

# ELECTRICITY NETWORK TRANSFORMATION ROADMAP

Future Market Platforms and Network Optimisation

Synthesis Report

Drawn from International Consultant Reports

2017-27





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## Executive Summary

By 2050, it is plausible that up to 50% of Australia's electricity volume (MWh) will be serviced by distributed generation sources. The Electricity Network Transformation Roadmap (The Roadmap) is therefore considering the dramatic changes in the nature and function of electricity networks to ensure the societal value arising from Australians' investment in Distributed Energy Resources (DERs) is maximised.

Given that vast numbers of DERs will continue to be privately owned, there is a growing realisation that supplementary market constructs will be required to incentivise DER services that benefit all electricity consumers by optimising electricity system efficiencies. Fortunately these changes are by no means unique to Australia and a number of other jurisdictions are considering market-based solutions which are considered in this report.

### International Consultant Insights and Reports

The Roadmap Program has been very fortunate to be informed by the expert perspective of three International Consulting firms highly experienced and respected in the transformation of electricity systems for a high DER future. These consultants are; **Tabors, Caramanis and Rudkevich (TCR)**; **Strategen Consulting**; and, **Newport Consulting Group**. These three firms brought expert knowledge derived from relevant knowledge and experience in power system development and operation from a technical, business and economic perspective, and a deep knowledge of transformational change gained from their involvement in the current policy discussions and setting future directions for transformation in the US.

Each of the expert consultants brought slightly different perspectives, and this complementary input has been particularly useful in developing Roadmap actions and insights. This has allowed alternative options to be considered, particularly in light of the different operating environment in Australia, and has provided robust information to analyse some of the preferred developments in Australia

The three International Consultants have provided detailed reference documents that have been highly valuable in developing the Roadmap to date, and that will also be very useful in considering some of the more detailed issues that have been set out in the Roadmap milestones. It is expected that this information will be used as a basis for addressing many of these questions and that further collaboration will occur as paralleled developments occur in a number of jurisdictions.

## The Synthesis Report

The intention of this Synthesis Report is to summarise the information and perspectives provided by each of the International Consultants and explain how it is relevant and has been used in developing the key milestones for Network Optimisation and Market Platforms in the development of the Roadmap.

While respecting the individual perspectives of the consultants, this Synthesis Report provides a concise description of the International Report findings relevant to the Australian context and the Roadmap program. As such it reports generally on the information provided by the three Reports, but builds further on these by providing some interpretation of the materials. It draws together some conclusions from the collective analysis and findings from each of the Reports. It also provides specific information from each of the reports to elaborate on individual findings where particularly relevant.

This report is intended to provide insights and recommendations to inform transformation of the electricity system to accommodate and efficiently leverage a growing range of DERs. It supports Roadmap findings and milestones, builds upon a range of Roadmap reports and is intended to guide further discussion and development across the electricity industry.

## International deployment

The International Consultants highlighted the use of DER in the US in particular. There were some common themes which appeared quite relevant in developing the Roadmap:

- DERs are recognised as capable of providing a range of benefits to the electricity system, including potentially providing services to networks which enable networks to integrate higher penetrations of DER while also potentially reducing the need for costly network augmentation.
- DER types vary in the services they can provide to electricity systems and it is important to note that individual types of DER are more suited to particular services as they each have different technical characteristics.
- Some of the technical limitations of individual types of DER can be mitigated through the use of more sophisticated controls, but it is important that each type of DER is properly specified from the outset to achieve this.
- A portfolio of different DERs is likely to provide significantly greater network benefits compared with the provision of a single type of DER at any one network location.

- There is a need for networks to enhance capabilities to better integrate growing numbers of DERs and provide more transparent information to DER participants.
- New distribution-level markets or incentives are needed to help customers understand where and how they can deploy different types of DER to unlock and provide broader market benefits.

These issues are important when considering the preferred methods for integrating DER with networks to derive the maximum benefits for the electricity system as a whole.

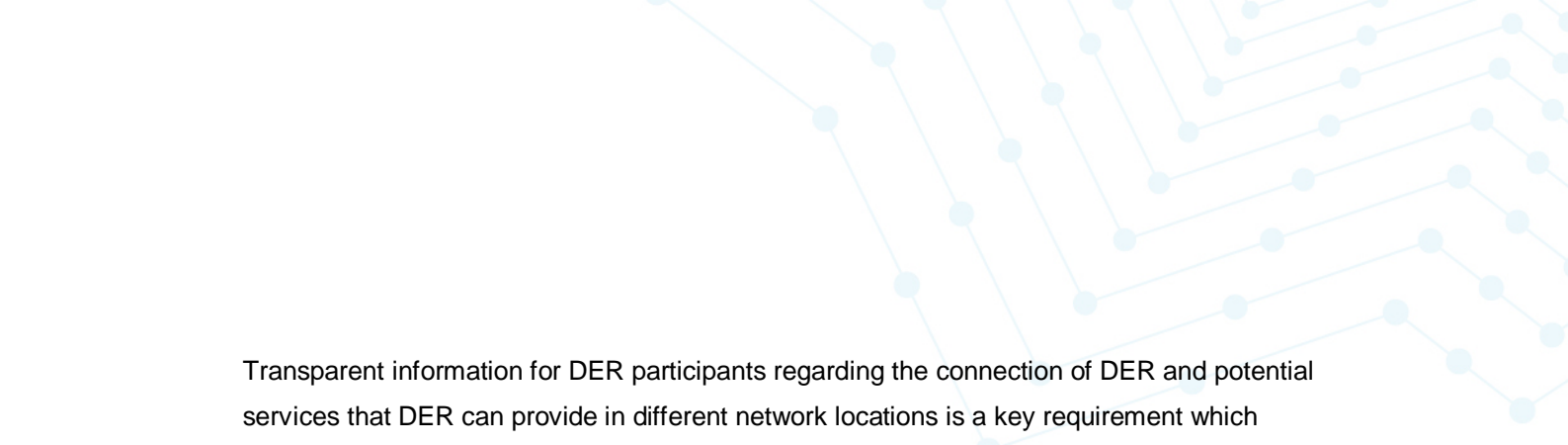
## DER Services and Value

There is a range of DER services that could provide value in different markets and that can be used for different purposes by networks. This builds on the potential for customer DERs to provide services to allow networks to defer or avoid the costs associated with traditional network augmentation in particular network areas. While the high-level functions of DER essentially relate to the provision of real and reactive power within certain time windows, this gives rise to a number of different benefits, and the potential for DER participants to derive value from their DER by participating in alternative markets. This report focuses on the benefits that DER services can provide to networks, but also considers how to realise these without precluding other benefits that DER owners or aggregators will seek across the electricity value chain.

Longer term development to allow the provision of network services by customer DERs will require that DER services can be rewarded on an economic basis for the value they provide. Price signals and incentives will be important in the longer term to encourage economically efficient DER development and investment, and there are various market alternatives that may develop to assist this.

In the shorter term, however, simpler administrative and commercial approaches may be most effective to reduce related transactions costs, and therefore lower the hurdle for DER to participate in active markets to provide network services. Approaches using competitive solicitation may be a simple and effective initial process both for signalling the value of the DER service (generally to overcome a network constraint to avoid or defer traditional forms of network investment) and compensating the DER provider appropriately for providing the service.

More sophisticated forms of incentives and price signals are likely to evolve as the size and sophistication of these markets increases. However, it is likely that the benefits of deferred network investment will be substantially greater than other benefits in the short term, and significant value will be obtained if this can be monetised early.



Transparent information for DER participants regarding the connection of DER and potential services that DER can provide in different network locations is a key requirement which requires more development. This may take the form of hosting analysis or heat maps which shows the location and amount of DER that can be accommodated or would add value at various network locations. This provision of network information will allow DER participants to become more engaged in how to connect their DERs to networks, network planning processes and ultimately provide them with better information for their DER investment decisions. This information is a key development to achieve a more customer focused investment framework.

Data provision and transparency is a consistent theme across the Roadmap proposals.

## Network Operations

It is important to recognise that the future network in a high DER world will be operationally complex, and it is critical when designing market and platform approaches to ensure that secure and reliable network operation is achieved on a sustainable basis. The development of sound operational practices, which includes a variety of new techniques for distribution system operation in particular will be key to the effective deployment of DER.

New operational approaches and paradigms will be required at many levels of networks and markets. Significant changes will be required in the way the network is planned, in developing and using forecasts, and the utilisation of intelligence for control, monitoring and operations, and the use of sophisticated new analytical approaches for optimising overall network performance.

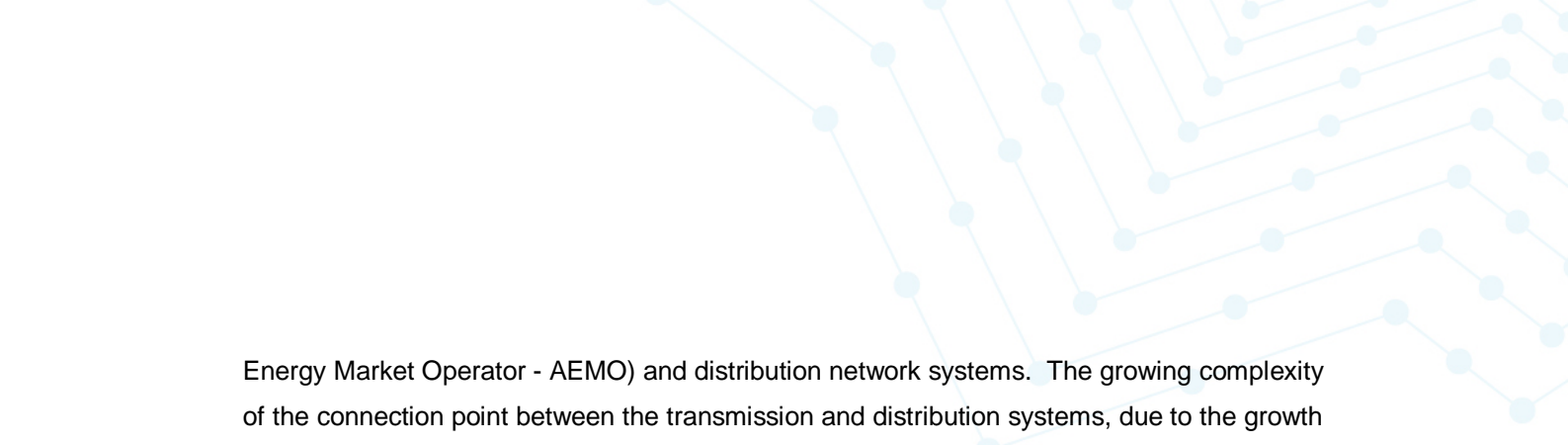
This will require the development of new systems and techniques, and require the development of detailed data models and analysis tools that allow the networks to carry out network optimisation studies for a range of future operating scenarios, as well as have more detailed and accurate real-time system operational capability.

Improved information on planning and forecasts will need to be provided to DER providers to allow them to participate more actively in planning processes.

A key component will be utilising the capability of DER to optimise the overall network performance. This in itself will require different modelling approaches, including the capacity to model the DER and its characteristics for providing the required level of optimisation for the network.

A specific consideration which is emerging as a critical issue in Australia is developing the capability to ensure management of the interface between the wholesale electricity market operator (Independent System Operator – ISO). This role is performed by the Australian





Energy Market Operator - AEMO) and distribution network systems. The growing complexity of the connection point between the transmission and distribution systems, due to the growth in renewable sources of generation at both the centralised and decentralised levels of the network, represents a significant level of uncertainty for AEMO, and effective approaches will need to be developed to allow the market operator to fulfil their role of ensuring power system security.

It is essential as a starting point that both transmission and distribution network service providers (NSPs) have visibility of the physical operation of DER participating in the wholesale market. The physical coordination of DER schedules and dispatch by AEMO and DER providers needs to be known by the distribution network operators to ensure that it can be accommodated over the distribution network. On the other hand, AEMO needs much more accurate information and forecasts of the likely loading at each transmission network connection point, including an estimate of changes to allow it to effectively operate the transmission system.

Newport Consulting recommends a measured three step process for developing more sophistication in network planning and operations incorporating DER, as follows:

**Stage 1 - Grid modernization - with low but growing levels of installed DER.**

The intelligent network is implemented with improved planning processes taking account of the possibility for DER to provide a lower cost option for meeting a future capacity need than traditional network augmentation approaches, and simple mechanisms to encourage this outcome. Preparations are being made for more advanced forecasting of the future incorporating DER and more advanced network modelling processes, including for example collection of accurate system data and network models to facilitate more accurate representation of the system in the future.

**Stage 2 - DER Integration – with moderate to high levels of DER penetration.**

The next stage involves addressing detailed technical issues associated with DER integration requiring more advanced operational design (for example protection and voltage control) to enable effective and efficient connection of growing fleets of DER. The additional volume of DER provides scope for aggregation to allow it to meet network needs reliably through DER services enabled through commercial contracts between customers, their agents (such as retailers or aggregators) and networks.

**Stage 3 - Distribution Level Energy markets – with very high DER penetration.**

This stage envisages a Distribution Level Energy Market with the potential for peer to peer trading. It could cover energy exchange that does not conceptually require use of the transmission network. This stage includes the conception of a market that supports high

volumes of transactions supporting many to many multi-directional energy flows. It is likely to be a longer-term development, perhaps more than a decade away, and this concept is considered further in the closing stages of this report.

## Markets for DER

There are existing and future markets in which DER could participate. This includes the existing wholesale electricity market, but in the future, could extend to more advanced retail markets and services, perhaps, depending on the potential benefits that are realised through the development of a broad market for DER services at the distribution level.

