self-sufficiency through storage and generation etc.). It is therefore essential that the operating platform for the future is inclusive in that it involves the network, the customer and service providers such as aggregators in all forming part of the overall solution to the management of the grid.

Key to enabling this will be the ability to take decisions at a local level and decentralised control systems will need to be widely installed to ensure efficient operation. The alternative of retaining a centralised control architecture will not be tenable given the scale of data flows that will exist and the need to operate different parts of the grid in different ways to cater for local conditions. There will still need to be some control function that has oversight of the entire network, but the 'day-to-day' (and indeed minute-to-minute) running of the network in terms of managing voltage and power flow for local areas will be delegated to a more distributed or hierarchical control structure.

The precise levels of data to be stored locally and transmitted back to central points will need to be determined and may vary between networks, with some preferring a more autonomous system and others wanting to have greater visibility at all levels. Clearly, the greater the amounts of data to be transferred, the greater the costs of the communications links and the data warehousing and processing. Indeed there is a decision to be taken about where this processing should be done and a favourable option could be to process locally and then transmit 'information' rather than transmitting 'data' as this is likely to be more efficient.

The decisions taken by the distributed control architecture are likely to be concerned with the way the network is configured and the services that may need to be procured from aggregators and other third parties. This will include the use of generation and storage to manage network balancing issues. Storage could be in the form of network owned and operated units, although this is probably unlikely to be the most economically efficient approach in many cases (except where the storage is being utilised as an alternative to dual circuit supplies to offer some redundancy). It is perhaps more likely that the storage services will be procured from the market either in the form of independent storage operators, or aggregators who contract with large numbers of small scale storage units (such as those found in customer premises) to offer services. Likewise, commercial arrangements with generators to provide balancing and voltage support services will be in place.

In all of these cases, thought needs to be given to how and when these services will be procured, and how much will be paid for these services. The size of the market will clearly be influenced by the 'readiness to pay' of the network in this respect and significant consideration will need to be paid to this as against the counterfactual approach to providing network security and balancing services to ensure appropriate value for money is being obtained. This is likely to link in to the need for advanced toolkits to model the impacts of such actions that were discussed in the previous section.

Along with procuring services from storage providers and generators, more wide-ranging demand side response will form part of the overall package of options to manage the network. However, it is important to realise the various different types of DSR which exist as they will be utilised in different ways. There is DSR that will be used by a TSO or DSO for balancing and frequency control; another type of response that would be sought by retailers for hedging against the wholesale generation price; and a final type which would be called upon by the DNO or TNO to alleviate network constraints in specific locations at specific times. The market for each of these will be different and the prioritisation given to these various, potentially competing, forms of response will be necessary.

Different techniques for operational management will also come to the fore. For example, using proactive fault identification and prevention measures rather than reactive fault repairs may become more important in cases where the network is now being operated without the same level of redundancy as had been provided in the past by dual assets.

The way in which pricing for electricity consumption is calculated will also change and customers will no longer be billed purely on volumetric terms in line with the number of kWh consumed. Instead, to offset the costs associated with providing 'back-up supplies' to customers that are rarely used, there will be a capacity charge (a fixed element to the bill) that will charge for the amount of demand a customer is allowed to draw at any given time, which may be supplemented by a variable (volumetrically metered) charge.

The way in which security of supply is measured is likely to also change. SAIDI and SAIFI measures are already applied differently to some different customer groups (e.g. those in the CBD versus rural customers). It is likely in future that these measures may be further expanded to account for customers who are primarily dependent on the grid for their supply, as against those with a degree of self-sufficiency who only utilise the grid as a back-up. Such customers will have different priority levels set to them and in some cases SAIDI and SAIFI may be replaced by some form of guaranteed standard whereby it will be incumbent upon the network operator to provide some form of supply restoration within a given time to those customers who do not have generation and storage.

One of the key challenges associated with being able to respond to the pace of change and the need to operate the network in a different manner than previously will be one of culture. The previous philosophies for the methods by which networks are planned and operated to allow for suitable resilience and redundancy will be subject to significant review in a more actively managed world. A mindset change will be required such that the DSO and TSO can regard solutions to network issues as being less longer-term (a few years rather than 40 – 50 year asset lives as they are today) coupled with the fact that solutions may not be 'perfect' meaning that the idea of planning for the worst case conditions and being safe in the knowledge that the network will operate as required will no longer be the norm and a number of approaches may be required to mitigate day-to-day issues including actively reconfiguring networks and engaging with multiple service providers to manage demands, voltage and frequency.

In order to ensure that the industry is ready for this transformation, there will need to be some updates to the regulatory framework, as previously discussed. Critically, though, there will also need to be buy-in from the entire supply-chain. If the solutions are not available and the supply chain is not ready to provide when the network requirements arise, then the network will not be able to operate in the most economically efficient manner. It is therefore essential that sign-posting is provided to allow the supply chain to gearing up and engage with the relevant networks to ensure that provisions are made in a timely manner.

6.1 Actions

6.1.1 Immediate

Develop a cross-sector engagement group – In order to address risks around pace of change, a cross-sector engagement group beyond network operators, involving the broader supply chain, regulator, government and new players such as EV manufacturers, aggregators etc. should be initiated. This should be populated with senior individuals such as CEOs from the DSO and TSO companies and similarly senior representation from other stakeholders. This will ensure that the industry-wide conversation on this subject continues and will aid with supply chain readiness and also with policy-making. By having senior management from DSOs and TSO s engaged, this will also drive the necessary culture change and communications within the networks businesses.

Agree the various roles of DSR – The use of DSR can be an efficient method to solve different network and system issues. However, there are distinct types of DSR that require engagement of different actors and can achieve different goals. The varying use cases for DSR should be considered now, such that trials in their appropriate use for different purposes can be initiated ahead of their ultimate need.

6.1.2 Within the next 5 years

Trial systems for decentralised control – The need for a distributed control architecture to make decisions and take actions at a local level will be key and this does not exist today. It is therefore essential that consideration be given to approaches to perform this function and that several of these be trialled to ensure they are fit-for-purpose and available in an off-the-shelf manner when required.

Agree DSR arbitrage – As there are multiple roles for DSR that have been explored, it is possible that there will be times when multiple DSR types are called simultaneously by different actors. It is therefore essential to have a process whereby there is some form of arbitrage to manage these calls and establish some sort of hierarchy such that the safe operation of the system is prioritised before allowing other market drivers to act.

Establish DSR communications mechanisms – Set out the communications mechanisms by which the various players in the DSR market will be notified, communicated with and actuated.

Agree DSR requirements with market – Inform the market of the requirement for DSR and agree the commercial rates and mechanisms by which this will be governed.

Review fitness for purpose of charging (DUoS) mechanism – In light of the changes to customer demand that are anticipated, it will be necessary in advance of these changes fully manifesting themselves to explore alternative charging mechanisms looking at capacity and volumetric charging.

Develop a customer engagement strategy – In the grid of the future the role of the customer will be more active and the way in which they engage with actors including the DSO, but also other commercial service providers will change significantly. In order to raise the profile of the DSO and TSO it will be necessary to define a strategy detailing how to communicate with customers along with what and when to communicate.

Develop a data strategy – The level of devices installed further into the network and the opportunities for them to communicate, store data and transmit this back to central locations will be far in excess of what it is today. Thought needs to be given by all operators to the development of data management strategies that will ensure that the appropriate amount of data is captured and is securely held (particularly if it has direct relevance to customers).

7. Summary: Technical Enablers (Telecoms)

In order to enable the grid of the future to operate, the level of communication and data exchange will be far greater than it is today; both in terms of the number of actors that need to be able to link with each other, and the amount of data and information that they each require.

As part of this analysis, each individual future world has been considered in detail with the key communications links that are required described in Appendix II – Appendix V. In each case, the nature of the communications has been classified according to its necessary:

- Security;
- Bandwidth;
- Latency;
- Reliability;
- Scalability; and
- Interoperability

The requirements according to these categories have been summarised in tabular form and each scored from 0 to 4 where 4 constitutes a very high level, 3 a high level, 2 a medium level, 1 a low level and 0 indicates a negligible or non-existent level. These requirements have then been expressed in terms of the difference when compared to the links that exist today, such that a high (positive) score signifies a significant increase in that functional requirement from the currently available communications links, while a zero score means no change from today. (A negative score suggests a slight weakening of the particular communications link.) This summary can be found in Appendix VI.

Clearly, while each future world has its own particular actors and requirements, there are some areas of commonality that exist. To demonstrate this, we have aggregated the various communication links from all future worlds together and weighted them to demonstrate the links that are likely to require the greatest level of attention and those that do not need significant modification to be fit for purpose. The outcome of this exercise is shown in Table 2 below.

In this table, a number of different actors have been amalgamated into classifications. For example, in various scenarios, actors such as aggregators, bundled service providers, customer service managers etc. exist. These have been collectively termed ‘commercial service provider’ here to allow for simple comparison of the likely communications links required, irrespective of the precise scenario and precise actors involved. It is also important to note that in some scenarios, one entity could take on the role of several actors.

Table 2 Communications links between actors showing the difference in technical communications requirements from those available today

Actors (Changes necessary to achieve requirements in a worst case scenario by 2030's)		Functional Requirements					
		Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
Commercial service provider	Commercial service provider	4	3	3	3	4	2
Commercial service provider	Customer - Small	3	2	2	2	4	3
Commercial service provider	Large generation & storage	3	2	2	2	1	1
Commercial service provider	Small / distributed generation & storage	2	-1	-1	-1	-1	1
Customer - Small	Small / distributed generation & storage	3	2	2	2	3	1
DSO	Commercial service provider	3	3	3	2	2	0
DSO	Customer - Large	1	2	1	1	0	0
DSO	Customer - Small	2	1	1	1	2	1
DSO	Government & Regulator	0	0	0	-1	0	3
DSO	Large generation & storage	3	1	1	3	1	2
DSO	TSO	0	2	2	0	0	0
Government & Regulator	Commercial service provider	0	0	0	-1	0	3
Large generation & storage	Commercial service provider	-1	-1	-1	-1	1	0
TSO	Commercial service provider	0	0	0	1	-1	0
TSO	Government & Regulator	0	0	0	-1	0	3
TSO	Large generation & storage	0	0	0	0	1	1

It can be seen from the table above that a number of the communications links identified as requiring the most significant change are those concerned with such ‘commercial service providers’. This is entirely to be expected as, in the main, these actors do not exist in today’s grid and hence their introduction will require the establishment of new links. The changes necessary to accommodate them are therefore of less interest in this regard (particularly to the current significant actors in the sector such as network operators) and should not be a cause for concern.

Links between existing actors are also indicated here, such as those between a DSO and TSO, or with customers, and it can be seen that in general, a smaller level of increase in the resilience of these links is necessary to facilitate grid functionality.

It is useful therefore not only to consider the changes in requirements from today to facilitate the grid of 10 – 20 years’ time, but also the absolute requirements of the various communication links identified here in the 2030s context. This is illustrated in Table 3 below.

Table 3 Functional requirements of communications links between actors in the 2030s

Actors (Required situation for each link in a worst case scenario by 2030's)		Functional Requirements: Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
Commercial service provider	Commercial service provider	4	3	3	3	4	2
Commercial service provider	Customer - Small	3	3	3	3	4	3
Commercial service provider	Large generation & storage	3	3	3	3	2	2
Commercial service provider	Small / distributed generation & storage	4	1	1	2	2	2
Customer - Small	Small / distributed generation & storage	3	3	3	3	4	3
DSO	Commercial service provider	4	3	3	3	2	2
DSO	Customer - Large	3	3	3	3	2	2
DSO	Customer - Small	2	1	1	1	2	1
DSO	Government & Regulator	2	1	1	1	1	4
DSO	Large generation & storage	3	2	3	3	2	2
DSO	TSO	4	3	3	3	1	1
Government & Regulator	Commercial service provider	2	1	1	1	1	4
Large generation & storage	Commercial service provider	3	1	2	2	2	1
TSO	Commercial service provider	3	1	3	3	1	2
TSO	Government & Regulator	2	1	1	1	1	4
TSO	Large generation & storage	3	2	3	3	2	2

It can be seen that particularly robust communications are required between the DSO – TSO and also the DSO – Commercial service providers, reflecting the importance that these third parties will play in the grid of the future. Similarly, strong communications are required between different service providers, but these are unlikely to be observable by current actors in the grid and as such, the mechanism by which these are established is likely to be different from the mechanism for strengthening existing links between industry actors. Instead, the establishment of such links will need to be part of the strategy of any new entrants to the market and the costs of their provision will form part of the business case for such players to participate.

The communications that has been discussed thus far represents the links between different actors. Clearly, the grid of the future also requires a great deal of communications between connected devices owned and operated by the same actor. To this end, the following table (Table 4) illustrates the communication requirements (using the same classifications and scale) of equipment that will be owned and operated on different points of the DSO network.

Table 4 Communications requirements at different levels of the DSO network

Communication Links - Within DSO Networks		Functional Requirements					
		Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
DSO	Zone substation	2	3	3	3	2	1
	MV network	2	2	3	2	3	2
	Distribution substation	2	2	3	2	3	2
	LV network	2	1	3	1	4	3
	Customer	3	1	2	1	4	4

At present the DSO has reasonable communications links at the zone substations level (through its SCADA infrastructure) and will have good communications at least to the outgoing circuit breakers on the MV network. However, communications at distribution substation and out on the LV network will be minimal if they are present at all.

It is these areas that require the greatest level of attention owing to the fact that there will be far more connected devices and the levels of visibility and reach into the network will be much greater to enable voltage and power flow management along with system balancing at a local level. Clearly the number of substations and devices at LV is far greater than that at MV and hence the need for scalability and interoperability is far greater and needs to be considered in advance of rolling equipment out on to the network. In particular, consideration should be given to systems that are extensible and multi-functional in being able to manage different solutions on a single platform (perhaps through having software algorithms that can be deployed onto a single piece of hardware to fulfil different roles, much in the same way as ‘apps’ are deployed onto mobile phone platforms to fulfil different functions). In this way, the system becomes much more scalable and extensible, using the same sensors and inputs (such as voltage and current monitoring devices) but being able to perform a multitude of operations based on these inputs.

This also aligns entirely with the need for greater levels of distributed intelligence and decentralised (or hierarchical) control on the network. It should be noted that achieving communications links that are sufficiently capable of performing this function at a reasonable cost has proved to be one of the more challenging elements of innovative trials globally and, as such, this should be prioritised as a key action early on. Without the communications, the smart devices installed on network will never be able to realise their potential and hence a balance must be struck between extremely reliable, yet expensive, communications media and those that are lower cost but may require greater levels of effort to overcome some of the engineering challenges involved in making them sufficiently robust.

8. Implications of scenarios for Australian power system

The following is based on information provided by CSIRO on 27th September 2016 pertaining to the uptake levels of various customer-side technologies and the impact on load forecasts on a state-by-state basis.

8.1 Analysis

The high-level impacts of the different potential future worlds were examined by looking at a period of time during both summer and winter in 2027 and comparing that with the base case demand levels anticipated in 2017. In all cases, these figures allow for the distributed generation connected, the anticipated levels of demand response and use of storage and electric vehicles. Therefore, the figures shown for demand are the net figures after all of these impacts have been taken into consideration.

By examining these figures, it is possible to establish that there are differences for different states in terms of the challenges that they will face and two are drawn out here for comparison.

Firstly, considering New South Wales, Figure 2 illustrates the demand in 2017 as a base case and also the demand in 2027 for each of the four potential future scenarios over the course of a week in summer.

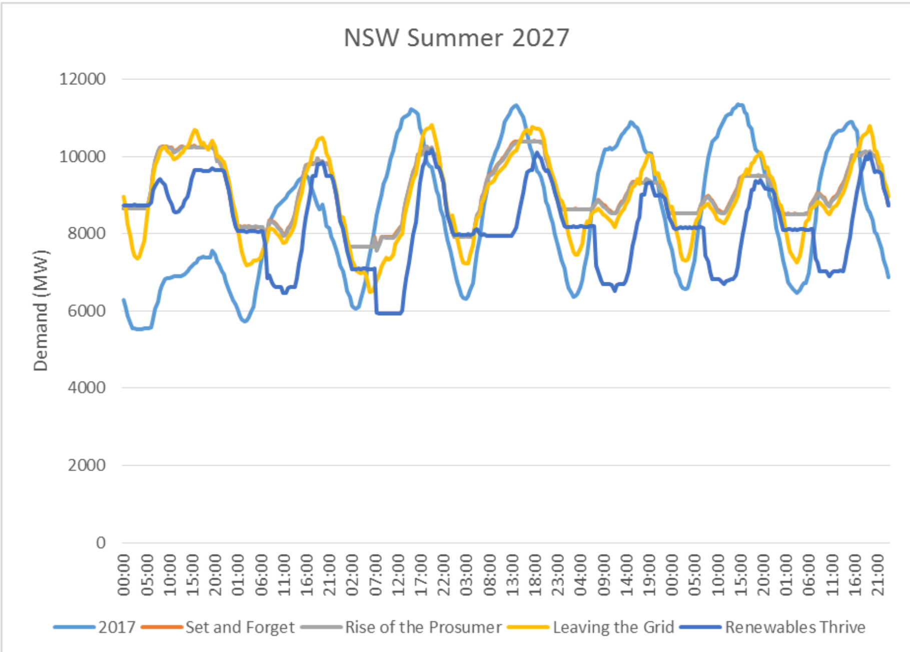


Figure 2 New South Wales summer demand in 2017 and 2027 (based on data from CSIRO)

It can be seen that for all scenarios there is an expectation in a reduction in peak demand and a narrowing of the band between maximum and minimum loading conditions. In theory, this should not pose excessive challenges in terms of balancing and frequency control. The chart does show an offset such that some days appear to vary more than others, but this may be as a result of an offset in the days of the week in the data provided by CSIRO, such that weekends may not be exactly in alignment.

Repeating this exercise for South Australia, a very different result is observed, as can be seen in Figure 3 below.

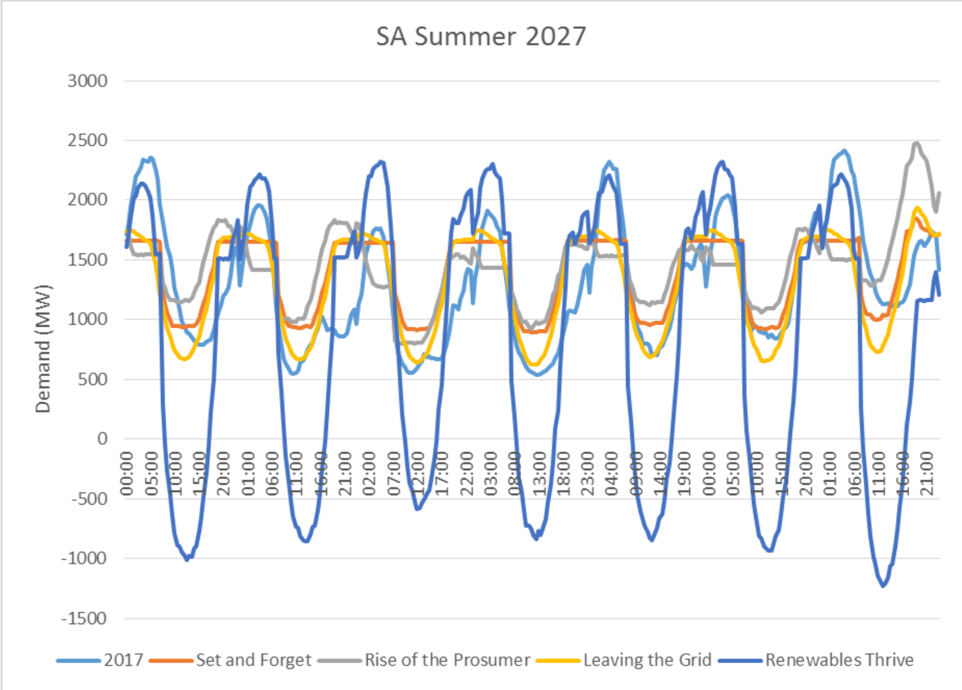


Figure 3 South Australia summer demand in 2017 and 2027 (based on data from CSIRO)

Here it can be seen that while in the majority of future scenarios the demand pattern remains fairly consistent, the Renewables Thrive scenario has a significantly different characteristic. In this scenario, which it should be noted contains the greatest uptake of storage, rooftop solar PV and electric vehicles, it is observed that the peak demand remains fairly consistent (increasing slightly) but the minimum demand observed is now a significant net export.

This will pose material challenges as the rate of change from South Australia consuming power to exporting power is rapid over the course of a day and managing these 'swings' on the network will be of particular concern. The analysis was repeated looking at a week in winter to confirm whether the exporting position was maintained to the same degree, finding that indeed on all days across the week South Australia was a net exporter of power, with the maximum export being up to 1GW, making it consistent with the summer demand curve in Figure 3.

In order to examine the effects of different potential future scenarios on a range of states, an analysis was performed to quantify the scale of difference between the anticipated demands in 2017 and 2027. If this scale of difference is '1' then this means there is no difference observed, while '2' indicates a doubling in demand and '0.5' a halving in demand. Figure 4 below demonstrates the scale of change expected for the 'Leaving the Grid' scenario.

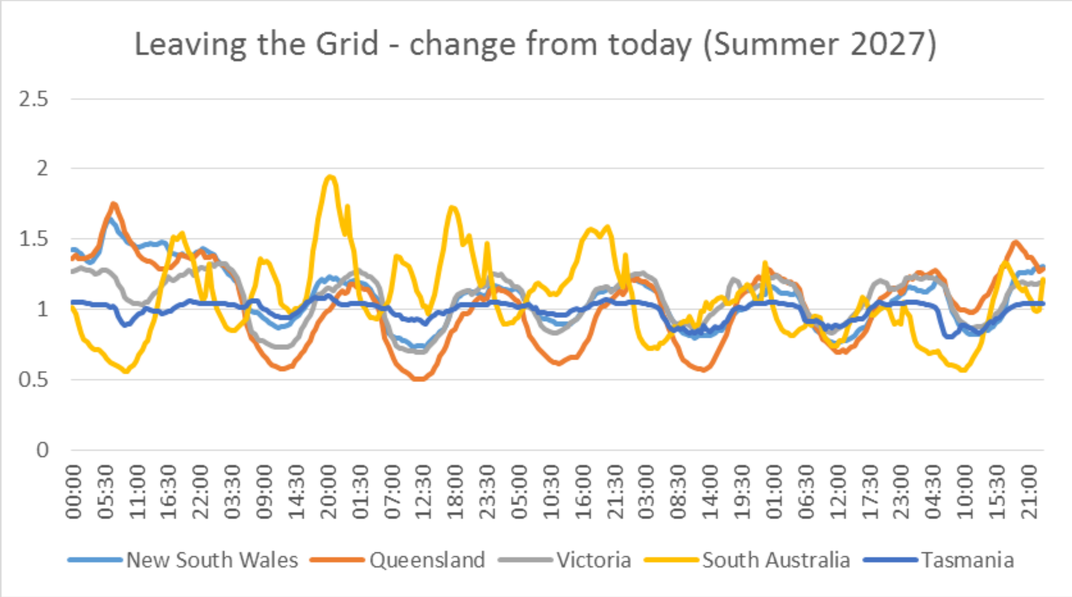


Figure 4 Expected demand by state in 2027 under the Leaving the Grid scenario (data from CSIRO)

It can be seen that the level of change remains close to unity in Tasmania and Victoria (and largely New South Wales), indicating that there is little effect in these states. Queensland and South Australia, however, experience more significant demand erosion with levels dropping to almost half those seen in 2017. Conversely, South Australia also experiences some significant increase (over 150% of the demand seen in 2017) at certain times, further providing evidence that demand swings will be crucial in this state. Again, it should be noted that there could be some offsetting of weekend as against weekdays in the data so some of the comparisons on certain days may be exaggerated.

Repeating this process for the Renewables Thrive scenario gives the profiles for individual states as seen in Figure 5.

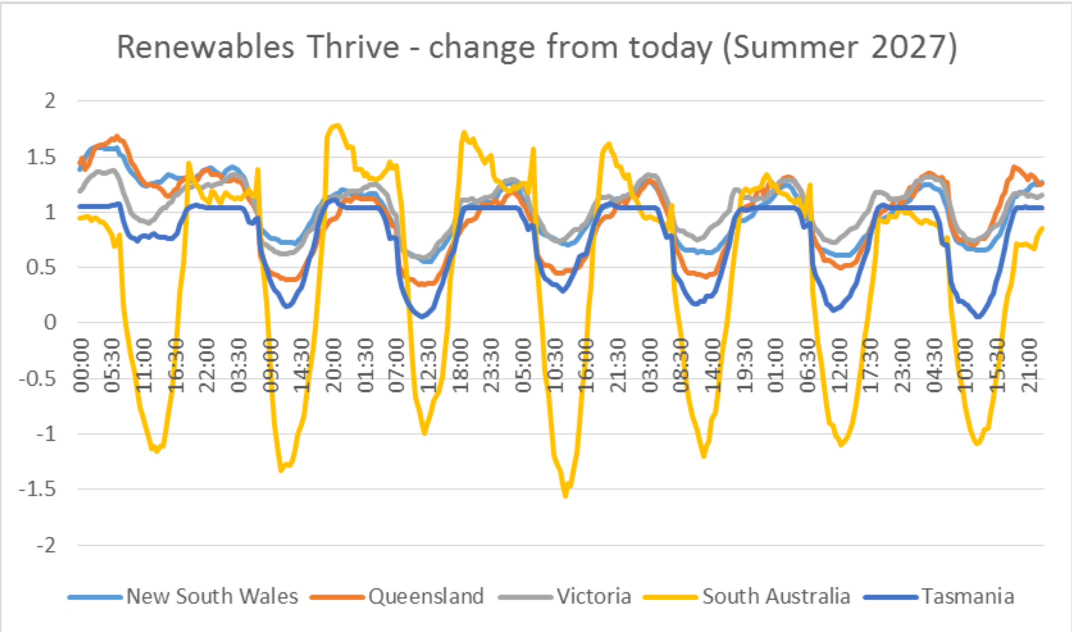


Figure 5 Expected demand by state in 2027 under the Renewables Thrive scenario (data from CSIRO)

Under this scenario, it can be observed that there is a greater level of demand erosion, with all states seeing material reductions. Tasmania in particular was relatively unaffected under the Leaving the

Grid scenario but has large reductions here, as does Queensland. South Australia remains 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.

8.2 Application

The modelling for the Network Transformation Roadmap that has been carried out by CSIRO provides a rich source of data for stakeholders to evaluate likely impacts. Clearly, these will vary by state (as indicated here) and also by the scenario that emerges.

Detail on each of the corresponding scenarios is provided in Appendices 2 to 5, with the common elements brought out in the Conclusions and Recommendations below.

This strengthens the point that it is important to attempt to understand at as early a stage as possible how customer behaviour and demand is likely to evolve and by monitoring uptake of key customer technologies on a state-by-state basis, it will inform the network operators as to how best to respond and prepare for the challenges ahead.

It is important to recognise that the electricity networks are becoming more dependent on the way in which their customers operate, from large generators to residential consumers. These behaviours are increasingly influenced by externalities outside of the control of the network businesses. Moreover, it is entirely plausible for one scenario to radically shift to another as a result of price drops in consumer technology, or the introduction or removal of governmental incentives. This magnifies the importance of network companies to constantly track and be aware of potential changes arising from policy or market conditions.

9. Conclusions and Recommendations

The following lists the key actions that should be taken forward with appropriate timescales indicated. These actions constitute a way to progress along a least regrets pathway to ensure the grid of the future will be fit for purpose, irrespective of the precise details regarding the future world which emerges.

9.1 Actions

9.1.1 Immediate

Increased monitoring – Greater visibility of network data (lagging indicator) and of customer behaviour (leading indicator) are essential in identifying the scenario that is manifesting and informing the necessary timing for further action.

Development of network ready solutions / services – New technological and commercial solutions must be available in an ‘off-the-shelf’ manner when they are required, meaning that prioritised innovation in this area needs to be undertaken now, lasting for the next 5 years.

Together with this prioritised list, there needs to be a framework established to provide standardised methods of capturing learning associated with: skills, data, customer and system integration

Scenario planning – Investment planning decisions must take due regard of potential future scenarios allowing businesses the opportunities to manage uncertainty and ‘flex’ to meet changing requirements.

Develop a cross-sector engagement group – In order to address risks around pace of change, a cross-sector engagement group beyond network operators, involving the broader supply chain, regulator, government and new players such as EV manufacturers, aggregators etc. should be initiated, populated by senior individuals.

Agree the various roles of DSR – The use of DSR can be an efficient method to solve different network and system issues, but there are distinct use cases and these should be considered now, in preparation for suitable trials.

9.1.2 Within the next 5 years

The following needs to be started in the short term with an aim to be complete and embedded within 5 years.

Planning tools – Existing tools alone will not be fit for purpose and tools which allow the evaluation of cost-benefits of the range of technological and commercial solutions that will be deployed must be developed.

DNO – DSO business strategy – Each network business should formulate a strategy for how they see their company operating by 2026 and beyond to determine how much of an active role they wish to have in system operation which will in turn inform the market as to the level of gaps that can be filled by new entrants.

- This strategy should include the extent to which the DNO envisages transitioning to a DSO
- These strategies can then be centrally assimilated by the ENA and communicated to the wider sector, thereby providing information regarding the common base for new participants in the market
- In turn, this will allow the market to respond and offer those services of greatest value to the various network and system operators

Trial systems for decentralised control – The need for a distributed control architecture to make decisions and take actions at a local level will be key and this does not exist today meaning it is essential that consideration be given to approaches to perform this function such that they are available in an off-the-shelf manner when required.

Agree DSR arbitrage – As there are multiple roles for DSR that have been explored, it is possible that there will be times when multiple DSR types are called simultaneously by different actors and some form of arbitrage between these will be essential.

Establish DSR communications mechanisms – Set out the communications mechanisms by which the various players in the DSR market will be notified, communicated with and actuated.

Agree DSR requirements with market – Inform the market of the requirement for DSR and agree the commercial rates and mechanisms by which this will be governed.

Review fitness for purpose of charging (DUoS) mechanism – In light of the changes to customer demand that are anticipated, it will be necessary in advance of these changes fully manifesting themselves to explore alternative charging mechanisms looking at capacity and volumetric charging.

Develop a customer engagement strategy – The customer will play a much more active role in the future and in order to raise the profile of this issue as well as that of the DSO and TSO it will be necessary to define a strategy detailing how to communicate with customers along with what and when to communicate.

Develop a data strategy – The amount of data that will be available from the greater numbers of devices installed further into the network will be significant and a strategy regarding how to handle this data from a security, management and efficiency perspective should be developed.

9.1.3 In the next 5 – 10 years

The following needs to be started in the short term with an aim to be complete and embedded within 5 – 10 years.

Evolution of regulatory model – The current regulatory framework will need to be revised to accommodate the various new entrants to the industry, the transition from DNO to DSO and the need for network security to increasingly make use of third parties rather than asset redundancy.

- In each innovative trial that is carried out, establish and capture any regulatory barriers to implementation into business as usual
- Use benchmarking techniques to learn from other global regulatory models and adopt best practice as and where appropriate

Systems engineering approach – when considering the deployment of new technology, the holistic impact on the network needs to be considered to ensure that the various solutions are having complementary effects rather than competing with each other in their efforts to manage power flow and local system balancing issues.

- The wider impacts of any new technology deployed on the network needs to be captured. Hence innovative trials should be designed in such a way to ensure this is achieved.
- Replication of trials is essential to demonstrate how technology works in several environments, engaging with different parts of the eco-system, rather than an isolated trial in one area that fails to identify all the potential impacts of new technology interacting with older assets including communications systems, protection, actuators and customers
- Control loops should be considered to ensure that the smaller loops (e.g. one for a local protection system, another for an automation system etc) interact in such a way so as to fit within the overarching control of the broader system
- Systems engineering is a discipline in its own right and therefore should be considered and addressed through the skills requirements identification process.

Training / education of staff – As new technologies are utilised on the network there is a need to ensure that all staff, particularly existing field staff who will encounter these devices, are fully aware of their operating regime.

- Review the outcomes of the Skills Assessment section of the Network Transformation Roadmap, ensuring that the skills identified in that document are aligned with the future needs set out here. For example, the need to coordinate big data systems management, increased communications requirements, commercial contract establishment, methods of engaging with customers etc.
- As innovative trials are completed, deploy a clear methodology to capture the skills required for successful implementation of the learning

The above recommendations constitute 'least regrets' across all potential future scenarios. If it is clear that a certain one of the future worlds is emerging, then the more detailed sections of this report relating to each specific future world should be considered.