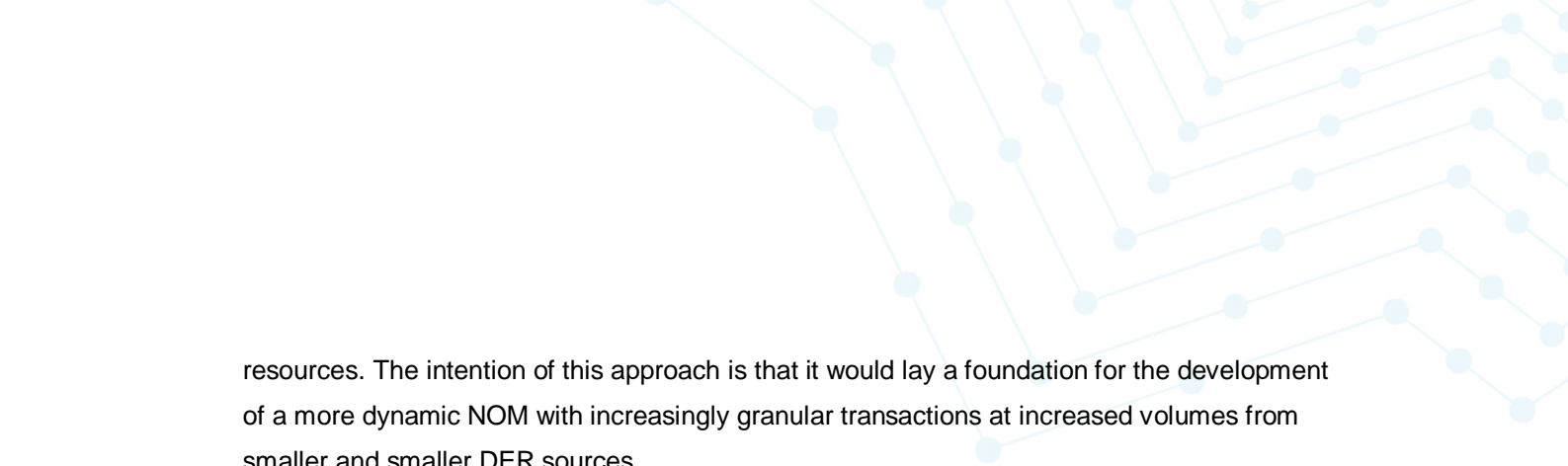
The emergence of a potential distribution level energy market could facilitate the sale of energy and other services from DER, essentially ranging from a “peer to peer” trade to a “many to many” transactions as an energy product. This market would also be likely to evolve over time, but all the International Reports suggested that the development of a fully functioning distribution level energy market would most likely take a very significant time to develop, probably in excess of a decade timeframe.

Of particular relevance to this project is the potential development of a **Network Optimisation Markets**. Network optimisation markets (**NOMs**) and the potential subsequent emergence of a digital network optimisation market (**dnOM**) are new markets that would allow the network businesses to obtain DER services on a commercial basis at the local network level. The operation of these markets optimises the outcomes of the combined DER and network operations to the overall benefit of all connected customers.

The NOM is the most interesting of the markets from a network perspective, and it is concluded that the development of a NOM is seen as a critical development to allow network businesses to unlock the potential for DER services to optimise network operations and reduce network costs in Australia.

The NOM provides a commercial framework for the networks to acquire DER services to optimise network operations. A NOM could take a number of different forms, and may also be subject to a staged development process. At one extreme network optimisation can be achieved without a market (or at least without a complex market), while on the other hand there is also the potential for a sophisticated option for implementing a digital and automated market supporting high volumes of transactions.

Initially a NOM may involve simple contracting or bulletin board approaches, and would adopt a process-based acquisition of DER for network optimisation rather than a dynamic market in the purest sense of the word. It is intended to be a simple approach with low transaction costs, but is only likely to be able to be accessed by large or aggregated fleets of DER



resources. The intention of this approach is that it would lay a foundation for the development of a more dynamic NOM with increasingly granular transactions at increased volumes from smaller and smaller DER sources.

The digital Network Optimisation Market (dNOM) would subsequently be a later development, and is a digital extension of the NOM. It provides a more dynamic and digital market platform and structure that allows DER customers to interact and respond more interactively with networks and to provide them with services. As such a dNOM will be able to cope with a very large number of market participants, DER services and transactions, with standardised specifications and other key, but standardised, contract terms. The parties buying and selling DER network-optimisation services would rely on highly automated digital procedures for service matching and market clearing.

There is very substantial overlap between a dNOM and the potential emergence of a distribution level energy market, and these concepts need to be considered in holistic manner as the mechanisms for determining and revealing prices on a locational and temporal basis would be the same, and metering and settlement processes would have a high degree of similarity. However, while this report examines the emergence of a localised energy market and its relationship to a dNOM, it focuses on the development of the NOM.

The development of network optimisation markets is viewed as a key point for further exploration in considering the transformation of the electricity sector in Australia. It has been specifically included in the key milestones to be achieved by the Roadmap in the next decade. This includes the development of simpler initial NOM as a no regrets action, with a later review to be undertaken to determine whether extension to a dNOM would be economically justified when there is sufficient operating experience and market maturity to make this judgement.

## **System Architecture**

The structural aspects of grids are important because structure sets the essential bounds on system behaviour. The grid must be treated as a network of interconnected structures that includes electric circuit structure, industry structure, market and regulatory structure, information and communication system structure, control and coordination structures, and also potentially addressing interactions with other industries and systems.

The primary purpose of developing a grid architecture is to manage the complexity and its most important outcome is the insight needed to make superior decisions about investment, planning, design, operation, and regulation of power grids.

Newport Consulting Group notes that developing future arrangements for a digitised market platform (DMP) or DER management system (DERMS) involves more detailed consideration

of the relationships between the parties and suggests care must be taken in trying to develop complex economic constructs to allow efficient operation of DER in a power system environment. There are many practical complexities associated with ensuring secure and reliable operation of the power system that may be compromised by a poor system architecture,

Similarly, the consideration of the appropriate industry structure that defines the relationships between the parties will be important to ensure the effective flow of information to enable the functions to be carried out in a way which meets the primary objectives in the deployment and optimisation of DER.

While not a key consideration of this report, current industry regulation approaches will also need to be reviewed to be consistent with the future market changes and this is addressed in a separate roadmap report and in *the Roadmap Report* itself.

## Roadmap Findings and Milestones

The International Reports provided three separate and very useful perspectives on the challenges facing the industry in accommodating a high DER future in Australia.

This provided an excellent basis for the Roadmap to draw specific shorter term conclusions to establish key milestones for developing and implementing the appropriate platforms to enable the development of the best possible electricity system structures for 2027 and beyond.

### Key Roadmap Findings:

#### Finding one

An integrated planning and development process is required for the future development of the power system and the ongoing innovation of DER services that will continually evolve. This is unlikely to occur if this development is not comprehensive and coordinated, for example if there is too much focus on isolated development of one or other of the new features. It will also require new technology and innovation to best manage the complexity associated with the increased level of DER. Fortunately, these do exist, but will need to be developed to address the specific issues raised in optimising the use of DER.

A holistic and innovative approach will be essential for development of the distribution level markets of any form, since they are more complex in many ways than the development of the NEM.

**Finding 1: Integrating high levels of intermittent renewable energy and DERs markedly increases the complexity of network management and requires the holistic application of advanced technologies and tools to ensure stable and efficient operation.**

### Finding two

Each of the International Reports noted that the first steps for network businesses to achieve access to DER services to improve overall performance could involve simple approaches including procurement through contestable tendering processes or even regulated procurement. This would be effective where it was required to defer network investment but could also provide potential services that a network could use in real time operations within the commercial conditions of a contract.

The networks will need to deploy sophisticated optimising algorithms to take full advantage of the DER services available. This will involve some system development activity which is outlined in Finding 2.

**Finding 2: The orchestration of DERs can provide valuable services that help optimise electricity network operation and provide customers with opportunities to participate in response to financial incentives.**

### Finding three

Each of the International Reports noted that a balanced set of objectives must be established to ensure that the required longer-term outcome of improved efficiency and performance would be achieved for customer benefit. There was a degree of commonality between even the specific design features that were suggested as necessary, in part based on the experience gained in early consideration of advanced approaches in the US. This leads to the conclusion that there is already a high degree of confidence relating to these features in a variety of different environments with different operating conditions that led directly to Finding 3.

**Finding 3: A range of market design features must be applied to ensure that customers, networks and society benefit from distributed energy resources orchestration.**

### Finding four

One of the most common conclusions drawn throughout the International Reports on a variety of subject matters was the need for a staged process using small incremental steps, perhaps involving trials, but not progressing to a more advanced stage until there was clear operating experience and the benefits and suitability of the approach had been tested, with sufficient information provided to allow progress to the next stage.

**Finding 4: The form of the NOM must evolve to increasing levels of sophistication and scope as experience is gained and the approach is proven.**

### Finding five

The International Reports all identified the need for and potential benefits to be realised through the implementation of a NOM. These findings were also consistent in consideration of the form and to a significant extent the underlying detail of a NOM. The conclusion from this is that a NOM is a required step, whether or not there is a more advanced subsequent stage. Therefore finding 5 follows.

**Finding 5: The development of a NOM is a no regrets action.**

### Concluding comments

The purpose of this report has been to draw on the knowledge and experience provided by three international consultants and documented in reports that were commissioned for the Roadmap Program. These reports have made a very valuable contribution to understanding the status of similar investigations in other jurisdictions, and also in identifying the challenges that have emerged as DER has been employed in other advanced jurisdictions.

In addition to reporting on the information provided in the International Reports this report has made some interpretations and developed approaches to be further explored as the *Roadmap* unfolds. However, the Roadmap program expects to continue working closely with overseas experts and Australian industry experts as *the Roadmap* program progresses to ensure that this program of work remains current with the latest thinking and international developments for maximum benefit in the Australian context.

## Introduction

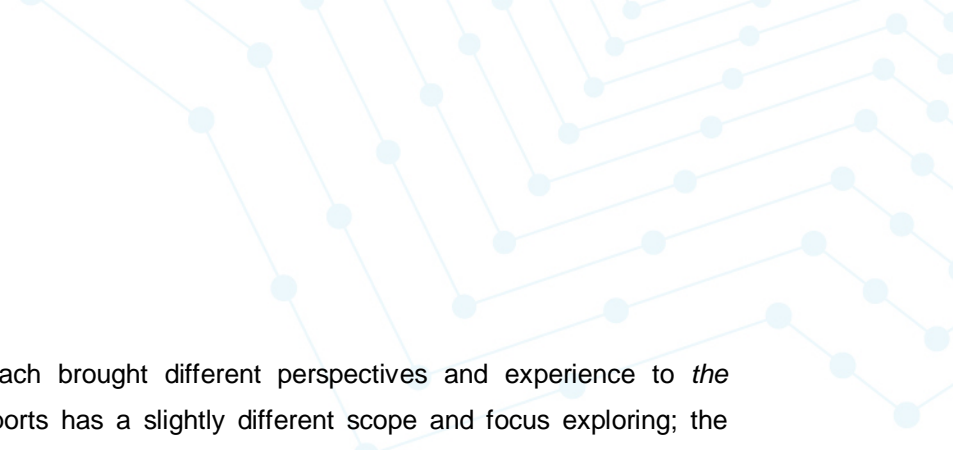
The purpose of this report is to summarise key findings of the investigations carried out as part of the Electricity Network Transformation Roadmap (*the Roadmap*) into the opportunities, approaches and benefits from the utilisation of Distributed Energy Resources (DER) in the future in Australia. Work was commissioned with three international consultants to obtain a range of expert perspectives on the approaches being investigated in overseas jurisdictions and identify the status of actual implementation. Each of the consultants provided a detailed report (International Report) that provided their findings.

The three International Reports provided are as follows:

- (TCR) “Network Optimisation Markets: Market Design and Economic Issues” - Prepared for CSIRO and ENA by Tabors, Caramanis and Rudkevich (TCR)**
- (S) “Architecting Australia’s Future Electricity Systems: A Global Survey” prepared for CSIRO by Strategen Consulting (Mark Higgins, Cedric Christensen and Shana Patadia)**
- (N) “Architecting Australia’s Future Electricity Systems” - prepared for CSIRO by Newport Consulting Group, LLC (Paul De Martini, Jeffrey Taft, Lorenzo Kristov, Abhishek Singh, Ezra Beeman)**

In these reports the Consultants have also considered possible implementation approaches for creating new market platforms in Australia to open up the full value of DERs for customers, networks and the broader electricity value chain in Australia. The consultants have acknowledged the unique conditions that exist here, while leveraging their specialist knowledge to apply key experience and insights to their understanding of the Australian context. In a limited number of cases, additional reports in the public domain are cited where relevant as is some content developed in parallel by both the consultants and Roadmap workshops.

While respecting the individual perspectives of the consultants, this **Synthesis Report aims to provide a concise description of the International Report findings relevant to the Australian context and *the Roadmap* program.** As such, it reports generally on the information provided by the three Reports, but builds further on these by providing some interpretation of the materials. It draws together some conclusions from the collective analysis and findings from each of the Reports. It also provides specific information from each of the reports to elaborate on individual findings.



The three Consultants have each brought different perspectives and experience to *the Roadmap* and each of their reports has a slightly different scope and focus exploring; the potential purpose and roles of the grid in a high-DER future; comparative analysis of emerging distribution system orchestration models, examples of DER utilisation and DER incentivisation as well as analysis of emerging examples of DER management systems and assessment of system architecture necessary to support these, and also; assessment of emerging digital market platforms and functionality.

Viewed together, the consultant reports provide a comprehensive review of the current status of development of DER in the US and internationally, covering technical issues, operational issues, markets and supporting infrastructure, and industry structure considerations as well as discussing some of the preferred arrangements for the future development of the sector.

These different perspectives have proven invaluable in allowing some conclusions to be drawn, including key Roadmap actions for the coming decade, but it is also recognised that there remains a significant amount of work to be carried out to further explore many of the concepts in these Reports, and particularly in applying them to the Australian context.

The international reports provide an assessment of the challenges in each of these areas and, in many cases, recommend a possible implementation approach for Australia. They also acknowledge the many outstanding questions remain to be addressed given the very formative stages of development in all jurisdictions.

The International Reports provide a substantial body of knowledge with many important insights that inform the developments being considered in Australia. The various findings of these reports have also been instructive for the development of the Roadmap's proposals for optimising DER value for the overall benefit of the customers that the electricity system serves. It is important to note, however, that the contents of this Synthesis Report and the Roadmap itself should not be considered as reflecting the official position of any or all of the consultants.



## Consultant Profiles

CSIRO has been pleased to work closely with a range of expert consultants in considering future Roadmap directions and milestones. The expert consultant material has been critical in shaping a range of future market platform considerations and design principles. A summary of the consultant profiles is provided below.

<p><b>Tabors Caramanis Rudkevich (TCR):</b></p>	<p>TCR is a highly-specialised team of internationally recognised thought leaders in electricity market analysis and design, digital market platforms and electricity regulation and policy.</p> <p>TCR have advised widely on the design, structure and restructuring of power markets globally. They have advised a range of large clients on platform strategies and have been heavily involved in a range of market reform activities across the U.S.</p>
<p><b>Strategen Consulting:</b></p>	<p>Strategen Consulting is a leading U.S. strategic advisory firm with deep expertise in grid-edge technology strategies deep experience within the U.S. power industry and clean energy sector with relationships with key U.S. utilities and regulators.</p> <p>Strategen have played a critical role in shaping many regulatory reforms that have created the vibrant renewables and grid-edge sectors across the U.S.</p>
<p><b>Newport Consulting Group:</b></p>	<p>Newport formed an expert team for their report contribution with experience across the U.S. and Australian electricity industries.</p> <p>Members of the Newport team have worked directly on several transformational policy reforms and business strategies across the U.S.</p> <p>With leading expertise in DER integration, market design, distribution planning, Transactive platform design, distribution system optimisation, locational marginal pricing design and business model transformation the Newport team have been involved in work occurring across NY REV and other global market leading examples of electricity system transformation and reform.</p>

# Development of DER in Australia

## Scope of DER in Australia

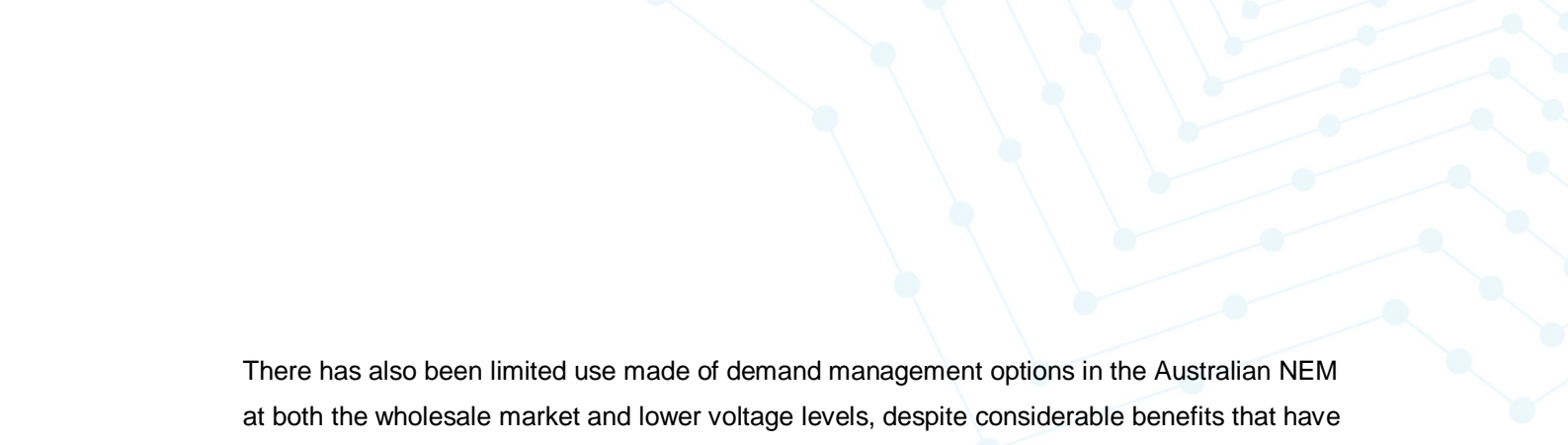
The penetration of Distributed Energy Resources (DER) in Australia is acknowledged as being towards the highest levels throughout the world and with faster levels of growth. Australia leads the world for example in the penetration of rooftop solar photovoltaic (solar PV) cells, with a penetration rate of roughly 15% of households on average with some states above 30%. This can be compared to Belgium, with the next highest level of penetration, with 7% average penetration. Other forms of DER are also gaining prominence as costs begin to fall, for example there is now significant interest in installation of batteries at the household level driven by Australia's relatively high electricity costs.

There has also been a focus on grid modernisation by network businesses in Australia, although there are differences in the rate and manner in which this has occurred. The most significant developments that have occurred have been based on the new capability provided by smart meters, and there have been considerable advances in the development of analytics to provide improved customer information.

Most networks have focused on developing intelligent network capability with improved data, network modelling, monitoring and control capability. Improved outage and network management systems have also been employed to enhance network operations and provide an improved customer service.

These improved edge-of-the-grid capabilities are enabling better information flow and multi-directional energy flows enabling customers to sell services to networks and other market actors. The traditional electricity supply chain is being replaced by emerging, multi-commercial relationships and energy service markets, underpinned by the growth of digital technology and platforms that are making it easier for customers to choose, connect and swap between different energy supply technologies. Customer expectations are shifting towards a more responsive grid, enabling streamlined connection of a growing range of products and services.

Australian network businesses are in turn exploring opportunities to modernise the grid to cater for changing customer expectations and choices and are also already exploring opportunities to utilise growing penetrations of customer DER to defer network augmentation. The regulatory investment test for networks (RIT-T and RIT-D) requires networks to seek interest in the provision of alternative options to network development. Networks must assess the economics of any proposals that are forthcoming before deciding to invest in traditional network augmentation solutions to emerging network constraints.



There has also been limited use made of demand management options in the Australian NEM at both the wholesale market and lower voltage levels, despite considerable benefits that have been demonstrated in its adoption. There has been a detailed review of the potential for demand management and customer participation through the AEMC Power of Choice Review<sup>1</sup>, but despite this, take up has been relatively low. Initially this was due to a lack of processes that allowed for simple deployment, while more recently the general decline in peak demand resulting from utilisation of solar PV and energy efficiency has meant that there are reduced benefits, except for a few specific locations where it has been adopted.

On the other hand, adoption and integration by the network businesses has been challenged by the very fast uptake and the limitation on some of the existing networks to accept high levels of solar PV capacity, particularly in rural areas with long feeders and low fault levels. This has resulted in limitations being placed on the connection of additional PV cells in some locations, with many network businesses seeking technical solutions to increase hosting capacity and also seeking to provide more transparent information to assist in managing this challenge.

The network businesses have also been challenged by the potential cost of upgrades to the network that are required to connect and integrate DER in to the existing networks. This includes not only the initial investment that might be required to provide the capacity to accommodate its infeed to the system, but also to provide the new intelligent functionality that is recognised as a foundational requirement for transforming networks to allow the efficient integration of DER into the future.

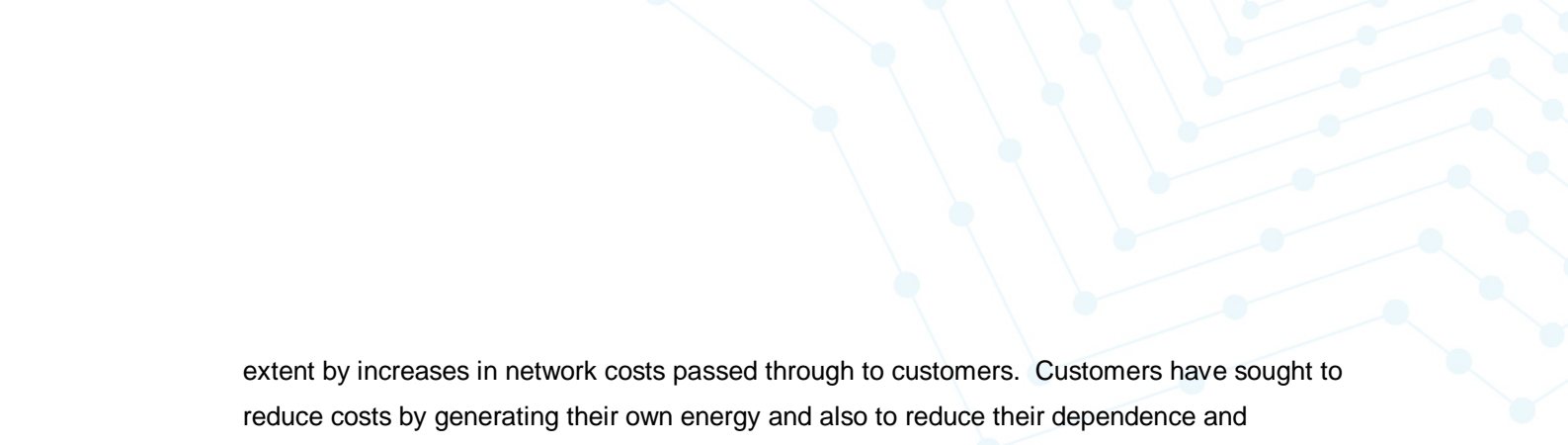
## Drivers for DER

It is interesting to note differences in both the motivation and the benefits for the development of DER in Australia compared to overseas. Generally, internationally DER has been developed as a response to concern over rising greenhouse gas emissions and as a response to government incentives or initiatives to reduce carbon, as well as to achieve a reduction in energy costs.

DER in Australia was driven initially by generous government subsidies and greenhouse reduction initiatives which dramatically reduced the cost of Solar PV in Australia. However, more recently, as these have been removed and reduced, customer uptake has been driven more by concern regarding the rapidly increasing costs of electricity, driven to a significant

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<sup>1</sup> Power of Choice, Australian Energy Market Commission: <http://www.aemc.gov.au/Major-Pages/Power-of-choice>



extent by increases in network costs passed through to customers. Customers have sought to reduce costs by generating their own energy and also to reduce their dependence and reliance on the networks. There is continuing motivation for the installation of PV cells since the costs continue to fall and there is a continuing rapid growth rate in the installed capacity of PV cells and other small DER installations in Australia as demonstrated in Electricity Network Transformation Roadmap modelling.<sup>2</sup>

Strategen highlights an apparent, potential anomaly where the reductions in electricity costs to customers from DER is less in Australia than overseas. This is because of the high network costs in Australia relative to overseas jurisdictions. In these circumstances, there has been considerable initial concern regarding the potential for many customers to leave the grid, resulting in significant residual costs being passed on to remaining customers. While inefficient investment in DER can result in increased costs for customers and networks, the Roadmap analysis has revealed that there is also significant potential value in utilising shared resources compared with the alternative of disconnecting from the grid (though there are cases where disconnecting from the grid is the more cost effective outcome) and there is now more focus on achieving the optimal outcome from the network perspective and making the most use of its amenity.

Another form of DER that is achieving significant interest at a government policy level is the potential for developing smaller network entities or minigrids, where a diversity of resources connected in localised area could take advantage of a local network to share resources and achieve a reliable supply. Several network businesses are taking early steps towards assessing the benefits of this approach, and addressing the technical challenges that it may introduce.

The initial thinking is that microgrids have the potential to play a significant role in the future of the Australian energy sector, given the unique geographic characteristics of the grid in Australia. There are many areas of very sparse population density currently being supplied by very long feeders, frequently traversing long distances across remote areas. The costs of both developing and maintaining powerlines over these long distances is very high compared to the number of customers that are supplied from them and microgrid solutions could offer more cost effective outcomes for customers.<sup>3</sup>

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<sup>2</sup> Electricity Network Transformation Roadmap, Key Concepts Report (Dec, 2016). Energy Networks Australia and CSIRO. <http://www.energynetworks.com.au/electricity-network-transformation-roadmap>

<sup>3</sup> Unlocking Value: Microgrids and stand-alone power systems: Roles and Incentives for Microgrids and stand-alone power systems (Sep, 2016). Prepared for CSIRO and Energy Networks Australia by Energeia.

## Challenges posed by DER

The emergence of DER is driving significant operational and management challenges for networks in the future. The detailed operational challenges are well documented, and many of these are addressed in the International Reports commissioned for the Roadmap program. These reports provide a variety of recommendations as to how best to navigate the future and address the many and diverse challenges to ensure that the future electricity sector in Australia meets customers' needs for a system that allows them to exercise growing choice in the way in which they use and address their electricity needs.

Two significant challenges that are consistently identified in the International Reports are:

- the future role of networks; and
- the operational paradigm.

These matters are central to the development of the Roadmap, and are important aspects dealt with in various ways in the International Reports. However, there are not unique answers provided to these questions. The issue of the roles and responsibilities of the networks and other industry bodies and participants is an important issue, but in developing the Roadmap it was considered that this would be better addressed after the preferred industry functions and requirements were better understood.

Nevertheless, it is important to note that there are unique operational challenges that need to be addressed in developing a dynamic, flexible and competitive future for DER. This will involve developing solutions to the complex problems of achieving the integration of economic and technical aspects of power system operation and maintenance of grid stability in a framework primarily driven by growing customer desire to exercise choice and control. While customers will have a broader range of choices in the future, which will provide greater levels of electricity autonomy, it is anticipated that most customers will remain connected to electricity networks. The future connection of diverse DER and load types has the capacity to enhance the performance of the overall system. Facilitating and empowering customer choice through enabling distribution system services will be critical to ensuring value for networks and their connected customers in the future.<sup>4</sup>

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<sup>4</sup> De Martini, The Evolving Distribution Grid, 2015

## International experience

### Status of DER development internationally

There is significant development of DER internationally and the International Reports provide insights into the status in various jurisdictions, mostly in the US. The highest profile activity to date has been in California and New York. While taking somewhat different pathways, in both these States there is a policy-led focus on transformation of the industry to achieve benefits from renewable energy (RE) and DERs now and into the future. The challenges of integrating RE and DERs into the existing networks has been recognised and there are initiatives in place to ensure that this can be achieved.