Appendix I The Grid Today

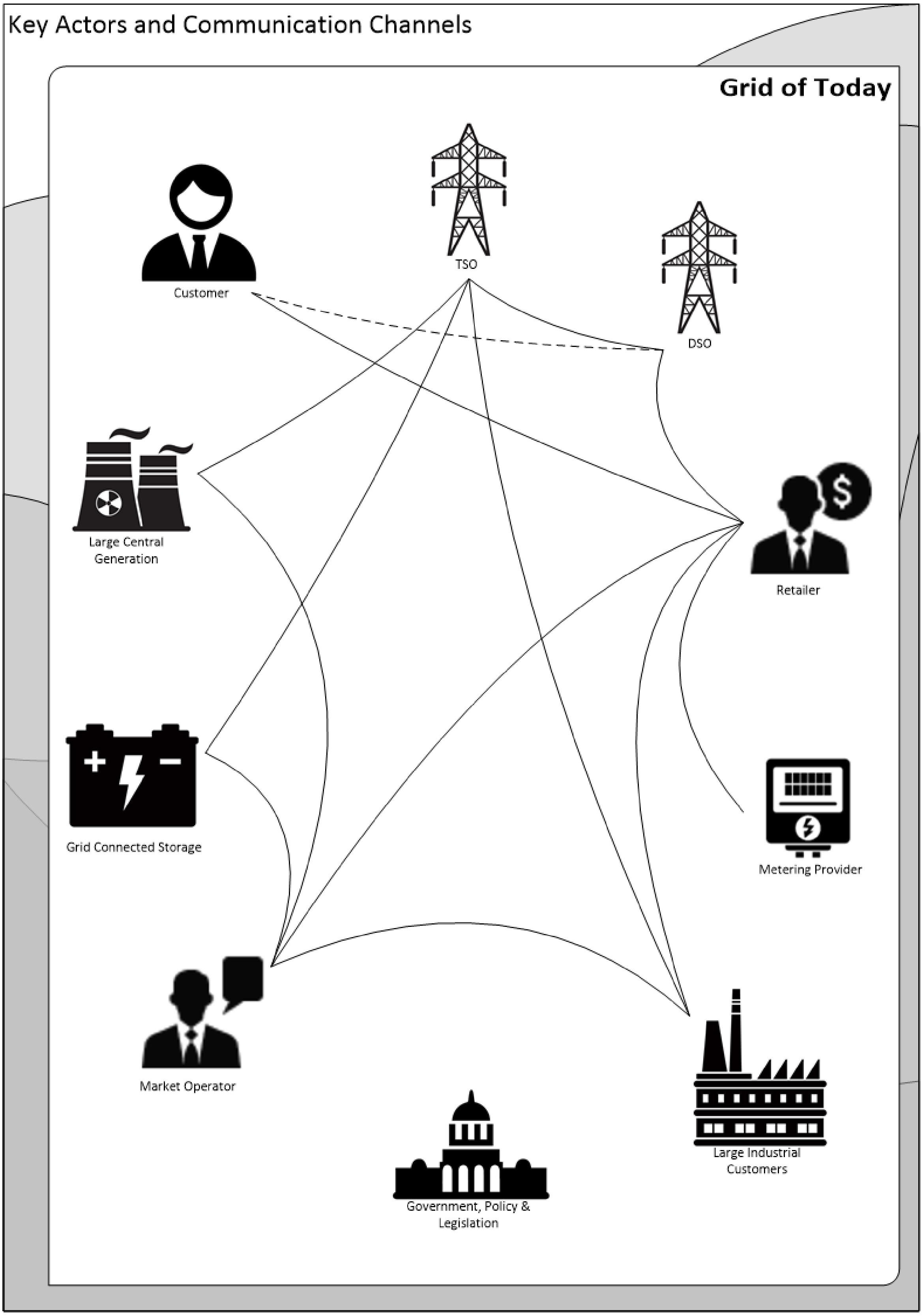


Figure 6 Grid of Today - Holistic View of Actors and Communication Channels

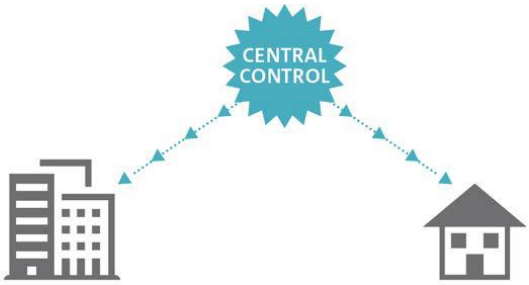
In order to effectively analyse future grid architecture, it is necessary to consider the grid of today. This allows for comparisons to be drawn between the today's relatively simple network structure, and the complexity of relationships and actors of the grid of the future. A diagrammatic representation of the key actors and relationships identified to have a crucial role in today's grid are shown in Figure 6.

In today's world the role of the customer within the system is limited; their primary relationship is with a retailer who provide with their energy bills. The customer's electricity consumption behaviour is passive but somewhat influenced by their energy pricing structure. Today, high numbers of Australian customers are turning to rooftop solar PV installations to reduce their energy bill. Some also make use of load control systems for appliances such as pool pumps and hot water heaters. Although some customers will have relationships with their DNO, this is limited and mostly occurs during new connections or network faults.

A key role within the existing electricity system is that of the retailer. They act as an interface between the customer; the market operator (AEMO), metering providers and the DNO. Ensuring that the sale and purchase of energy is competitive and that customers' expectations are managed. AEMO manages Australia's National Electricity Market (NEM) and delivers a range of market and planning functions for the energy and power systems.

The role of the distribution network operator (DNO) is one of operation and maintenance of the existing infrastructure as well as restorative and new works. Although they monitor network conditions they cannot be said to act system operators in the same way as the transmission system operator (TSO). The TSO is responsible for both the operation, maintenance and monitoring of the transmission system. They also provide balancing services to the network and liaise directly with central generation and large customers to ensure nationwide network stability. Large (industrial) customers, central generators and storage are also involved in the electricity system although they have peripheral roles with the grid itself and are managed by the TSO, and in some cases the DNO. The majority of electricity is still provided by a few, large central generation facilities.

Appendix II Future World Analysis – Set and Forget



In the 'set and forget' scenario, residential and commercial customers have become open and receptive of battery storage and demand side management solutions. They prefer to play a minimal role in the system, choosing solutions that work automatically or under the control of an outside agent.

Customers set their preferences (either directly through parameter settings, or indirectly through purchasing choices) and allow their storage and DSR solutions to be automatically managed by a third party, aiming to ensure the best return and reward according to their tariff.

Set and Forget - Holistic View of Future World

Figure 7 represents the key actors and relationships identified to have a crucial role if the 'set and forget' future network conditions are to be realised. Many of the identified actors and relationships can be readily understood and are found in an analysis of the grid of today. However, some are new. For this reason, the new actors and relationships that are in place to support this world will be discussed in greater detail:

In this scenario, the customer has limited relationships with other actors but there are still changes from their traditional behaviour as they must now 'set' their DER/DSR preferences. Additionally, they will likely develop a relationship with a Customer Service Manager (CSM). These CSMs are able to manage a large number of individual customer's energy accounts, taking advantage of the deregulated energy market. They are in place to provide a link between the Bundled Service Provider and the customer. Their role is to ensure customer satisfaction and acceptance of outside control by making sure their needs continue to be met. They may target customers by geography, demographic or style of service.

The Bundled Service Providers (BSP) are outside agents with an interest in managing customer activity. They may provide multiple services to customers outside of the power system, including managing calendars, finances and health/fitness. Maximising on their customer knowledge, they are able to provide control for the customers DER/DSR solutions to deliver acceptable service and rewards to the customer in line with their chosen preferences. This interaction may take many forms, including automation schemes, predictive analytics or human management. The BSPs' relationships are in place to control customer equipment, react to changes in customer expectations and monitor live pricing signals. It is likely these agents will also interact with 3rd Party Aggregators, allowing them to group responses and access better rewards.

The 3rd Party Aggregator is essential for this scenario, as can be seen from its relationships. Its role is to combine available storage, generation and DSR within the system. This actor could perform aggregation in a variety of ways, e.g. by type of technology, load or by geography/customer demographic. The actor also has a strong relationship with the energy trading provider to provide economies of scale across the energy system by aggregating response. This allows for lower energy prices, which can be passed to the customer. They are also able to provide the DSO/TSO with large scale demand responses by aggregating the output of smaller equipment.

Critically, the scenario cannot be delivered without Smart Appliance and DER OEMs. These actors will provide customers with the technology to provide generation, DSR or storage. It is also necessary for this technology to interact with the BSP who, as stated previously, will be controlling the response delivered by the customer's equipment.

The role of the DSO and TSO are largely unchanged, barring the new interaction with the 3rd Party Aggregator.

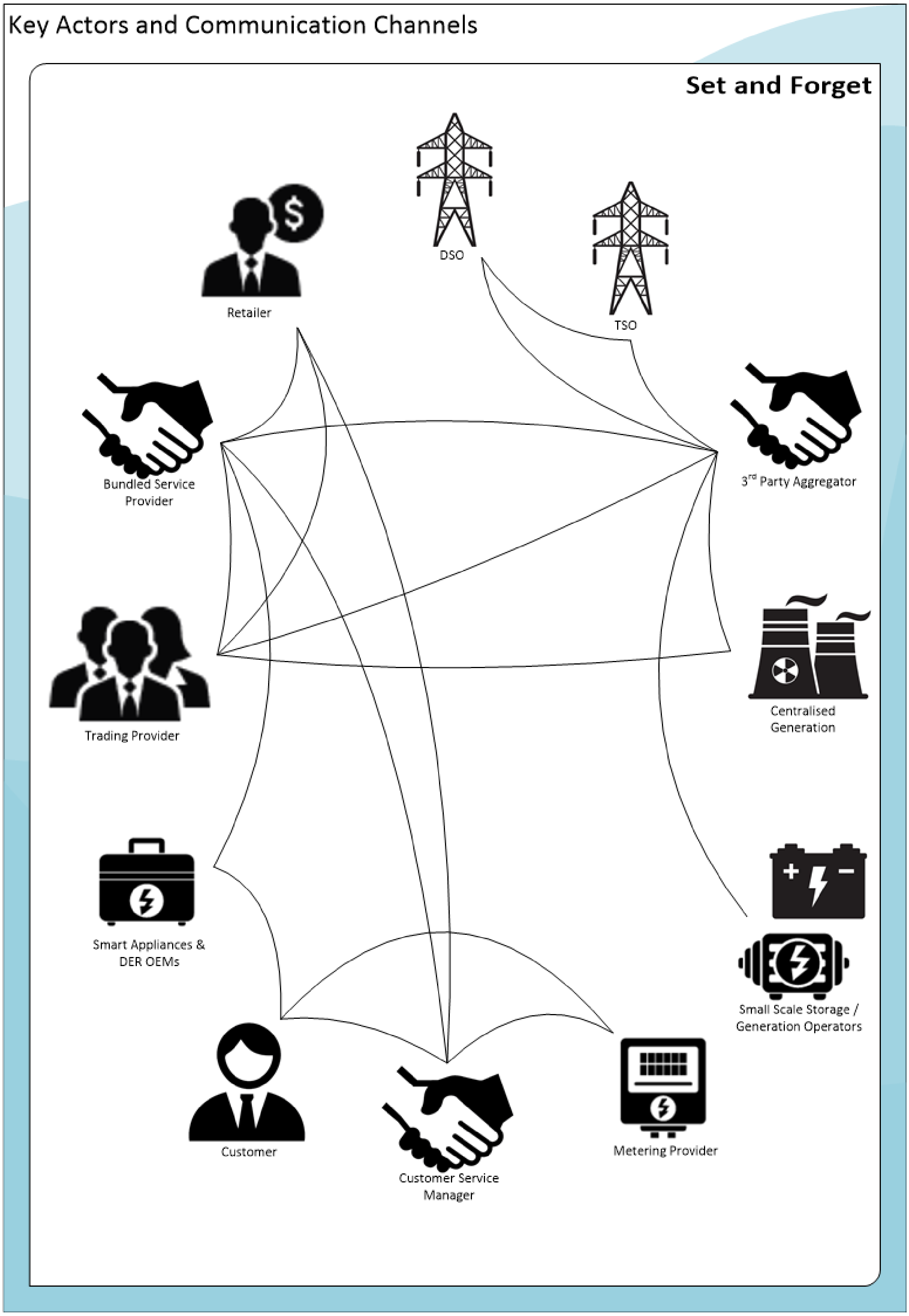


Figure 7 Set and Forget - Holistic View of Key Actors and Communication Channels

Set and Forget - Grid design and operation

a. Functional description of DSO and TSO activity

In this scenario, the role of the TSO and DSO are broadly similar to that of today. New actors have come into being to provide valuable services to both network operators and customers. The change has been driven by technical necessity, and the market has provided a competitive solution.

The TSO continues to operate actively, and remains responsible for overall system frequency balancing. This is achieved via interaction with a relatively small number of large generators or commercial (3rd party) aggregators. The services on offer from the aggregators allow for rapid load reductions and increases, providing a flexible basis by which the TSO can manage the grid.

The DSO now acts in a semi-passive manner; parts of the network rely on customer demand response support. Whilst the DSO is responsible for the provision of signals to call for demand response, it does not have the end relationship with the customer, but instead procures these services through a range of aggregators (e.g. 3rd party aggregators, bundled service providers, customer service managers). Load management and voltage control services are abundant and well understood, there is an emerging market for fault level and power quality (harmonics reductions) services.

In some weaker or islanded areas of the network, the DSO has delegated responsibility for frequency control and response from the TSO. However, this practice is not widespread.

b. Optimum design and operating parameters

- *Inertia changes*
- *Amount of response needed to maintain inertia*
- *Alternative technologies to manage RoCoF*

System inertia and network fault level is falling as more centralised synchronous plant has been replaced with inverter coupled generation. This has resulted in a less electrically 'stiff' system.

TSOs and DSOs have started to install some synthetic inertia such as electrical energy storage, SVCs and (in some instances) flywheels, to address the issue. Meshing of previously radial networks has been shown to give benefits, increasing fault levels, whilst also giving rise to improved SAIDI / SAIFI performance.

Aggregators are starting to offer inertia / fault level services to the TSO/DSO using demand response but these are relatively new.

Due to reduced system inertia, the limitations of RoCoF protection are problematic. Alternative anti-islanding technologies, such as vector-shift or frequency-forcing are widely deployed. With improved communications infrastructure, island-enabling technologies such as syncrophasor protection become technically and commercially feasible and are being actively considered by DSOs to enable continued system operation during periods of grid separation.

c. Limitations on existing Regulatory Investment Test – Transmission, with a focus on power system security and solutions needed

The Regulatory model has evolved from that in place today. Whilst not radically different, it has had to cater for the number of new entrants who have come into the market, ensuring they are suitably licenced to offer services, and have the safeguards in place to protect end customers.

Minimum technical specifications have had to be developed by the TSO/DSO for services, and these have been signed off by a range of key stakeholders including the Regulator. With this in place, it has provided the level playing field for competition between providers to drive down costs to an economic optimum.

The justification for infrastructure reinforcement / asset replacement has had to adapt to consider the role(s) for commercial solutions as well as asset driven solutions. This is more complex than the past and decision support (software) tools have entered the market to assist on both a strategic and tactical level.

Demand and generation growth is less visible than it once was, and the aggregators have a key role in providing forecasting data to TSO/DSO in ensuring they can deal with peak demands, e.g. following faults or black-start.

Network performance targets (SAIDI/SAIFI) continue to tighten as citizens rely on the electricity grid for their everyday life.

At the same time, dependency on the electrical grid has increased significantly for the transport and communication infrastructure. Climate change will also increase the dependency of the water sector on the electrical grid for active flood prevention measures. Taken together, this results in a significant shift in the criticality of the electrical network (both geographically and in magnitude)

As a result, tougher penalties for loss of supply to these sectors have been introduced to reflect this change and to drive best practice.

d. Solutions to efficiently design, control and operate grid connected and non-connected 'mini' grids and actions needed for implementation

New actors via the various aggregators have been key, this includes:

- 3rd party aggregators are an important B2B (business to business) interface operating between the TSO/DSO and the service provider.

- At residential level, the Customer Service Manager(s) provide a critical interface to the householder. The CSM can provide services either to a bundled service provider or directly to a 3rd party aggregator. These have grown into trusted, value-adding partners supporting a range of services between the customer and the DSO; speaking the right language to either party.

- Bundled service providers have evolved to provide services for similar technologies, such as: using groups of appliances (e.g. a nationwide white goods OEM or EV OEM); a group of assets (e.g. an aggregated electric vehicle charging service / electrical energy storage), etc.

In order to get the most out of these service providers, the TSO/DSO has had to make provision for the monitoring and signalling at critical points of the network. In addition to the technical requirements, new commercial people have been introduced to the TSO/DSO to negotiate and manage the commercial contracts.

Where commercial contracts / aggregators cannot be used, new solutions have been adopted by TSO/DNOs alongside the traditional network as lower cost alternatives to reinforcement.

e. Optimal requirements to address balancing challenge

Provision of greater flexibility from new sources of load/generation, i.e. fast ramp up (e.g. generation or DSR) to manage throughout the day, or between days

System balancing is managed in the main through demand response, enacted via the aggregators as described above. The adoption and harnessing of many users provides significant control and flexibility with many hundreds or thousands of MWs available for rapid response.

Speed of response, ramp rates, kW / kWh (or MW/MWh) of response are clearly communicated between aggregator and end customer at the time contracts are agreed. The DSO/TSO agrees contacts with the aggregators, then provides automated signals to enact the service as and when required.

Set and Forget - Operating platform

a. the operating platform to allow full optimisation and coordination of the various parameters in this scenario

The key difference of this scenario is the use of aggregators to facilitate technical services in the most cost optimal commercial model. It depends on having the right mechanisms to allow new actors, or an expanded role for existing actors to enter this market, including:

- 3rd party aggregators – enhanced role from that used today
- Customer service manager(s) / bundled service providers – new actor(s) but fundamental for effective and enduring engagement from residential customers

Critical to the success of this is ensuring the DSO/TSO can interact with these parties in an open and transparent market.

Where commercial services cannot be procured, the DSO/TSO roll out their own technical solutions. These augment the traditional network, deployed based on economics of each circumstance. As the volume of solutions increases, decision support tools will be rolled out to assist DSO/TSO planners in designing the network.

b. credible strategies for network operation and control to alleviate technical constraints and maximise the benefits of new demands/generation

The technical constraints can be categorised into:

- Maintaining system frequency
- Grid design, operations and management
- Field operations

In this scenario, these can be alleviated via the following strategies:

System frequency is maintained via direct interface to large generators and via aggregators as described earlier in this section. The aggregators provide services into the same market as used by large centralised generation today. An 'inertia market' may also be needed to allow commercial providers to fulfil this specific need. Such an 'inertia market' would value both the rotating plant in existing thermal generation, and for large industrial customers operating big motors. In this scenario, it could be accessed by aggregation service providers who can contract with many smaller items of rotating plant, then provided as a service to either the TSO or DSO. Where the market is not able to provide a solution via a commercial service, the TSO (or DSO in instances of delegated frequency control) will deploy specific technical solutions such as strategically located SVCs, electrical energy storage and, in some instances, flywheels.

Grid design, operations and maintenance for the TSO/DSO networks will use a combination of commercial aggregation services and network technology solutions. Commercial services could be used with all customer types connected at all voltage levels. Alternative 'smart' network solutions will be viewed alongside commercial services, and traditional reinforcement/asset replacement.

In all of the above instances, solution selection will always favour the most cost effective, taking into account whole-life costing rather than simply the initial capital outlay.

c. Optimal mechanisms to maintain levels of system performance re. stability and optimisation

In a state where there are potentially many measurements being fed real-time to numerous aggregators and many hundreds of thousands of devices, it is essential that the systems are configured in a way that make them:

- **Autonomous**: there should be no need for human intervention once commissioned
- **Stable**: the right data must be passed to the right system – it is not acceptable for critical infrastructure to potentially require a manual reset
- **Scalable**: The systems need to be able to scale from the initial few, to the eventual many
- **Secure**: the system must be secure to prevent any unauthorised access or control
- **Dependable**: the TSO/DSO needs to have confidence that the system will operate when requested

The increased complexity of DSO operations (and corresponding increase in the number of protection zones) may lead to an increase in the number of interruptions, although these would be expected to be correspondingly smaller in magnitude and duration.

Field operations will continue broadly as they do today, albeit field operatives will need to be trained in all new solutions. For example, it is likely that field operators will increasingly encounter remotely-controlled assets or automated restoration systems. This will lead to new operating regimes (such as islanded operation) that will be unfamiliar to experienced field operatives. In addition, increased use of predictive diagnostics will mean that interventions on the network will be increasingly preventative (rather than post-fault repair), requiring field operatives to have a different set of skills to carry out those interventions. This is a crucial, often overlooked, area which if not done at the right point, will hamper and slow adoption of new systems and practices.

Another area of concern is the inadvertent introduction of new common-mode failure mechanisms (such as the loss of a communications network or widespread cyber-vulnerability). It is therefore important that any solutions that are wrapped around (or integrated with) the physical network assets are equally robust and that they do not build in additional risk to the TSO/DSO.

d. strategy on detailed technical issues, i.e. managing frequency and voltage stability

The technical issues raised by this scenario can be grouped into:

- **Frequency management (TSO)** – ensuring the correct balance of generation to demand and vice versa.
- **Stability management (TSO)** – ensuring protection systems can operate in sufficient timeframe to allow generators to remain connected post fault, to remain stable.
- **Load management (TSO/DSO)** – the ability of the physical assets to accommodate different demand profiles, possibly operating above nameplate rating.
- **Voltage control (DSO)** – the requirement for all customers to receive voltages within agreed statutory limits at all times.
- **Fault level management (TSO/DSO)** – the ability to both ensure that switchgear operates within its fault rating, and the ability to ensure that there is sufficient fault energy to ensure the correct operation of protection systems.

- **Power quality (DSO)** – the ability to ensure the waveform quality of the power received by a customer (e.g. free from damaging levels of harmonics, voltage flicker or significant voltage step changes).

In each instance, the TSO/DSO will need to assess which issues are being caused, and where. In this scenario, there will be a combination of both:

- **Customer supported solutions**: commercial solutions linking to a customers' use, contracted either directly, or via an aggregation body. Customers can be connected at any voltage level and can consist of demand, generation or both.

- **Network supported solutions**: those deployed directly by the TSO/DSO without a link to the customer

The strategy for selection should be driven by the optimal $ of each solution for the situation in hand.

e. technical challenges to enable this scenario

Operational readiness

- Ensuring the right communication systems are in place to ensure fast, reliable and secure channels between the network operator and aggregator(s).

General points

- Dealing with reduced fault level: ensuring protection systems operate with lower system fault level

- Increased power quality issues with more LCT and lower source impedance

Solution identification

- As previously discussed there are a range of asset-centric solutions that will be required by the DSO/TSO, in addition to the commercial solutions described in this scenario.

- Model the network to understand which are most suitable in this scenario

- The key solutions to manage the issues described above need to be tested, and deployment plans put in place.

In addition to the above technical points there is a requirement for the DSO/TSO to accept any cultural change that may be necessary to adopt new solutions.

f. the framework to facilitate DSR and appropriate monitoring

Market readiness

- The DSO/TSO needs to clearly specify the services they need (location, estimated number of events per year, speed of operation, duration of event, etc.), and the payment values ($) and payment mechanisms that would be used for these services. This would provide sufficient clarity to initiate a market, or indeed drive the discussion around the true value of the service.

- Providing a market structure such that a number of entrants can offer the solution, allowing competition to ensure prices are proportionate

Operational confidence

- Provision of monitoring on the network at key points for signalling from the DSO/TSO to a range of actors.

- Ensuring the signal gets through, and ensuring these are acted upon when received, are the two critical areas to ensure the system operates harmoniously.

Set and Forget - Technical enablers (telecoms)

This section considers those links which are new for this scenario, rather than the existing communications links. Communications links with similar attributes have been grouped together, they are ordered A-F with A being a one to one relationship; F being a one to many relationship.

2030's Scenario	Actors		Functional Requirements					
			Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open
Set & Forget	Centralised Generation	Commercial service provider	4	1	2	2	4	1
	Commercial service provider	Commercial service provider	4	2	2	2	4	3
	Commercial service provider	Customer - Small	3	3	3	3	2	2
	Commercial service provider	Large generation & storage	3	1	2	2	4	1
	Commercial service provider	Small / distributed generation & storage	4	1	2	2	4	1
	DSO	Commercial service provider	4	3	3	3	1	2
	DSO	TSO	4	3	3	3	1	2
	TSO	Commercial service provider	3	3	3	3	2	2
	TSO	Large generation & storage	3	1	2	2	4	1

A. DSO/TSO to 3rd Party Aggregator

- **Functional requirements:** communications used for monitoring and control for network operations. With this in mind needs to have: high security, low(er) bandwidth, medium latency, high reliability/resilience

- **Immediate communications needs:** likely to be in place between TSO and aggregator; new for DSO

- **Longer term communications:** deploy as new services are put in place between TSO/DSO and aggregator(s)

- **Scalability of communications:** low (limited deployment)

- **Cyber security:** high (must be secure: limited channels so can pay more per channel for high security)

- **Open standards and interoperability:** medium (ideally have a common standard across Australia to allow a range of 3rd parties to operate across the country)

B. 3rd Party Aggregator to Bundled Service Provider / Trading Provider

- **Functional requirements:** communications used to signal for multiple responses including trading information - needs very high security, higher bandwidth, high latency, and high reliability/resilience

- **Immediate communications needs:** similar needs to trading to centralised generation as exists today

- **Longer term communications:** BSP are newer players and will need to have these communications in place prior to operation

- **Scalability of communications:** low-medium (limited deployment)

- **Cyber security:** high (must be highly secure: limited channels so can pay more per channel for high security)

- **Open standards and interoperability:** medium (ideally have a common standard across Australia to allow a range of 3rd parties to operate across the country)

C. Customer Service Manager to Metering Provider / Retailer / Bundled Service Provider

- **Functional requirements:** communications used to signal for multiple responses including trading information - needs high security, higher bandwidth, high latency, and high reliability/resilience

- **Immediate communications needs:** As B, similar starting point as that from trading to centralised generation as exists today. We expect there to be a number of Customer Service Managers for either different customer groups, geographies, service provision, etc.

- **Longer term communications:** Communications links to be funded between these commercial entities without any involvement from DSO/TSO. An expectation that these would need to be in place prior to the providers offering the service.

- **Scalability of communications:** low-medium (would need to scale to a range of providers)

- **Cyber security:** medium-high (must be secure to prevent unauthorised access)

- **Open standards and interoperability:** low-medium (ideally have a common standard across Australia to allow a range of providers/generators to operate across the country)

D. 3rd party aggregator to independent storage provider / smaller generators

- **Functional requirements:** communications used to signal for a response, needs to have medium-high security, low(er) bandwidth, low latency, medium reliability/resilience

- **Immediate communications needs:** would use existing commercial solutions

- **Longer term communications:** deploy as new services are established between 3rd parties and storage providers / smaller generators

- **Scalability of communications:** medium (will need to scale to possibly tens of thousands of providers/generators)

- **Cyber security:** medium (needs to be secure, although limited impact if hacked only between 3rd party and any one provider/generator)

- **Open standards and interoperability:** low-medium (ideally have a common standard across Australia to allow a range of providers/generators to operate across the country, but could be proprietary for any given 3rd party aggregator)

E. Customer Service Manager to Customer

- **Functional requirements:** communications between the end user and the service provider (Customer Service Manager), used for monitoring and control. In this scenario, it is expected that there will be a number of CSMs offering services to up to a few thousand/hundreds of thousands of customers. Needs to have good security, medium bandwidth, lower latency, medium reliability/resilience.

- **Immediate communications needs:** deploy as new services are put in place between CSM and customer. Likely to piggy back on existing communications into the home, e.g. TCP/IP (Internet), etc.

- **Longer term communications:** Likely to remain using some form of Internet connection

- **Scalability of communications:** medium-high (needs to scale to hundreds of thousands of customers)

- **Cyber security:** medium-high (this link provides the interface to the customer, whilst it needs to be secure to protect data privacy, there is limited damage that could occur if hacked)

- **Open standards and interoperability:** high (would favour being an open standard in order to facilitate competition between CSMs – a need to define this as the market starts to form)

F. Bundled Service Provider to Smart Appliances & DER OEM

- **Functional requirements:** communications used for monitoring and control to a number of in home appliances. Could be signalling to hundreds of thousands or even millions of devices, needs to be secure, low(er) bandwidth (due to volume), medium latency, medium reliability/resilience. In this mode the BSP could be the product manufacturer offering services across all of their products.

- **Immediate communications needs:** Use product vendors favoured solution, linking to existing communications e.g. TCP/IP, etc.

- **Longer term communications:** Depends on the strategy of the product vendor

- **Scalability of communications:** high (a need to be widely scalable to millions of devices)

- **Cyber security:** high (needs to be secure to prevent hacking and 3rd party control. Likely to be a target for attack, so would need to well maintained)

- **Open standards and interoperability:** Low (could be proprietary for a given manufacturer in this instance – this could also be used to obfuscate, assisting with cyber security)

Set and Forget - SGAM Framework

Component Layer

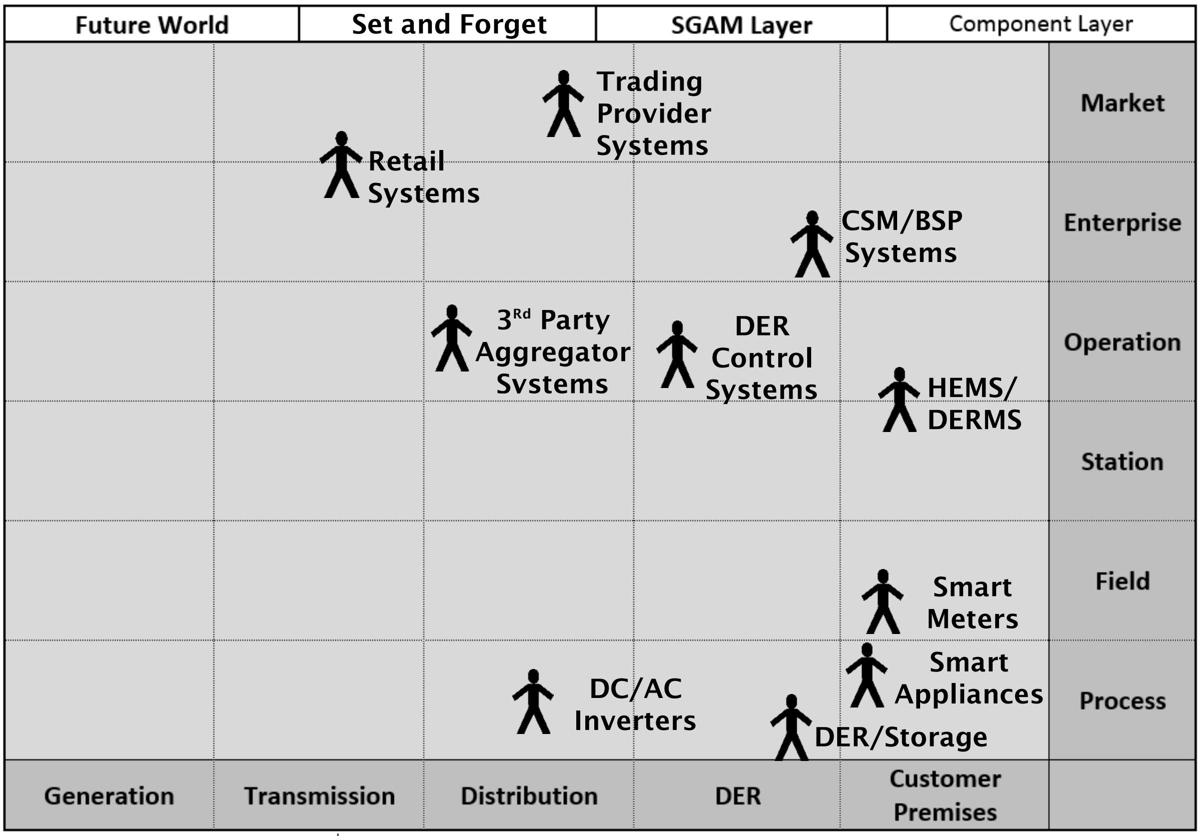


Figure 8 Set and Forget - SGAM Component Layer

When developing an SGAM model to define the grid architecture required to enable a future use case, or scenario encompassing a set of use cases, it is first necessary to identify critical components. These are the components that must be in place in order to provide the functionality, information and communication needed to facilitate the future scenario. The above component layer has been populated by examining the holistic view in Figure 7and example use cases identified to be most prevalent in the 'Set and Forget' future world. The use cases most applicable to this future world, derived from extensive reviews of workshop materials are highlighted in the table below.

Table 1 Set and Forget - Example Use Cases

Future Worlds	Demand Response	Dynamic Load Balancing	V2G	EV Co-ordination	DER Generation	HAN to Grid	Enable DER Market	Energy Storage	Dynamic Asset Control	Peer-to-Peer Trading	Customer Grid Interface	Micro Grid
Set and Forget	X	X	X		X	X	X	X			X	
Rise of the Prosumer	X		X	X	X		X	X	X	X	X	
Leaving the Grid								X		X		X
Renewables Thrive			X	X	X	X	X	X	X	X		

It is envisioned that Smart Appliances (appliances capable of remote control and management) and Distributed Energy Resources (DER), including storage components, will form part of this world. They will be situated between the customer's premises and the DER space. These, along with DC to AC inverters, will form the equipment responsible for delivering the physical change in electrical load on the network. Smart Meters will be ubiquitous amongst customers in this world, as will Home Energy Management Systems (HEMS). The former will meter consumption, while the latter provides the control interface for appliances, DER and storage; both will be within the customer premises. At the moment these technologies are possible, but not widespread, at the consumer/commercial level.

Additional components required by the future world include DER Control Systems. These perform a similar role to the domestic scale HEMS, but at DER level. This control system contains the physical equipment needed to control the operations of DER scale generation and storage. This equipment may receive its operating philosophy/instructions directly from a distribution system operator (DSO). However, in the Set and Forget Scenario there will likely be an intermediary in the form of a 3rd Party Aggregator. To facilitate this demand/response aggregation, it will be necessary for the aggregator to operate computer systems. These must incorporate the necessary software and technology to deliver the service. Similarly, other computer systems will be required to deliver the future world. These will include: a CSM platform and system for managing customer need, a secure trading system to facilitate transactions for aggregators on behalf of CSMs and finally retail systems capable of interacting with the trading platform and new smart meters. Again, at the component layer these systems refer to the physical equipment required to provide the necessary technical function.