The challenges being addressed include:

- Future system reliability, with an acknowledgement that system reliability is likely to become an issue when RE penetration levels exceed 30% depending on location
- Management of the increasingly extreme evening ramp is already an emerging issue in some places. This results from the very rapid changes in demand that occurs in the late afternoon as people return home from work, and the relatively sharp drop off in supply from solar PV as its contribution reduces relatively rapidly during the early evening
- Oversupply and curtailments of DER leading to fluctuation in supply
- Ancillary services shortages
- Localised voltage spikes, and overvoltages resulting from load rejection
- Flicker
- Reverse flow and resulting safety issues

Initiatives for the use of DER as an alternative to network augmentation has commenced in the US. It is only in the planning phase in New York. California is more advanced, but even there the possibly greater DER potential is only recognised rather than having been fully implemented. Demand side development which could provide a suitable market solution to some network capacity issues is inhibited by rigid US rate structures and has not yet emerged to the extent needed to have a marked influence on network investment costs.

Generally, it is recognised that new grid technologies are required to manage the technical and operational considerations for the system to allow for the increased levels of DER required to meet the greenhouse gas emission targets. This is a specific concern in California

where the most challenging targets have been set for localised increased penetration and integration of DER.

As a consequence initiatives have commenced in US jurisdictions to take advantage of DER as an integrated part of achieving reduced emission levels and derive the potential economic benefits, while ensuring that the technical performance of the power system is not compromised.


## California

California policy makers have been very proactive in developing constructive approaches to encourage and manage the widespread connection of RE and DER. The Californian approach has been focused toward a mandates-driven model of incentivising and integrating low carbon generation sources.

California has mandated a number of DER programs to ensure that they can meet aggressive carbon reduction targets, and to ensure that they are able to maintain high levels of energy security with no reliance on polluting generation from within the State. As a consequence California has been at the leading edge on modernising the grid within the United States and has the most challenging targets for greenhouse gas reduction.

An integrated resource planning process has been developed as an administrative response to ensure that the Californian utilities meet the schedule for achieving the State's greenhouse emissions reductions targets, renewable portfolio standards, and other state policy objectives. The recent legislation requires each utility to generate Distribution Resource Plans (DRPs) to:

- Identify optimal locations for the deployment of distributed resources
- Evaluate the locational benefits and costs of distributed resources connected to the distribution networks
- Propose or identify standard tariffs, contracts, or other mechanisms for the deployment of cost-effective distributed resources that satisfy distribution planning objectives
- Propose cost-effective methods of effectively coordinating existing CPUC approved programs, incentives, and tariffs which maximise the locational benefits and minimise the incremental costs of distributed resources
- Identify any additional utility spending necessary to integrate cost-effective distributed resources into distribution planning consistent with the goal of yielding net benefits to ratepayers
- Identify barriers to the deployment of distributed resources.



The California Public Utility Commission (CPUC) formalised this role and set in motion the regulatory process for DRP development, outlining its specific guidance to the utilities in the following areas.

- Integration Capacity and Locational Value Analysis – provides specific guidance on how each DRP must incorporate analyses of grid integration (hosting) capacity of DER, the quantification of DER locational value, and the future growth of DERs. Future growth analysis is to incorporate three planning scenarios: current trajectory, high DER, and Expanded Preferred Resources.
- Demonstration and Deployment – requires utilities to propose a series of demonstration projects in each of the following areas:
  - Dynamic Integrated Capacity Analysis
  - Optimal Location Benefit Analysis Methodology
  - DER Locational Benefits
  - Distribution Operations at High Penetrations of DERs
  - DER Dispatch to Meet Reliability Needs
- Data Access – requires utilities to propose policies and procedures for data sharing as well as plans for making available data on grid conditions.
- Tariffs and Contracts – requires utilities to develop recommendations on how locational values could be integrated into existing tariffs for DERs, recommendations for new services, tariff structures or incentives for DER that could be implemented as part of demonstration programs, and recommendations for further refinements to Interconnection policies that account for locational values.
- Safety Considerations – description of how utilities will facilitate compliance with safety and reliability standards and recommendations on potential changes to these standards for DER. Description of major safety considerations related to DER and how they might be mitigated.
- Barriers to Deployment – includes barriers to DER integration, barriers to the realisation of DER benefits, including those from existing operational and infrastructure capabilities.

The CPUC requires for DRPs to be prepared by the utilities every two years, following submission of the first DRP in July of 2015.



The **More Than Smart Working Group**<sup>5</sup> paper adopted in concept by the CPUC, points the way to a future in which the role of the distribution utilities would evolve, initially, to a **Minimal Distribution System Operator (DSO) model**. The Minimal DSO model assumes that, in addition to its traditional operations and reliability functions, the utility would take on enhanced functions, including:

- Managing distributed reliability services for many DER types including independent micro-grids
- Providing situational awareness to the balancing authority (ISO) involving forecasting, real-time measurement and reconciliation of net load, dispatchable DER resources, and real and reactive power flows
- Reliability coordination at the Transmission/Distribution interface
- Neutral market coordination

Care is taken to note that the Minimal DSO model has network operational responsibilities only, and does not require that the DSO be inserted into wholesale market operations and related economic transactions between parties involving DER.

The second stage of grid and business model transformation envisioned by the More than Smart paper is defined as **DER Integration into Operations**. In this stage, a broad range of DER services (e.g., voltage/reactive power, power quality, power flow control and reliability services) would be incorporated into an open-access, distribution-level market. The value and pricing of these services would be transparent and include both a local and system-level valuation component. In this phase of grid transformation, the DSO would expand its role to provide the platform for conducting these market operations.

FERC recently approved a proposal from the California Independent System Operator (CAISO) that makes provision for DER participation in the California wholesale market. Although most DER installations fall well below the 500kW minimum size requirement that CAISO has for participating in wholesale markets, the new ruling allows for Distributed Energy Resource Providers (DERPs) to aggregate smaller DER installations in order to meet this size requirement, subject to various CAISO requirements.

As expressed in this Rulemaking, the CPUC's vision for demand response is to:

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<sup>5</sup> <http://morethansmart.org/engage/working-group/>

- Create a competitive demand response procurement process that may require the use of both demand-side and supply-side demand response resources
- Increase the penetration of demand response programs by examining how demand response programs are offered and procured and by reducing the barriers to entry for new customers
- Retool demand response to align with the grid's needs and enhance the role of demand response in the state's energy policy
- Create demand response programs that contribute to the efficient use of resources, take advantage of competitive markets, and are simple to administer
- Make it possible for third-party aggregators to play a much larger role in the procurement of supply-side demand response
- Consider extending demand response funding cycles.

Under the demand management program, the aggregated demand response resources will be directly into the CAISO day-ahead energy market as follows:

- Reliability Demand Response Product -- day-ahead economic and real-time emergency energy bids on behalf of retail emergency-triggered demand response programs.
- Proxy Demand Response -- bids into the CAISO market as supply and provides services such as energy, non-spin, residual commitment. The market dispatches economic day ahead and real-time.

This approach could be characterised as an administrative and mandated approach rather than a more open market or competitive approach. This possibly reflects the very challenging targets that have been proposed and the strong desire to ensure that there is minimal risk that they may not be achieved. It represents a measured and structured approach to developing DER and addressing demand response DER integration issues, with incremental changes to markets and policies to allow distributed resources to more actively participate in existing grid services.

This may in part reflect the experience gained from the Californian energy crisis of 2000.

## New York

New York was one of the first U.S. states to introduce retail competition into its electricity markets and as such has a vibrant competitive retail market. Additionally, New York has authorized the formation of Community Choice Aggregators (CCA) which are non-profit energy service providers that provide default electric service for a specific geographic area usually

associated with a county. As such, the four major transmission and distribution utilities are primarily wires companies, providing retail electric service, at cost, to customers only when customers choose not to select an alternate competitive supplier and are not served by a CCA. The New York Independent System Operator is responsible for operating bulk power markets and transmission system in the State.

Compared with New York, California policy makers have been very proactive in developing constructive approaches to encourage and manage the widespread connection of RE and DER, including the monetisation of the locational value of DER for wholesale and distribution. The Californian approach has been a combination of mandates and new distribution operational markets to incentivize and integrate low carbon generation sources. California is expecting DER to grow to about 40% of peak by 2025. New York by contrast will be less than 10% by then. This is a primary reason California is moving more quickly in practice than New York.

New York's Clean Energy Standard, established by Governor Cuomo in November of 2015, established a requirement that, by 2030, 50% of the electricity consumed in the state must come from clean energy sources. As of 2015, renewables accounted for approximately 23% of the state's electricity consumption.

New York policy makers have been strongly focused on establishing a market-based model at the distribution level to incentivize DER installation and operation in response to market signals. This has also involved an aggressive focus on utility business models and supporting regulatory reforms.

In April, 2014 the state's Public Service Commission opened a "Proceeding on Motion of the Commission in regard to Reforming the Energy Vision" (New York REV)<sup>6</sup>. It identified the following drivers for change:

- Cost pressure caused by the need to replace aging supply and delivery infrastructure.
- Increased customer reliance on reliable and high-quality electricity.
- The need to reduce carbon emissions and the associated costs and threats to infrastructure posed by increasingly severe climate events.
- Security threats to electric systems, both cyber and physical.

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<sup>6</sup> [http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/26be8a93967e604785257cc40066b91a/\\$FILE/ATTK0J3L.pdf/Reforming%20The%20Energy%20Vision%20\(REV\)%20REPORT%204.25.%202014.pdf](http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/26be8a93967e604785257cc40066b91a/$FILE/ATTK0J3L.pdf/Reforming%20The%20Energy%20Vision%20(REV)%20REPORT%204.25.%202014.pdf)

- Technology developments in distributed generation and information systems, which challenge incumbent systems and present opportunities for transformation of those systems.
- Electric price volatility caused by increasingly greater dependence on natural gas as a primary generation fuel source.

The Staff Report and Proposal defined a future concept of the utility as a **Distribution Services Platform Provider (DSPP)**. The role of the DSPP would be to:

- Create a flexible platform for new energy products and services;
- Incorporate DER into planning and operations to achieve the optimal means for meeting customer reliability needs;
- Create markets, tariffs, and operational systems to enable behind the meter resource providers to monetise products and services that will provide value to the utility system and thus to all customers; and
- Establish a platform to support demand-side markets and technology innovation [that would] allow for large scale deployment of clean DER, including energy storage that complements renewables, into the electric system.

The resources to be provided into the market would include energy efficiency, predictive demand management, demand response, distributed generation, building management systems, and microgrids. The DSPP would serve as both the interface between retail customers and the distribution markets, and between the set of retail customers with the New York Independent System Operator. The Staff Report also included proposed changes to traditional rate-making structures, allowing for a variety of revenue opportunities for utilities that would be decoupled from capital investments and/or the volume of electricity sales.

A subsequent Order by the NYPSC confirmed that the regulated network businesses would be required to provide the role of Distribution System Platform Provider. It was defined to include three main roles:

- Integrated System Planning – building on the traditional capital planning utilities have done, but incorporating a broader range of considerations that would support the development of DER alternatives that meet current and future system requirements.
- Grid Operations – incorporation of DERs into the utilities' traditional role of managing grid operation and reliability

- Market Operations – development of mechanisms to enable a market for DER products and services. Initially, the DSPPs would acquire DER products and services through RFPs or auctions.

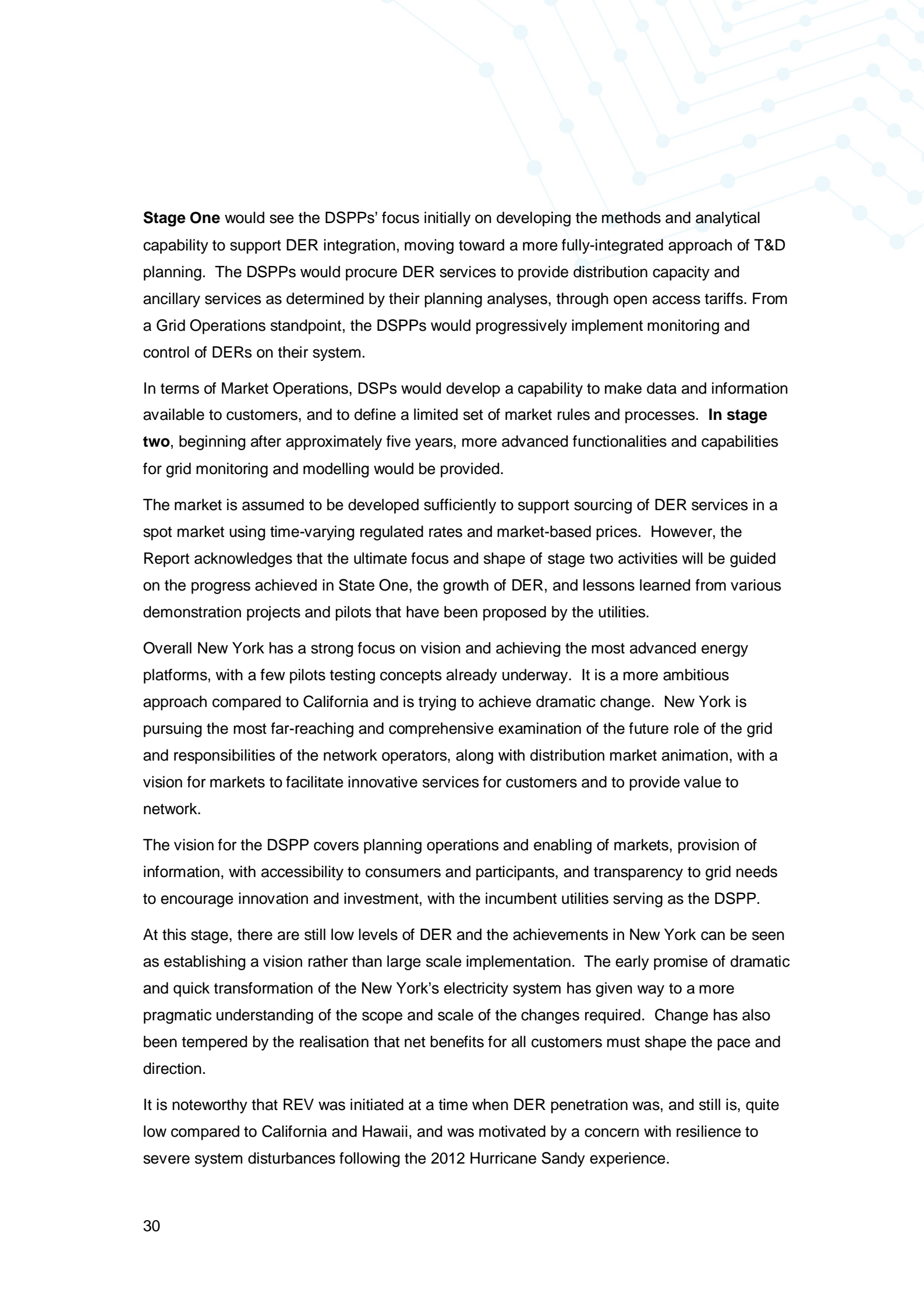
The release of the Final Report of the Market Design and Platform Technology Working Group in August 2015 built on this definition of DSPP roles to include<sup>7</sup>:

- Enhanced Distribution Planning – enhancements to traditional distribution system planning to better integrate DERs into the distribution system, and improve coordination between distribution system planning and transmission planning activities in the state. This includes the development of a uniform methodology to determine short and long term forecasts of distribution marginal capital and operational costs.
- Expanded Distribution Grid Operations – expanded distribution grid operations to better optimise load, supply and other power parameters at the local distribution level ... [enabling] the orchestration of multi-directional power flows resulting from increased DER penetration as the market matures, improved cyber-security, and improved load and network monitoring and visibility to aid in situational awareness and rapid response to atypical events.
- Distribution Market Operations – managing market operations and processes, and administering markets, identifying the standardised products to be transacted and the associated market rules with stakeholder and Commission involvement, maintaining an awareness of DERs system wide, designing and conducting RFPs or auctions to acquire DERs, facilitating and processing market transactions, and measuring and verifying participant performance.
- Data Requirements – make available customer and distribution system data to market participants with a degree of granularity and, in a manner, that will best facilitate market participation, while ensuring customer data privacy and security.
- Platform Technologies – geospatial models of connectivity and system characteristics, sensing and control technologies needed to maintain a stable and reliable grid, optimisation tools that consider demand response (demand response) capabilities and the generation output of existing and new DERs in the grid.

This Report also describes a two-stage approach to the transition to markets and platforms, although there was much greater specificity about the necessary first steps in Stage One.

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<sup>7</sup> [http://nyssmartgrid.com/wp-content/uploads/MDPT-Report\\_150817\\_Final.pdf](http://nyssmartgrid.com/wp-content/uploads/MDPT-Report_150817_Final.pdf)



**Stage One** would see the DSPPs' focus initially on developing the methods and analytical capability to support DER integration, moving toward a more fully-integrated approach of T&D planning. The DSPPs would procure DER services to provide distribution capacity and ancillary services as determined by their planning analyses, through open access tariffs. From a Grid Operations standpoint, the DSPPs would progressively implement monitoring and control of DERs on their system.

In terms of Market Operations, DSPs would develop a capability to make data and information available to customers, and to define a limited set of market rules and processes. **In stage two**, beginning after approximately five years, more advanced functionalities and capabilities for grid monitoring and modelling would be provided.

The market is assumed to be developed sufficiently to support sourcing of DER services in a spot market using time-varying regulated rates and market-based prices. However, the Report acknowledges that the ultimate focus and shape of stage two activities will be guided on the progress achieved in State One, the growth of DER, and lessons learned from various demonstration projects and pilots that have been proposed by the utilities.

Overall New York has a strong focus on vision and achieving the most advanced energy platforms, with a few pilots testing concepts already underway. It is a more ambitious approach compared to California and is trying to achieve dramatic change. New York is pursuing the most far-reaching and comprehensive examination of the future role of the grid and responsibilities of the network operators, along with distribution market animation, with a vision for markets to facilitate innovative services for customers and to provide value to network.

The vision for the DSPP covers planning operations and enabling of markets, provision of information, with accessibility to consumers and participants, and transparency to grid needs to encourage innovation and investment, with the incumbent utilities serving as the DSPP.

At this stage, there are still low levels of DER and the achievements in New York can be seen as establishing a vision rather than large scale implementation. The early promise of dramatic and quick transformation of the New York's electricity system has given way to a more pragmatic understanding of the scope and scale of the changes required. Change has also been tempered by the realisation that net benefits for all customers must shape the pace and direction.

It is noteworthy that REV was initiated at a time when DER penetration was, and still is, quite low compared to California and Hawaii, and was motivated by a concern with resilience to severe system disturbances following the 2012 Hurricane Sandy experience.

## Texas

Texas most closely mirror Australia's disaggregated electricity market structure with competitive retail and regulated networks with a competitive wholesale market. Distributed solar PV and distributed storage do not receive any state incentives or special tariffs to spur adoption. As such, these types of DER must compete with wholesale based energy prices and so little development has occurred. The competitive retail market failed to independently pursue energy efficiency and demand response, so Texas has reinstated utility demand side management programs to meet state self-sufficiency objectives that allow Texas to uniquely operate outside federal regulatory jurisdiction.

The Public Utilities Commission of Texas established a target of 10,000 MW of installed renewable capacity by January 1, 2025. The State has already achieved this target and no new targets have been set. In 2015, 11.7% of the Electricity Reliability Council of Texas (ERCOT) provided electricity came from wind and less than 1% from solar generation.

There have only been relatively preliminary discussions about the future role of DER with relatively low electricity prices limiting demand for alternatives such as DERs.

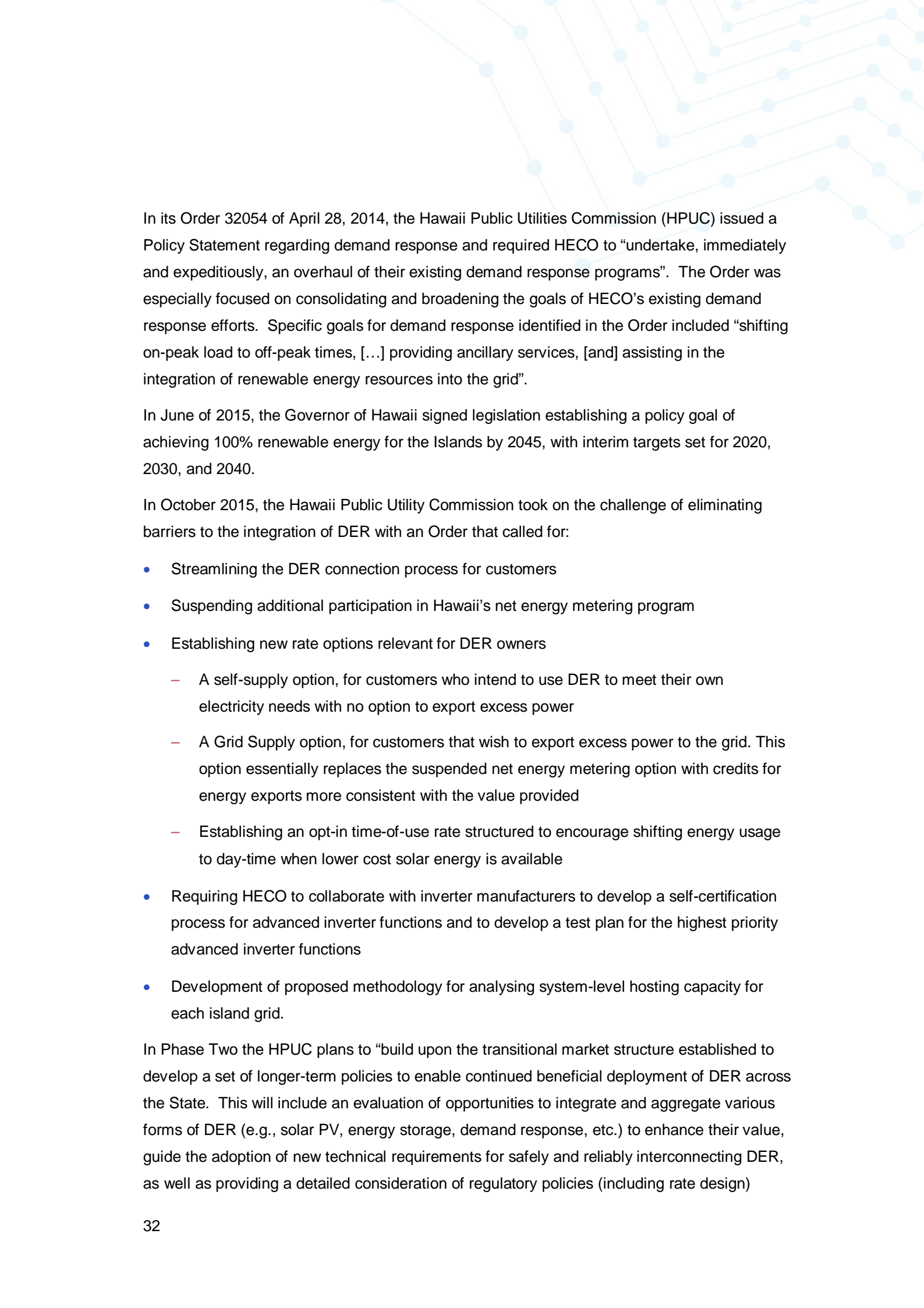
As Texas has a market structure most like Australia, any experience gained could be expected to be most usefully transferrable to our local context, so it is unfortunate that this experience is limited in terms of managing growing penetrations of DERs and RE.

## Hawaii

Hawaii is implementing policy and regulation to support a balanced approach for DER to replace other energy source, grid modernization, and distribution capacity increases to facilitate PV connection

Hawaii's electricity utilities are structured according to a traditional, vertically-integrated structure. Utilities provide generation, transmission, distribution, and electricity retail services. Hawaii does not have a wholesale market or system operator operating independently from the vertically integrated utilities.

Since essentially all fossil fuels must be imported into the state, the cost of generation in Hawaii has been higher than any other state in the US. In 2015, 23.4% of the state's electricity was provided by renewable sources, with solar PV, wind, and biomass as the primary renewable sources. As of 2016 Hawaii is the U.S. state with the highest penetration level of rooftop solar installations. As of June 2016, 65,751 Hawaiian Electric Company (HECO) customers (approximately 14.4% of the total customer base, a comparable level to Australia) had installed solar PV systems with a total capacity of 533 MW.



In its Order 32054 of April 28, 2014, the Hawaii Public Utilities Commission (HPUC) issued a Policy Statement regarding demand response and required HECO to “undertake, immediately and expeditiously, an overhaul of their existing demand response programs”. The Order was especially focused on consolidating and broadening the goals of HECO’s existing demand response efforts. Specific goals for demand response identified in the Order included “shifting on-peak load to off-peak times, [...] providing ancillary services, [and] assisting in the integration of renewable energy resources into the grid”.

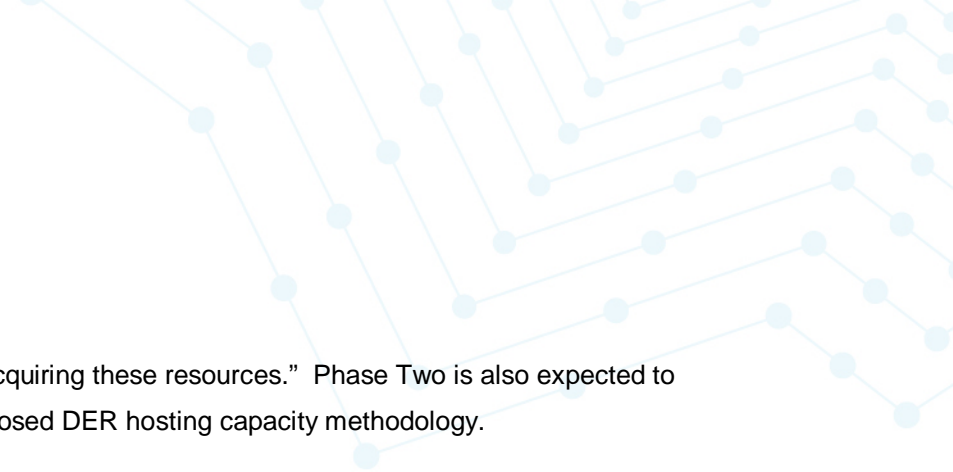
In June of 2015, the Governor of Hawaii signed legislation establishing a policy goal of achieving 100% renewable energy for the Islands by 2045, with interim targets set for 2020, 2030, and 2040.

In October 2015, the Hawaii Public Utility Commission took on the challenge of eliminating barriers to the integration of DER with an Order that called for:

- Streamlining the DER connection process for customers
- Suspending additional participation in Hawaii’s net energy metering program
- Establishing new rate options relevant for DER owners
  - A self-supply option, for customers who intend to use DER to meet their own electricity needs with no option to export excess power
  - A Grid Supply option, for customers that wish to export excess power to the grid. This option essentially replaces the suspended net energy metering option with credits for energy exports more consistent with the value provided
  - Establishing an opt-in time-of-use rate structured to encourage shifting energy usage to day-time when lower cost solar energy is available
- Requiring HECO to collaborate with inverter manufacturers to develop a self-certification process for advanced inverter functions and to develop a test plan for the highest priority advanced inverter functions
- Development of proposed methodology for analysing system-level hosting capacity for each island grid.