Business Layer

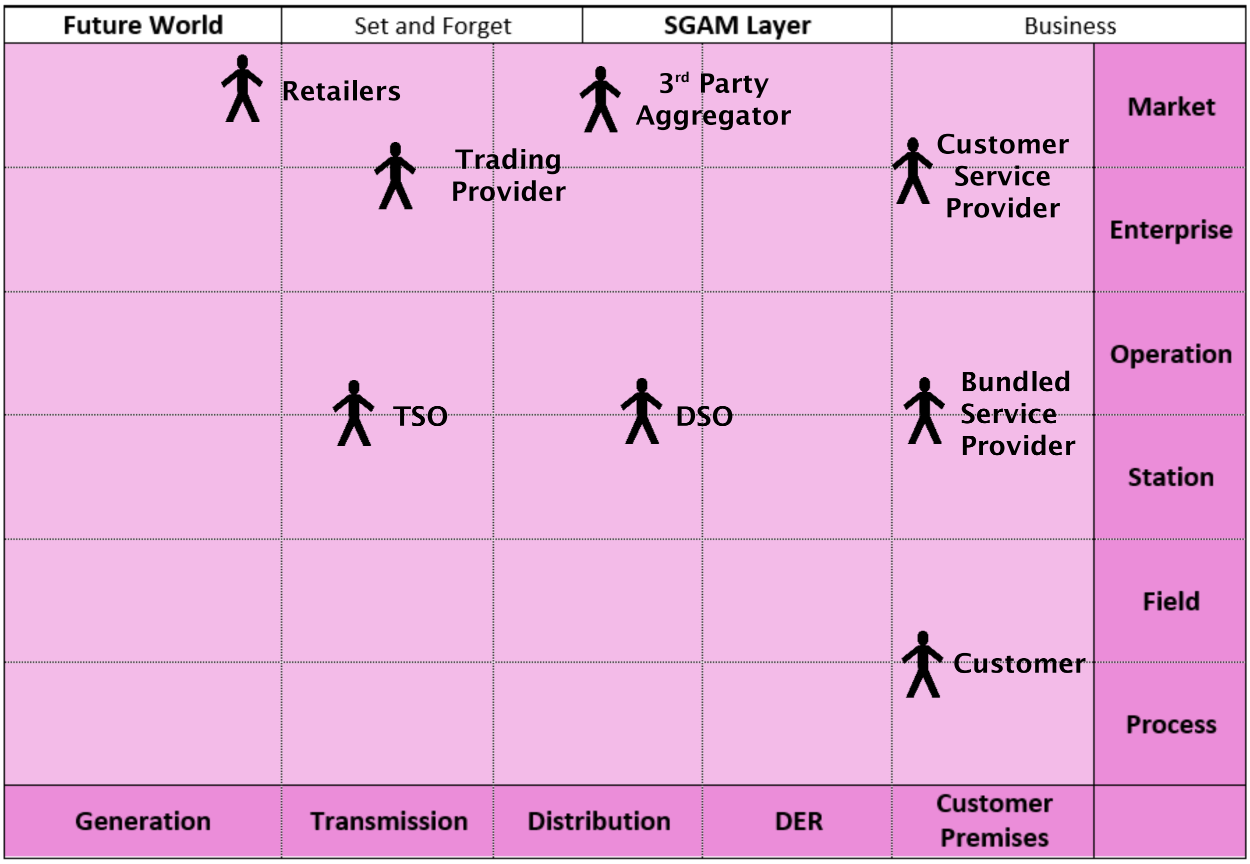


Figure 9 Set and Forget - SGAM Business Layer

The content of the business layer is drawn from the holistic view of actors presented in Figure 7. Importantly, the identified actors may not be specific businesses but rather the services provided by a business-like entity. Each actor could be provided by multiple competing businesses or, in contrast, one business may provide the services of many actors.

The business layer does not define which form is taken, only that the actors identified have a stake in the processes, services and organisations within the Set and Forget world. Through the nature of the future world, the role of the Customer within the scenario is broadly similar to the Customer of today. A significant change is the interaction with their HEMS/DER/Smart Appliances or CSM in order to 'set' their preferences for demand side response (DSR). This interaction places their stake in the world within the customer premises domain and the at the process/field zone level, where they interact directly with the components or CSM. The business layer can also be used to set out the role of new business entities within the future world. The BSP provides the control instructions for the customer's equipment. As such, its business interest is within the customer's premise, while its function of providing monitoring and control places it across the operation and field zones. Similarly, the DSO may deliver monitoring and control services to larger scale DER. The CSMs' main interests are clearly customer focussed and their commercial services and trading interests places them across the enterprise and market zones.

The business of the 3rd Party Aggregator sits within the market zone. This is due to their role in providing retail and energy trading functions. These services will be delivered at the Distribution and DER scale. They are able to access this scale through communicating with and aggregating demand/response from BSPs at lower scale values. Again, this aggregation service may take many forms: aggregators may group demand from certain appliances, certain times of day, by geography or by customer demographic.

Function Layer

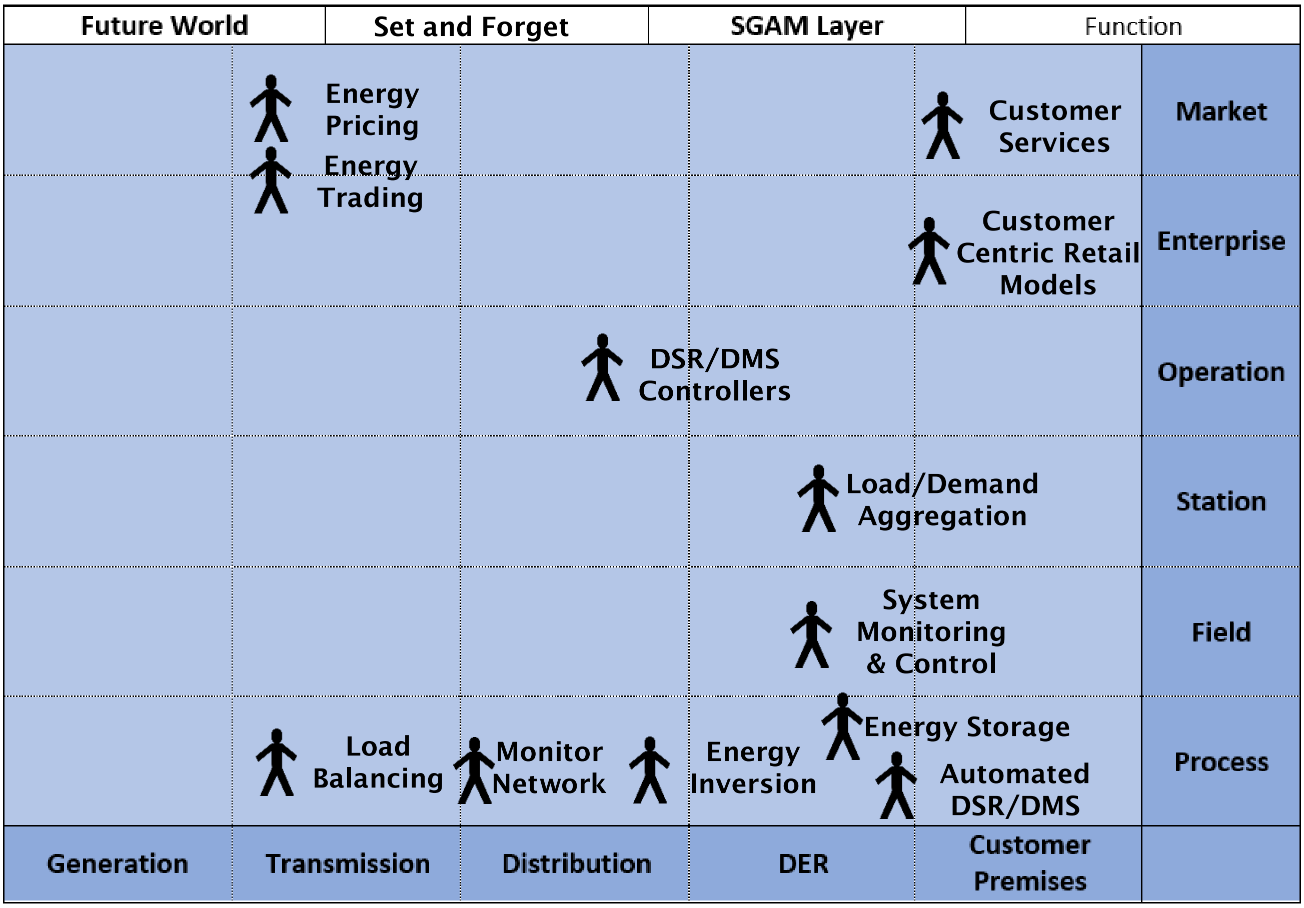


Figure 10 Set and Forget - SGAM Function Layer

This layer shows the components, business models and the holistic overview to accommodate the use cases that define the future world. The identified functionality is made possible by the components and services provided by the component and business layer.

To allow for the future world, the essential functionality across the system is mapped onto the layer above. Importantly, the DSO and TSO must monitor the network condition in order to identify when a DSR is required to alleviate the strain on the network. This network need must then be readily met by an aggregation service capable of amassing the response. The response is delivered by issuing a control instruction to equipment capable of automatically adjusting load.

Customer services must be in place that are capable of monitoring customer satisfaction with their level of service. This function sits within the enterprise zone and interacts at the domestic/commercial customer level.

The critical functions identified that are not widely available at the consumer/commercial level include domestic automation of DSR and DMS. Although this is technologically possible, there is definite room for development of Smart Appliances and other domestic/commercial scale solutions that can provide DER/DSR. Similarly, this equipment must interact with ubiquitous monitoring and control equipment in the form of Smart Meters and HEMS. This equipment will provide the desired functionality, but the world of today is pointedly removed from this level of uptake of smart control technology. Solutions capable of providing this functionality are technical enablers for the Set and Forget scenario.

The function layer is supported by the transfer of information to inform the decisions made within the function layer.

Information Layer

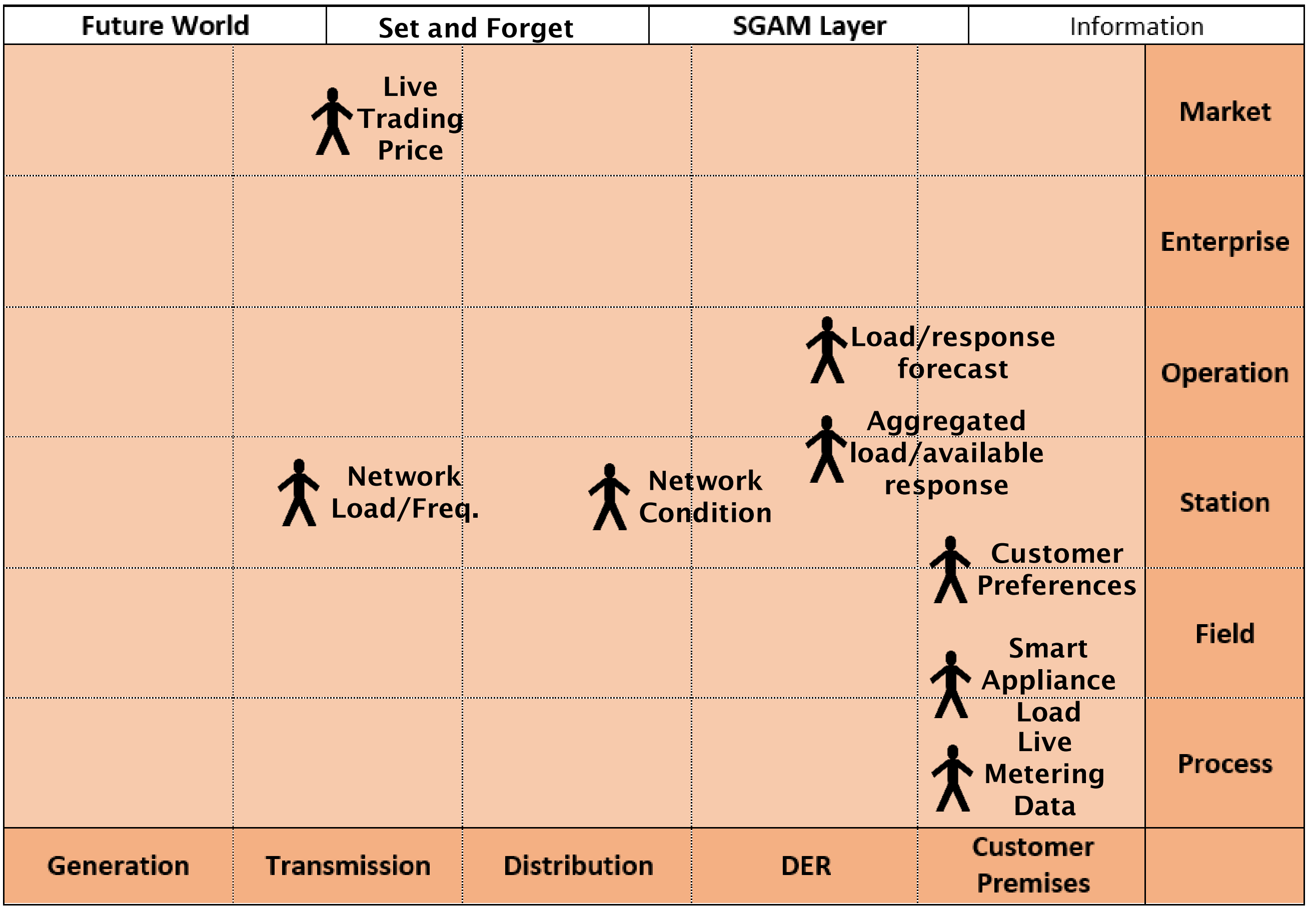


Figure 11 Set and Forget - SGAM Information Layer

The information layer describes the data or data models which must be collected and passed between actors to achieve the functionality set out in the previous layer. Information is transferred between actors and components as set out in the Communication layer (Figure 12). Where possible, the transfer of information has been linked between two or more components to aid with the visualisation of the processes. However, the SGAM positions are based on the role the information plays within the system, not the position of the component or actor it is transferred between.

Information must be collected in real-time on the state of the network. This will be used to inform the decision to request DSR solutions. The style of information required will be system-wide frequency, local network load and capacity limits, as well as voltage levels and power quality. This information is collected at the Transmission-Distribution-DER scale.

Several datasets are generated within the customer premises, including the customer preferences that are used to 'set' DSR availability to the system. This will be updated relatively infrequently. The customers metering data and smart appliance load will be transferred more frequently, as the system will rely on this information to determine DSR availability at a given moment. Using the customer preferences and live loading data, it is possible to produce information on the aggregated load/response at any given time and to forecast these values in advance.

Other critical pieces of information include the live electricity trading price. This sits within the market zone, as it directly facilities energy trading. It is also within the transmission domain, as it is a system wide price.

Communication Layer

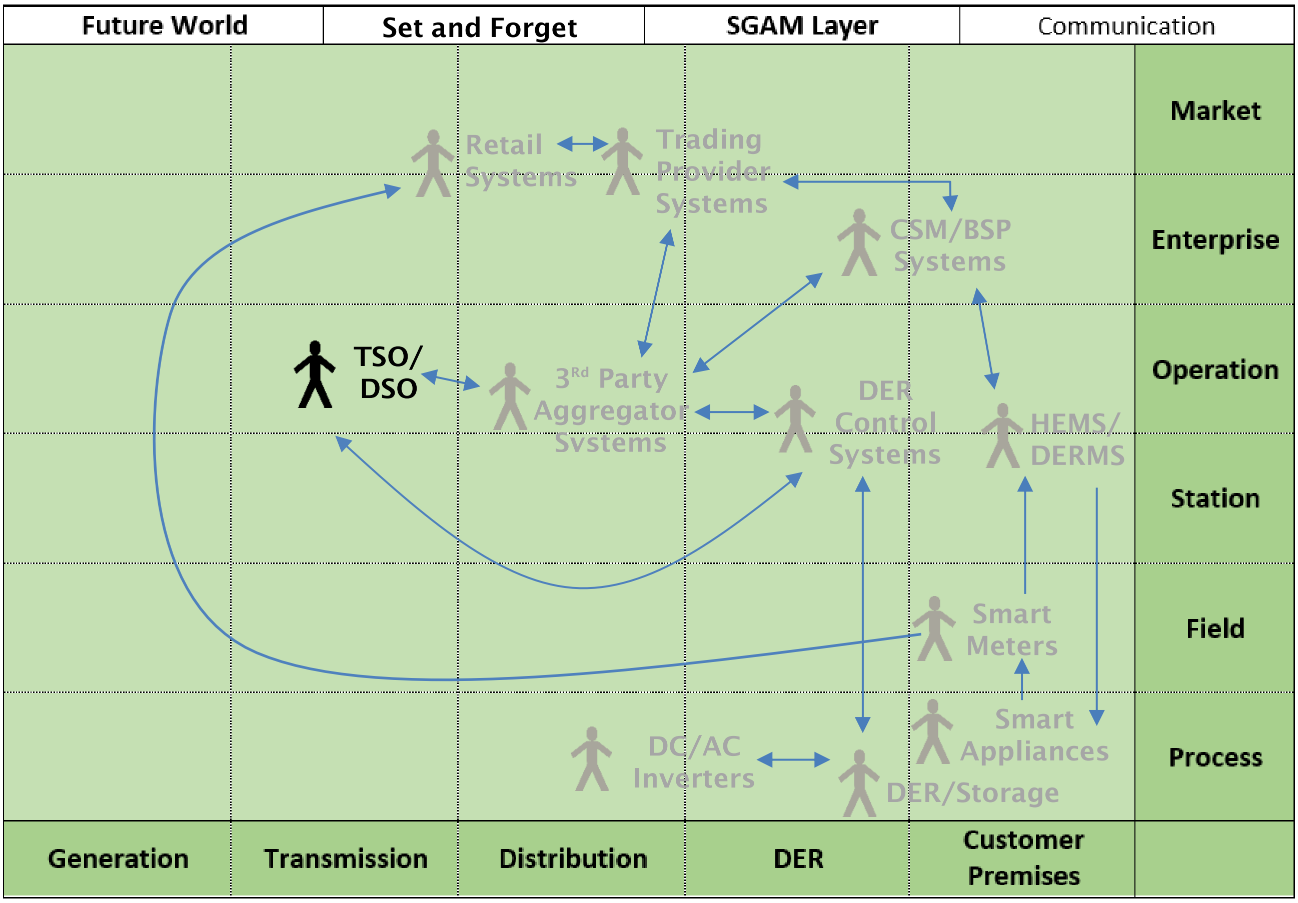


Figure 12 Set and Forget - SGAM Communication Layer

In this layer, the actors that are depicted in the colour grey have been directly transposed from the component layer. Additional actors have been added for completion. Although it is possible to include several more actors within this layer, it would repeat information shown in the holistic view of actors and communication channels (Figure 12), which clearly illustrates communication paths. These paths are tabulated in the Technical Enablers section above.

The communication layer demonstrates the pathways that exist between components (and some actors) to facilitate the exchange of information described in the information layer to achieve the functionality set out in the function layer. The exact mechanism for communication connectivity, such as GPRS, IP, DNP3 or otherwise is not defined at this stage, as there is room for technical innovation in this regard.

Key communication pathways include the exchange of information between Smart Appliances, Smart Meters and HEMS, as this will allow for the control of customer load to enable DSR solutions. Smart Meters could also communicate consumption directly to energy retailers. Similarly, the HEMS and DER Control Systems must receive control instructions from outside agencies, whether that be the CSM/BSP systems or directly from the DSO/TSO. Although there are many connectivity options capable of delivering this communication path, it is likely that an agreed Standard for securely transferring DSR instruction en-masse to specific appliances would be developed. Such a Standard is not currently available.

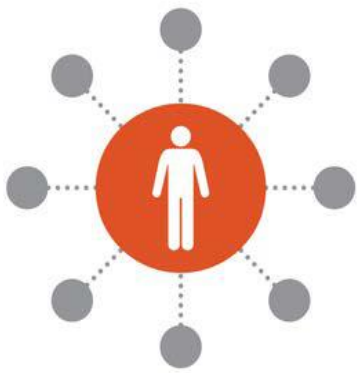
In order to deliver the aggregation services, the 3rd Party Aggregators must communicate with the control systems to access the total available response. In turn, there must a communication stream with the DSO/TSO to receive requests based on network need and with the trading provider to access to live pricing values.

Appendix III Future World Analysis – Rise of the Prosumer

The ‘Rise of the Prosumer’ scenario describes a case where customers take an active role in the power system; far more so than those in the ‘set and forget’ world. It also involves the prolific uptake of roof-top PV by all customers, including those without roof-space who may choose to purchase roof-top PV elsewhere.

The market facilitates customer desire for peer-to-peer trading and provides storage solutions for on-site consumption. The distribution and transmission network plays a peripheral role at the outset of this world but has the possibility to provide the infrastructure for energy trading in the future.

‘Prosumers’ choose the level of generation, storage, trading and pricing tariffs that suit them from a wide variety of options provided by the market.



Customer-centric model
where customers consume, trade, generate and store electricity.

Rise of the Prosumer - Holistic View of Future World

Figure 13 illustrates the key actors and communication channels that have been identified to serve an important role within the world. Clearly this diagram is not exhaustive and some actors represent the nature of the anticipated business models rather than a strict definition of the future enterprise. For instance, Rooftop Services is the industry that leases/purchases roof space for the purpose of increasing PV surface area. Their purpose is to allow consumers, even those without roofs, to purchase an area of roof space and thereby access energy generation. The business offers wholesale PV generated power by purchased roof area, not by energy volume. This industry is representative of a host of potential players that may emerge in the ‘Rise of the Prosumer’ world. Their mantra is for customers to access innovative energy trading, consuming and generating services.

Clearly, the ‘Rise of the Prosumer’ world is a customer centric model. This is highlighted by the level of interactions they are involved with in

Figure 13. Within this world, the customer plays an active role in the control of all of their electrical assets: load, generation and storage. In order to achieve this level of interaction, OEMs of this equipment must offer the facility to easily control their assets.

Customers are also involved in the retail aspect of their electricity consumption and export, actively interacting with retailers and energy service companies (ESCos) that allow for the devolution of energy trading. Customers may enter into energy contracts that significantly differ from the metering/billing of today’s world. In order to facilitate this significantly enhanced customer involvement, there is requirement for a sophisticated user-end interface to monitor and display system data in a user friendly manner. Businesses that fall within the above definition of ‘Rooftop Services’ will provide this.

Government policy heavily influences the nature of this world and is in place to ensure new trading structures are regulated and equipment is compliant. Emissions are also heavily regulated and renewable incentives are in place. Financial Markets are present for two reasons: to fund the central generation required to provide base-load and to support ESCo-style trading formats.

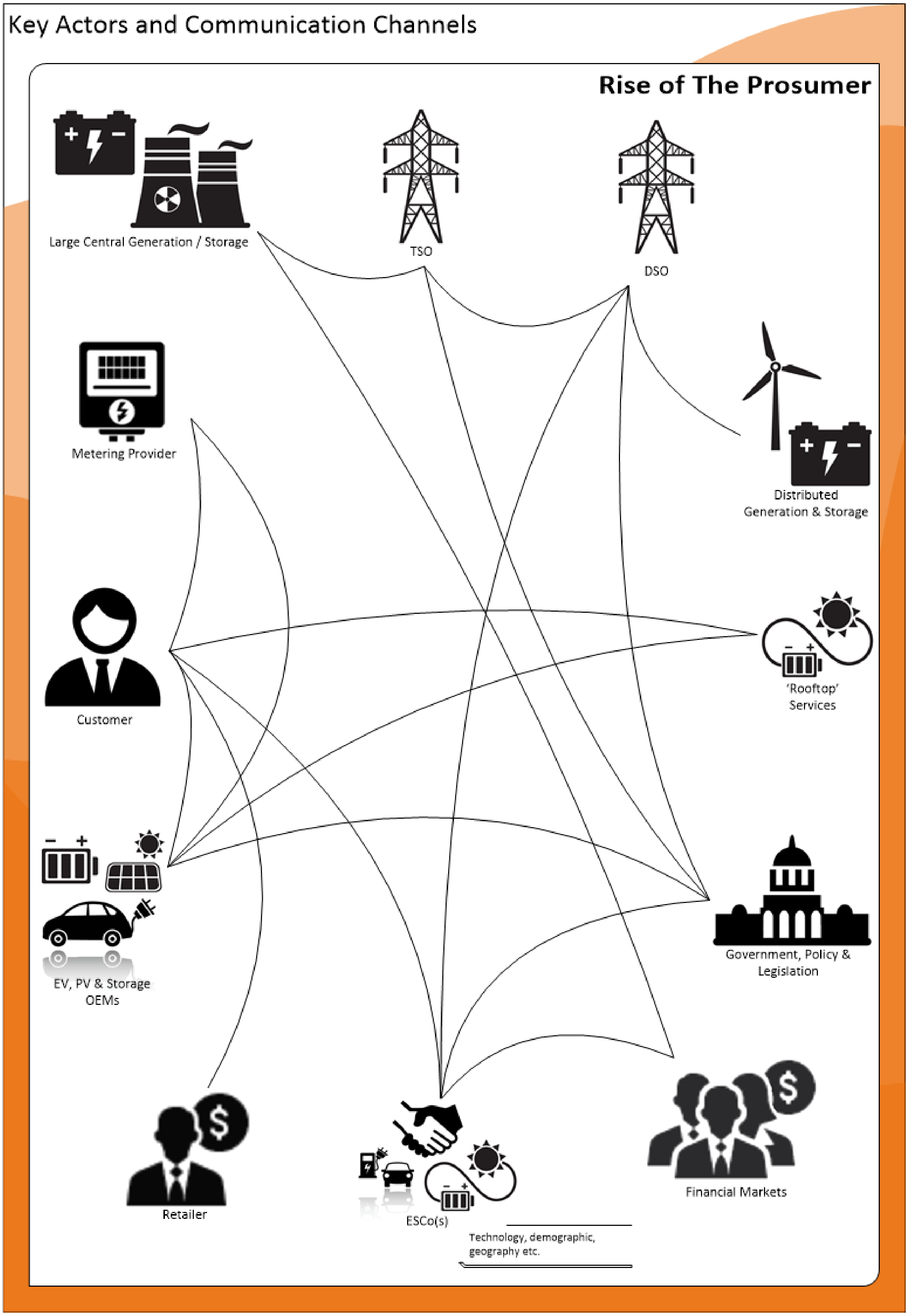


Figure 13 Rise of the Prosumer - Holistic View of Key Actors and Communication Channels

Rise of the Prosumer – Grid design and operation

a. Functional description of DSO and TSO activity

In this scenario, the roles of the TSO and DSO face significant change, moving from a central control role to a peripheral role with increased uncertainty as dynamic market forces dictate power flows across electricity networks. Unlike today's networks, the power flows would be de-centralised, transferring energy from low voltage to other low voltage or high voltage nodes.

Customers are active and make choices in terms of the equipment they choose to own and operate to ensure their lifestyles are accommodated and they achieve a return on their investment. Much more of the nation's electricity supply is derived from solar and the challenges of intermittent supply are overcome by home energy storage and customer's being incentivised to adapt their electricity use. Householders and small businesses become engaged in energy trading, relying on technology to maximise returns within the constraints of day-to-day needs. Spare distributed generation capacity or stored energy will be traded and the DSO will predominately exist to facilitate this trading.

The DSO now acts in a passive manner, but is exposed to market changes that may dynamically alter where power is transferred. The DSO will need to adapt technically to manage the distribution system within operational constraints in this de-centralised model.

The TSO would maintain a role in managing the macroscopic balance of energy supply and demand. Finer control would be facilitated through a management layer above a range of aggregators (e.g. 3rd party aggregators, bundled service providers, customer service managers). This would not necessarily be operated by the TSO. The aggregator's systems would also need to cater for DSO needs to ensure that local network constraints are not breached.

Key points:

- New technology and market mechanisms will seek to flatten overall demand as peaks can be moved about, but if the market is strong it may still cause local issues (as household energy may be exported to other areas of the grid)
- Will need strong protection against islanding
- The transition brings challenges and customers will have the ability to go off-grid temporarily

b. Optimum design and operating parameters

- *Inertia changes*
- *Amount of response needed to maintain inertia*
- *Alternative technologies to manage RoCoF*

System inertia and network fault level is falling as more centralised synchronous plant has been replaced with inverter coupled generation. This has resulted in a less electrically 'stiff' system.

TSOs and DSOs have started to install some synthetic inertia such as electrical energy storage, SVCs and (in some instances) flywheels, to address the issue. Meshing of previously radial networks has been shown to give benefits, increasing fault levels, whilst also giving rise to improved SAIDI / SAIFI performance.

Aggregators are starting to offer inertia / fault level services to the TSO/DSO using demand response but these are relatively new.

Due to much reduced system inertia, the limitations of RoCoF protection are very problematic. Alternative anti-islanding technologies, such as vector-shift or frequency-forcing are widely deployed. With improved communications infrastructure, island-enabling technologies such as syncrophasor protection become technically and commercially feasible and are being actively adopted by DSOs to enable continued system operation during periods of grid separation.

c. Limitations on existing Regulatory Investment Test – Transmission, with a focus on power system security and solutions needed

The Regulatory model has changed significantly from that in place today. Firstly the model will need to cater for the range of equipment that will be installed in customer's premises. The equipment will need to be sympathetic to all stakeholders in the energy system, ensuring that customers are protected, the energy markets operate effectively and TSO/DSO systems operate within network constraints, both from an individual perspective (e.g. harmonics) and aggregated (e.g. local network constraints such as equipment ratings).

Regarding infrastructure reinforcement / asset replacement, the DSO will also need to be able to tap into the demand markets on a local level. The costs of load-related asset replacement will only be justified when they compare favourably against market prices to de-load assets. Increasingly customers will rely less on the grid with lower peaks and moving to net zero energy consumption. At a household level, the grid will primarily serve as an energy trading facilitator when it is more advantageous to export energy rather than store or use it.

Demand and generation growth is much less visible to the DSO/TSO as it is masked by the complex interaction between customer equipment, customer behaviour and energy trading market strength. The aggregators have a key role in providing forecasting data to TSO/DSO in ensuring they can deal with peak demands, e.g. following faults or black-start.

Network performance targets (SAIDI/SAIFI) continue to tighten as citizens rely on the electricity grid for their everyday life. The rise of the prosumer will serve to flatten peaks for the DSO where local system peaks coincide with the national system, as the strong market will drive costs higher in these periods.

At the same time, dependency on the electrical grid has increased significantly for the transport and communication infrastructure. Climate change may will also increase the dependency of the water sector on the electrical grid for active flood prevention measures. Meanwhile, customers with local generation and storage become less dependent on continuous supply from the grid. Taken together, this results in a significant shift in the criticality of the electrical network (demographically, geographically and in magnitude).

As a result, penalties for loss of supply will vary to reflect these changes and to drive best practice.

d. Solutions to efficiently design, control and operate grid connected and non connected 'mini' grids and actions needed for implementation

Customer-centric systems that can interact with the grid will include energy storage, EV/V2G charge management and solar PV in additional to more traditional ripple control. These may be controlled through a HEMS or interact with aggregators directly. The operation of this equipment will be dictated by a complex blend of customer preference and market forces. The DSO will have access to the systems through the aggregators in order to manage the grid within operational constraints.

There will be two forms of interaction with these systems:

- The DSO enters the competitive market alongside other players for demand services;
- The DSO has protection systems built into systems to enable automatic disconnection where necessary.

The DSO will have built de-centralised control systems into the network to ensure that the potential variability of power flows that the energy market may bring can be effectively measured and managed.

e. Optimal requirements to address balancing challenge

- *Provision of greater flexibility from new sources of load/generation, i.e. fast ramp up (e.g. generation or DSR) to manage throughout the day, or between days*

In this scenario the flexible energy available to facilitate system balancing is abundant and customers are much more actively engaged with their energy supply compared to today's world. System balancing can therefore be achieved through a combination of large base-load plant and demand response services, enacted via the aggregators. The adoption and harnessing of many users provides significant control and flexibility with many hundreds or thousands of MWs available for rapid response.

Speed of response, ramp rates, kW / kWh (or MW/MWh) of response are clearly communicated between aggregator and end customer at the time contracts are agreed. The DSO/TSO agrees contacts with the aggregators, then provides automated signals to enact the service as and when required.

Rise of the Prosumer – Operating platform

a. the operating platform to allow full optimisation and coordination of the various parameters in this scenario

This scenario may lead to the DSO supplying less energy overall, and as customers will be better able to meet their own energy needs, the average utilisation of grid assets is likely to fall. However, distributed generation is intermittent and the installed capacity of generation when aggregated will be substantial in some areas leading to the DSO needing to manage grid assets to avoid ratings excursions.

The use of demand aggregators that can reduce load such as EV charging, air conditioning and home energy storage charging will form a key part of demand management by the DSO.

In many areas power flows will be unconventional, i.e. not flowing from the high voltage system to the low voltage system and the DSO will have far greater control, deeper into the network to ensure the system remains within its design limits. This is facilitated through many de-centralised control systems, managing disparate areas of the grid, such as pinch points. The DSO will also benefit from having much more granular reconfiguration options in the high voltage system in order to safely move power around at different times of the day.

Where commercial services cannot be procured, the DSO/TSO roll out their own technical solutions. These augment the traditional network, deployed based on economics of each circumstance. As the volume of solutions increases, decision support tools will be rolled out to assist DSO/TSO planners in designing the network.

As this scenario is market driven, the DSO/TSO will develop complex forecasting tools that allow them to assess ahead of need when procurement of demand services is unavoidable due to predicted network constraints.

- Need good forecasting and DSO will need a strong relationship with the market in order to predict when issues will occur
- DSO/TSO will need to deal with intermittency of generation, where generation is in abundance, loads on distribution networks will be about transferring from areas with generation capacity to those without (sub-urban, urban, rural). National markets do not consider location but this is vital for DSO operation
- Where distributed generation is weak, the grid will take the more traditional role of top down power flows. This will give rise to the need of much greater control of voltages and a more dynamic network configuration.

b. credible strategies for network operation and control to alleviate technical constraints and maximise the benefits of new demands/generation

System frequency balancing will be maintained through direct interface with large generators and via aggregators to procure demand services from end customers. Sufficient large generation is needed to maintain system inertia and mechanisms would be developed to place value on rotating generation plant and high inertia demand such as large industrial motors.

The networks will face far greater variability of power flows than they do today, the DSO will install de-centralised control systems that can measure asset constraints, understand flexible load that is connected to the assets, and if necessary autonomously request support from demand aggregators. The volume of these constraints precludes the use of manned control centres for this purpose.

In today's world it can be acceptable to measure loads in real-time and base future operational decisions on these. The variability of both daily load curves and longer term market driven changes will mean that the DSO has had to develop complex forecasting tools to assist them make business decisions regarding the cost of asset replacement vs. demand services to mitigate against the asset replacement.

c. Optimal mechanisms to maintain levels of system performance re. stability and optimisation

All systems will operate autonomously and equipment from a variety of manufacturers will work together seamlessly through the development and testing of system integration standards.

This scenario will lead to overall lower levels of load transfer, particularly from the higher voltages, so load-related asset replacement will be sparse. Instead, the challenges will be around system stability and protection. Protection schemes become more complex as the DSO has installed more reconfiguration points (e.g. telematics switches) and also meshes the network where it is appropriate.

The increased complexity of DSO operations (and corresponding increase in the number of protection zones) may lead to an increase in the number of interruptions, although these would be expected to be correspondingly smaller in magnitude and duration.

Field operations will continue broadly as they do today, albeit field operatives will need to be trained in all new solutions. For example, it is likely that field operators will increasingly encounter remotely-controlled assets or automated restoration systems. This will lead to new operating regimes (such as islanded operation and highly variable and unpredictable plant loading) that will be unfamiliar to experienced field operatives. In addition, increased use of predictive diagnostics will mean that interventions on the network will be increasingly preventative (rather than post-fault repair), requiring field operatives to have a different set of skills to carry out those interventions. This is a crucial, often overlooked, area which if not done at the right point, will hamper and slow adoption of new systems and practices.