In Phase Two the HPUC plans to “build upon the transitional market structure established to develop a set of longer-term policies to enable continued beneficial deployment of DER across the State. This will include an evaluation of opportunities to integrate and aggregate various forms of DER (e.g., solar PV, energy storage, demand response, etc.) to enhance their value, guide the adoption of new technical requirements for safely and reliably interconnecting DER, as well as providing a detailed consideration of regulatory policies (including rate design)





appropriate for cost-effectively acquiring these resources.” Phase Two is also expected to include a review of HECO’s proposed DER hosting capacity methodology.

## Globally

Strategen also highlight the emergence of new platform models in both Germany and the Netherlands, where new entities are being formed to provide platforms that allow customers to trade directly with each other.

In the Netherlands, there have been a number of pilot projects established for DER, where there is an emerging focus on peer to peer energy transactions.

Germany has some companies exploring opportunities for transactive energy and creating customer facing platforms but these endeavours are still in the very earliest stages of development.

## General lessons from international deployment

There is a diversity in the way DER has been developed and utilised in overseas jurisdictions. The reports commissioned for the Roadmap project highlighted these, but more importantly have identified some important considerations and learnings that have emerged for the various uses to which DER has been employed.

The following points summarise the consistent outcomes from this experience which are very relevant in developing the Roadmap, as follows:

- There is an extensive and diverse range of services and benefits that DER has been used for across the various jurisdictions, but individual types of DER have specific individual characteristics that mean that they each can only provide some of the overall services, or that they are more suited to certain services. Technical characteristics in particular may limit the use of some forms of DER, especially without any modifying controller functionality. For example, wind turbines are unable to provide inertial response for faults, PV cells (without 4 quadrant inverter control) cannot provide direct voltage support and many devices are limited in the times they can provide a response.
- Some limitations of individual DER can be supplemented or overcome through the use of more sophisticated controls. In many cases these can be used to address the challenges that the introduction of the DER causes in the first instance. Accordingly, it is important to ensure that DER is properly specified from the outset to ensure that its introduction can be used to improve the efficiency of the overall system.
- Unified resources involving diversified combinations of devices and products may provide significantly more benefits from the provision of a single type of DER at any one location. Such a combination of DER may also be able to provide multiple benefits at different times and in different markets, that can significantly improve the business case.
- There is a need for networks to enhance capabilities to better integrate and connect growing numbers of DERs while also providing more transparent network analytics and data to identify how and where DER integration can be of benefit to the networks themselves.
- There is a need for new markets or incentives to help customers understand where and how they can deploy different types of DER for broader market (and thereby personal) benefit. However, the way in which different jurisdictions have gone about creating such incentives and markets differs markedly.

# Benefits of DER

## Services Provided by DER

There are several ways of considering the services that can be provided by DER in the Australian context. Each of the reports has considered this slightly differently, and have also drawn on the experience overseas in identifying the specific services that can be provided.

At the highest level TCR postulate that there are only three services that are provided by DER, namely; energy; reactive power, and; reserves, where reserves is a guarantee of the availability of energy at a future time.

These basic products have the potential to provide a range of services in various markets and these have been summarized as follows:

- Provision of energy to customers through the wholesale electricity market, including for day ahead markets;
- Capacity through reserves for a range of sources and locations, including overall system reserve, local reserves and flexible reserves;
- Provision of ancillary services including frequency control, spinning reserve (available on line), non-spinning reserve (available for rapid start up typically within 1-3 minutes) and supplemental reserves (available in 1 hour);
- Voltage support at all network levels, but particularly and uniquely suited for control at the distribution level where voltage control can be a challenge where there is high DER concentration;
- Capacity support to reduce network investment (long term planning);
- Capacity to relieve network constraints in real time operation, including following contingency events;
- Improve quality of supply for distribution, for example flicker management;
- Reliability by allowing fast reconnection during abnormal conditions, and resiliency by allowing formation of islands or managing outage conditions;
- Allow retail customers the ability to manage their bills through judicious use of DER based on time of use tariffs; and
- Back up supply.

# Responsive Distributed Energy Resource Values

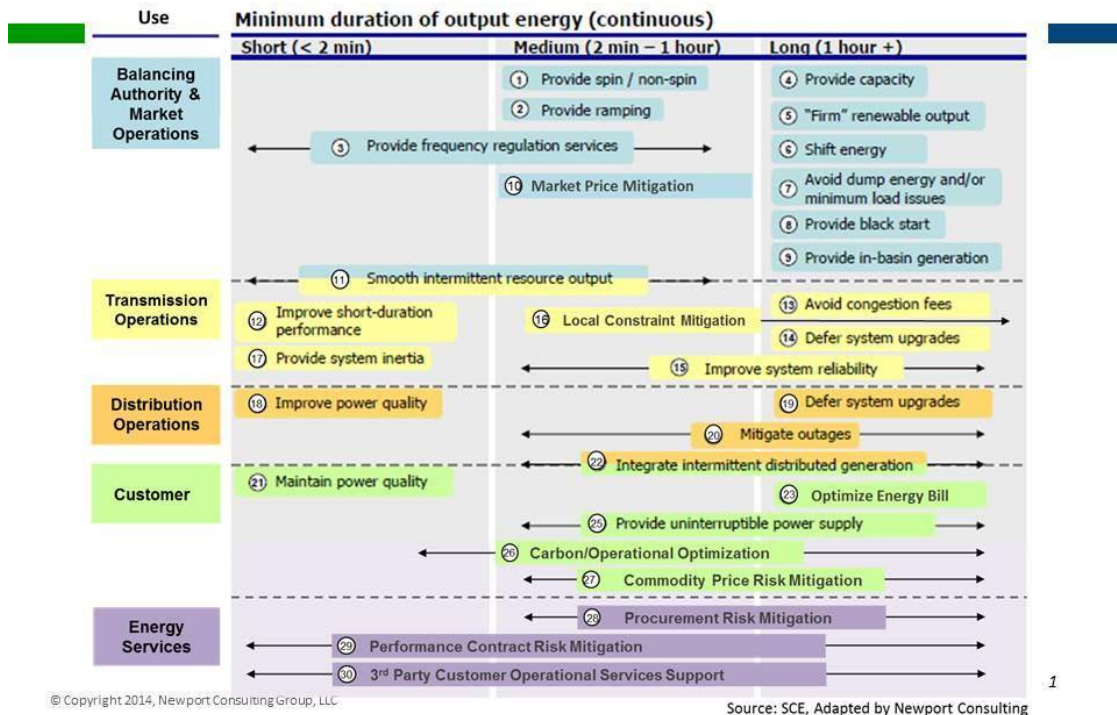


Figure 1: Responsive DER Services (Newport Consulting)

It is important to recognise that participation in some of these markets, including future markets, requires certain technical qualifications that cannot necessarily be achieved by all DER. Figure 1 provides further information on some of the services that can be delivered by DER, with the specific technical capability that is necessary to realise them on a consistent and reliable basis. The most significant determinant in considering whether specific DER is suitable for providing a service is the time responsiveness and the certainty of availability of the service when it is required. This ultimately is impacted by the DERs' ability to achieve fast ramp rates, and whether or not it is dispatchable. These characteristics are critical if DER is to provide frequency regulation or fast contingency reserve capability for example.

Markets	Categories of Products, Resources, Services	Demand Response	Photovoltaic	DG (fossil)	EV Charging	Storage
Bulk Power - Spot Energy Market	generation, offers submitted day-ahead		Today	Today		Today
	Scheduled load	Today				Today
	generation, in real time		Today	Today	Future	Today
	Demand side participation	Today				Today
Bulk Power - Ancillary Services Market	Frequency Control (regulation, contingency)	future reg down only		Today	Future	Today
	Network support/ control. Voltage control		with advanced inverters	with advanced controls	future with advanced inverters	future with advanced inverters
	Network support/control. Network loading	Today				Today
	System Restart (Black Start)		Future	Today		Future
NOM / dNOM	commitment to reduce net energy during future time period	Today		Today		Future
	voltage control, power factor		with advanced inverters	with advanced controls	future with advanced inverters	future with advanced inverters
	frequency control	future reg down only		Today	Future	Today
Distribution level energy market	generation, scheduled day-ahead		Today	Today		Today
	generation, in real time		Today	Today	Future	Today

Table 1: Technical Ability of DER Technologies to Provide Electric Products (TCR)

A further complication in utilising DER for these services is the additional complexity involved in managing increasingly large numbers of smaller DER to achieve these services. While in theory these individual devices can be aggregated to provide a similar service, and the diversity may be used to provide an increased level of certainty over the provision of the required level of capacity, there is significant additional technical complexity in ensuring that a large fleet of devices can act in a coordinated manner to achieve the very fast response times required for some services. This also results in additional transaction costs that is likely to delay widespread introduction until more automated digital markets or platforms can facilitate this.

## Benefits achieved from DER

The benefits provided by DER are delivered across the electricity value chain, and it useful to identify the key aspects on this basis. Table 2 drawn from the Newport Consulting report shows components of value from DER mapped to the value chain as similarly adopted in California and New York's benefits-cost framework. Each of these components represent

potential discrete value streams that may be monetised. In many cases a single DER product will provide value across multiple components of the value chain.

This may be especially true of the services provided to the distribution sector which are of particular interest to the Roadmap. It is apparent that some of these benefits are provided by “energy in the right place at the right time” (with the required level of “firmness”) which may also provide value in the wholesale market for example.

It is also interesting to note that the benefits for the distribution sector are relatively small in number compared to all the benefits claimed. This must be kept in mind when considering the preferred approaches for transacting the value of DER for the distribution sector in the Roadmap program.

	Value Component	Definition
Wholesale	WECC Bulk Power System Benefits	Regional BPS benefits not reflected in System Energy Price or LMP
	System Energy Price	Estimate of CA marginal wholesale system-wide value of energy
	Wholesale Energy	Reduced quantity of energy produced based on net load
	Resource Adequacy	Reduction in capacity required to meet Local RA and/or System RA
	Flexible Capacity	Reduced need for resources for system balancing
	Wholesale Ancillary Services	Reduced system operational requirements for electricity grid reliability
	RPS Generation & Interconnection Costs	Reduced RPS energy prices, integration costs, quantities of energy & capacity
	Transmission Capacity	Reduced need for system & local area transmission capacity
	Transmission Congestion + Losses	Avoided locational transmission losses and congestion
Distribution	Wholesale Market Charges	LSE specific reduced wholesale market & transmission access charges
	Subtransmission, Substation & Feeder Capacity	Reduced need for local distribution upgrades
	Distribution Losses	Value of energy due to losses bet. BPS and distribution points of delivery
	Distribution Power Quality + Reactive Power	Improved transient & steady-state voltage, harmonics & reactive power
	Distribution Reliability + Resiliency	Reduced frequency and duration of outages & ability to withstand and recover from external threats
Customer & Societal	Distribution Safety	Improved public safety and reduced potential for property damage
	Customer Choice	Customer & societal value from robust market for customer alternatives
	Emissions (CO2, Criteria Pollutants & Health Impacts)	Reduction in state and local emissions and public and private health costs
	Energy Security	Reduced risks derived from greater supply diversity
	Water & Land Use	Synergies with water management, environmental benefits & property value
Economic Impact	State or local net economic impact (e.g., jobs, investment, GDP, tax income)	

Table 2: California’s More Than Smart Value Components (Newport Consulting)

## Parties transacting DER services

The parties that buy and sell DER services will evolve as suitable markets or processes develop allowing them to transact their services with reducing transaction costs. In the shorter term this includes a more ‘administrative’ approach to market-making together with the forging of the new regulatory structures required to govern the operation of the future system. Initially it is most likely that selection will be restricted to larger providers of the services, because this is easier to transact initially with greater levels of confidence, and may be achieved with scaled

transaction costs that are compatible with the benefits obtained. This is likely to be achieved either through individual contracts or through direct participation in the existing wholesale market.

Table 3 drawn from the TCR report provides an indication of the various buyers and sellers that are likely to emerge in the Australian context for DER.

<b>Markets</b>	<b>Categories of Products, Resources, Services</b>	<b>Potential Buyers</b>	<b>Potential Sellers of DER with these capabilities<sup>8</sup></b>
Bulk Power - Spot Energy Market	generation, scheduled day-ahead	AEMO	dispatchable energy
	Scheduled load		dispatchable demand response
	generation, in real time		real energy
	Demand side participation		demand response
Bulk Power - Ancillary Services Market	Frequency Control (regulation, contingency)	AEMO	dispatchable demand response
	Network support/ control. Voltage control		dispatchable reactive power
	Network support/control. Network loading		dispatchable demand response
	Network support/control Transient and Oscillatory Stability		Reserves reactive power and real energy reduction
	System Restart		dispatchable real energy, dispatchable reactive power
NOM/dNOM <sup>9</sup> - Network Optimisation	commitment to reduce net energy during future time period	NSPs	dispatchable generation
	voltage control, power factor		dispatchable reactive power
	frequency control		dispatchable demand response
Distribution-level energy market	generation, scheduled day-ahead	Retailers, Large Customers	dispatchable generation
	generation, in real time		generation

Table 1 Potential Markets for DER products and services in the Australian context (TCR)

<sup>8</sup> Parties who control operation of DER are small generation aggregators, non-market embedded generators and some retailers and large customers.

<sup>9</sup> Network Optimisation Markets (NOM) / digital Network Optimisation Markets (dNOM) concepts are explored later in this report

### DER services for energy and customer markets

The evolving market for buyers and sellers of electricity services in Australia has been consistent with the experience in the US where, in some states, energy from DER is being bid into the wholesale electricity market, either from large DERs in their own right or in some cases through an aggregator. The wholesale electricity market provides DER customers with an additional source of value, but recognising that in many cases there have been other incentives provided to encourage their development in the first instance.

In the longer-term there are many possible options for a range of new service providers that will provide value added services using DER, and it can be anticipated that many additional parties could be involved in the buying and selling of services from DER. These include individual owners, aggregators or other forms of intermediaries, including existing retailers. DER services could also be provided, or procured, at different levels within networks, including the possibility that networks provide some of the network related DER services themselves.

As previously noted there are likely to be many new parties that offer a range of new services from DER, which they will achieve by purchasing individual resources and packaging them for optimum benefit in all available markets. In this sense these parties are both buyers and sellers of DER services, and are likely to both buy and sell from multiple parties and in multiple markets.

### Networks transacting DER services

An important consideration of *the Roadmap* is the development of models that enable the large scale provision of DER services as an important new means for improving utilisation of the overall electricity system. There is potential for a growing range of parties that may be the ultimate purchasers of network related DER services, including transmission and distribution network owners. This would open up the potential for customers to participate directly in enhancing the efficiency of network operations in return for direct financial benefit (funded through reduced network costs) as outlined in Figure 2. Market operators could also purchase network related services directly, including services that are currently provided as part of an ancillary services market.



SOURCE OF VALUE	TYPE AND ACCESSIBILITY OF VALUE	
Wholesale market	Financial	✓✓✓✓✓
Transmission Networks	Financial	✓?
Distribution Networks	Financial	✓?
Customer self-consumption	Financial	✓✓✓✓✓

Figure 2: Uncertain processes for achieving network benefits of DER

The potential network optimisation benefits that can be provided by DER are reasonably well understood in Australia. However, there is currently less certainty in how this important component of the DER ‘value stack’ may be unlocked, monetized and transacted as the mechanisms for achieving it are not as well developed, as shown in Figure 2. This means that the full range of value that orchestrated DER can provide to Australia’s electricity system cannot yet be realised, at least not in a low transaction cost environment.

### Facilitating involvement

A reasonable objective for an increasingly decentralised electricity future is to encourage the development of competitive markets that facilitate the structures and processes that reduce transaction costs, maximise flexibility for trading, and optimise the use of, and animate growing DER services for the collective benefits of all participants. This means maximising the number and types of market actors that can participate together with the number of markets in which they can operate.

In the longer term this may extend to many to many or peer to peer energy market transactions involving many individual buyers and sellers or groups. However this would require the development of more sophisticated energy markets based on transactive market principles, and requiring fundamentally new trading and pricing arrangements for networks. These approaches are unlikely to emerge in the short term, and are covered in later sections on market development in this paper.

However, all the international reports consistently suggest that there would be considerable challenges involved in developing a more complex form of markets for DER, both for network and energy related services, and that it was not clear that the benefits associated with these would be sufficient to outweigh the costs. At best it was seen that this would be an evolutionary and incremental process, built on progressive, demonstrated successes, that would likely take for than a decade to evolve in the US and Europe.

This also seems to suggest then, that new market players would also develop on an evolutionary basis over this period.

## Valuing DER for Networks

The motivation for individual parties to invest in a given type and size of DER resource at a specific location will be increasingly influenced by the mechanisms in place that reward the provision of network optimisation services. There are some examples where DER has not been implemented, not because they would not provide overall benefits that would justify the costs, but because the total value of the benefits cannot be realised by the owner with the current market arrangements. For example, this situation has occurred for the deployment of storage in Texas, which has been assessed as providing a broad range of valuable services for both networks and connected customers. However since networks are limited to meeting reliability and stability needs, as opposed to serving broader market needs, they have been unable to justify the development of storage on this restricted range of benefits, and it has therefore not occurred.

This could be expected to be a challenge in the Australian context where the disaggregation of the market is similar to Texas, and similar problems of split incentives may emerge unless accurate economic incentives can be provided across all stages of the value chain, or alternative regulatory measures are adopted.

This is in fact currently a common situation given the formative stages of market development. In California, non-synchronous generation resources are allowed to be dispatched in the wholesale electricity market, but this is limited as no aggregation of DER is allowed, and it must be capable of achieving specified ramp rates to be eligible. In Hawaii, where utilities are vertically integrated, there is no wholesale market and there is no energy price visibility due to the small scale of their disaggregated market.

More sophisticated and accurate means of signalling DER value will be an important prerequisite for allowing the optimal types, locations and levels of DER to develop in an environment where most such decisions are made by private individuals or businesses.

This may be a particular challenge in Australia where the market is more disaggregated than in many overseas markets. The challenge of split incentives may increase the difficulty in providing DER providers with sufficient rewards for them to be motivated to provide the service. An additional challenge is providing clear price signals to customers to highlight the benefit of DER services that could be provided without creating undue complexity due to competing or additional price signals from other sectors of the electricity value chain (e.g. wholesale and ancillary service signals).

## Administrative approaches for assessing DER value

The value of DER services for network optimisation purposes is heavily dependent on location and time. The benefits also depend on many existing factors and characteristics of the existing network, measured in both the long-term as the avoided costs of future augmentation, and the short-term as operational benefits associated with the costs of losses, constraints and avoided outages.

There are also additional operational benefits and customer value that may be even more difficult to value in financial terms, but that could also be provided to DER customers through a transparent market mechanism. As noted above, the development of valuation approaches is likely to need to evolve over time as the maturity of markets develops as well as the clarity of the value that is provided by DER increases with experience. Given the mandates-driven emphasis of California's policy direction, administratively determined DER services value has been the primary mode of valuation. This more deterministic approach may initially be simpler in the absence of a functioning market but may ultimately prove less scalable.

### Avoided network investment costs

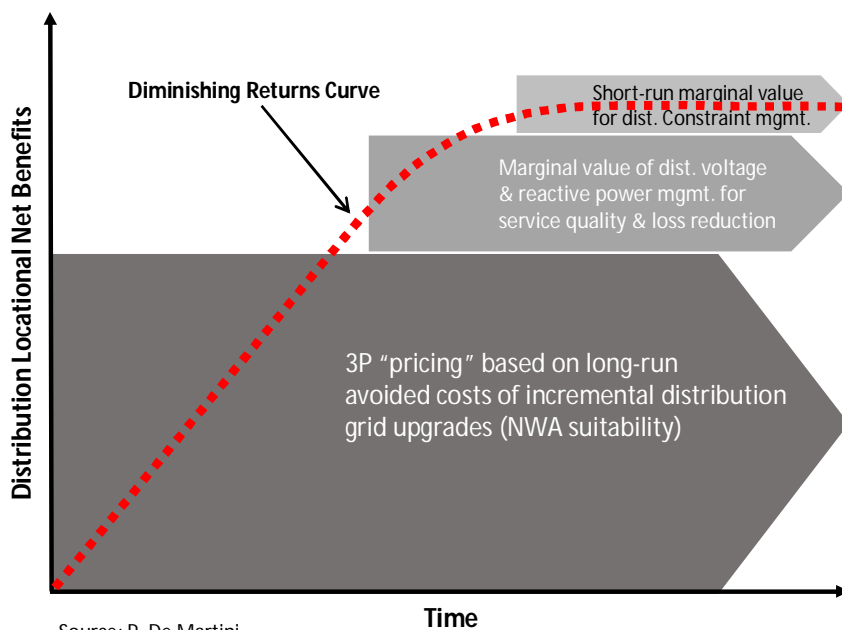
The international reports suggest that significant benefits are likely to be provided by DER through avoided costs of deferral of network investment. In fact, Newport estimates that this may comprise around 80% of the total benefits that can be provided in conjunction with network operations. Consequentially, it is suggested that the highest priority should be given to providing a transparent mechanism for measuring and signalling the long run marginal cost (LRMC) component of the avoided network augmentation cost. This can be achieved by, either calculating a value using network planning analysis for the avoided network augmentation costs, or by conducting an auction seeking non-network augmentation proposals, including DER options. Networks can then use the LRMC as the justification for contracting with specific DER providers to meet network needs through alternative services at lower cost than traditional network solutions.

This would achieve a significant portion of the benefits of DER to the networks with relatively simple mechanisms and with relatively small lead times for its provision.

Transmission and distribution avoided investment cost is recognised as a difficult value to assess in an objective manner. It is inevitably subjective since it depends on a number of complex forecasts and the value of augmentation, therefore avoided cost, can change with time. The challenge is to balance accuracy with complexity, and to provide approaches which are as transparent and consistent as possible, to deal with the very high degree of uncertainty and volatility inherent in this method.

This conclusion appears to be supported by the International Reports, including Newport Consulting who present Figure 3, demonstrating that optimal level of benefits from DER services might be achieved without needing to implement the complexity and sophistication inherent in more competitive, dynamic market based approaches relying on marginal locational pricing for example. Newport also highlight the growing risk involved in managing growing fleets of DER based on increasingly complicated locational price signals.

$$\text{Locational Net Benefits} = \text{Locational Value of DER} - (\text{System Integration Costs} + \text{Operational Risks})$$



Source: P. De Martini

**Note:**

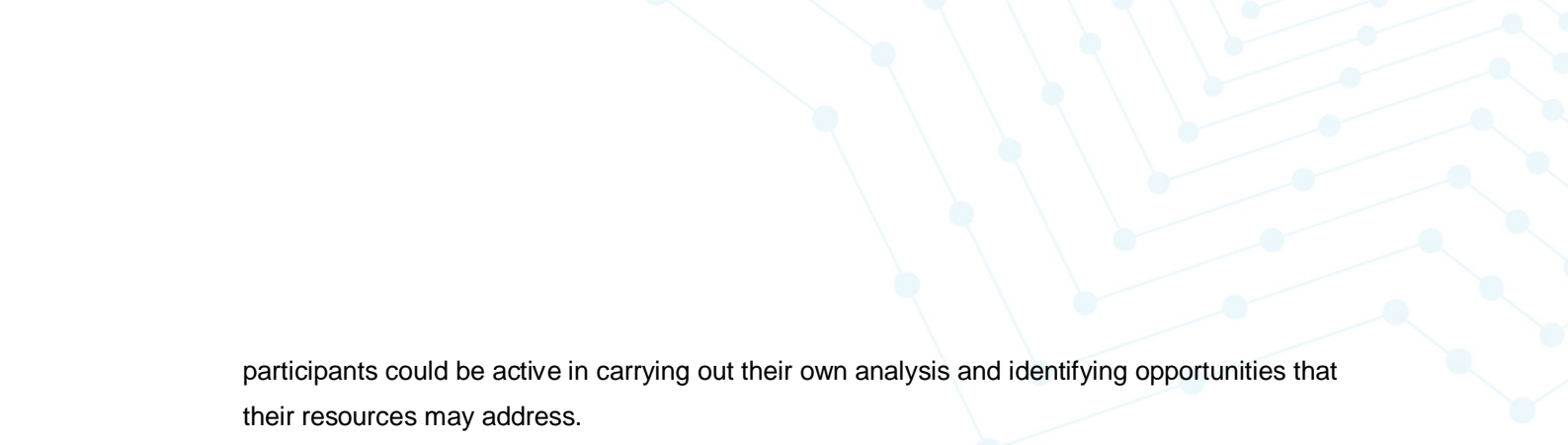
System Integration Costs are those utility investments necessary to integrate, monitor, control, optimize and settle DER provided grid services

Operational risks include the increased risk of failure due to increasing interaction risks created by the interaction between customers, distributed energy resources, markets and elements of the electric network as the number of devices grow and the locational and temporal granularity increase

Figure 3: Realisation of benefits from DER (Newport)<sup>10</sup>

The reports conclude that development of a network based DER services market would best be accompanied by the provision of data and information relating to the characteristics of the power system, and the forecasts that have been used in analysing the future in order that

<sup>10</sup> Provided by Paul De Martini – Newport Consulting Group



participants could be active in carrying out their own analysis and identifying opportunities that their resources may address.

It is also likely that the form of value assessment may be able to be implemented on a staged basis, initially being adopted at higher voltage levels within the network and applied to larger DER proposals, such as the case in California beginning with a minimum sized of DER capacity. This is because it is more likely that analysis can be readily undertaken for these investments as the network data is more readily and publicly available, and the calculations are better defined.

The three International Reports all note that this requirement is already being introduced in many US jurisdictions. Initiatives for use of DER services as an alternative to traditional network options has commenced in both New York and California but most of this is still in the planning phase, and significant levels of DER have not yet been brought forward for this purpose. Nevertheless, competitive solicitation or bilateral contracting is starting to be used, in conjunction with an integrated planning approach.

One of the key reasons why an integrated planning approach is being used is that it allows the network to obtain alternative resources with more certainty than achieved through more open market approaches in this formative stage of development. Market approaches are uncertain for both the DER provider (financial returns on investment) and the network (availability when needed). Off market pricing, such as that achieved through solicitation and bilateral contracting, is preferred in United States jurisdictions, at least as a starting point.

Competitive solicitation is the preferred approach, as it provides more competitive disciplines on the acquisition of the service. Bilateral contracts have been used, but these are the exception and generally the last resort. Regulatory approval is required to ensure that the proposed arrangement is fair, and that the cost is not inflated, adding another layer of complexity and uncertainty to this approach.

## **Valuation of DER using market-based approaches**

While California policy makers have emphasized a more administrative approach to the valuation of DER network services, the New York REV process seeks to maximise the function of competitive markets in this valuation process. This naturally requires that an active distribution-level market for the DER services develops in a timely way and, as such, New York REV seeks to establish and 'animate' appropriate market structures and liquidity. This is still at a formative stage and is proving to be a complex undertaking, but has nonetheless captured the imagination of global experts and policy makers alike.

More broadly, DER is permitted to participate to varying degrees in US wholesale markets to provide energy, capacity, deferral of transmission network augmentation or ancillary services, but generally with restrictions. Texas, PJM and California allow DER to participate in wholesale markets but only for relatively large scale DERs. There are concerns regarding the qualification for participation in the wholesale market, with initial uncertainty regarding its provision when required, but this is being overcome with experience in California.