Another area of concern is the inadvertent introduction of new common-mode failure mechanisms (such as the loss of a communications network or widespread cyber-vulnerability). It is therefore important that any solutions that are wrapped around (or integrated with) the physical network assets are equally robust and that they do not build in additional risk to the TSO/DSO.

d. strategy on detailed technical issues, i.e. managing frequency and voltage stability

The key issues that will need to be addressed are:

- Municipal energy markets do not consider local issues, ensuring aggregation services are sympathetic to the network and, for example, do not lead to export in a local area exceeding local grid constraints will be necessary;
- Over time there will be increased reliance on inverter connected distributed generation. Fault ride through capability will need to be considered to assist with overall system stability along with procurement of inertia services.

e. technical challenges to enable this scenario

The key technical challenges to enable this scenario will be:

- Developing the regulatory framework to ensure that customers and networks are protected from market mechanisms
- Dealing with reduced fault level: ensuring protection systems operate with lower system fault level
- The control environment will be much more complex than that of today's network, with many control nodes installed deeper into networks. In some areas it may be necessary to form a hierarchical control network to manage wider areas whilst still managing local constraints.

f. the framework to facilitate DSR and appropriate monitoring

In this scenario DSR would be initially facilitated by the TSO to develop demand aggregators. This would initially be driven from the features of particular equipment, such as the controlled charging of EVs. Once a market is established, it will be necessary over time to increase the reach of the demand services by offering rates that are attractive to customers to secure their engagement.

The operational facilities that are required would be developed through trials on areas of the network ahead of need. This is important to ensure that the inevitable technical issues are solved without having to rely on the systems for system operation.

Rise of the Prosumer – Technical enablers (telecoms)

This section considers those links which are new for this scenario, rather than the existing communications links. Communications links with similar attributes have been grouped together, they are ordered A-F with A being a one to one relationship; F being a one to many relationship.

2030's Scenario	Actors		Functional Requirements					
			Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
Rise of the Prosumer	Commercial service provider	Commercial service provider	3	3	3	3	4	3
	Commercial service provider	Customer - Small	3	2	2	2	4	3
	Commercial service provider	Large generation & storage	4	1	1	2	2	2
	DSO	Commercial service provider	2	1	1	1	2	1
	DSO	Government & Regulator	3	3	3	3	4	2
	DSO	Small / distributed generation & storage	3	1	2	2	3	1
	DSO	TSO	3	2	1	2	3	3
	Government & Regulator	Commercial service provider	3	3	3	3	2	2
	TSO	Government & Regulator	3	2	1	2	4	3
	TSO	Large generation & storage	2	1	1	1	2	1

A. DSO/TSO to Distributed Generation & Storage / Large Central Generation & Storage

- **Functional requirements:** communications used for monitoring and control for network operations. With this in mind needs to have: high security, medium bandwidth, high latency, high reliability/resilience

- **Immediate communications needs:** likely to be in place between DSO / TSO and large central generation; new for DSO and other stakeholders as they enter the market
- **Longer term communications:** deploy as new services are established between TSO/DSO and distributed generation & storage providers as equipment and services are commissioned.
- **Scalability of communications:** medium
- **Cyber security:** high (must be secure: limited channels so can pay more per channel for high security)
- **Open standards and interoperability:** medium (ideally have a common standard across Australia to allow a range of 3rd parties to operate across the country)

B. DSO to ESCo(s)

- **Functional requirements:** communications used to signal for multiple responses - needs very high security, higher bandwidth, high latency, and high reliability/resilience
- **Immediate communications needs:** similar needs to those existing today
- **Longer term communications:** these communications will need to be in place prior to operation
- **Scalability of communications:** low-medium (limited deployment)
- **Cyber security:** high (must be highly secure: limited channels so can pay more per channel for high security)
- **Open standards and interoperability:** medium (ideally have a common standard across Australia to allow a range of 3rd parties to operate across the country)

C. Large Central Generation / Storage to Financial Markets

- **Functional requirements:** communications used to signal for multiple responses including trading information - needs high security, higher bandwidth, high latency, and high reliability/resilience
- **Immediate communications needs:** As B, similar starting point as that from trading to centralised generation as exists today.
- **Longer term communications:** Communications links funded between these commercial entities without any involvement from DSO/TSO. An expectation that these would need to be in place prior to the providers offering the service.
- **Scalability of communications:** low-medium (would need to scale to a range of providers)
- **Cyber security:** medium-high (must be secure to prevent unauthorised access)
- **Open standards and interoperability:** low-medium (ideally have a common standard across Australia to allow a range of providers/generators to operate across the country)

D. Rooftop Services / Metering Providers to EV, PV & Storage OEMs

- **Functional requirements:** communications used to signal for a response, needs to have medium-high security, low(er) bandwidth, low latency, medium reliability/resilience
- **Immediate communications needs:** would use existing commercial solutions

- **Longer term communications:** deploy as new services are established between 3rd parties and storage providers / smaller generators

- **Scalability of communications:** medium (will need to scale to possibly tens of thousands of providers/generators)

- **Cyber security:** medium (needs to be secure, although limited impact if hacked only between 3rd party and any one provider/generator)

- **Open standards and interoperability:** low-medium (ideally have a common standard across Australia to allow a range of providers/generators to operate across the country, but could be proprietary for any given 3rd party aggregator)

E. Metering Providers / Retailers / Rooftop Services / ESCo(s) to Customers

- **Functional requirements:** communications between the end user and multiple commercial entities used for monitoring and control. In this scenario, it is expected that there will be a number of commercial entities offering services to up to the majority of available customers, equating to potentially millions of end devices. Needs to have good security, medium bandwidth, lower latency, medium reliability/resilience.

- **Immediate communications needs:** deploy as new services are put in place between commercial entities and customer. Likely to piggy back on existing communications into the home, e.g. TCP/IP (Internet), etc.

- **Longer term communications:** Likely to remain using some form of Internet connection

- **Scalability of communications:** high (a need to be widely scalable to millions of devices)

- **Cyber security:** medium-high (this link provides the interface to the customer, whilst it needs to be secure to protect data privacy, there is limited damage that could occur if hacked)

- **Open standards and interoperability:** high (would favour being an open standard in order to facilitate competition between ESCo(s) – a need to define this as the market starts to form)

F. EV, PV & Storage OEMs to Customers

- **Functional requirements:** communications used for monitoring and control to a number of in home privately owned assets such as home energy storage and EVs. Could be signalling to hundreds of thousands or even millions of devices, needs to be secure, low(er) bandwidth (due to volume), medium latency, medium reliability/resilience. In this mode the product manufacturer may be offering services to the industry and customers spanning their product ranges.

- **Immediate communications needs:** Use product vendors favoured solution, linking to existing communications e.g. TCP/IP, etc.

- **Longer term communications:** Depends on the strategy of the product vendor

- **Scalability of communications:** high (a need to be widely scalable to millions of devices)

- **Cyber security:** high (needs to be secure to prevent hacking and 3rd party control. Likely to be a target for attack, so would need to well maintained)

- **Open standards and interoperability:** Low (could be proprietary for a given manufacturer in this instance – this could also be used to obfuscate, assisting with cyber security)

Rise of the Prosumer - SGAM Framework

Component Layer

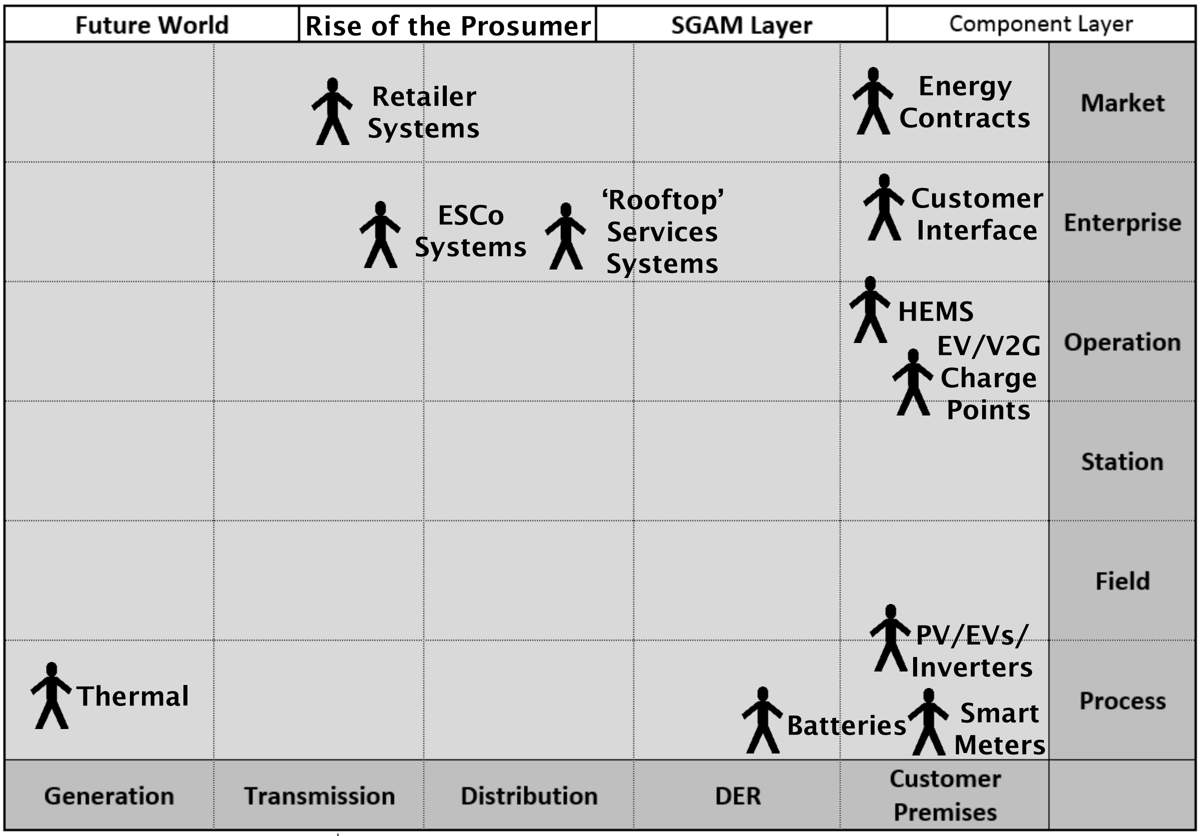


Figure 14 Rise of the Prosumer - SGAM Component Layer

The components identified within this layer which must be in place in order to provide the functionality, information and communication pathways needed to facilitate the future scenario. The layer has been populated by examining the holistic view in

Figure 13 and the use cases identified to be most prevalent in the 'Rise of the Prosumer' future world. The use cases most applicable to this future world, derived from extensive reviews of workshop materials are highlighted in the table below:

Table 2 Rise of the Prosumer - Example Use Cases

Future Worlds	Demand Response	Dynamic Load Balancing	V2G	EV Co-ordination	DER Generation	HAN to Grid	Enable DER Market	Energy Storage	Dynamic Asset Control	Peer-to-Peer Trading	Customer Grid Interface	Micro Grid
Set and Forget	X	X	X		X	X	X	X			X	
Rise of the Prosumer	X		X	X	X		X	X	X	X	X	
Leaving the Grid								X		X		X
Renewables Thrive			X	X	X	X	X	X	X	X		

In this world, where the customer is centric to the operation of the system and plays an active role in energy consumption, generation and trading, it is envisioned that the electrification of vehicles, the proliferation of customer PV and energy storage all become critical. As such, all three of these technologies are identified on the component layer. The components are situated within the customer premises at the process level; this is where the physical equipment that impacts the grid occurs. Electric Vehicles (EVs) are not a standalone technology and their implementation requires a charge point infrastructure to support them, typically a combination of public and domestic charging facilities. With the increased customer comfort and uptake of storage technology it is also envisioned that vehicle to grid (V2G) technology will form part of this world. This is where EVs are able to both charge from and discharge to the power grid.

Also within the customers' premise is a HEMS. This equipment will monitor and allow for control of a customer's electrical assets. The customer's active role in this world requires them to interact with their HEMS, as such a customer interface component will be required. This interface describes the physical equipment necessary for customers to access a graphical user interface (GUI) in order to monitor and control their electricity consumption, trading and generation.

Energy Contracts are a market component applicable at the customer scale. This is necessary to facilitate customers generating, storing and trading energy - possibly between peers. This behaviour mandates the introduction of non-traditional energy contracts to define the customers' trading position and revenue mechanisms.

In addition to the hard energy transformation components and market trading components within the world, other components include computer systems in place to manage the energy trading and processes within the scenario. These include energy retailer systems, energy service company (ESCo) systems and the systems of the 'rooftop' services industry.

Business Layer

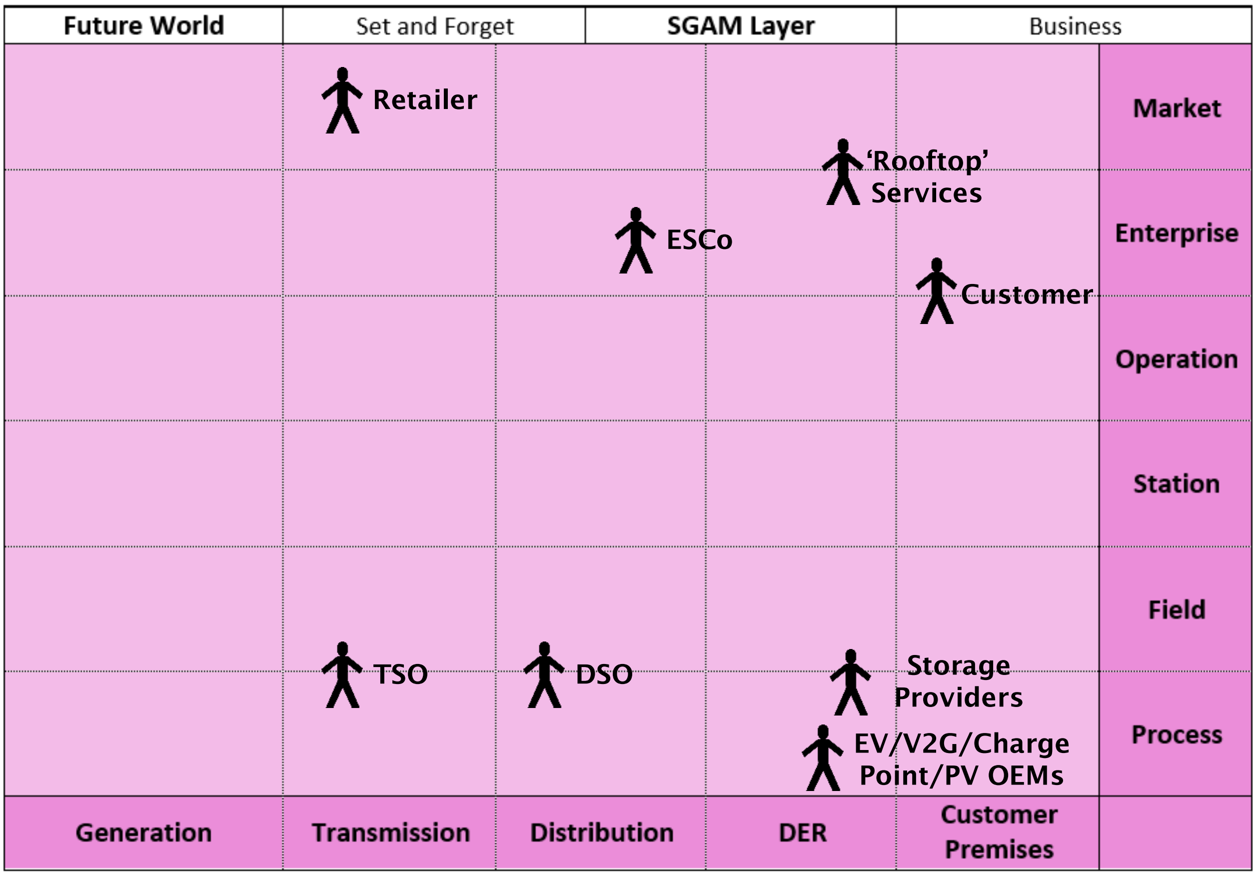


Figure 15 Rise of the Prosumer - SGAM Business Layer

The content of the business layer is drawn from the holistic view of actors presented

Figure 13. Importantly, the identified actors may not be specific businesses but rather the services provided by a business-like entity. Each actor could be provided by multiple competing businesses or, in contrast, one business may provide the services of many actors. The business layer does not define which form is taken only that the actors identified have a stake in the processes, services and organisations within the 'Rise of the Prosumer' world.

The customer centric nature of this world leads to the style of business services offered within the scenario, including that of a supply chain. For instance, the business organisations responsible for the providing the physical equipment within the customers' premises are mainly in place to supply customers with EVs, PV equipment, charging facilities and V2G infrastructure. It is not the role of these businesses to deliver a continuing service to the customer, who will adopt this responsibility instead. Additionally, the role of the DSO and TSO in this scenario, particularly in the years leading up to 2025, are considered to be peripheral. As such they continue to deliver, maintain and operate the electricity infrastructure and protection/monitoring equipment. They develop some new business interactions, identified in Figure 15.

The customers' business case is situated across the enterprise and operation layer, indicating they have an active role in the commercial energy trading processes and the control of their domestic energy appliances. The 'rooftop' services industry, which serves as an example for any business supplying services of this nature, sits across the enterprise and market levels as their role will be to provide the soft infrastructure and trading access to customers; the industry will also interact with OEMs to provide the physical equipment.

ESCos provide the commercial interface between energy retailers and customers, although it is possible for individual customers to establish themselves as personal ESCos.

Function Layer

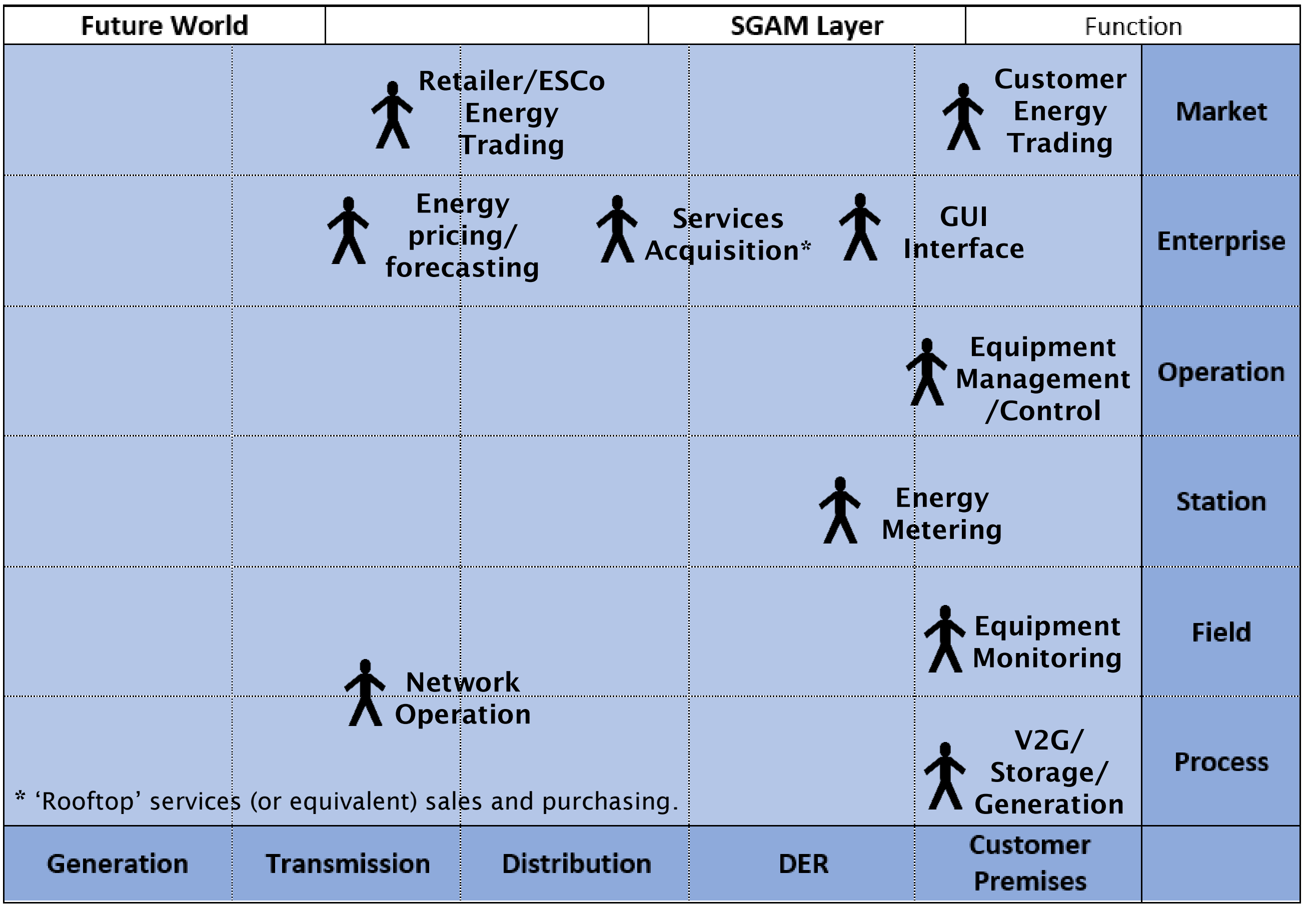


Figure 16 Rise of the Prosumer - SGAM Function Layer

This layer shows the components, business models and the holistic overview to accommodate the use cases that define the future world. The identified functionality is made possible by the components and services provided by the component and business layer.

To allow for the future world, the essential functionality across the system is mapped onto the layer above. Clearly the functional role of components, from Figure 16,, is to deliver a technical or market service, these provide the physical storage, generation (PV), energy metering and monitoring/control within the customers premises. They also provide the energy trading mechanism at the customer-market level, which is facilitated through the customers trading contract.

The function of Network Operation remains similar to that of the functionality within today's world. The DSO/TSO will continue to operate and maintain the network and will be engaged in some part with the new behaviour of the system, shown in Figure 17 below.

A critical function within this layer is the GUI customer interface. This is the mechanism by which the customer can access their energy monitoring, control and metering data. The function provided by this interface is the physical portal for the customer to receive information and pass instructions to their energy system regarding consumption, storage, generation and trading.

It is also an important function of this world to facilitate energy trading at all levels. For this reason, detailed and readily available energy prices must be calculated live and forecast in advance to support the trading infrastructure. This trading infrastructure will be provided by the retailer/ESCo or other similar agent.

Information Layer

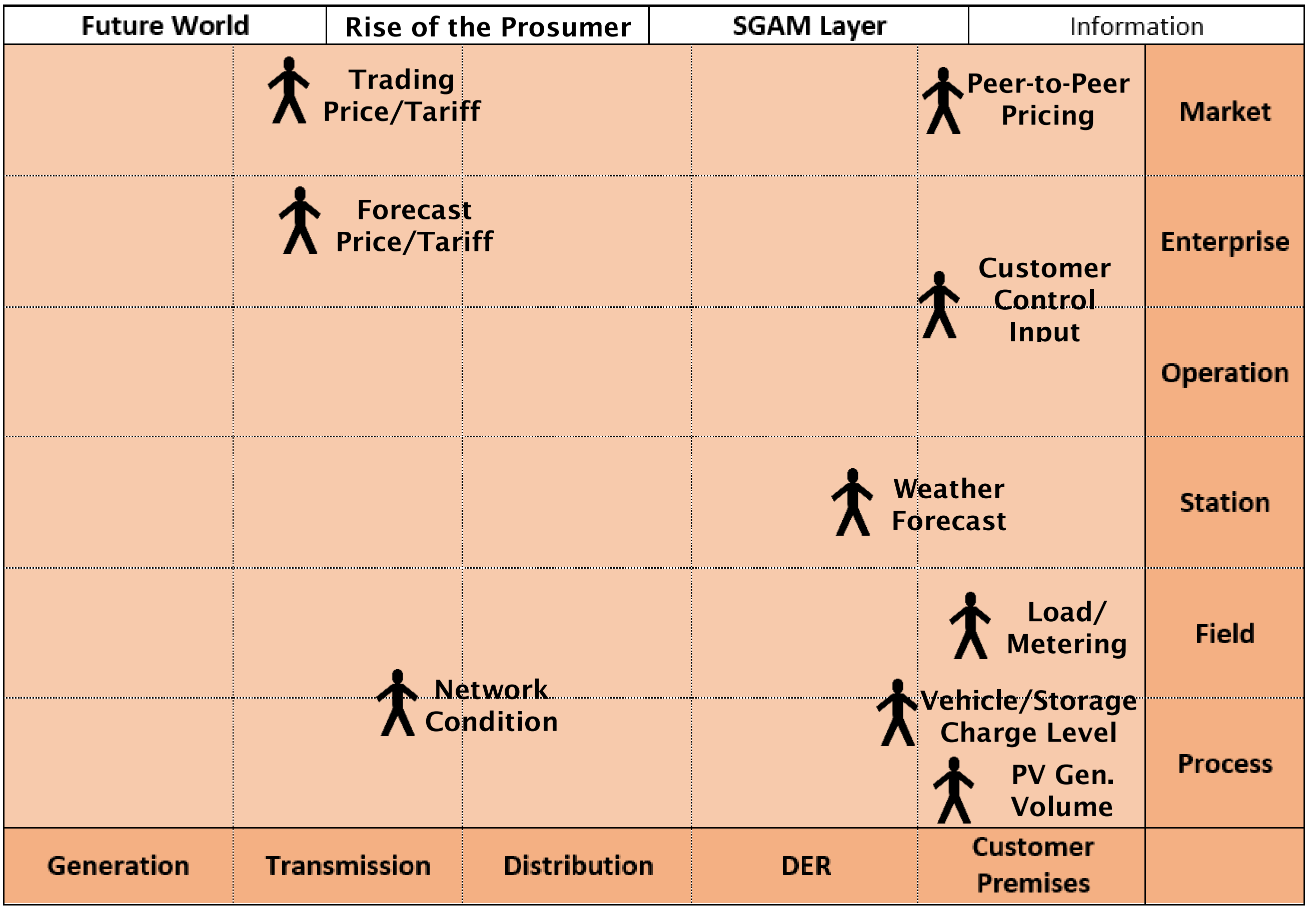


Figure 17 Rise of the Prosumer - SGAM Information Layer

The information layer describes the data or data models which must be collected and passed between actors to achieve the functionality set out in Figure 17. Information is transferred between actors and components as set out in the Communication layer (Figure 18). Where possible, the transfer of information has been linked between two or more components to aid with the visualisation of the processes. However, the SGAM positions of information are based on the role it plays within the system, not the position of the component or actor it is transferred between.

To facilitate the system, the customer must be able to access the following data and controls:

- The volume of energy they generate, whether by PV or other means.
- The charge level of any storage they have, whether using batteries or EVs combined with V2G technology.
- Any on-site electrical load they have at a given time.
- Access to the purchase and sale price of power available to them at a given time.
- Simple control of any one of their generating, storage or consuming assets.
- Option to sell or purchase storage.

The above information actors have been mapped over the information layer in order to provide customers with the required flexibility and functionality to achieve the above points. The weather forecast is deemed an important piece of information as it strongly correlates with PV generation and air conditioning/heating load. It is therefore a useful tool for demand/generation modelling.

It is clear that there are many more pieces of information that must be collected and passed between the system, but in the interests of brevity only those that are considered to be of particular relevance to this scenario are detailed in Figure 17.

Communication Layer

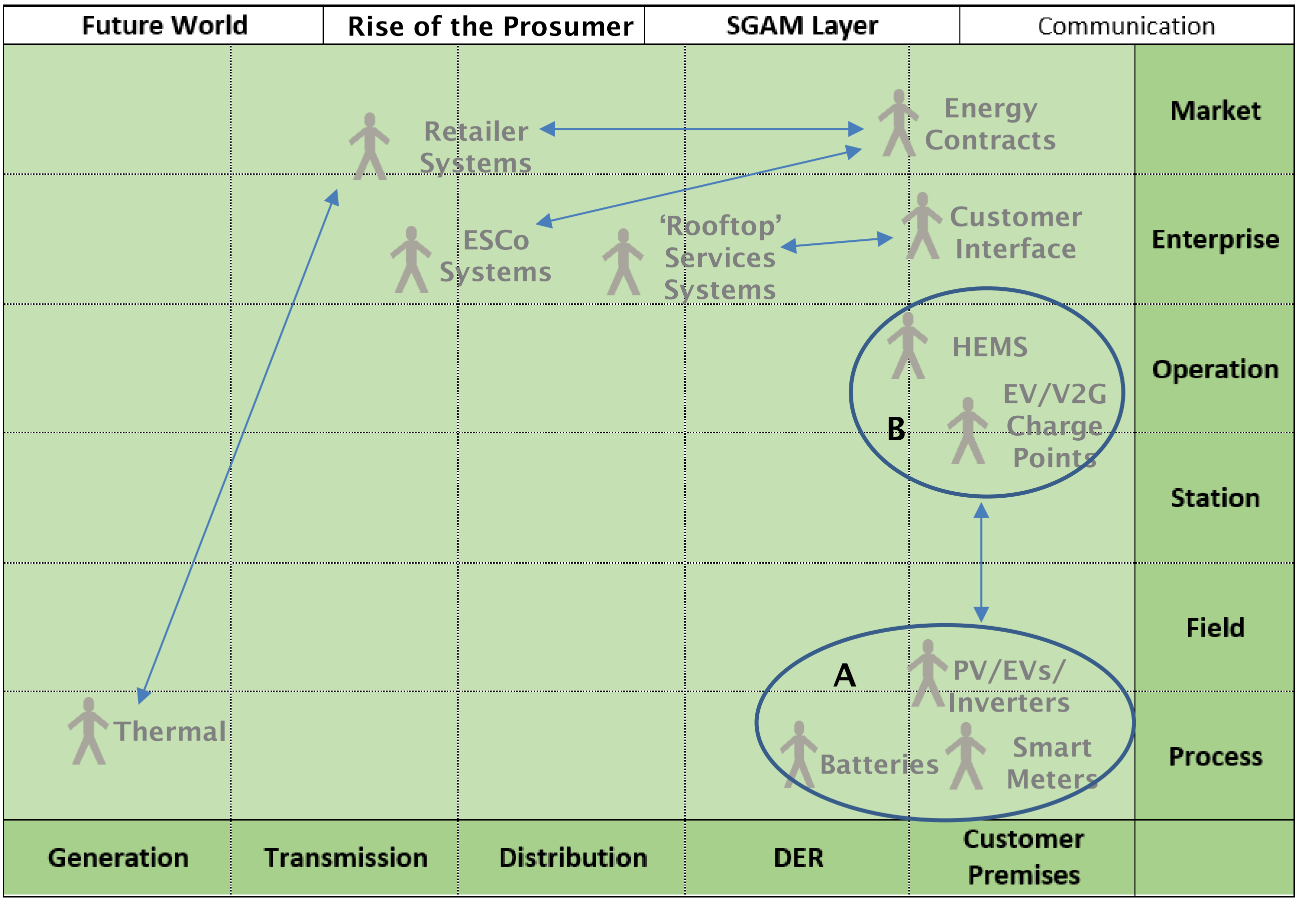


Figure 18 Rise of the Prosumer - SGAM Communication Layer

The actors are grey in colour as they have been directly transposed from the component layer. Although it is possible to include several more actors within this layer, it would repeat information shown in the holistic view of actors and communication channels (Figure 7),), which clearly illustrates communication paths. The communication layer demonstrates the pathways that exist between components (and actors to facilitate the exchange of information described in the information layer to achieve the functionality set out in the function layer.

There are two main functions that are enabled by the effective communication of information between different components in this scenario. These are:

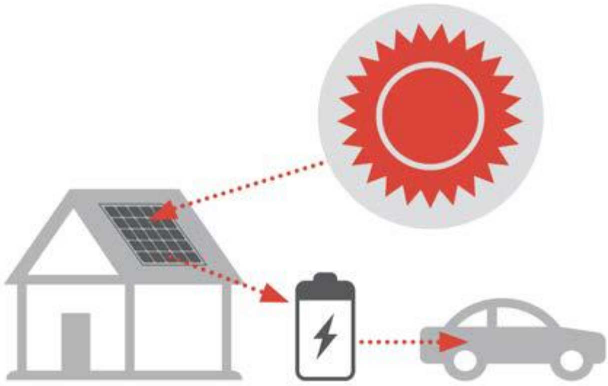
1. The ability to operate an electricity trading market for customers and retailers alike,
2. Increased customer operability of their electrical assets consumption, storage and generation.

The first of these points is enabled by communication between customers and retailers through their energy trading contracts. There is currently a gap which prevents customers from 'selling' power back to the grid. As such, there is a need for innovation if this world is to be realised. As detailed previously, an ESCo may play an intermediary role in this relationship: it may act on behalf of many customers or even individuals and could facilitate this trading relationship.

The second of these points is enabled by the Customers Interface component and its relationship with the electrical asset control equipment, collected in group A. In turn, this control equipment must communicate instructions to the physical electrical equipment, in group B. These communication relationships, although technically feasible, would likely require the development of a secure Standardised approach to enable rapid uptake of compliant equipment.

Appendix IV Future World Analysis – Leaving the Grid

In this scenario, utilities realise the need for customer's energy bills to reflect the cost of supplying electricity, rather than just volume consumed. However most small customers lack the equipment to properly meter capacity. This leads to a combination of volume and capacity tariffs. This pricing mechanism leads to low returns for PV generation, which discourages new uptake. Customers with EVs are also increasingly comfortable with the idea of energy storage.



Leaving the Grid - Holistic View of Future World

As customers become more active in the energy system, owning and operating distributed generation, energy storage and energy 'smart' appliances, there becomes less reliance on the grid. As the expense of operating the system has to be met across less kWh import there becomes less justification for staying connected. Customers may choose to leave the grid completely and rely solely on their technology or they may stay connected purely to allow energy trading of spare generation or storage capacity. Overall this scenario leads to less load on the grid, and hence less revenues for the TSO/DSO whilst cost pressures are maintained to support those still connected. The role of the TSO/DSO is relegated to provision of backup services in case customer owned technology fails or to deal with abnormal generation intermittency.

Regulatory changes are developed to attempt to fairly distribute the costs between those reliant on the grid and those not, despite disparity of volumes of energy imported (e.g. ratio of standing charge and per unit charge). Customer protection is needed for those unable to off-grid and those in rural locations where they would face disproportionately high charges compared to city/dense environments.

The lower levels of system inertia lead to installation of SVCs and energy storage where commercial 'inertia services' are unavailable.

RoCoF based protection is largely phased out due to reliability as the system frequency exhibits greater non-fault instability. New methods are rolled out such as frequency-forcing and vector-shift. Islanding is increasingly permitted, enabled through syncrophasor protection devices.

Levels of investment are low due to lower revenues and a tough justification environment with reducing demand. This is partly alleviated through reduced reliability targets and planning standards. This leads to far less infrastructure investment to improve reliability, instead focussing on an operating model of using mobile generation whilst faults are addressed.

As grid defection deepens, maintaining system frequency becomes more challenging as there are less commercial entities with which to contract with for demand services and less revenues to invest in assets such as energy storage.

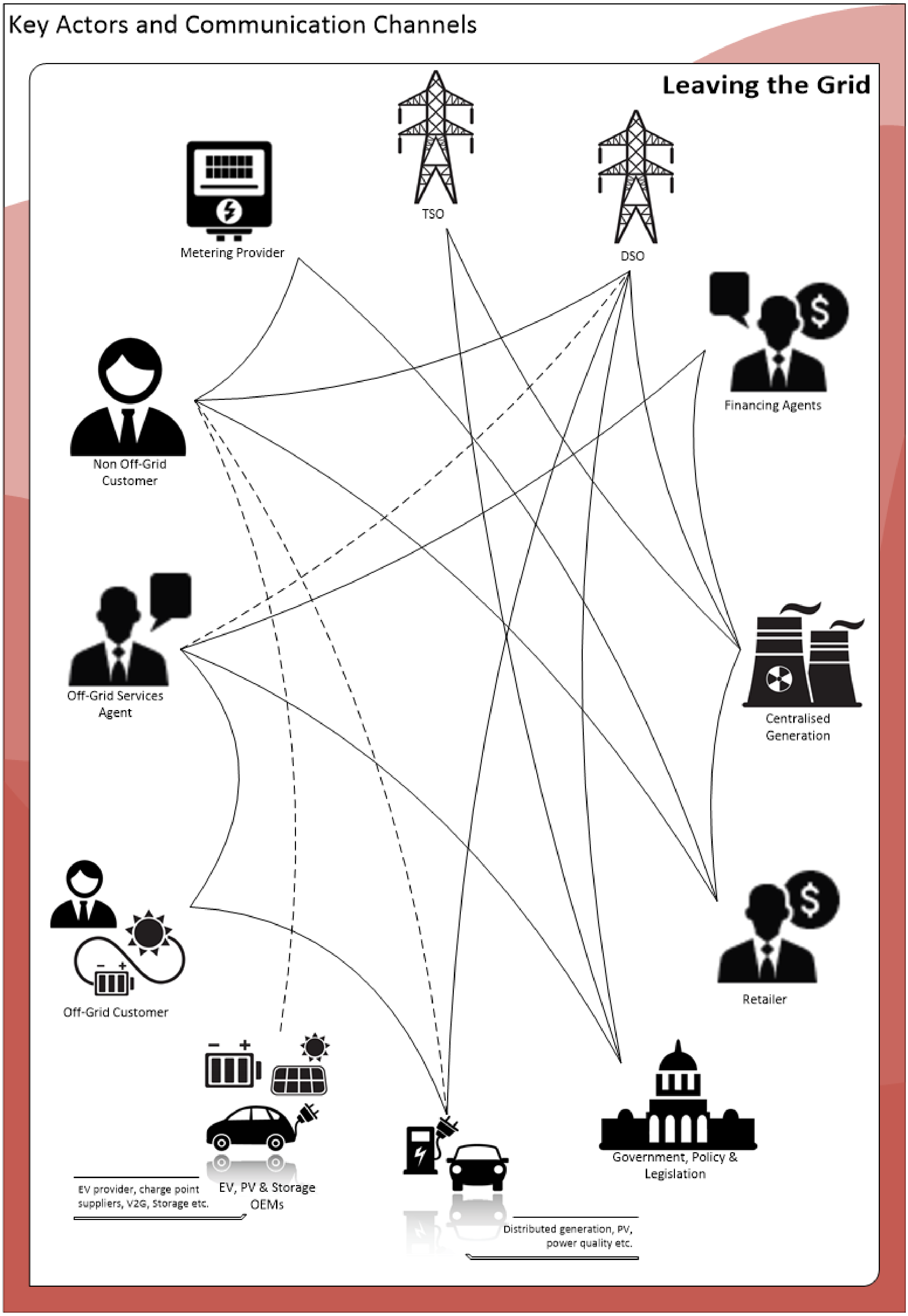


Figure 19 Leaving the Grid - Holistic View of Key Actors and Communication Channels

Leaving the Grid – Grid design and operation

a. Functional description of DSO and TSO activity

In a world where 'off-gridding' has become a common practice, clearly there are significant changes in the activity of both a TSO and DSO. There is clearly still a need for a network at this point for two reasons. Firstly, not all customers have left the grid and those that are 'non-off-grid customers' require the network to provide the services that it has done in the past and secondly, there needs to be some physical infrastructure present to facilitate energy trading.

While the TSO retains its responsibility for dispatching large generation, the fact that a significant number of customers are now off-grid means that demand levels will be falling and the level of control that can be exerted will be reduced.

At the DSO level, unlike some other scenarios, there is not a great deal of interaction with customers in terms of requesting demand response services. Customers are more self-sufficient and are using their own generation and storage to meet their specific energy requirements, rather than offering services to the DSO or looking to maximise gains from energy trading. This means that the DSO can still act as a line of last resort for such customers - in effect becoming the standby power supply to the home. Balancing this against the volumetric metering employed for the customers who have remained on-grid poses serious challenges to the sustainability of DSO business models.

b. Optimum design and operating parameters

- *Inertia changes*
- *Amount of response needed to maintain inertia*
- *Alternative technologies to manage RoCoF*

System inertia and network fault level is falling rapidly as more centralised synchronous plant has been replaced with inverter-coupled generation and overall demand levels reduce significantly via wide scale grid defection. This has resulted in a much less electrically 'stiff' system.

TSOs and DSOs have started to install some synthetic inertia such as SVCs and electrical energy storage to address the issue but frequency management is a particular challenge in some areas of the network and RoCoF schemes are no longer used. Alternative anti-islanding technologies, such as vector-shift or frequency-forcing are widely deployed. With improved communications infrastructure, island-enabling technologies such as syncrophasor protection become technically and commercially feasible and are being actively adopted by DSOs to enable continued system operation during periods of grid separation.

Meshing of previously radial networks has been shown to give some benefits, such as increasing fault levels, but requires the use of more advanced adaptive protection schemes to manage the variable power flows that exist.

c. Limitations on existing Regulatory Investment Test – Transmission, with a focus on power system security and solutions needed

The Regulatory landscape has shifted dramatically in response to the changing customer behaviour and new approaches required by network operators to ensure they can provide the infrastructure necessary at an equitable cost to all customers (those that are on- and off-grid).

The reduction in demand from wide scale grid defection has resulted in traditional revenue streams arising from volumetric metering to be eroded. In order to ensure that the costs of operating the network are not disproportionately borne by the customers that have remained connected to the grid, network operators require a different means of gaining sufficient income and hence capacity charging has been introduced - meaning that any customers wishing to retain a network back-up supply are required to pay a charge for this service.

Despite this, revenues continue to be low and the level of investment in the network has therefore reduced. Any refurbishment required must be justified as to the economic value it delivers against a backdrop of prevailing demand reduction expected for the future. This has led to the managed decline of the more uneconomic areas of the network to maintain (i.e. those in rural locations where long lengths of overhead lines feed sparsely populated areas) with network investment being more focused on those areas of critical infrastructure in cities.

The level of redundancy within the network has reduced and planning standards have been adjusted to provide different levels of compliance and SAIDI/SAIFI targets are only preserved in the highly urban areas. In less populated areas they have been replaced by regulatory ‘guaranteed standards’ which mean that customers who rely on the grid are guaranteed to have their supplies restored within a fixed number of hours. In practice this means that DSOs have taken to employing a significant fleet of mobile generators rather than providing resilience in network design practices as such investment cannot be justified from a regulatory perspective.

d. Solutions to efficiently design, control and operate grid connected and non connected ‘mini’ grids and actions needed for implementation

Given the large numbers of customers that are now operating in an off-grid manner as their normal arrangement, a number of solutions to aid in this behaviour have been adopted. At an individual customer level, this takes the form of home energy management systems and power quality management to ensure that the frequency and voltage within the home remains constant. In the case where customers retain a grid connection but use it only sparingly, there would need to be products to ensure synchronisation between the household energy network and that of the grid. All of these solutions could be provided by an off-grid services agent either purely through selling products to a customer, or perhaps through managing such functions at a more aggregated mini-grid level.

At present, such a service provider does not exist and the products and services that they offer in this future world are not readily available in today’s market place. Such products would need to develop in their maturity and the service provider would emerge to fill this gap in the sector and fulfil an important role in this scenario.

Given the mistrust that has arisen between network operators and customers in this future world, it is unlikely that network operators would seek to act as such off-grid agents.

e. Optimal requirements to address balancing challenge

- *Provision of greater flexibility from new sources of load/generation, i.e. fast ramp up (e.g. generation or DSR) to manage throughout the day, or between days*

In the world of wide scale grid defection, there is limited interaction between customers and the DSO and therefore there is limited opportunity to make use of DSR or generation services at a residential level.

However, balancing at a fairly local level could be problematic as the expectation is that demand will be low, but there could be short-term rises in demand as customers make use of their grid connection perhaps just at limited times of the day/year. This may present an opportunity for commercial operators of storage or generation services to engage with the DSO, or alternatively (and perhaps more likely) the DSO will own and operate a wider fleet of storage and generation, rather than having significant redundancy within its traditional network.

Leaving the Grid – Operating platform

a. the operating platform to allow full optimisation and coordination of the various parameters in this scenario

In this scenario, the actions of the customers who have gone off-grid require the successful integration of various home energy management systems and equipment to ensure that the electricity supply within the home is at the right voltage and frequency and that synchronisation with the grid can occur.

Therefore the critical features are the development and deployment of these tools to customers, via an off-grid services provider. Similarly, there needs to be a platform whereby this provider can manage a number of customers across a mini-grid. This platform needs to be technically capable of interfacing with the home energy management systems of customers, and it would be useful if it also provided energy trading functionality allowing customers to benefit from selling electricity via the grid in the event that they are generating more than they require to either use or store locally.

b. credible strategies for network operation and control to alleviate technical constraints and maximise the benefits of new demands/generation

The technical constraints can be categorised into:

- Maintaining system frequency
- Grid design, operations and management
- Field operations

In this scenario, these can be alleviated via the following strategies:

System-wide frequency is maintained via the TSO having direct interface to large generators, but at a more local level, the frequency will need to be managed by the DSO, or at a very granular level by the off-grid services provider as appropriate. It is likely that the DSO will have at its disposal (either through ownership, or procuring services from third parties) specific technical solutions such as strategically located SVCs, electrical energy storage or even flywheels.

Grid design, operations and maintenance for the TSO/DSO networks will now focus more on managing the grid at a lower level and performing local balancing services to meet demand requirements through the use of increased generation and storage rather than via large-scale generation and an extensive higher voltage network.

Field operations will focus more on the management of these new assets (storage and generators) and less on the installation and maintenance of the higher voltage assets.

c. Optimal mechanisms to maintain levels of system performance re. stability and optimisation

In a world where a significant number of customers operate in an off-grid manner, there is likely to be less incentive and economic case for a network operator to invest in traditional assets that only serve as a ‘backup’ means of power supply in many cases. SAIDI and SAIFI therefore take on less importance, as previously described, and may be replaced by some guaranteed standard of restoration within a given time frame (which could be achieved through network switching or the deployment of generation).

In order to ensure system performance is maintained, there is likely to be the need for new commercial models whereby the network operator can recover revenue form customers who use its services infrequently, for example via capacity rather than volumetric charges.

With regard to the stability of the system, it is critical that the interface from the 'home grid' to the 'distribution grid' is effectively managed and that suitable forecasting can be performed of likely power flows (i.e. when the customer requires power from the grid as there are insufficient levels available from their own generation and storage). The synchronisation between the home and distribution grid needs to be effectively managed and it is likely that off-grid services agents will be critical in ensuring this is achieved. Such agents may also be responsible for load forecasting at a very local level and interfacing with the network operator who will then require more complex systems to facilitate local balancing through the use of its own despatchable generation and storage systems to ensure the grid remains stable.

In terms of performance optimisation, there will also be a need to perform regular business case assessments of the need for additional generation or storage capacity in different sections of the network.

d. strategy on detailed technical issues, i.e. managing frequency and voltage stability

The technical issues raised by this scenario can be grouped into:

- **Frequency management (TSO/DSO)** – ensuring the correct balance of generation to demand and vice versa.

- **Load management (TSO/DSO)** – the ability of the physical assets to accommodate different demand profiles, possible operating above nameplate rating.

- **Voltage control (DSO)** – the ability of the network to manage the fluctuations that will arise as customers vary between consuming their own power, exporting power to the grid, and potentially drawing power from the grid at different times of day/year.

- **Fault level management (TSO/DSO)** – the ability to ensure that there is sufficient fault energy to ensure the correct operation of protection systems.

- **Power quality (DSO)** – the ability to ensure the waveform quality of the power received by a customer (e.g. free from damaging levels of harmonics, voltage flicker or significant voltage step changes).

In each instance, the TSO/DSO will need to assess which issues are being caused, and where. In this scenario, the majority of issues will be related to the fact that demand levels are far lower, generation at domestic level is higher (but is unlikely to have much export to the grid) and the network needs to be able to cope with the times when the transition from customers consuming their own generated power to drawing power from the grid occurs.

e. technical challenges to enable this scenario

Solution availability for customers and other actors

- Ensuring the home energy management systems are available together with the necessary voltage and frequency monitoring and synchronisation tools to enable the off-grid operation of customers

- Developing the platform that will be used by off-grid service providers to aggregate and manage the mini-grids and potentially facilitate local energy trading

DSO challenges

- Local balancing will be required and this will necessitate real time operation of despatchable generation and storage systems

In addition to the above technical points, there is a requirement for the DSO to embrace a significant cultural change in the way that networks are designed and operated. This will need to take into account the reduced reliance on them for many customers.

f. the framework to facilitate DSR and appropriate monitoring

In this scenario, there will be less widespread DSR services being procured than in other future worlds. As stated previously, the DSO may well need to make use of storage and generation to balance locally, but it is much more likely that this would be controlled and dispatched by the DSO rather than called upon via a DSR framework.

As such, the DSO will require monitoring of network load and the generation and storage available in real time, but will not require the same level of engagement as in some of the other scenarios via a commercial platform to third parties looking to provide services to the DSO.

Leaving the Grid – Technical enablers (telecoms)

This section considers those links which are new for this scenario, rather than the existing communications links. Communications links with similar attributes have been grouped together, they are ordered A-F with A being a one to one relationship; F being a one to many relationship.

2030's Scenario	Actors		Functional Requirements					
			Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
Leaving the Grid	Commercial service provider	Commercial service provider	3	2	3	3	2	4
	Commercial service provider	Customer - Small	4	3	3	3	1	4
	Commercial service provider	Large generation & storage	2	1	1	1	1	4
	DSO	Commercial service provider	4	3	3	3	2	2
	DSO	Customer - Small	4	3	3	3	2	2
	DSO	Government & Regulator	4	3	3	3	2	2
	DSO	Large generation & storage	3	1	3	3	1	2
	Government & Regulator	Commercial service provider	3	1	1	3	1	2
	Large generation & storage	Commercial service provider	2	1	1	1	1	4
	TSO	Government & Regulator	2	1	1	1	2	1
	TSO	Large generation & storage	3	3	3	3	2	2

A. DSO/TSO to Central Generation

- **Functional requirements:** communications used for monitoring and control for network operations. With this in mind needs to have: high security, low(er) bandwidth, low latency, high reliability/resilience
- **Immediate communications needs:** likely to be in place all parties
- **Longer term communications:** deploy as new generation plant is commissioned to replace ageing plant
- **Scalability of communications:** low (limited deployment)
- **Cyber security:** high (must be secure: limited channels so can pay more per channel for high security)
- **Open standards and interoperability:** low (limited occurrences of this being required)

B. DSO/TSO to EV Charge Point Network

- **Functional requirements:** communications used to signal for multiple responses including trading information - needs very high security, higher bandwidth, high latency, and high reliability/resilience
- **Immediate communications needs:** similar needs to trading to centralised generation as exists today
- **Longer term communications:** EV Charge Point Networks are newer players and will need to have these communications in place prior to operation
- **Scalability of communications:** low-medium (limited deployment)
- **Cyber security:** high (must be highly secure: limited channels so can pay more per channel for high security)
- **Open standards and interoperability:** medium (ideally have a common standard across Australia to allow a range of 3rd parties to operate across the country)

C. Retailers / Meter Provider to Non off grid customer

- **Functional requirements:** communications used to signal for multiple responses including trading information - needs high security, higher bandwidth, high latency, and high reliability/resilience
- **Immediate communications needs:** As B, similar starting point as that from trading to centralised generation as exists today.
- **Longer term communications:** Communications links to be funded between these entities without any involvement from DSO/TSO. An expectation that these would need to be in place prior to the providers offering the service.
- **Scalability of communications:** low-medium (would need to scale to a range of providers)
- **Cyber security:** medium-high (must be secure to prevent unauthorised access)
- **Open standards and interoperability:** low-medium (ideally have a common standard across Australia to allow a range of providers/generators to operate across the country)

D. DSO / Meter Provider / Retailers to Non-Off Grid Customer

- **Functional requirements:** communications used to signal for a response, needs to have medium-high security, low(er) bandwidth, low latency, medium reliability/resilience
- **Immediate communications needs:** would use existing solutions as relationship to the non-off grid customer will not be significantly different to current requirements
- **Longer term communications:** unlikely to require changes to available methods
- **Scalability of communications:** high (will need to scale to possibly hundreds of thousands of customers)
- **Cyber security:** medium (needs to be secure, although limited impact if hacked only between 3rd party and any one provider/generator)
- **Open standards and interoperability:** low-medium (ideally have a common standard across Australia to allow a range of retailers to operate across the country)

E. EV Charge Point Network to Off Grid Customer

- **Functional requirements:** communications between the end user and an EV Charge Point Network used for monitoring and control. In this scenario, it is expected that there will be a number of Charge Point Networks offering services to up to the majority of available customers, equating to potentially millions of end devices. Needs to have good security, medium bandwidth, lower latency, medium reliability/resilience.

- **Immediate communications needs:** deploy as new services are put in place between Charge Point Network and customer. Likely to piggy back on existing communications into the home, e.g. TCP/IP (Internet), etc.

- **Longer term communications:** Likely to remain using some form of Internet connection

- **Scalability of communications:** high (a need to be widely scalable to millions of devices)

- **Cyber security:** medium-high (this link provides the interface to the customer, whilst it needs to be secure to protect data privacy, there is limited damage that could occur if hacked)

- **Open standards and interoperability:** high (would favour being an open standard in order to facilitate competition between Charge Point Network Providers – a need to define this as the market starts to form)

F. Off Grid Services Agent to Off Grid Customer

- **Functional requirements:** communications used for monitoring and control to a number of in home appliances. Could be signalling to hundreds of thousands or even millions of devices, needs to be secure, low(er) bandwidth (due to volume), medium latency, medium reliability/resilience. In this mode the BSP could be the product manufacturer offering services across all of their products.

- **Immediate communications needs:** Use product vendors favoured solution, linking to existing communications e.g. TCP/IP, etc.

- **Longer term communications:** Depends on the strategy of the product vendor

- **Scalability of communications:** high (a need to be widely scalable to millions of devices)

- **Cyber security:** high (needs to be secure to prevent hacking and 3rd party control. Likely to be a target for attack, so would need to well maintained)

- **Open standards and interoperability:** Low (could be proprietary for a given manufacturer in this instance – this could also be used to obfuscate, assisting with cyber security)

Leaving the Grid - SGAM Framework

Component Layer

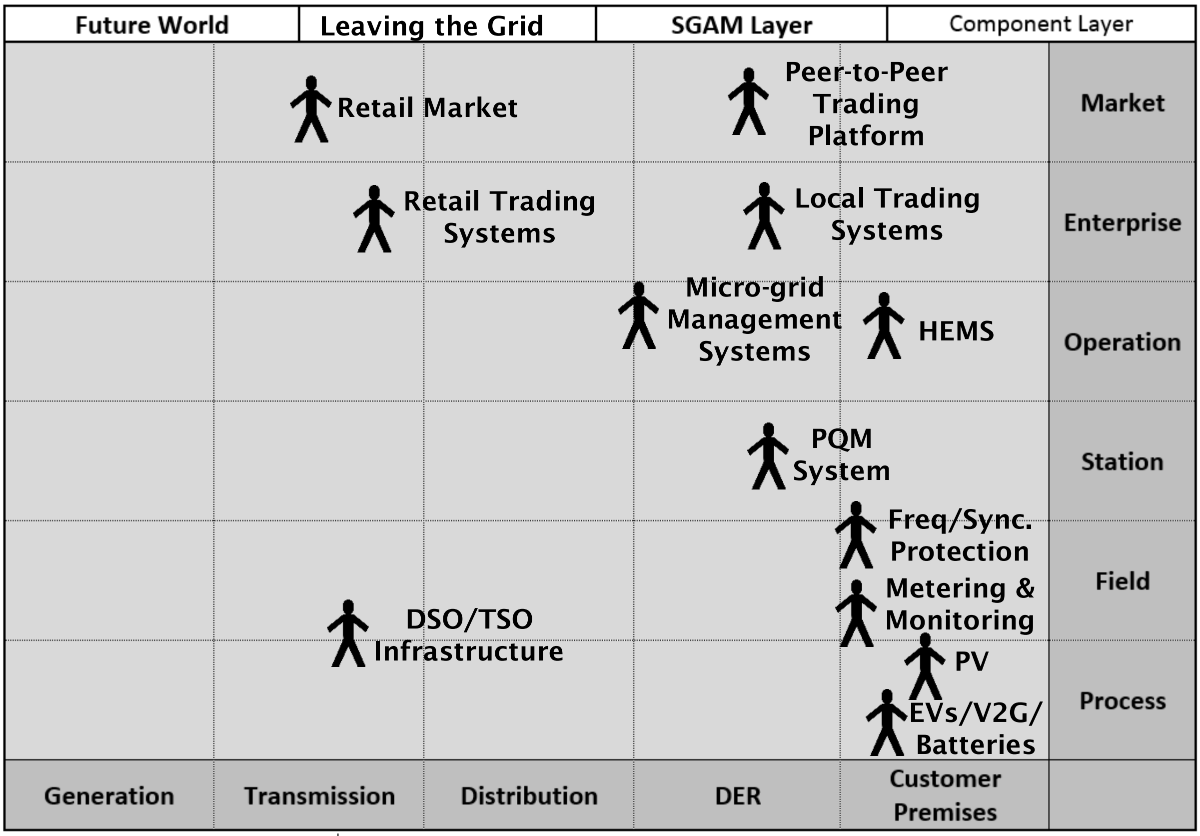


Figure 20 Leaving the Grid- SGAM Component Layer

The components identified within this layer are applicable to the **'Off-Grid Customer'** from Figure 19. For the sake of brevity and to avoid diagram complexity the **'Non Off-Grid Customer'** has not been modelled. This is suitable, as their behaviour up to 2025 does not significantly vary from today's customers. The chosen components have been selected to provide the functionality, information and communication pathways needed to facilitate the future scenario. The layer has been populated by examining the holistic view in Figure 19 and the use cases identified to be most prevalent in the 'Leaving the Grid' future world. The use cases most applicable to this future world, derived from extensive reviews of workshop materials are highlighted in Table 3 below:

Table 3 Leaving the Grid - Example Use Cases

Future Worlds	Demand Response	Dynamic Load Balancing	V2G	EV Co-ordination	DER Generation	HAN to Grid	Enable DER Market	Energy Storage	Dynamic Asset Control	Peer-to-Peer Trading	Customer Grid Interface	Micro Grid
Set and Forget	X	X	X		X	X	X	X			X	
Rise of the Prosumer	X		X	X	X		X	X	X	X	X	
Leaving the Grid								X		X		X
Renewables Thrive			X	X	X	X	X	X	X	X		

The identified components in the layer are not exhaustive but present an illustrative depiction of the type of equipment that will be necessary to facilitate the world based on the identified use cases from Table 3 and the holistic view presented in Figure 19. The components identified in the layer can be considered in three types:

1. The physical equipment/hardware installed at the domestic/commercial scale customer premises to deliver technical means to 'Leave the Grid' and control/protect the electrical assets.
2. The systems/software in place across the system to allow for the monitoring/metering of energy and power quality management (PQM).
3. The non-physical trading 'environments'/platforms which facilitate the sale and purchase of electricity within the system. (micro-grid and ties to wider grid)

The physical equipment at the customer's site is similar to the equipment identified in the 'Rise of the Prosumer' scenario. The variation is in how the technology is implemented. In this scenario the components are used to deliver a secure electricity supply to the customer rather than facilitating trading. In addition to this equipment, as the customer is becoming more self-reliant on energy supply, they will adopt an increased responsibility for power quality monitoring and its associated equipment, i.e. frequency/synchronisation/voltage monitoring components. Small customers have volume meters but these only serve to continue the disincentive to export generated power as the returns are poor.

The customer has also adopted software systems that manage the data from their monitoring equipment and can be used to control and optimise the system performance, ensuring customers are fully utilising their generated power and storage, rather than consuming from the grid. These systems are technologically possible, but are not widely commercially available. This must be addressed by a world where customers would rather consume than export power.

The components that provide the non-physical trading environment are multi-layered. Firstly, they can exist at a peer-to-peer level, where customers trade within a market of individuals competing for available power. This trading can be facilitated in many forms, i.e. geographically specific or based on subscriptions to a trading platform. This trading should be supported by a wider network/traditional retail style business model for managing the purchase of power. At the time of writing, a method for peer-to-peer trading is not unanimously agreed or available. For this world to be realised the, mechanism would need to be regulated by Government policy.

Business Layer

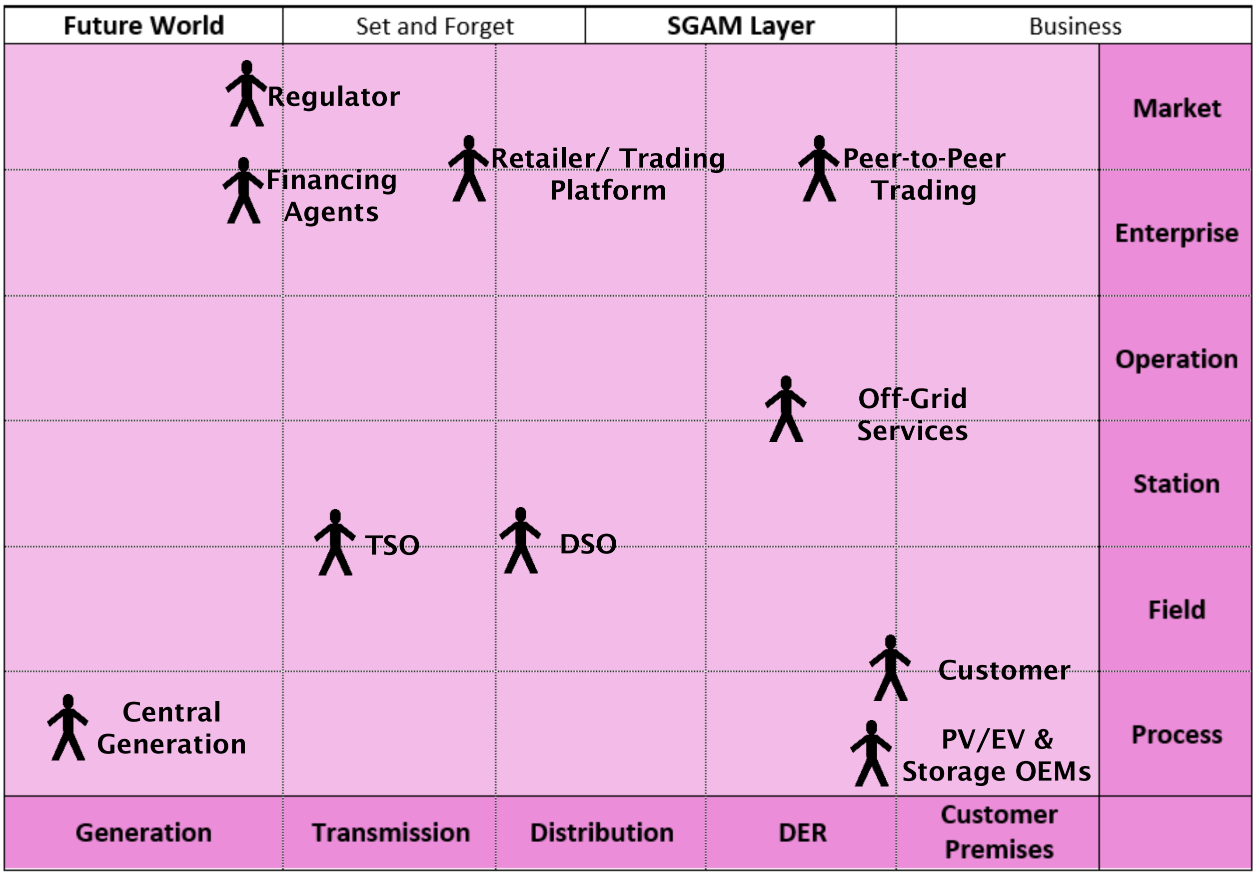


Figure 21 Leaving the Grid - SGAM Business Layer

The content of the business layer is drawn from the holistic view of actors presented in Figure 19. Importantly, the identified actors may not be specific businesses but rather the services provided by a business-like entity. Each actor could be provided by multiple competing businesses or, in contrast, one business may provide the services of many actors. The business layer does not define which form is taken only that the actors identified have a stake in the processes, services and organisations within the 'Leaving the Grid' world.

The business models within the world have been identified as those which are necessary to accommodate the uptake of the components from Figure 20 and the holistic overview in Figure 19. One business actor identified as being of significant relevance is the Off-Grid Services player. This actor could embody a number of critical services needed within the world. As a minimum, it is foreseen that they will engage with Off Grid Customers by supplying the hardware and software necessary for them to increase their electricity self-reliance, such as PQM equipment, HEMS and Micro-grid management systems. A more involved version of this actor could involve them actively managing micro-grid networks on behalf of customers, who would own the connected assets. Concurrently this actor also embodies the developers/enablers of the automation and monitoring equipment needed to allow customers to optimise their generation consumption and minimise export. Clearly they are a significant agent within this scenario, yet they exist in a gap in today's market, although the services they offer are technically feasible. If this world was to come to fruition, these actors would play an important role and would need to be developed.

The businesses operating in the market sector must accommodate both peer-to-peer trading and the whole-network energy retailer model. They are shown on the layer as retailer and peer-to-peer trading platforms. Regulations will also play an important role in this scenario ensuring technology and trading infrastructure is safely and fairly implemented.

Function Layer

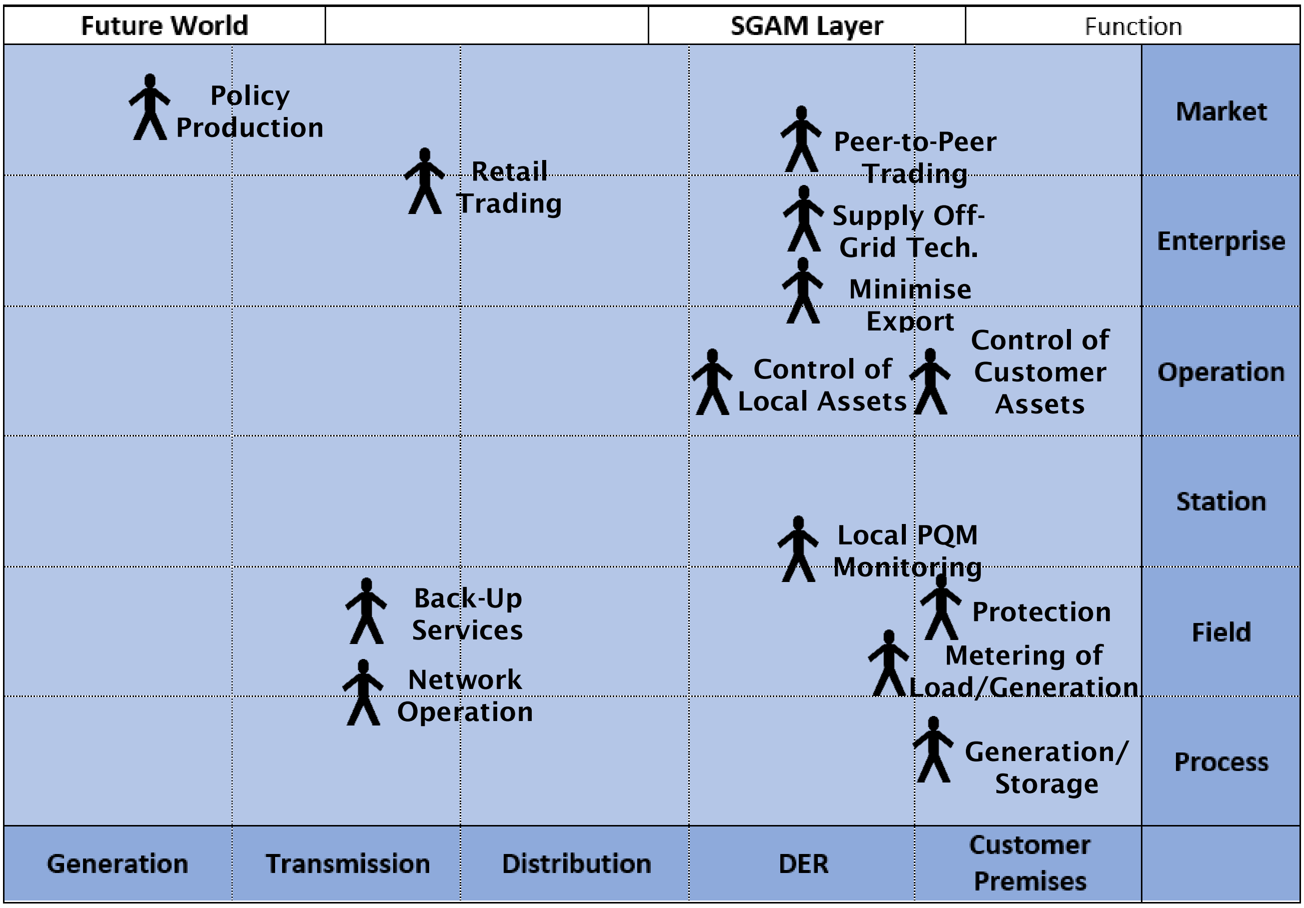


Figure 22 Leaving the Grid - SGAM Function Layer

This layer shows the components, business models and the holistic overview to accommodate the use cases that define the future world. The identified functionality is made possible by the components and services provided by the component and business layer. In order to deliver the 'Leaving the Grid' scenario the above functions are mapped across the SGAM function layer to describe the element of the power system responsible for delivering the functionality of the actor. The functions of this scenario can be considered in two categories:

1. **Control of Electrical Assets** – This functionality is provided by the system's physical assets. To control the assets, it is necessary to meter both the generation and load of the customer on site. It is also necessary to have any protection and PQM systems in place to avoid the dangers of any voltage/frequency/synchronisations variations from the grid. After establishing the levels and quality of power, it is possible to control the consumption/storage/generation levels through a power electronics system (HEMS, Micro-grid Management Systems). This technology is available, but cost prohibitive to the average consumer. An optimised control system could be used to minimise the power exported to the grid and maximise revenues/return.

2. **Trading of Electrical Energy** – The energy trading functionality is provided by both a peer-to-peer trading facilitator and the traditional retail systems. Peer-to-peer offers a potential off-grid solution within a micro-grid, while the retail systems are in place to support connections to the wider grid.

The function of the regulator is to produce policies which can be used to ensure customer off-grid equipment is safely installed and the peer-to-peer trading market is properly regulated. These policies are significant enablers for this scenario.

Information Layer

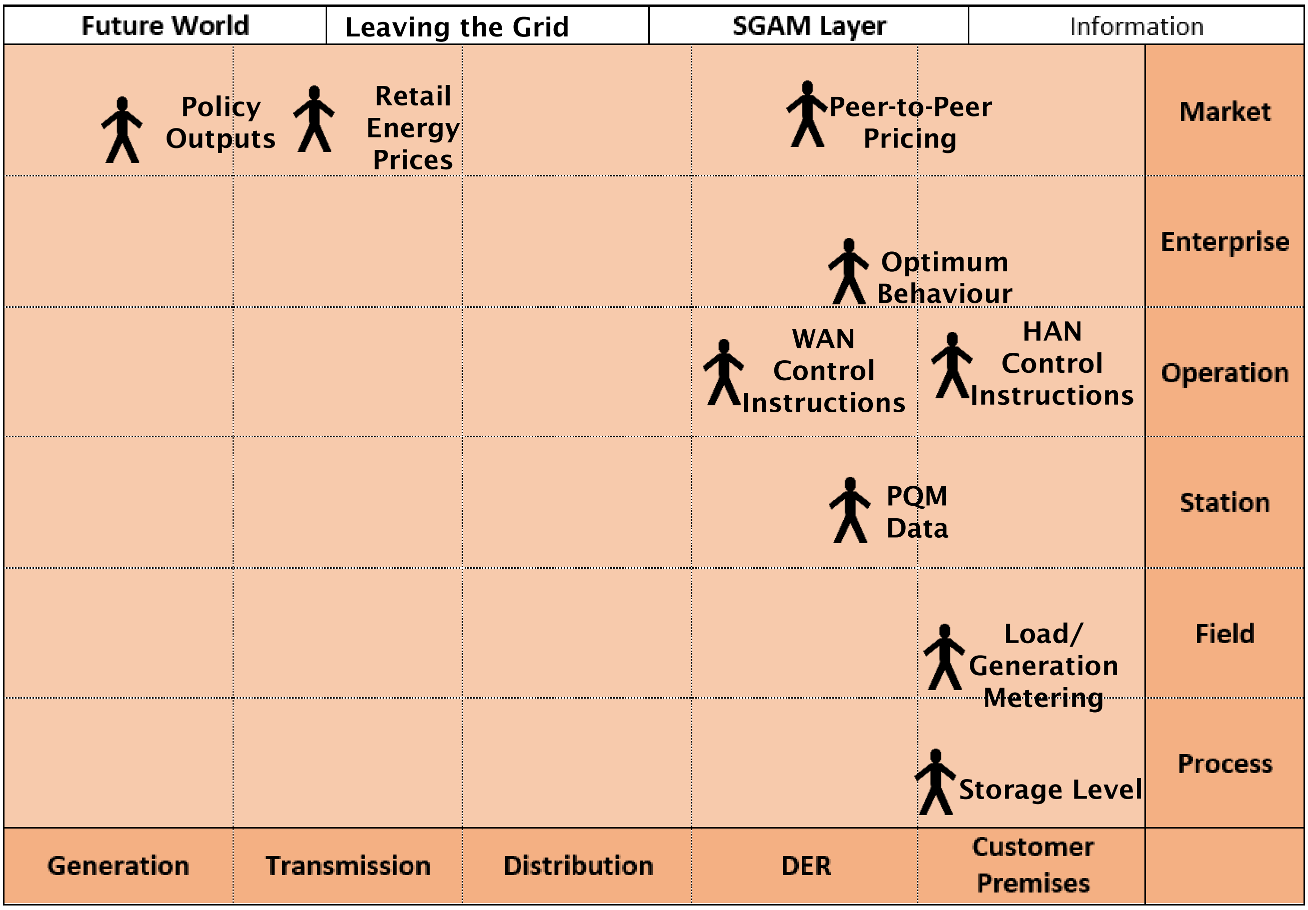


Figure 23 Leaving the Grid - SGAM Information Layer

The information layer describes the data or data models which must be collected and passed between actors to achieve the functionality set out in the previous layer. Information is transferred between actors and components as set out in the Communication layer (Figure 24). Where possible, the transfer of information has been linked between two or more components to aid with the visualisation of the processes. However, the SGAM positions are based on the role the information plays within the system, not the position of the component or actor it is transferred between.

The information that must be passed between actors and components in order to deliver the functionality required can be considered as follows:

- Level of charge of storage. This will affect the customers' ability to charge or discharge.
- The volume of energy generated and consumed by the customer at any given time. The 'Off Grid Customer' will wish to minimise exported power so will choose to store or consume any extra generation if possible.
- The PQM data is essential to ensure the customer is operating safely and must be monitored in real time.
- Control instructions within the home area network (HAN) will be generated by the HEMS or Micro-grid managements system in a wide area network (WAN). These instructions will adjust the customer's electrical asset behaviour.
- The optimum behaviour is set to minimise the customers grid export and maximise consumption. It will inform the control instructions.

It is clear that the system will contain much more information, but in the interests of brevity, only the information considered to be of particular relevance to this scenario are detailed in Figure 23.

Communication Layer

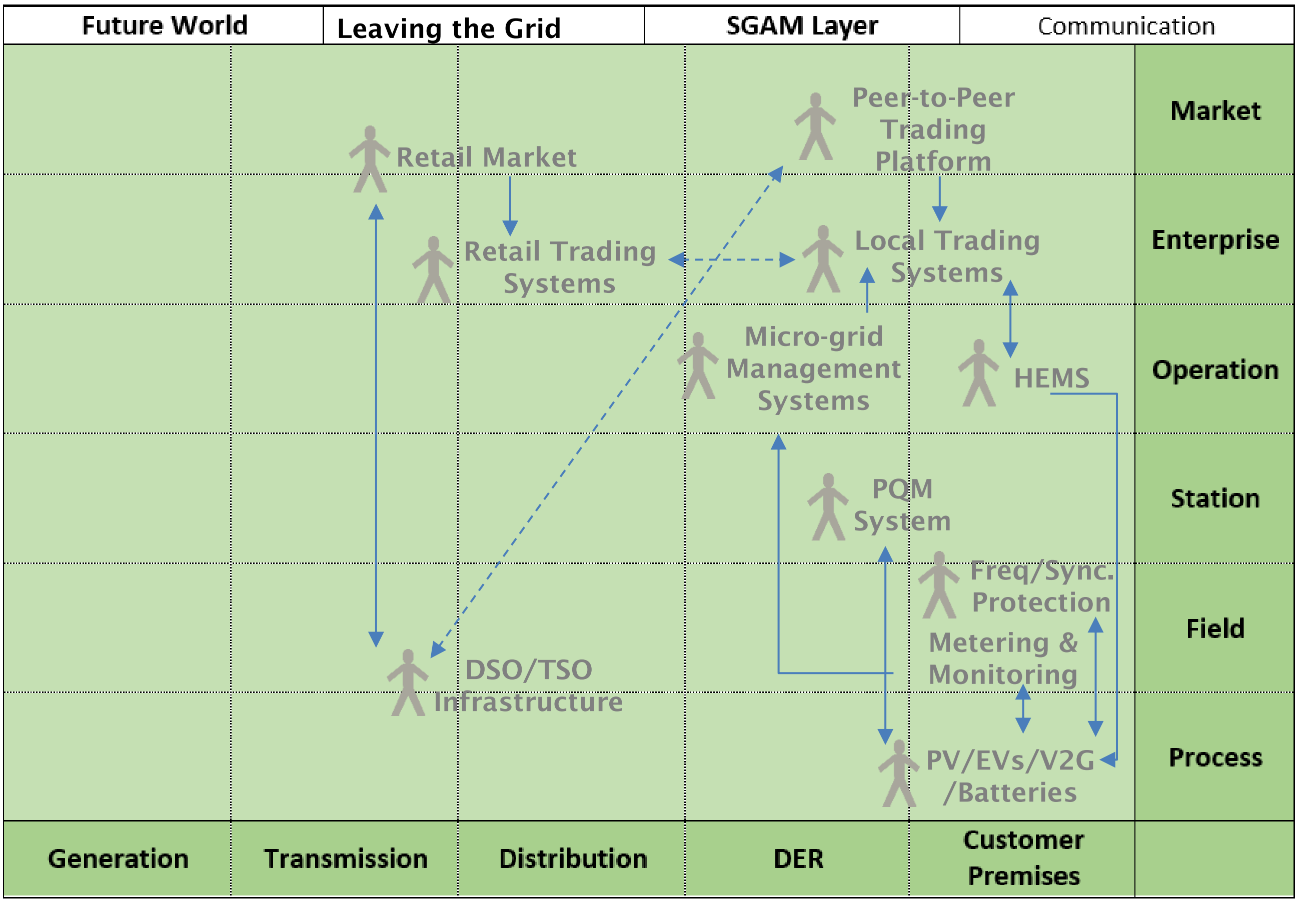


Figure 24 Leaving the Grid - SGAM Communication Layer

Although it is possible to include several more actors within this layer, it would repeat information shown in the holistic view of actors and communication channels (Figure 24), which clearly illustrates communication paths. The communication layer demonstrates the pathways that exist between components and actors to facilitate the exchange of information described in the information layer to achieve the functionality set out in the function layer.

There are two main functions that are enabled by the effective communication of information between different components in this scenario. These are:

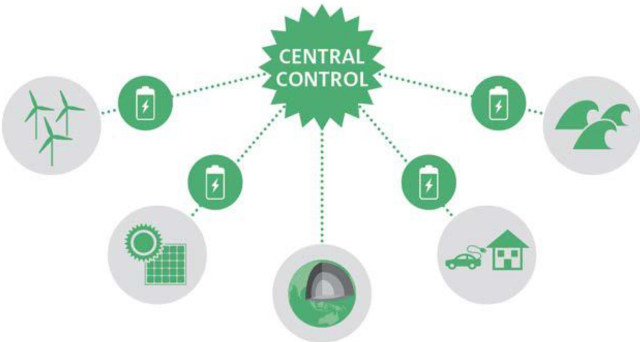
1. The ability to operate an electricity trading market for customers and retailers alike.
2. Increased customer operability of their electrical assets consumption, storage and generation.

The first of these points is enabled by communication between customers and retailers through their energy trading contracts. There is currently a gap which prevents customers from ‘selling’ power back to the grid. As such, there is a need for innovation if this world is to be realised. As detailed previously, an ESCo may play an intermediary role in this relationship: it may act on behalf of many customers or even individuals and could facilitate this trading relationship.

The second of these points is enabled by the Customers Interface component and its relationship with the electrical asset control equipment, collected in group A. In turn, this control equipment must communicate instructions to the physical electrical equipment, in group B. These communication relationships, although technically feasible, would likely require the development of a secure Standardised approach to enable rapid uptake of compliant equipment.

Appendix V Future World Analysis – Renewables Thrive

At a political level, Australia debates a number of emission reduction policy mechanisms while individually significant numbers of residential and commercial customers make their own choices to move towards systems based around renewables and storage as their economic viability expands to an increasing number of applications, grid-side and on-site.



Renewables Thrive - Holistic View of Future World

This scenario involves the wide-scale deployment of renewable generation across the network from transmission connected large generation to small scale distributed generation such as rooftop PV. Electricity is generated from 96% renewable sources, from a diverse set of technologies (PV, wind, tidal, wave, etc) and a key issue is dealing with frequency variations due to intermittency.

The role is the TSO/DSO remains largely unchanged compared to today's world the bulk of generation is done at central plants and low voltage connected demand is masked due to the wide-scale adoption of solar PV and within premises energy storage.

The TSO manages demand by engaging with large generators to alter load and generation demands on the network, also engaging with demand aggregators to entice responses from customers through control of their energy storage systems. The DSO accesses response where it is needed on local networks.

Protection systems based on RoCoF become unstable with a system dominated by renewables and other techniques have been deployed such as frequency-forcing and vector-shift. Energy storage is used to mitigate the impact. Islanding becomes beneficial in certain cases, enabled by syncrophasor protection schemes.

Much of the activity of the DSO is commercial management of a series of aggregators to help manage constraints on the distribution system. Where services are scant, infrastructure solutions such as grid-scale energy storage are deployed by the DSO but a more common model is ownership by a third party.

A key function of the DSO, compared to today's operating context, will be to implement and maintain complex Active Network Management systems and associated monitoring and communications systems to alleviate constraints on the network through generation curtailment and demand shifting.

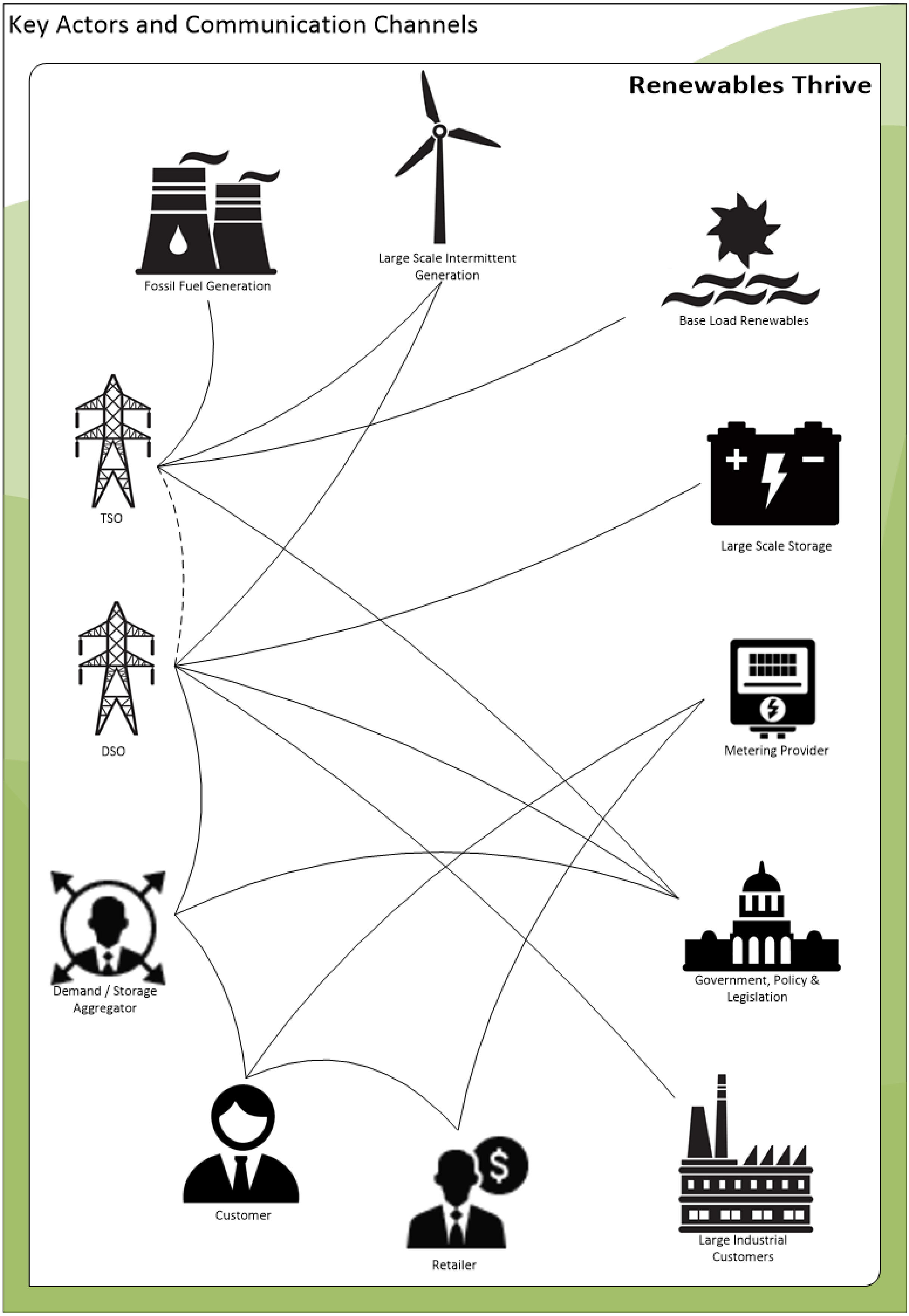


Figure 25 Renewables Thrive - Holistic View of Key Actors and Communication Channels

Renewables Thrive – Grid design and operation

a. Functional description of DSO and TSO activity

In this particular future world, while there has been widespread uptake of renewable generation and storage, the critical roles played by the DSO and TSO have not fundamentally changed much. The TSO retains its responsibility for system balancing and this is now made more complex by the fact that, at large grid-scale, there are greater numbers of renewable generators rather than traditional fossil-fuel generators. However, the significant uptake of generation at a residential level (coupled with storage) has meant that demand has fallen. Managing frequency in a world of intermittent generation is more challenging than it was previously.

At DSO level, relationships have remained fairly static, although the networks have observed considerable reductions in demand. However, the network still performs an essential role acting as a conduit for bidirectional power flow; customers are engaged in using their generation to both offset their own demand and export to the grid at different times. The fact that customers have generation and storage at their disposal means that DSR schemes are a more attractive way of managing network load and act as an alternative to traditional investment in reinforcement schemes in many cases. To this end, the DSO has more engagement with aggregators than previously, but still retains the link to customers in very much the way it exists today.

b. Optimum design and operating parameters

- *Inertia changes*
- *Amount of response needed to maintain inertia*
- *Alternative technologies to manage RoCoF*

System inertia and network fault level is falling rapidly as more centralised synchronous plant has been replaced with inverter coupled generation and overall demand levels reduce significantly via wide scale grid defection. This has resulted in a much less electrically ‘stiff’ system and markets have developed for providing inertia to the system operator.

TSOs and DSOs have started to install some synthetic inertia such as SVCs and electrical energy storage to address the issue but frequency management is a particular challenge in some areas of the network and the limitations of RoCoF protection are problematic. Alternative anti-islanding technologies, such as vector-shift or frequency-forcing are deployed. With improved communications infrastructure, island-enabling technologies such as syncrophasor protection become technically and commercially feasible and are being actively considered by DSOs to enable continued system operation during periods of grid separation. The need to deploy increased levels of energy storage that can respond instantaneously to changes in system balancing and help control frequency has increased significantly so as to provide some mitigation to RoCoF issues.

c. Limitations on existing Regulatory Investment Test – Transmission, with a focus on power system security and solutions needed

Prevailing demand reduction, brought about through the widespread use of generation and storage, means that there is less of a business case to reinforce networks via traditional means.

Instead, it is more attractive to have services at the disposal of the system operator that can assist in load management, but also in contributing to other network management issues, such as frequency. To this end, the deployment of technologies such as storage that can serve these multiple purposes, and the increased use of DSR via aggregators is now favoured over traditional reinforcement.

This does not mean that there is no requirement to build new infrastructure, as some of the ageing assets in critical areas still require replacement, but the traditional asset base is not growing in the same way as it did previously; with new asset classes (such as storage) replacing the previous investment in transformers and circuits. Increased use of predictive diagnostics will mean that interventions on the network will be increasingly preventative (rather than post-fault repair)

Security is therefore still adequately achieved in this manner and SAIDI/SAIFI targets remain in force to ensure efficient network operation.

d. Solutions to efficiently design, control and operate grid connected and non-connected 'mini' grids and actions needed for implementation

Customer-centric systems that can interact with the grid will include energy storage, EV/V2G charge management and solar PV in addition to more traditional ripple control. These may be controlled through a Home Energy Management System or could interact with aggregators directly. The operation of this equipment will be dictated by a complex blend of customer preference and market forces. The DSO will have access to the systems through the aggregators in order to manage power flows and overcome balancing issues on the grid.

There will be two forms of interaction with these systems:

- The DSO enters the competitive market alongside other players for demand services.
- The DSO has protection systems built into systems to enable automatic disconnection where necessary.

The DSO will have built de-centralised control systems into the network to ensure that the potential variability of power flows that the energy market may bring can be effectively measured and managed. Where necessary, this is likely to also include some forecasting elements of likely load to assist with the cost-effective procurement of services from aggregators.

e. Optimal requirements to address balancing challenge

- *Provision of greater flexibility from new sources of load/generation, i.e. fast ramp up (e.g. generation or DSR) to manage throughout the day, or between days*

In this scenario the flexible energy available to facilitate system balancing is much more abundant than today and customers are, in general, more actively engaged with their energy supply compared to today's world. System balancing can therefore be achieved through a combination of large base-load plant coupled with more locally focused demand response services, enacted via the aggregators. The adoption and harnessing of many users provides significant control and flexibility with many hundreds or thousands of MWs available for rapid response and could be attractive to a TSO as well as at DSO level.

Speed of response, ramp rates, kW / kWh (or MW/MWh) of response are clearly communicated between aggregator and end customer at the time contracts are agreed. The DSO/TSO agrees contacts with the aggregators, then provides automated signals to enact the service as and when required. Again, forecasting has become more key in this world to ensure value for money is obtained through these contracts.

Renewables Thrive – Operating platform

a. the operating platform to allow full optimisation and coordination of the various parameters in this scenario

In this future world, customers have access to their own generation and storage and are able to offer demand response services to the grid through these technologies, together with electric vehicle charging optimisation (or vehicle to grid services).

The overall demand levels are lower than those of today and the DSO needs to make use of these services that could be offered by customers (usually via aggregators) to manage the power flows and frequency of the distribution system. Asset utilisation is generally lower and greater emphasis is placed on these commercial relationships to manage potentially bidirectional network flows.

In order to maximise the benefit from these relationships, the DSO will need to have greater visibility of the network at a deeper level into the grid than it does today. This leads to the requirement for monitoring and some distributed intelligence and decentralised control at zone substation level and even deeper into the network at distribution substation level. In order to make full use of this decentralised architecture for decision making purposes, some forecasting tools will also be required. These are critical in ensuring that the correct decisions are taken regarding engagement with aggregators and the issuing of commands to ramp up/down generation/demand from solar PV and electric vehicle chargers etc.

Of course, even in this world of thriving renewables, there are still customers who do not have generation and storage and the DSO needs to be able to cater for these customers. In network areas where there is a low penetration of the technologies previously discussed, the DSO function remains very much as it is today, looking at top-down power flows through the network delivering energy via assets that are utilised to the same degree as they are today and making investment and operational decisions in much the same way as is currently the approach. The one way in which this varies is that there may be opportunities to 'match' areas of high generation with areas of low generation (via the forecasting tools previously described) and transport the energy between them effectively to mitigate any potential network overloading issues that would otherwise occur.

b. credible strategies for network operation and control to alleviate technical constraints and maximise the benefits of new demands/generation

At a system-wide level, the TSO will maintain frequency balancing via direct interface with large generators, as today, and via aggregators to procure demand services from end customers if necessary. Sufficient large generation is needed to maintain system inertia and mechanisms would be developed to place value on rotating generation plant and high inertia demand such as large industrial motors to compensate for the lack of inertia provided by grid-scale renewable generators.

At a more local level, the DSO will require far greater visibility of power flow within the network, down to the lower voltages. The monitoring required to achieve this will also be used to contribute to a decentralised control architecture that allows decisions on network actions to be taken more locally. This decision-making process will involve the need or otherwise to engage demand aggregators at different times and will require forecasting techniques that are more advanced than those deployed today. This decentralised approach is necessary as the option of using centralised control rooms and backhauling all of the network data to a central location only to then have commands issued all the way back down the chain is inefficient and costly.

c. Optimal mechanisms to maintain levels of system performance re. stability and optimisation

The decentralised approach described above needs to be aligned such that there is commonality of equipment and methods (or at least commonality in operating systems) across the network. It would not be appropriate to use different bespoke systems in different locations as this makes managing the overall network and maintaining such systems in the future far more challenging. It would be advisable to use common hardware and make any necessary changes to operation within the software.

Given the decentralised nature of operation, it is likely that the DSO may have more potential switching points. For example, it may be possible for the distributed intelligence to reconfigure some LV networks to better balance demand levels. This leads to more complex protection systems to manage the greater variability in network configuration and loading conditions that will be seen.

d. strategy on detailed technical issues, i.e. managing frequency and voltage stability

The technical issues raised by this scenario can be grouped into:

- **Frequency management (TSO/DSO)** – ensuring the correct balance of generation to demand and vice versa.

- **Load management (TSO/DSO)** – the ability of the physical assets to accommodate different demand profiles, possible operating above nameplate rating.

- **Voltage control (DSO)** – the ability of the network to manage the fluctuations that will arise as customers vary between consuming their own power, exporting power to the grid, and potentially drawing power from the grid at different times of day/year.

- **Fault level management (TSO/DSO)** – the ability to ensure that there is sufficient fault energy to ensure the correct operation of protection systems.

- **Power quality (DSO)** – the ability to ensure the waveform quality of the power received by a customer (e.g. free from damaging levels of harmonics, voltage flicker or significant voltage step changes).

In each instance, the TSO/DSO will need to assess which issues are being caused, and where. In this scenario, the majority of issues will be related to the fact that demand levels are far lower, generation at domestic level is higher and the flows on the grid will be far more complex than before.

The decentralised control architecture utilised by the DSO will need to continually monitor the voltage, load and frequency of the system and have forecasting tools in these areas. This will allow the system to make appropriate decisions as to how and when to reconfigure the network or engage with aggregators to increase/reduce the levels of demand/generation experienced by the local network.

While it is much more efficient to make these decisions and enact them at a local level, there is still a need to report the decisions that are being taken back to a central control function where the DSO will be able to take an overarching view of system-wide positions with regard to these technical issues. In this way it will be possible to ensure that the wider strategy remains effective. For example, if it can be seen that the number of times aggregators are being called upon is increasing, the DSO may wish to consider using its own generation or storage assets in these network areas as this may prove more cost-effective over the longer term.

e. technical challenges to enable this scenario

The key technical challenges in enabling this scenario are in the development of suitable decentralised control architecture systems that can operate independently and report back to a central control function.

Linked to this is the need to have suitable links (both in the sense of robust communication links but also in the sense of suitable commercial relationships) with aggregators to ensure appropriate responses to commands can be provided.

Furthermore, there will be increased switching points on the network to allow for reconfiguration to mitigate local balancing and voltage management issues. This requires the suitable testing and deployment of new devices that can be called upon when required.

Finally, there is also the need for the ability to forecast network conditions to ensure that adequate responses to these conditions are put in place.

f. the framework to facilitate DSR and appropriate monitoring

DSR plays an important role in this future world as the DSO engages via aggregators with customers and uses their technologies (solar PV, storage, electric vehicles etc.) to either add to or reduce the demand as necessary to match other network conditions.

Further to this, the TSO may well wish to engage via aggregators with a very wide group of customers (or alternatively with large energy users) to enable the TSO to effect changes to the system-wide demand that have a consequential impact on voltage or frequency of the system.

The commercial relationships need to be in place to ensure this can be done effectively and there need to be robust communications links with the aggregators. Furthermore, the level of forecasting information that is available needs to be more significant and more advanced than it is today.

The rates of incentive that are offered to aggregators (or indeed to individual customers) would need to be reviewed regularly to ensure that the network is delivering value for money by using these arrangements rather than alternative approaches such as deploying DSO-operated storage devices or using traditional reinforcement means to reconfigure the network such that it operates differently in areas that are particularly affected and require large amounts of DSR to be called.

Renewables Thrive – technical enablers (telecoms)

This section considers those links which are new for this scenario, rather than the existing communications links. Communications links with similar attributes have been grouped together, they are ordered A-F with A being a one to one relationship; F being a one to many relationship.

2030's Scenario	Actors		Functional Requirements					
			Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
Renewables Thrive	Commercial service provider	Commercial service provider	3	1	2	3	1	2
	Commercial service provider	Customer - Small	3	2	2	3	2	2
	DSO	Commercial service provider	3	1	3	3	1	2
	DSO	Customer - Large	3	1	2	2	1	1
	DSO	Government Policy & Regulation	3	1	1	2	2	1
	DSO	Large generation & storage	2	1	1	1	1	4
	DSO	TSO	2	1	1	1	1	4
	Government & Regulator	Commercial service provider	3	1	2	3	1	2
	TSO	Government & Regulator	3	2	3	3	1	1
	TSO	Large generation & storage	2	1	1	1	1	4

A. TSO to Base-Load Renewables / Large Scale Intermittent Generation / Fossil Fuel Generation / Large Scale Storage

- **Functional requirements:** communications used for monitoring and control for network operations. With this in mind needs to have: high security, low(er) bandwidth, low latency, high reliability/resilience
- **Immediate communications needs:** existing methods to be used where they exist already
- **Longer term communications:** deploy as new generation or storage plant is commissioned
- **Scalability of communications:** medium (moderate deployment)
- **Cyber security:** high (must be secure: limited channels so can pay more per channel for high security)
- **Open standards and interoperability:** low (limited occurrences of this being required)

B. DSO to Demand / Storage Aggregator

- **Functional requirements:** communications used to signal for multiple responses including trading information - needs very high security, higher bandwidth, medium latency, and high reliability/resilience
- **Immediate communications needs:** similar needs to trading to centralised generation as exists today
- **Longer term communications:** EV Charge Point Networks are newer players and will need to have these communications in place prior to operation
- **Scalability of communications:** low-medium (limited deployment)
- **Cyber security:** high (must be highly secure: limited channels so can pay more per channel for high security)
- **Open standards and interoperability:** medium (ideally have a common standard across Australia to allow a range of 3rd parties to operate across the country)

C. DSO to Large Industrial Customers

- **Functional requirements:** communications used to signal for multiple responses - needs high security, higher bandwidth, high latency, and high reliability/resilience
- **Immediate communications needs:** As B, similar starting point as that from existing communications with large scale industrial customers
- **Longer term communications:** Update and refine communications as appropriate given individual company capabilities
- **Scalability of communications:** low-medium (would need to scale to a range of providers)
- **Cyber security:** medium-high (must be secure to prevent unauthorised access)
- **Open standards and interoperability:** low-medium (ideally have a common standard across Australia to allow a range of providers/generators to operate across the country)

D. Retailers to Meter Operators

- **Functional requirements:** communications used to provide usage information for billing. Needs to have good security, medium bandwidth, lower latency, medium reliability/resilience.
- **Immediate communications needs:** would use existing solution
- **Longer term communications:** unlikely to require changes to available methods
- **Scalability of communications:** medium (will need to scale to possibly tens of thousands of customers)
- **Cyber security:** medium (needs to be secure, although limited impact if hacked only between 3rd party and any one provider/generator)
- **Open standards and interoperability:** low-medium (ideally have a common standard across Australia to allow a range of retailers to operate across the country)

E. Retailers / Meter Operators to Customer

- **Functional requirements:** communications used to provide usage information for billing and system management purposes. Needs to have good security, medium bandwidth, lower latency, medium reliability/resilience.

- **Immediate communications needs:** deploy as new technology becomes available. Likely to piggy back on existing communications into the home, e.g. TCP/IP (Internet), etc.

- **Longer term communications:** Likely to remain using some form of Internet connection

- **Scalability of communications:** high (a need to be widely scalable to millions of devices)

- **Cyber security:** medium-high (this link provides the interface to the customer, whilst it needs to be secure to protect data privacy, there is limited damage that could occur if hacked)

- **Open standards and interoperability:** high (would favour being an open standard in order to facilitate competition between Charge Point Network Providers – a need to define this as the market starts to form)

F. Demand / Storage Aggregator to Customer

- **Functional requirements:** communications used for monitoring and control to a number of in home appliances. Could be signalling to hundreds of thousands or even millions of devices, needs to be secure, low(er) bandwidth (due to volume), medium latency, medium reliability/resilience.

- **Immediate communications needs:** Use product vendors favoured solution, linking to existing communications e.g. TCP/IP, etc.

- **Longer term communications:** Depends on the strategy of the product vendor

- **Scalability of communications:** high (a need to be widely scalable to millions of devices)

- **Cyber security:** high (needs to be secure to prevent hacking and 3rd party control. Likely to be a target for attack, so would need to well maintained)

- **Open standards and interoperability:** Low (could be proprietary for a given manufacturer in this instance – this could also be used to obfuscate, assisting with cyber security)

Renewables Thrive - SGAM Model

Component Layer

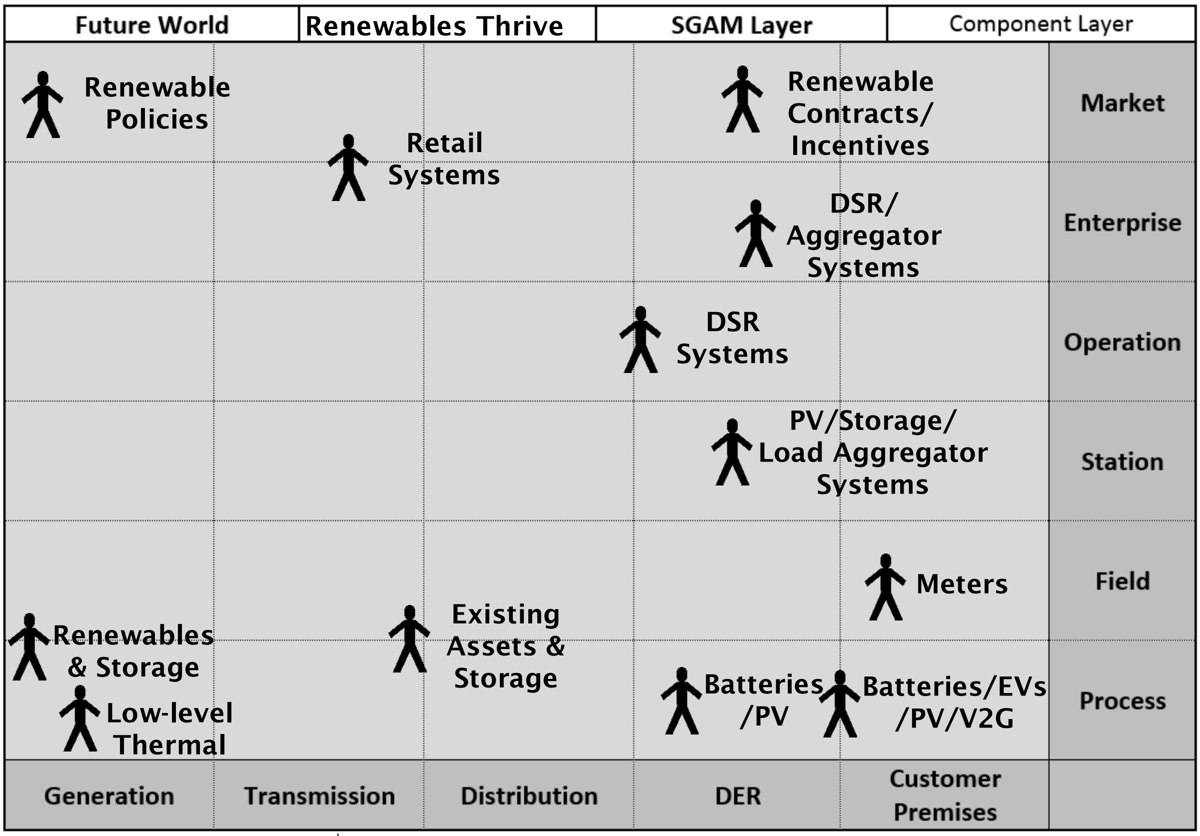


Figure 26 Renewables Thrive - SGAM Component Layer

The components identified within this layer must be in place in order to provide the functionality, information and communication pathways needed to facilitate the future scenario. The layer has been populated by examining the holistic view in Figure 25 and the use cases identified to be most prevalent in the Rise of the Prosumer future world. The use cases most applicable to this future world, derived from extensive reviews of workshop materials are highlighted in Table 4 below:

Table 4 Renewables Thrive - Example Use Cases

Future Worlds	Demand Response	Dynamic Load Balancing	V2G	EV Co-ordination	DER Generation	HAN to Grid	Enable DER Market	Energy Storage	Dynamic Asset Control	Peer-to-Peer Trading	Customer Grid Interface	Micro Grid
Set and Forget	X	X	X		X	X	X	X			X	
Rise of the Prosumer	X		X	X	X		X	X	X	X	X	
Leaving the Grid								X		X		X
Renewables Thrive			X	X	X	X	X	X	X	X		

Within this scenario, the uptake of PV and storage is ubiquitous at all levels of generation, from utility to domestic scale premises. With this rapid uptake of generation and energy storage systems, there is an equally a rapid uptake of the supporting and auxiliary systems, including protection, monitoring, power quality and inversion equipment. For the sake of brevity and in order to keep diagrams simplistic and easy to understand, these components have been excluded from the component layer. However, in reality these systems must also become ubiquitous; it is important to consider that when implementing new technologies, the enabling and supporting equipment is equally important.

The national base-load will be provided by renewable sources, mainly PV, in large centralised locations, this allows the existing transmission and distribution network to be utilised rather than becoming a useless asset. Uptake of storage at distribution level and above allows for peak demand to be met without additional generation.

For the scenario to be successful it will likely require DSR solutions to alleviate load at peak time, similar to the 'set and forget' world. An aggregation system will compile available DSR response in order to achieve the most efficient network response. These aggregators will require systems across the DER and Customer scale domains capable of optimising and issuing a DSR instruction.

Non-physical components that are vital to the success of the scenario include the introduction of renewable incentive policies and contracts to encourage the uptake of PV and storage. Without these mechanisms in place, it is unlikely the scenario will achieve its ambitious target of 96% of energy from renewable sources by 2050.

Existing retail systems for the sale and purchase of electricity will continue to be suitable.

Business Layer

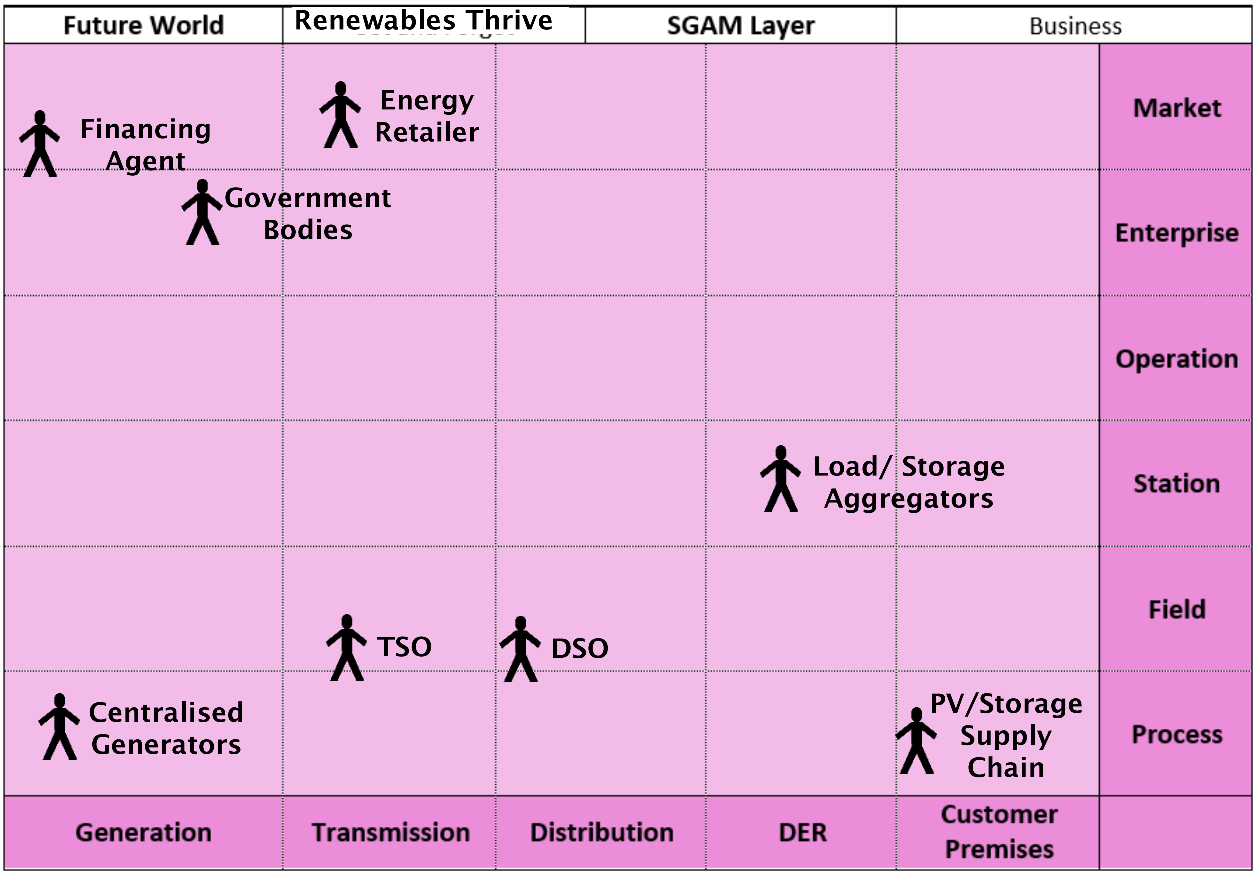


Figure 27 Renewables Thrive - SGAM Business Layer

The content of the business layer is drawn from the holistic view of actors presented in Figure 25. Importantly, the identified actors may not be specific businesses but rather the services provided by a business-like entity. Each actor could be provided by multiple competing businesses or, in contrast, one business may provide the services of many actors. The business layer does not define which form is taken only that the actors identified have a stake in the processes, services and organisations within the 'Renewables Thrive' world.

The nature of this world is less customer-centric than the alternative scenarios and is instead focused on the continuing success of the central system of generation, transmission and distribution with the objective of shifting from fossil fuels to renewable energy. This scenario is the most similar to the world of today in this sense. This shift to renewable energy will be made possible through funding from the Financing Agent. Depending on the eventual division of storage/generation capacity connected at either the distribution or transmission level will determine whether the DSO or TSO has the more dominant relationship with the retailer and control over the system.

The Government Bodies actor is in place to ensure the continuation of renewable incentives for all scales of renewable connections. It is also within their responsibility to prepare the contracts to discourage the use of non-renewable fuels, through the sale of fossil fuel credits (or equivalent).

The Load/Storage Aggregator will operate across the DER and Customer scale domains, their business function is to aggregate the available load or storage charge/discharge either by geography/network zone/style of load/storage in order to sell the response to the network. Customers will be able to generate revenue from their electrical assets through this means and it ensure network security. The DSO/TSO will facilitate these organisations.

The Energy Retailer will continue to act in much the same way as it currently behaves in the world of today, operated by AEMO or an equivalent.

Function Layer

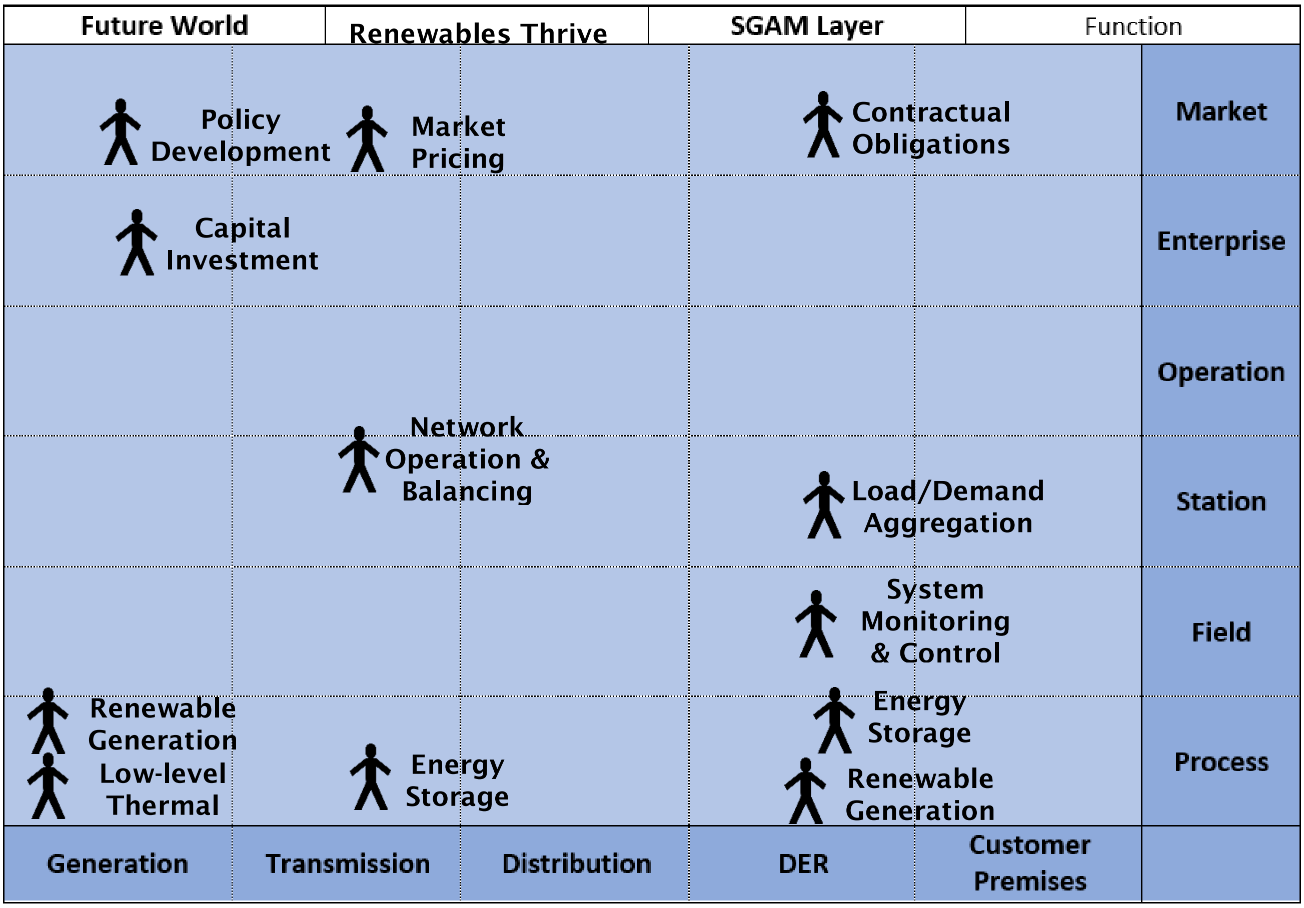


Figure 28 Renewables Thrive - SGAM Function Layer

This layer shows the components, business models and the holistic overview to accommodate the use cases that define the future world. The identified functionality is made possible by the components and services provided by the component and business layer. In order to deliver the 'Renewables Thrive' scenario the above functions are mapped across the SGAM function layer to describe the element of the power system responsible for delivering the functionality of the actor.

The core functionality of this scenario is the large scale generation and storage of renewable power at all levels of the utility infrastructure. This is driven by the Capital Investment funding of such projects. Clearly, for this functionality to be in place, the funding must be sourced. Either the market is so heavily de-regulated that private investment is abundant, or the projects are heavily government subsidised. Whichever is the case (and clearly there are intermediate measures), the funding for this capital investment is not currently available. To enable this world to come to fruition, a method for providing capital investment must be obtained.

The function provided by the Load/Demand aggregators follows from the description of the business case from the previous layer. Similarly, the System Monitoring and Control functions are in place to support the Storage and Generation equipment and allow for the aggregation systems to communicate their aggregation requirements with the physical assets.

The function of the Policies and Contracts within the systems are to legislate, regulate and encourage the uptake of renewable energy sourced power at all levels of the power system.

Information Layer

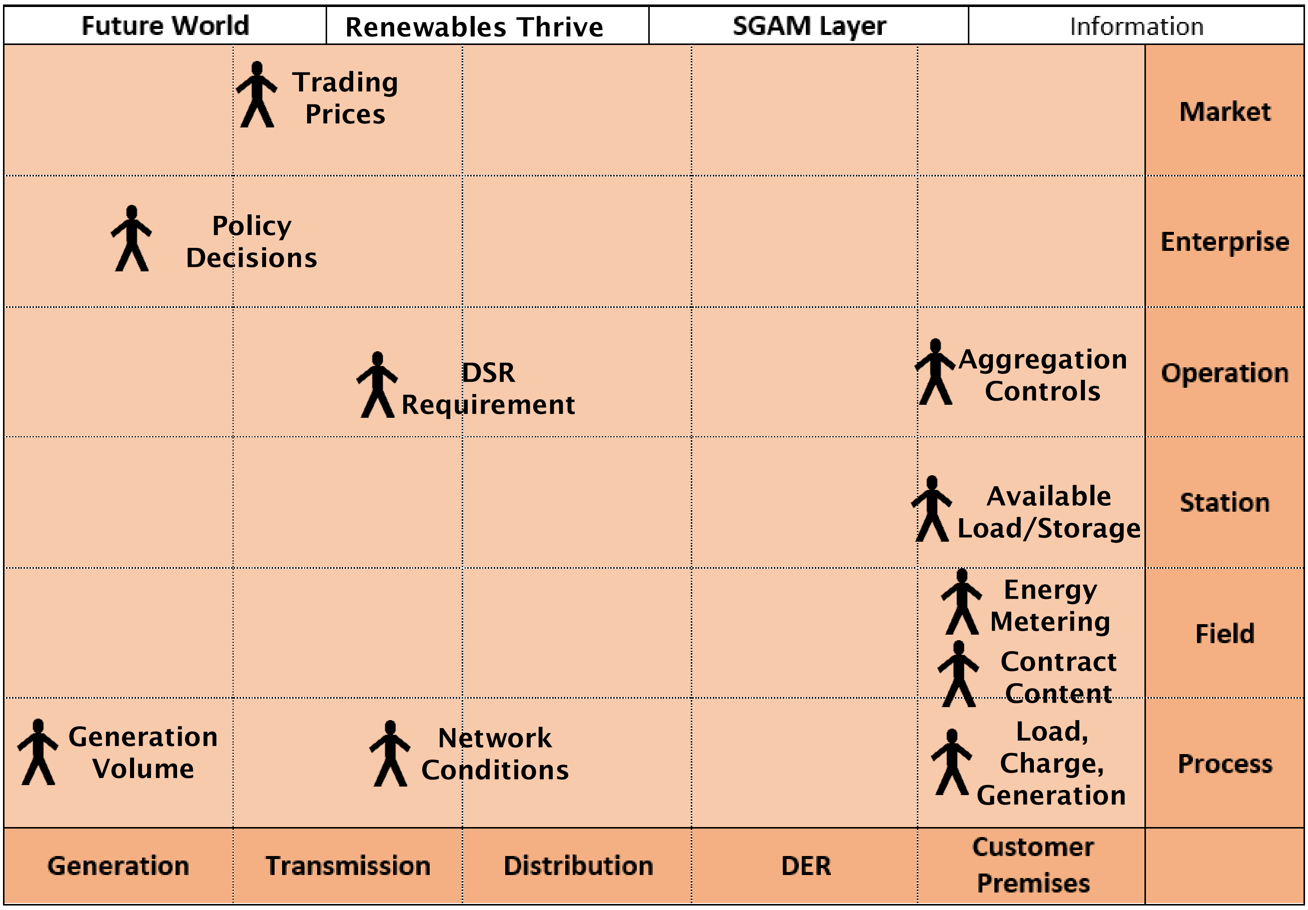


Figure 29 Renewables Thrive - SGAM Information Layer

The information layer describes the data or data models which must be collected and passed between actors to achieve the functionality set out in the previous layer. Information is transferred between actors and components as set out in the Communication layer (). Where possible the transfer of information has been linked between two or more components to aid with the visualisation of the processes. However, the SGAM positions are based on the role the information plays within the system, not the position of the component or actor it is transferred between.

The information passed between actors within the system is largely similar to the style of information being passed in the world of today; noticeable differences occur due to the abundance of smaller scale PV and the need for DSR arising from a potentially intermittent base-load. A breakdown of information within the system is as follows:

- Real-time quantity of energy generated and balanced with consumption using network frequency.
- Customer consumption metered and DSR availability monitored in real time.
- Network need for an aggregated DSR response is generated when network conditions are worsening or there is a forecast dip in generation/peak in demand. Which technology is used to pass this information is not immediately clear and will need to be developed to enable this scenario.
- Live price of electricity used for metering and potentially to encourage DSR.

The sources of the information and where it is most applicable to the scenario, considering a system wide approach, is mapped to the layer above.

Communication Layer

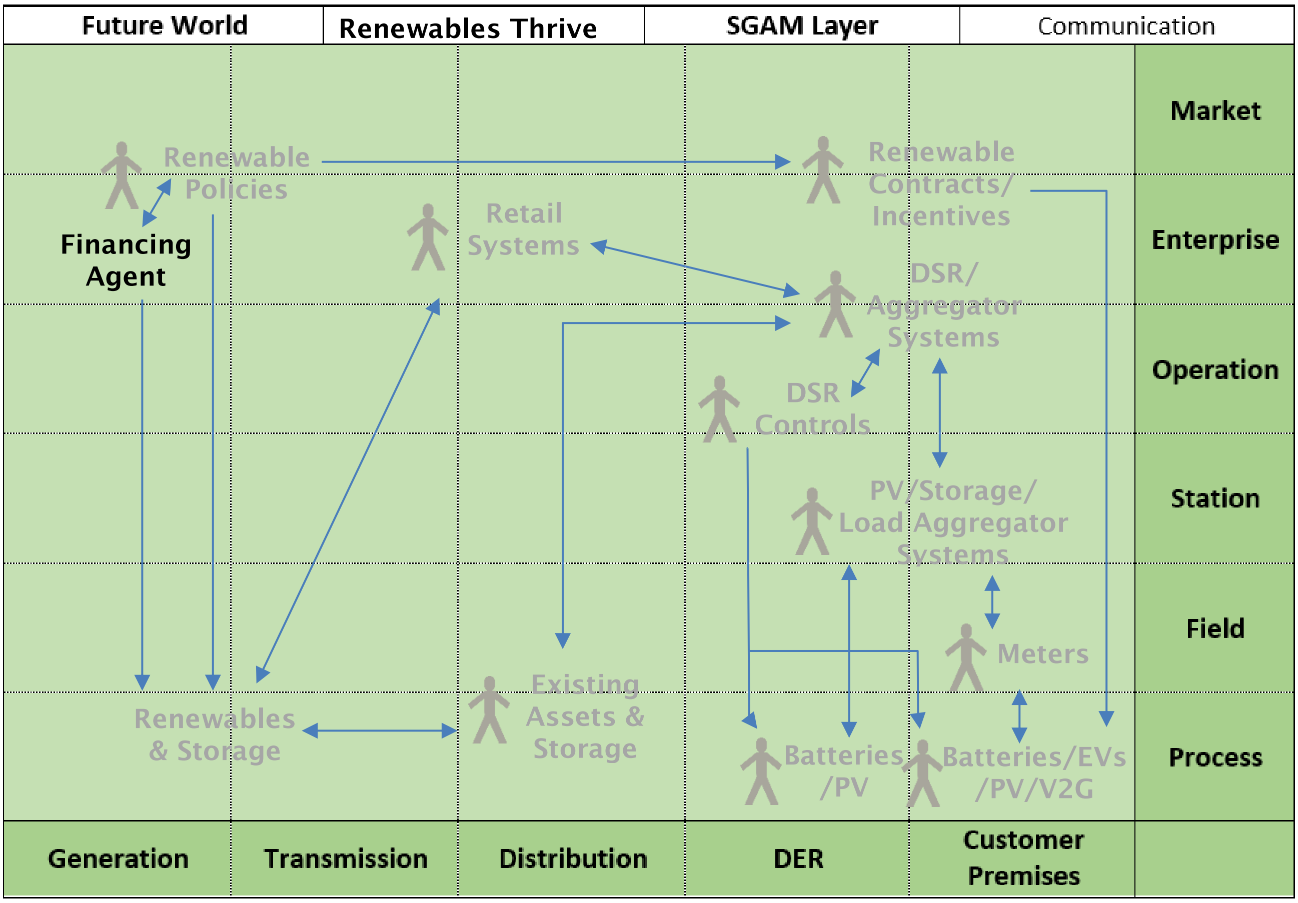


Figure 30 Renewables Thrive - SGAM Communication Layer

The actors are grey in colour as they have been directly transposed from the component layer. Although it is possible to include several more actors within this layer, it would repeat information shown in the holistic view of actors and communication channels (Figure 30), which clearly illustrates communication paths. The communication layer demonstrates the pathways that exist between components and actors to facilitate the exchange of information described in the information layer to achieve the functionality set out in the function layer.

Communication channels between large scale central renewable generation and retailers continues in a similar way to that of the world of today, allowing for pricing to set by AEMO or equivalent. Similarly, passing information between generators and the DSO/TSO systems allows for system balancing function, which lies with the central generators and grid operators. Large scale renewables/storage also receive planning information from policies and funding from financial agents who are incentivised by the policies.

The DSR functionality is achieved by passing information from the DER and customer equipment through metering technology to central load/demand aggregators, this information must be collected in real time. Aggregators combine this information with network condition and need for a DSR response, the need for an aggregated response is then passed to the DSR control equipment which issues instructions to the power equipment.

A noticeable difference in this solution is the lack of customer interaction with the technology. This simplifies communications, but the need for a secure, interoperable and Standardised method for passing information from customer equipment to an aggregation service is still essential and not currently available.

Appendix VI Telecoms Requirements

2030's Delta from 2016	Actors		Functional Requirements					
			Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
Set and Forget	DSO	TSO	0	2	2	0	0	0
		3rd Party Aggregator	0	0	0	1	-1	0
	TSO	3rd Party Aggregator	0	0	0	1	-1	0
		Centralised Generation	0	0	0	0	0	0
	3rd Party Aggregator	Centralised Generation	3	1	2	2	1	1
		Small Scale Storage / Generation Operators	2	-1	-1	-1	-1	1
		Trading Provider	4	3	3	3	1	2
		Bundled Services Provider	4	3	3	3	1	2
	Centralised Generation	Trading Provider	-1	-1	-1	-1	0	0
	Metering Provider	Customer Services Manager	3	3	3	3	2	2
		Customer	0	1	0	0	-1	1
	Customer Services Manager	Customer	2	2	1	2	3	3
		Bundled Services Provider	3	1	2	2	4	1
		Retailer	3	1	2	2	4	1
	Customer	Smart Appliances & DER OEMs	3	1	2	2	4	2
	Smart Appliances & DER OEMs	Bundled Services Provider	4	1	2	2	4	1
	Trading Provider	Bundled Services Provider	4	1	2	2	4	1
		Retailer	1	0	1	0	0	0
	Bundled Services Provider	Retailer	4	1	2	2	4	1
Rise of the Prosumer	DSO	TSO	0	2	2	0	0	0
		Distributed Generation & Storage	0	0	0	0	-1	0

2030's Delta from 2016	Actors		Functional Requirements					
			Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
		Government Policy & Regulation	0	0	0	-1	0	3
		ESCo(s)	1	2	2	2	0	1
	TSO	Government Policy & Regulation	0	0	0	-1	0	3
		Large Scale Central Generation / Storage	0	-1	-1	0	0	1
	Rooftop' Services	Customer	3	2	1	2	3	3
		EV, PV & Storage OEMs	3	1	1	2	2	2
	Government Policy & Regulation	EV, PV & Storage OEMs	0	0	0	-1	0	3
		ESCo(s)	0	0	0	-1	0	3
	Financial Markets	ESCo(s)	0	2	2	1	0	1
		Large Scale Central Generation / Storage	0	2	2	1	0	1
	ESCo(s)	Customer	0	1	0	0	0	2
	Retailer	Customer	0	1	0	0	-1	2
	EV, PV & Storage OEMs	Customer	1	0	1	1	0	0
		Metering Provider	3	1	1	2	2	2
	Customer	Metering Provider	1	1	0	0	-1	1
Leaving the Grid	DSO	Central Generation	-1	0	0	0	0	0
		Government Policy & Regulation	0	0	0	-1	0	3
		EV Charge Point Network	4	3	3	3	2	2
		Off Grid Services Agent	4	3	3	3	2	2
		Non-Off Grid Customer	2	1	1	1	2	1
	TSO	Central Generation	0	-1	-1	0	0	0
		Government Policy & Regulation	0	0	0	-1	0	3
	Financing Agents	Central Generation	0	0	0	0	0	0
		Off Grid Services Agent	3	1	1	2	2	1
	Central Generation	Retailers	-1	-1	-2	-1	1	0

2030's Delta from 2016	Actors		Functional Requirements					
			Security	Bandwidth	Latency	Reliability	Scalability	Interoperability / Open Standards
	Retailers	Meter Provider	0	1	0	0	-1	0
		Non-Off Grid Customer	0	2	2	1	0	1
	Government Policy & Regulation	Off Grid Services Agent	0	0	0	-1	0	3
	EV Charge Point Network	*Non-Off Grid Customer*	2	1	1	1	2	1
		Off Grid Customer	3	2	1	2	4	3
	PV, EV & Storage Suppliers	*Non-Off Grid Customer*	0	0	0	0	-1	0
	Off Grid Customer	*Off Grid Services Agent*	3	1	2	2	4	1
	Non-Off Grid Customer	Meter Provider	1	2	2	1	0	0
Renewables Thrive	DSO	TSO	0	2	2	0	0	0
		Large Scale Intermittent Generation	3	1	1	3	1	2
		Large Scale Storage	3	1	1	3	1	2
		Government Policy & Regulation	0	0	0	-1	0	3
		Large Industrial Customers	1	2	1	1	0	0
		Demand / Storage Aggregator	1	1	0	0	1	1
	TSO	Fossil Fuel Generation	0	-1	-1	0	0	1
		Large Scale Intermittent Generation	0	-1	-1	0	0	1
		Base-Load Renewables	0	0	-1	0	1	0
		Government Policy & Regulation	0	0	0	-1	0	3
	Meter Operators	Retailer	0	1	0	0	-1	0
		Customer	1	1	0	0	-1	1
	Government Policy & Regulation	Demand / Storage Aggregator	0	0	0	-1	0	3
	Retailer	Customer	0	1	0	0	-1	2
	Customer	Demand / Storage Aggregator	3	2	2	2	3	1

Appendix VII Use Cases

The following use cases were devised by ENA as being applicable to the future grid scenarios. The use cases were tested with a wide range of stakeholders who sought to identify the necessary changes in the grid to facilitate the delivery of these use cases. This informed the development of the SGAM frameworks that were constructed for the respective future worlds as the applicability of the use cases to each scenario was evaluated and is given in a table in this section. Some of the key themes that were distilled from the Australian stakeholder workshop and the analysis performed by EA Technology are then summarised in the 'Key Use Case Themes' table at the foot of this section.

1. **Demand Response:** Will today's suite of mechanisms and incentives for utilities, business, industrial, and residential customers to cut energy use during times of peak demand or when power reliability is at risk, and/or to ensure for the timely restoration of supply following a prolonged local failure

   Rationale: Demand response is necessary for optimising the balance of power supply and demand.

2. **Dynamic Load Balancing:** Monitoring and display of power-system components and performance across interconnections and over large geographic areas in near real-time. Provide automated and secure management of demand, generation and other energy resources and auxiliary services with a focus on expected dynamic load and generation balancing that will be required as renewable penetration increases.

   Rationale: The goals of situational awareness are to understand and ultimately optimise the management of power-network components, behaviour, and performance, as well as to anticipate, prevent, or respond to problems before disruptions can arise.

3. **Electric Vehicle to Grid Interaction:** Enabling large-scale integration of plug-in electric vehicles (PEVs).

   Rationale: Electric Vehicles could be viewed as a special case of mobile customer communications or can be aggregated by fleet operations. Electric vehicles can also be considered both an electric load as well as a form of electric storage with the potential for power injection capabilities. Integration of Electric Vehicles will also need to be considered in regard to interoperability with market and revenue cycle services as well as real time distribution operations.

4. **Coordination of Electric Vehicles:** What is required to enable all-electric vehicles or Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric vehicles (PHEVs), and plug-in conversions of hybrid electric vehicles to be charged at home or at a roaming location?

   Rationale: To allow for integration of EVs, requirements such as the ability to manage charging at home as well as roaming location, as well as, EV (electric vehicle) information transfer to BEMS and BEMS controls EV's electric charge and discharge

5. **Distributed Energy Generation / Injection:** Distributed Energy Resources (DER), small-scale power generation sources located close to where electricity is used, provides an alternative to or an enhancement of the traditional electric power grid. Particular focus should be considered for enabling DER to add extra technical value (synthetic inertia, volt/var support, etc.).

   Rationale: It allows managing of electrical power generating/injection system to be used within the end user premise environment such as home, building.

6. **Home Area Network to Grid Interaction:** Inside the user's premise, PEV (Plug-in Electric Vehicle), PV (Photo Voltaic system), home appliances, and household equipment participate in a home network and in local management that GW (Gateway) governs. Energy Service Interface

(ESI) is allowed to handle charging and power management for home appliance including PEV. Street light control, Instant Read, Pricing Signal could be considered sub-items under the management of ESI as well.

Rationale: This service provides various management capabilities of using electric energy such as monitoring, control and operation of various devices which are used in home environments by considering two different types of devices; smart home devices with electric metering and communication capabilities and legacy home devices without such capabilities.

7. **Enable DER Market Operations:** Market Operations includes the requirements and functions necessary to operate existing and future energy markets and associated services. Market Operations functions range from operating electric pricing and information exchange to establish electric and energy services pricing such as day ahead energy, ancillary services and exchange of bulk power.

   Rationale: Market operations require interaction with energy and service providers as well as independent systems operators and regional transmission operators.

8. **Energy Storage:** How do we integrate energy storage to maximise benefits for all. For example, focusing on enabling ES to add extra technical value (synthetic inertia, volt/var support, etc. Smaller forms of energy storage (ES) are anticipated within distribution systems as well as bulk power systems.

   Rationale: How do we ensure energy storage is correctly integrated into transmission and distribution operations?

9. **Dynamic Asset Optimisation:** Maximising performance of feeders, transformers, and other components of networked distribution systems and integrating with transmission systems and customer operations. As Smart Grid capabilities, such as AMI and DR, are developed, and as large numbers of Distributed Energy Resources (DER) and PEVs are deployed, the automation of distribution systems becomes increasingly more important to the efficient and reliable operation of the overall power system.

   Rationale: The anticipated benefits of distribution grid management include increased reliability, reductions in peak loads, and improved capabilities for managing distributed sources of renewable energy.

10. **Peer-to-Peer trading:** What mechanisms will be required by the future energy system to better enable peer to peer trading

    Rationale: Peer-to-peer platforms can empower consumers to directly buy and list a diverse set of products and services.

11. **Customer / Grid Interface Infrastructure systems:** What is required to develop current Customer / Grid Interface Infrastructure systems to better enable implementation of residential DR and to serve as the chief mechanism for implementing dynamic pricing.

    Rationale: It consists of the communications hardware and software and associated system and data management software that creates a two-way network between advanced meters and utility business systems, enabling collection and distribution of information to customers and other parties, such as competitive retail suppliers or the utility itself. Advanced meter infrastructure provides customers dynamic pricing of electricity and it can help utilities achieve necessary load reductions.

12. **Micro grid Management & Grid Interaction:** What mechanisms are needed to enable and allow connected micro grids to manage their own power needs, utilise the benefits of connecting to the main network (i.e. trading, reliability, security), but can also operate independently if islanded from the grid.

Rationale: Micro grids are low-voltage and/or medium-voltage grid equipped with additional installations which aggregates and manages largely autonomously its own supply- and demand-side resources. However, if left uncontrolled could cause significant disruption to the networks operation.

Use Cases Applied to Future Worlds

Use Case / Future Worlds	1 Demand Response	2 Dynamic Load Balancing	3 V2G	4 EV Co-ordination	5 DER Generation	6 HAN to Grid	7 Enable DER Market	8 Energy Storage	9 Dynamic Asset Control	10 Peer-to-Peer Trading	11 Customer Grid Interface	12 Micro Grid
Set and Forget	X	X	X		X	X	X	X			X	
Rise of the Prosumer	X		X	X	X		X	X	X	X	X	
Leaving the Grid								X		X		X
Renewables Thrive			X	X	X	X	X	X	X	X		

Key Use Case Themes from Australia Stakeholder Workshops 1

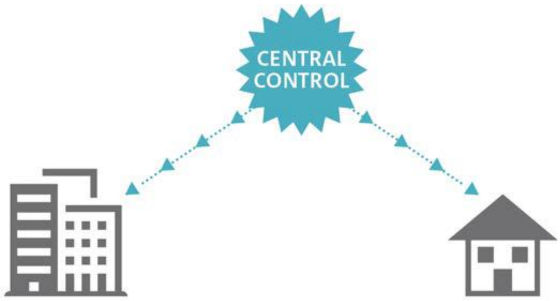
Use Case	1 - Demand Response	2 - Dynamic Load Balancing	3 - V2G	4 - EV Co-ordination	5 - DER Generation	6 - HAN to Grid
Characteristics	Network monitoring, DR available, Statistics heavy.	Renewables, shifting load, auto-grid, secure-supply,	EV metering - Buy & Sell, Smooth network load, EVs dominate	Accurate Network model/monitor, controlled charge. Charge interop.	Volt/Var services, reduced grid use, Renewables	Home managed by customer/agent Communications platform. Market driven
Components	Batteries, BEMS, easy interaction,	Metering, sensors, IT platform, SCADA, auto network	Public + Home charging, user interface (GUI), EVs,	Charging standards,	Smart inverter, HEMS, PV,	Smart Meter, HEMS,
Function	Decision/optimisation, request/feedback,	Control of DER, auto switching,	OEMs compliant, predictive driving, **EV is DER.**	Customer interface, smart charge, Driven by V2G	Cross-component communications, delivery of grid services.	Central Control, Forecasting,
Information	Real time, weather forecast, load,	Forecasting, state of switch, load, network condition	Local + aggregated, SoC, availability, trading info.	SoC, charge preferences, minimum charge levels,	Energy trading prices, availability,	Demand data (time/quant),
Innovation	Information management, LV automation, AC/DC	Standards, technology, secure reliable communications	V2G charge points, software, markets, Vehicle ability	Car-car, car-grid, communications, protocol/standard	AS4777, standards, algorithms,	Develop market, technology,
Communications	Secure communication between DNO and DR agents – devices/customer/agency	PLC, internet, SCADA DNP3	Regular 'ping', wireless, secure, open protocols,	Charging protocol,	Sensors, internet connectivity,	Common data platform/protocol, price differential
Challenges	Reliable communications between Customer and network	Level of investment, system reliability,	Market accept, No peak -> no investment. Low price - high use	Planning, data security, charge infrastructure	Accurate and frequent price points	Infant market.
Actors	Consumer, DNO, DR ventures	TSO/DNO, supply chain.	EV owners, public CNOs, DNO,	Drivers, Auto OEM, Charge OEM, DNO,	DER owners, DNO, customers, agents.	Customer, DNO, 'community agent'

Key Use Case Themes from Australia Stakeholder Workshops 2

Key Use Case Themes From Australia Stakeholder Workshops 2						
Use Case	**7 - DER Market**	**8 - Energy Storage**	**9 - Dynamic Asset Control**	**10 - Peer-to-Peer**	**11 - Customer-Grid Interface**	**12 - Micro Grid**
Characteristics	Contestable market, renewables dominate, V2G/EV,	Network services, micro grid, PQM,	Micro-area management, reverse power, decentral control.	Trading infrastructure,	Open market (competitive Neutrality)	Sync. + integration control, V2G, Renewables,
Components	HEMS, communications, Smart meters	Utility/domestic Battery, meters, Power inversion	LV sensors, auto NOPs,	Meters, contracts in place,	Smart meters, inverters, communications channel,	Home/Local EMS.
Function	Interact with market and participant	Accurate price signals, forecasting,	Algorithms, Advance DMS, Volt/Var, Fault switch	Real-time market, interface,	HAN/WAN monitoring, Grid monitoring	Monitor and match S+D. Frequency Sync.
Information	Trades, load, time,	Gen V Demand, price points/tariff,	Sensor data, network loads	Tariff information, availability,	Customer' load/generation, forecasts, prices	Diagnostics, load, SoC, match S+D, prices, forecast
Innovation	Standards/protocols,	Standards, supply chain, best operation practice.	Reliable communications methods, technology offering	P2P platform, local pricing,	privacy, communications, aggregate data, network modelling	Micro grid standards, SHAM, market/suppliers, islanding regs,
Communications	HEMS to DSO, Near real-time, Security,	Limited communications (internal management)	PLC, real-time,	Secure trading, local network,	Secure, aggregated, standardised/interop systems	Local, secure, real time, power quality,
Challenges	Availability, liability, contracts infant supply chain	Who controls supply?	Decentralised control and re-integration,	Easy interface, settling/balancing,	Data privacy, volume of data,	Decentralised freq. islanding, security of supply, regulation, safety
Actors	DER operators, DNO,	Customer, DNO, suppliers, retailers.	DNO, communication agent	Middle-man retailers, supply chain, DER 'peers'.	DNO, community, retailer,	Communities, Customers, Micro-grid operators

Appendix VIII Scenario Overview

Scenario 1: 'Set and forget'



Following the availability of cost effective battery storage towards 2020, residential and commercial customers become open to taking up demand management.

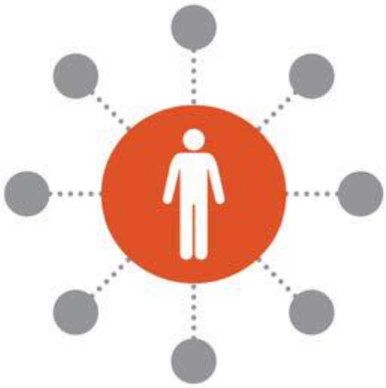
Retail tariff deregulation and competition reforms in metering services make offering consumers new electricity service options easier. The level of customer engagement is light, however, and customers prefer to rely on their utility company for the solutions for contracting, integrating and operating demand response. Customers lead busy lives and want to 'set and forget' their demand management once they've worked out which level of demand control suits them. For example, community or on-site battery control systems automatically adjust their operation to minimise the customer's electricity bill according to their retail tariff which now includes more rewards for managing their load.

2025 The first decade to 2025 was a critical period of learning for customers, retailers and networks alike as it became evident that battery storage would be used in a variety of different ways, on-site with customers, with and without solar and embedded in distribution networks. Retail price signals to customers led to changes in demand that were not always to the advantage of the system as a whole. Consequently some battery owners were dismayed as subsequent tariff changes eroded the return they expected to receive. By the end of the decade it emerged that customers preferred the whole system to self-organise the most mutually advantageous business model for all, delivered by a partnership of consumers, networks and retailers. Some of these arrangements begin to take the form of bundled utility services and comfort level packages.

2050 By 2050 a centralised, set and forget, model of managing demand through retail and network control and reward systems has been established and other demand management technologies such as air-conditioning system control have also become important. Smart meters and alternative technologies are ubiquitous, providing the infrastructure for cost reflective network and retail pricing arrangements, inclusion of other large appliances in demand management schemes, and efficient operation of on-site storage to shift demand when it is not practical to ramp down appliances.

Specialised markets for industrial demand reduction are streamlined. Customers take up on-site generation and electric vehicles as well, but, overall, centralised generation and transmission remain dominant. Centrally coordinated peak demand management has been gradually successful in presenting a viable alternative approach to reducing power bills.

Scenario 2: 'Rise of the prosumer'



Customer-centric model
where customers consume, trade, generate and store electricity.

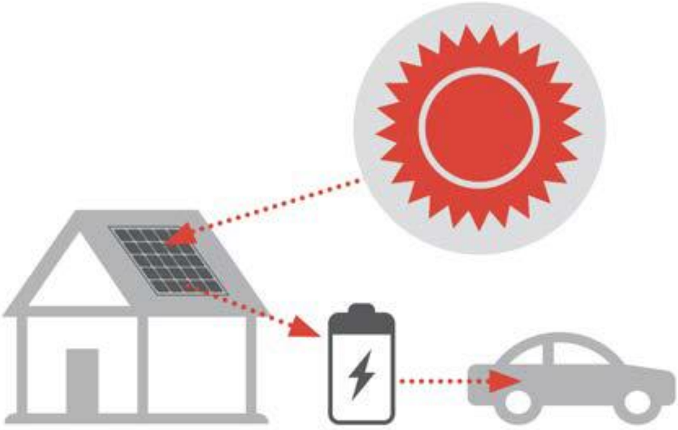
Over several decades, lowering costs of solar photovoltaic panels, and flexible new business models has meant that eventually nearly every residential consumer with a usable roof space takes up solar power. Not owning a home does not prevent uptake because retailers facilitate the sale of rooftop solar output between roof owners and non-roof owners making every roof space valuable. Through this approach renters and apartment dwellers are able to access roof-top solar power. Other approaches such as building integrated solar and increasing panel numbers in shaded aspects also extend the reach of this technology. Small customers maintain a preference as a group for volume based retail pricing which maximises the return from their solar systems and retail pricing rules do not force anyone to switch to alternative pricing structures (i.e. an opt-in system), although a minority who judge they can benefit do switch.

2025 Retailers and energy service companies embrace prosumers' needs and compete to provide them with financing arrangements where needed and the best opportunities for trading power or using it on site through storage systems. With some exceptions, transmission and distribution networks only provide a peripheral role during this period to 2025 as they were unable to move fast enough to develop the infrastructure and business models to compete effectively with alternative service providers.

2050 To create further value for customers' distribution networks work in partnership with retailers and consumers to establish a grid-edge market that provides clearer price signals and utilises the network as a platform for transactions, while a variety of companies compete to carry out the integration and facilitation roles.

Consumers choose the level of control they require from a wide variety of plans. A popular plan involves using batteries from electric vehicles as storage at the end of their vehicle life. Electric vehicles are popular in passenger and light commercial vehicle transport, reducing the demand for oil in Australia. Centralised generation and transmission are constrained in terms of growth but are still performing their important functions in the system.

Scenario 3: 'Leaving the grid'



Recognising the need for customers to receive a price signal that indicates both the costs of supplying network capacity, as well as the traditional volume charges, and that most small customers lack the metering required to measure capacity, in most states electricity pricing is transitioned towards a combination of fixed charge and volume pricing, also known as a declining block tariff. Low returns for use of on-site solar generation associated with this pricing structure slows, but does not halt, new adoption and builds customer distrust for utilities in those who already own solar systems. Large-scale uptake of electrification for light vehicles builds customers' comfort with operating storage systems but the pricing structure does not initially encourage their adoption in buildings.

2025 Discourse about customer's seeking to disconnect continues but the cost and reliability of a battery and storage based off-grid system remains very unattractive for the decade to 2025 for all but a small number of fast adopters. However, consumers of all levels remain equally unhappy with utilities as retail prices begin to rise in the late 2020s due to low utilisation of networks and increases in generation costs associated with tightening supply and greenhouse gas reduction policies.

2050 From 2035, new energy service companies seeing a market opportunity make available building control systems and interfaces that take care of most of the details of operating a completely off-grid system for the customer.

As battery costs decline, an increasing number of customers, particularly in states with already high solar uptake, begin to wonder whether there is sufficient benefit in staying connected (much like they did with landlines during the rapid uptake of mobile phones). A trickle of disconnections becomes an avalanche because, in a self-reinforcing cycle, off-grid system costs decline the more they are adopted. Customers remaining on the system are those who do not own an appropriate building and industrial customers whose loads can't be easily accommodated by on-site generation. Some new development and fringe of grid communities adopt disconnected mini-grid systems rather than individual systems.

Scenario 4: 'Renewables thrive'

At a political level, Australia debates a number of emission reduction policy mechanisms while individually significant numbers of residential and commercial customers make their own choices to move towards systems based around renewables and storage as their economic viability expands to an increasing number of applications, grid-side and on-site.

2025 By 2025, renewable electricity generating technologies are found to cost less than expected, largely as a result of deliberate programs and targets introduced in countries across the world to deploy them and bring down their costs. While a moderate carbon pricing scheme is maintained for the remainder of the economy, the success of these renewable target policies results in the introduction of a linearly phased 100 per cent renewable target by 2050 for the centralised electricity generation sector.

Besides emission reduction, the renewable target is also seen as an opportunity for Australia to build new technology supply industries and to develop regions expected to be the focus of renewable deployments. Technology cost reductions mean that it is economically feasible to deploy battery storage in place of natural gas as the primary back-up system for managing peak demand and renewable energy supply variability.

Transmission service providers face their greatest challenge in retiring transmission assets near end-of-life associated with closing fossil plants while building new assets to connect renewable resources to the grid. This is partially managed by encouraging renewables to locate with potential-to-be-under-utilised transmission lines.

2050 Storage is deployed and controlled both at transmission and generation utility-scale and distribution network locations as well as on-site with customers, shifting demand and storage charging loads to the middle of the day to take advantage of high large-scale solar and decentralised rooftop solar output. The distribution network is tasked with integrating these processes. Some customers maintain on-site back-up power (for example, diesel) for remote and uninterruptible power applications, offsetting these emissions by purchasing credits from other sectors, such as carbon forestry. Residential, commercial and industrial customers are rewarded for participating in peak demand management.

Overall, the renewable share, taken as a share of both centralised and on-site generation, is 96 per cent by 2050.

Appendix IX Detail on SGAM Framework

Introduction

In order to identify what the grid of the future may look like, the approach we are adopting is in line with the Smart Grid Architecture Model (SGAM) Framework.

Suitability of SGAM

The SGAM model has been produced as a result of work carried out in Europe by the Smart Grid Coordination Group, with input from three technical committees (CEN[1], CENELEC[2] and ETSI[3]). It builds on earlier work carried out to develop conceptual models and reference architectures, particularly the work conducted in the USA by National Institute of Standards and Technology (NIST). There are some important developments in the SGAM framework over some of the earlier architectures, which make it well-suited to the mapping exercise required as part of the Network Transformation Roadmap project.

It is important to note that the aim of the SGAM framework was to encompass the learnings and objectives from previous work and, as such, it is intended to be coherent with all other models while resolving additional issues, such as considering distributed energy resource and providing increased flexibility.[4]

The SGAM Framework offers support for the design of smart grid use cases with an architectural approach allowing for a representation of interoperability viewpoints in a technology neutral manner, both for current implementation of the electrical grid and future implementations of the smart grid. It is a three-dimensional model that is merging the dimension of five *interoperability layers* (Business, Function, Information, Communication and Component) with the two dimensions of the Smart Grid Plane, i.e. *zones* (representing the hierarchical levels of power system management: Process, Field, Station, Operation, Enterprise and Market) and *domains* (covering the complete electrical energy conversion chain: Bulk Generation, Transmission, Distribution, DER and Customers Premises).

Using SGAM

In order to utilise this approach, it is necessary to consider potential ‘use-cases’ or ‘scenarios’; a use case can be represented in terms of the actors who participate in the system, the new or existing devices necessary to provide appropriate functionality, infrastructures, functions, communication and information standards and business objectives. Consistency of the layers is provided by standards, which are applicable to the implementation of the use case. Analysis is technology neutral.

The following two extracts are taken from the SGAM framework report.[5]

- **Extract 1** – This considers the SGAM Framework, introducing the interoperable layers, and the two dimensional smart grid plane (incorporating zones and domains, that was briefly described earlier)

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[1] Comité Européen de Normalisation
[2] Comité Européen de Normalisation Electrotechnique
[3] European Telecommunications Standard Institute
[4] “Smart Grid Reference Architecture”, CEN-CENELEC-ETSI Smart Grid Coordination Group (November 2012). Pg. 14.
[5] “Smart Grid Reference Architecture”, CEN-CENELEC-ETSI Smart Grid Coordination Group (November 2012) available at http://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf

- **Extract 2** – This discusses the process for mapping Use Cases on to the SGAM framework and briefly describes how the various layers within the model are built up for each use case

Extract 1: The SGAM Framework

7.2 SGAM Framework Elements

7.2.1 General

The SGAM framework and its methodology are intended to present the design of smart grid use cases in an architectural viewpoint allowing it both- specific but also neutral regarding solution and technology. In accordance to the present scope of the M/490 program, the SGAM framework allows the validation of smart grid use cases and their support by standards.

The SGAM framework consists of five layers representing business objectives and processes, functions, information exchange and models, communication protocols and components. These five layers represent an abstract and condensed version of the interoperability categories introduced in section 7.1.3. Each layer covers the smart grid plane, which is spanned by electrical domains and information management zones (section 7.2.3). The intention of this model is to represent on which zones of information management interactions between domains take place. It allows the presentation of the current state of implementations in the electrical grid, but furthermore to depict the evolution to future smart grid scenarios by supporting the principles universality, localization, consistency, flexibility and interoperability.

7.2.2 SGAM Interoperability Layers

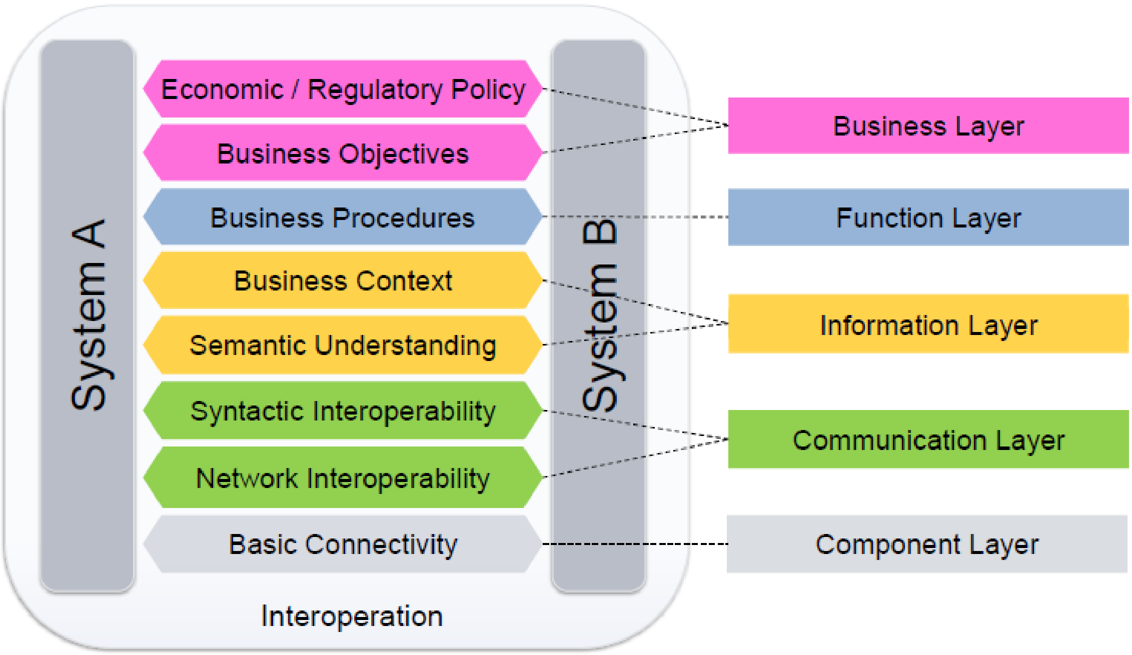

Figure 6: Grouping into interoperability layers

In order to allow a clear presentation and simple handling of the architecture model, the interoperability categories described in section 7.1.3 are aggregated into five abstract interoperability layers (refer to Figure 6). However in case of a detailed analysis of interoperability aspects, the abstraction can be unfolded.

7.2.2.1 Business Layer

The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. Also business capabilities and business processes can be represented in this layer. In this way it supports business executives in decision making related to (new) business models and specific business projects (business case) as well as regulators in defining new market models. The Business layer is addressed in more detail in paragraph 8.1.

7.2.2.2 Function Layer

The function layer describes functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality which is independent from actors.

7.2.2.3 Information Layer

The information layer describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.

7.2.2.4 Communication Layer

The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.

7.2.2.5 Component Layer

The emphasis of the component layer is the physical distribution of all participating components in the smart grid context. This includes system actors, applications, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.

7.2.3 SGAM - Smart Grid Plane

In general power system management distinguishes between electrical process and information management viewpoints. These viewpoints can be partitioned into the physical domains of the electrical energy conversion chain and the hierarchical zones (or levels) for the management of the electrical process (refer to [IEC62357-2011, IEC 62264-2003]). Applying this concept to the smart grid conceptual model introduced in section 6.3 allows the foundation of the *Smart Grid Plane* (see Figure 7.). This smart grid plane enables the representation on which levels (hierarchical zones) of power system management interactions between domains take place.

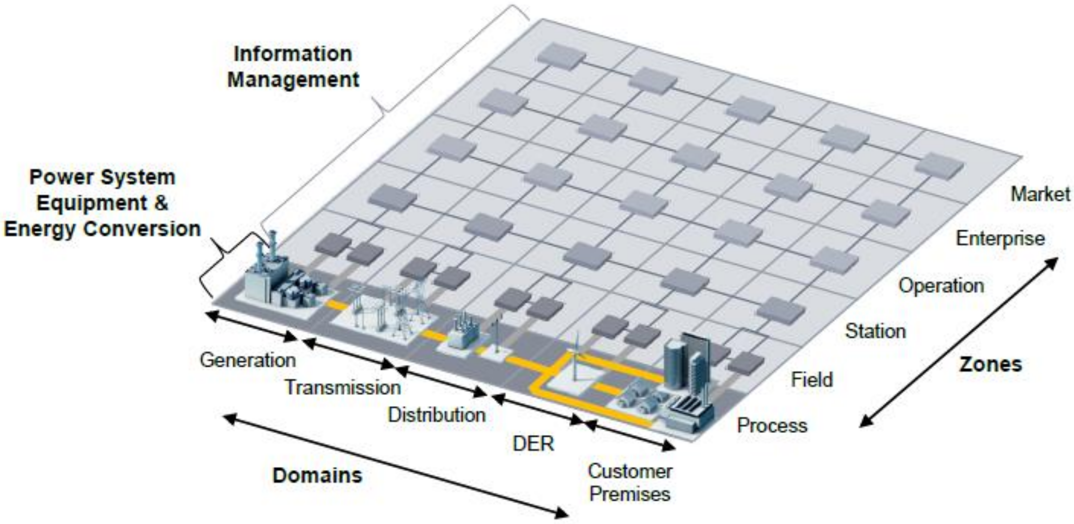

Figure 7: Smart Grid plane - domains and hierarchical zones

According to this concept those domains, which are physically related to the electrical grid (Bulk Generation, Transmission, Distribution, DER, Customer Premises) are arranged according to the electrical energy conversion chain. The conceptual domains Operations and Market are part of the information management and represent specific hierarchical zones. The conceptual domain Service Provider represents a group of actors which has universal role in the context of smart grid. This means that a Service Provider can be located at any segment of the smart grid plane according to the role he has in a specific case.

7.2.4 SGAM Domains

The *Smart Grid Plane* covers the complete electrical energy conversion chain. This includes the domains listed in Table 2:

Table 2: SGAM Domains

Domain	Description
Bulk Generation	Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plant (i.e. PV, CSP)– 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 public distribution grid, applying small-scale power generation technologies (typically in the range of 3 kW to 10.000 kW). These distributed electrical resources may be directly controlled by DSO
Customer Premises	Hosting both - end users of electricity, also producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbors, shopping centers, homes). Also generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines… are hosted

7.2.5 SGAM Zones

The SGAM zones represent the hierarchical levels of power system management [IEC62357-2011]. These zones reflect a hierarchical model which considers the concept of aggregation and functional separation in power system management. The basic idea of this hierarchical model is laid down in the Purdue Reference Model for computer-integrated manufacturing which was adopted by IEC 62264-1 standard for ―enterprise-control system integration‖ [IEC 62264-2003]. This model was also applied to power system management. This is described in IEC 62357 ―Reference architecture for object models services‖ [IEC 62357-2003, IEC 62357-1-2012].

The concept of aggregation considers multiple aspects in power system management:

- Data aggregation – data from the field zone is usually aggregated or concentrated in the station zone in order to reduce the amount of data to be communicated and processed in the operation zone

- Spatial aggregation – from distinct location to wider area (e.g. HV/MV power system equipment is usually arranged in bays, several bays form a substation; multiple DER form a plant station, DER meters in customer premises are aggregated by concentrators for a neighbourhood)

In addition to aggregation the partitioning in zones follows the concept of functional separation. Different functions are assigned to specific zones. The reason for this assignment is typically the specific nature of functions, but also considering user philosophies. Real-time functions are typically in the field and station zone (metering, protection, phasor-measurement, automation…). Functions which cover an area, multiple substations or plants, city districts are usually located in operation zone (e.g. wide area monitoring, generation scheduling, load management, balancing, area power system supervision and control, meter data management…).

The SGAM zones are described in Table 3.

Table 3: SGAM Zones

Zone	Description
Process	Including the physical, chemical or spatial transformations of energy (electricity, solar, heat, water, wind …) and the physical equipment directly involved. (e.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads any kind of sensors and actuators which are part or directly connected to the process,…).
Field	Including equipment to protect, control and monitor the process 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 areal aggregation level for field level, e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision…
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 …), e.g. asset management, logistics, work force 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..

In general organisations can have actors in several domains and zones. In the smart grid plane the areas of the activity of these actors can be shown. E.g. according to the business area of a transmission utility it is likely that the utility covers all segments of the transmission domain, from process to market.

A service provider offering weather forecast information for distribution system operators and DER operators could be located to the market zone interacting with the operation zone in the distribution and DER domain.

7.2.6 SGAM Framework

The SGAM framework is established by merging the concept of the interoperability layers defined in section 7.2.2 with the previous introduced smart grid plane. This merge results in a model (see Figure 31) which spans three dimensions:

- Domain
- Interoperability (Layer)
- Zone

Consisting of the five interoperability layers the SGAM framework allows the representation of entities and their relationships in the context of smart grid domains, information management hierarchies and in consideration of interoperability aspects.

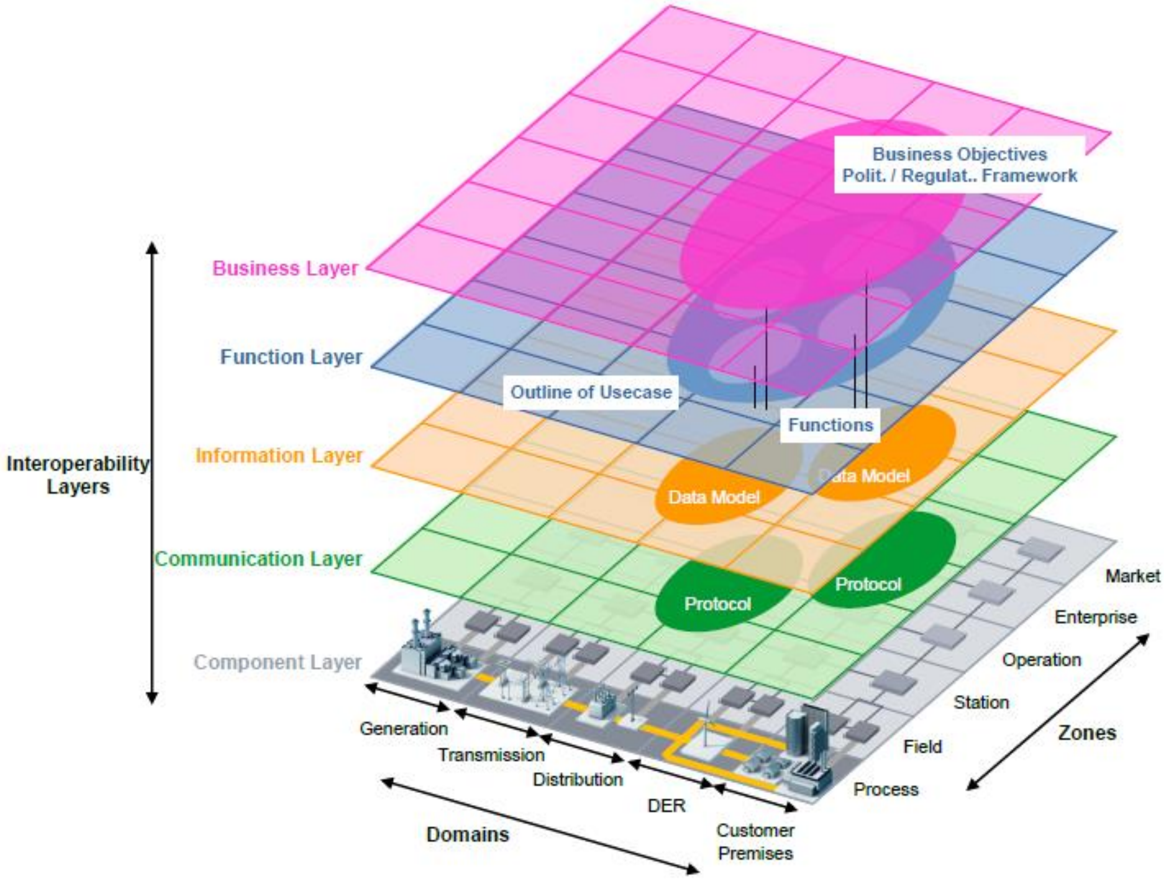

Figure 31 SGAM Framework

Extract 2: Mapping use-cases (scenarios) on to the framework

7.3.3 Mapping of use cases to SGAM framework

This section describes the basic process to map use cases to the SGAM framework. A detailed example can be found in annex B.2.4.

The mapping process can be applied to the following tasks, which are considered relevant for the present mandate M/490:

- Mapping of use cases in order to validate the support by standards
- Identifying gaps in respect to standards
- Mapping of existing architectures into a general view
- Developing smart grid architectures.

On overview of the process and its steps is depicted in Figure 12. Depending on the task the process can be carried out iteratively.

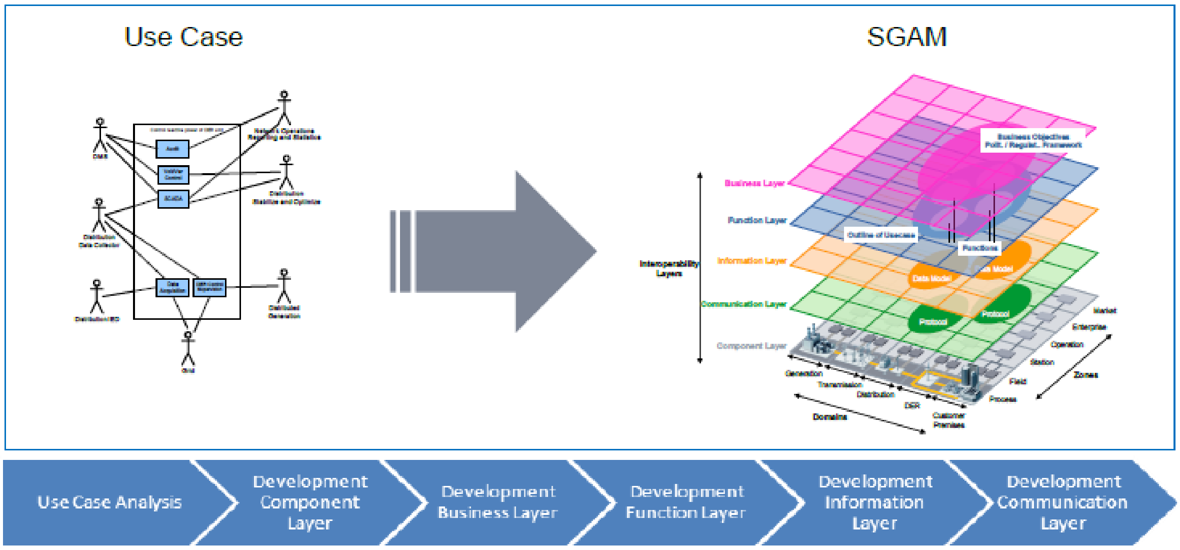

Figure 12: Use case mapping process to SGAM

7.3.3.1 Use Case Analysis

The starting point is an analysis of the use case to be mapped. It needs to be verified that a use case description provides the sufficient information which is necessary for the mapping. This information includes:

- Name, scope and objective
- Use case diagram
- Actor names, types
- Preconditions, assumptions, post conditions
- Use case steps

- Information which is exchanged among actors
- Functional and non-functional requirements.

The use case template considered by M/490 Sustainable Process WG provides the required information. It is crucial that hard constraints are identified from a use case description. These constraints may have impact on the sequence of steps carried out for the mapping process.

7.3.3.2 Development of the Component Layer

The content of the component layer is derived from the use case information on actors. As actors can be of type devices, applications, persons and organizations, these can be associated to domains relevant for the underlying use case. In the same manner the hierarchical zones can be identified indicating where individual actors reside.

7.3.3.3 Development of the Business Layer

The business layer is intended to host the business processes, services and organizations which are linked to the use case to be mapped. This includes also the business objectives, economic and regulatory constraints underlying to the use case. These business entities are located to the appropriate domain and zone.

7.3.3.4 Development of the Function Layer

The function layer is intended to represent functions and their interrelations in respect to domains and zones. Functions are derived from the use case by extracting its functionality. Typically a use case consists of several sub use cases with specific relationships. These sub use case can be transformed to functions when formulating them in an abstract and actor independent way.

7.3.3.5 Development of the Information Layer

The information layer describes the information that is being used and exchanged between functions, services and components. The information objects which are exchanged between actors are derived from the use case description in form of use case steps and sequence diagrams. Underlying canonical data models are identified by analysis of available standards if these provide support for the exchanged information objects. Information objects and canonical data models are located to the appropriate domain and zone being used.

7.3.3.6 Development of the Communication Layer

The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between the use case actors. Appropriate protocols and mechanisms are identified on the basis of the information objects and canonical data models and by consideration of non-functional requirements of the use case. Protocols and mechanisms are located to the appropriate domain and zone being used.

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