Texas has also developed options based on size for DER participation in wholesale market, but aggregators are not permitted to participate. Depending on the size and characteristics of the specific DER it may or may not be dispatched, but in all cases, receive a variant of the nodal price.

Hawaii does not have a wholesale market with transparent nodal prices, but has implemented a scheme to compensate large scale export to the grid through a tariff, however again small PV is not currently compensated in this approach. Consideration is starting to be given to an effective means of compensating smaller PV.

In addition, demand management approaches are also being developed to provide a market for the provision of demand response services. Again, these are in the early stages of development, but initial mechanisms have been implemented in California and New York.

Smaller PV in all jurisdictions is therefore generally compensated only to the extent that it allows an offset through retail tariffs. However, this does not reflect actual value, and is generally very distortionary using current tariff structures, as these were established to reflect the energy and network costs associated with traditional network supplies and have not yet been modified significantly to accommodate DER and two-way energy provision.

### **Economic pricing incentives**

The development of effective DER markets requires the economic value of DER to be revealed and transparently available for participants to capture. The International Reports consider this issue in some detail, but generally recognise the very significant challenges associated with this, in particular:

- DER can provide a broad range of services in different markets;
- The value changes with time and location; and
- There are varying degrees of risk associated with the provision of the service.

It is desirable to establish a transparent and universal approach for valuing DER services, as the first step to considering whether it is too complex to implement in an operating market framework. Consideration has been given to this challenge in the International Reports and it

is acknowledged that the development of a suitable approach would be the prerequisite for developing a 'transactive' energy framework.

As such, consideration is given to the development of **Locational Marginal Pricing at the distribution level (DLMP)**. An alternative approach also proposed is described as **Locational Marginal Pricing plus Distribution costs (LMP+D)**. It appears that there are different positions taken in the U.S. on the suitability and veracity of these respective approaches.

Both approaches are aimed at providing accurate signals of the value of investment in DER. The DLMP option is a very granular approach based primarily on market prices; the LMP+D option is a less granular approach based in part on market prices and in part on administrative estimates of the long-run marginal costs that would be avoided by DER services provided at the specific location. For example, DLMPs for energy would reflect the market value of energy withdrawals or injections at each major connection point on the distribution system during each pricing interval, e.g. every half-hour across the NEM. These DLMPs would reflect LMPs as well as all network costs associated with energy withdrawals or injections at each node during each pricing interval including the value of losses, asset degradation, constraints and reliability. DLMPs would therefore vary dynamically with both time and location, i.e., each connection point.

#### [Distribution Locational Marginal Pricing](#)

The following comments are relevant for this approach:

- This approach theoretically provides the most accurate, economic short run pricing signals by signalling the true cost of delivered energy including the transport costs for each location at a point in time;
- It is complex as it requires a very detailed model of the entire system upstream of the connection point, that is, of the entire distribution system at any point in time, and is also variable with changes that might occur in other parts of the network, including other new connections of DER;
- It is transparent (separate from complexity) as the prices are unique and reproducible based on a known physical model of the network with known operating conditions;
- The signals provided are appropriate for long term investment decision making, but rely on participants forecasting the outcomes of the prices in the future and using this to assess the costs that would be avoided through the investment in DER.

### Locational Marginal Pricing plus Distribution Costs

The LMP+D approach, depending on how it is implemented, provides a potentially less granular signal based on LMPs plus an administratively determined estimate of the value of the avoided Distribution cost (D). (Currently in Australia, local spot energy prices are determined at each transmission connection point based on the regional reference node price modified for the impact of transmission losses, while the local spot energy price applicable to the purchase or sale of energy at a given distribution network connection point within a region is equal to the local spot energy price at transmission network connection point serving that distribution network connection multiplied by the distribution system loss factor applicable to that distribution network connection point).

The following points are relevant:

- The key difference of the LMP+D approach is that the projected long-run marginal costs of future investment in distribution augmentation is explicitly included as part of the price signal. Ideally this does not change the price signal, but it substitutes the market based assessment made by participants under the DLMP option with an administratively derived estimate calculated by the network business;
- The approach is less transparent, as estimating the cost of network investment is inherently scenario based and will depend on the assumption chosen for use in the analysis;
- The price signal will change after the investment;
- The approach is less complicated in the complex real time determination of the short run costs of the operation of the distribution network do not need to be calculated.

Ultimately the difference in the approaches comes down to considering whether it is preferable leaving the determination of efficient price signals to a competitive market assessment, or whether network businesses are in a better position to determine the avoided cost of future network investment based on their specialist knowledge of the future requirements. In other words, a choice will need to be made between a competitive market, and a regulated solution, dictated by the potential for market failure if these pricing approaches are to be considered further.

The choice may also be impacted by practicality considerations or the nature of developments of other markets. The LMP+D may be simpler to implement, and also may allow the separate



development of a market for DER to provide services to networks whereas DLMP might be more suited to a more integrated energy and network market approach<sup>11</sup>.

Both these pricing approaches may be sequential stages of an evolution from simpler approaches that involve competitive sourcing to identify the value of DER to the network. This is most likely since there is general agreement that mature markets based on either of the above approaches are not likely to develop for many years because of the technical and commercial development that will be required to underpin their application.

## DER heat maps

The use of “heat maps” to show the locations where the addition of DER is more feasible is being developed in a number of US States. Hosting capacity analysis is being used to identify those areas where DER can be added without the need for additional network support and/or augmentation to allow it to be connected. This allows the cost of adding DER to be minimised through assessment and publication of hosting capacity. Heat maps extend this approach to provide an indication of locations where DER can be added to improve the performance of the integrated network and DER, in other words indicating the value that is likely to be achieved if DER was to be located at that point in the network.

California (PGE) is currently developing a “heat map” approach to show best location for adding DER and have made some data public, while SCE is using a load capacity requirement procurement method and have solicited DER at preferred locations.

Similar approaches being used in NY to defer network augmentation.

This capability is currently being developed by some utilities in Australia, and is expected to be more widely adopted as it is included as a shorter-term milestone in the Roadmap.

## Differences in Australia

There are some additional challenges that may arise in Australia in using the existing markets to appropriately value DER services. These include:

- Australia has an energy only wholesale electricity market, which does not explicitly value capacity. In most US wholesale electricity markets, with the notable exception of Texas, capacity is explicitly valued, and this provides a simpler transparent and potentially a more

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<sup>11</sup> New York REV is considering starting with an LMP+D approach and then moving to a more granular DLMP approach in a second phase of development. Staff Report and Recommendations in the Value of Distributed Energy Resources Proceeding. New York Department of Public Service (Oct, 2016).

complete basis for identifying the value of DER. In Australia it will be necessary for DER developers to forecast the future reflection of the intrinsic value of capacity on the future wholesaler electricity market prices, which is a more challenging task; and

- There is less disaggregation in the market sectors in the US, resulting in little separation between the wholesale electricity market, distribution services and retail services as there is in Australia. The increased degree of market separation in Australia leads to fragmentation of markets where DER provides value, resulting in additional challenges for signalling the total value of DER services through clear (and simple) economic incentives. There is also less ability for mandated or administrative approaches for providing incentives directly to residential and small commercial end-use customers compared to the less separated U.S. market structures.

On the other hand, it should be easier to move to more competitive market forms in Australia given the extent to which that has already been achieved compared to the US.

## Monetising the benefits

There are four basic mechanisms which have and can be used in the future to compensate DER providers for their services. These are:

- Markets;
- Tariffs;
- Bilateral deals; and
- Incentives.

The most important of these for medium and longer term development is compensation of an economically determined value through effective markets. Accordingly, this is given more consideration in the International Reports than the alternative mechanisms, many of which have been developed as an interim approach to encourage development of DER and provide some incentive for its development. These approaches are further explored below:

### Market compensation for DER

Compensation through market-based price formation is the most economically efficient approach for rewarding DER providers for their services as it allows true market prices to be established. As such it should minimise the cost of these services and should provide the greatest opportunity for DER developers to capture the correct value. However, a market would have to address uncertainty as to whether DER will be able to provide the necessary

firmness of the service, and it may be difficult for DER buyers to make investment decisions, especially in the early stages of market development.

Except for wholesale electricity markets, the use of markets that include locational, marginal prices for DER through a LMP approach has not been implemented anywhere in the world. There are some market mechanisms for some DER, for example larger DER can access the wholesale electricity market in Australia and some other jurisdictions. However, this only provides compensation for part of their value. Therefore, approaches are being considered in the US that involve use of LMP at the wholesale level with additional payments for services not covered by markets, which is also intended to encourage provision of ancillary or shortage type products<sup>12</sup>.

There are some initial trials being conducted into forms of markets that may facilitate identification of the value of DER. This includes a block chain trial in Perth which may support market revealed value<sup>13</sup>.

## Tariffs

The DER owner can use their DER to save money through retail bill management and the tariffs. Under simple energy tariffs the owner saves the costs of the energy they produce at the prevailing tariff. More sophisticated tariff options allow customers to save money, more aligned to the value provided by the DER through methods such as demand charge avoidance, and time-of-use price arbitrage, or self-consumption regimes.

Even though tariffs are being reformed generally to provide improved cost-reflective economic signals, including the use of demand based tariffs, traditional forms of tariffs remain a blunt instrument for providing DER incentives, neither allowing DER to provide locational services that are fully aligned with grid needs, nor compensating them for providing a range of more sophisticated products than simple energy delivery. Much more significant tariff reform would be required to substantially improve the ability of tariff approaches alone to achieve economic outcomes, potentially involving temporally and locationally varying tariffs. Tariff reform is explored and analysed in detail in a separate Roadmap report and in the Roadmap Report itself<sup>14</sup>.

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<sup>12</sup> For example: Staff Report and Recommendations in the Value of Distributed Energy Resources Proceeding. New York Department of Public Service (Oct, 2016).

<sup>13</sup> Power Ledger

<sup>14</sup> Network Pricing and Incentives Reform. Prepared by ENERGEIA for the Energy Networks Association (Aug, 2016)

## Competitive solicitation

Competitive solicitations and bilateral contracting are frequently used to procure incremental energy resources in the United States, and also Australia. They have mostly been applied as alternative for network investment, and has generally focused on larger generation options. They are designed to encourage competition between project developers, so as to secure new renewable supply at the lowest cost. As such, the price paid to procure DER services is determined by the most cost-effective bid able to meet the project characteristics.

Development of these approaches for DERs is likely to take some time as generally resources are small. However, it is possible that aggregators or new service providers could enter the market and rely on these mechanisms.

There are several challenges to be overcome in adopting this approach:

- Markets may lack liquidity especially initially;
- There may not be sufficient homogeneity for DER at diverse locations and there may be significant differences in the characteristics and operation of DER that make it difficult to achieve accurate price formation, or allow different DER to compete;
- Project characteristics and specific needs must be sufficiently clear and well delineated to allow a variety of resources to compete;
- In solicitations that involve new products and services like flexible resources and demand side management, it can become very resource intensive for the purchasing utility and regulators (if their supervision is required) to compare offers with different options involving different mixes of DER resources, and therefore meeting different needs at different costs;
- Utilities control many of the factors that go into the procurement, and will seek to ensure that the project characteristics are aligned with their distribution level needs, rather than considering feasible options that may be presented, including considering any trade-offs that may be beneficial.

Nevertheless, the implementation of a contracting approach with competitive tenders is likely to represent the best initial approach to developing a more competitive market for DER services. The above points to the challenges that will need to be addressed in order to achieve the desired objectives.

## Incentives

Incentives are generally taken to refer to out of market pricing. These have frequently been used in Australia to promote the development of specific DER. For example, specific financial incentives have been used to encourage home owners to install energy saving measure, including PV cells and home efficiency measures, while a range of attractive feed in tariff options were offered in some States that provided a significant encouragement for PV installation, although these have now largely been wound back or disappeared.

Because of this history and the fact that such incentives have not generally been economically based they are not generally viewed favourably by the industry. However, it is not necessarily the case that such incentives are distortionary and off-market economic incentives may need to be developed as an approach to providing a way of establishing the economic value of DER services that cannot otherwise be compensated, either because there is no current market in place, or the service is not incorporated into current tariff services.

Some more sophisticated and targeted off market incentive approaches are now emerging which do have improved incentive properties and may encourage more economic outcomes. This includes the “Peaksmart” program as demonstrated by Energex in Queensland which is priced based on the capability of demand management of appliances to defer future network augmentation costs.<sup>15</sup>

Ancillary services may fall into this category, at least for an interim period, and therefore specific off market incentives (that reflect their value) may be the only feasible approach for compensating DER for these services.

## Emerging DER Valuation Methodologies and Systems


Various complex analytical tools are being developed or considered which identify the value of DER, but all are dealing with different levels complexity and are still in development phase. In addition to trials in California and New York, there are several approaches being explored to develop analytical valuation models and frameworks. This includes the Lawrence Berkeley National Lab (LBNL) - FINDER Model and the National Renewable Energy Laboratory (NREL) - Integrated Distributed-generation PV Value Study (DGPV)<sup>16</sup>.

The FINDER “model quantifies changes in utility costs and revenues with the addition of demand-side and DERs, like energy efficiency, demand response, distributed solar, combined

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<sup>15</sup> PeakSmart program: [www.energex.com.au/home/control-your-energy](http://www.energex.com.au/home/control-your-energy)

<sup>16</sup> Strategen Consulting Report citing: Satchwell, Andy. FINDER Model. Berkeley Lab Electricity Markets and Policy Group, 2016. Web. <<https://emp.lbl.gov/finder-model>>.



heat-and-power (CHP) and gas micro turbines, as well as the financial impacts of DERs to utility shareholders and customers”.

The FINDER Model is an effort to consider the impacts on utility customers who take energy efficiency measures or install DERs and those who do not install any new technologies, and considers the societal impact and the utility revenue impact of these DER penetration changes.

A study by NREL analysed the costs and benefits of distributed-generation photovoltaics, by classifying them into seven categories: energy, environmental impact, transmission and distribution losses, generation capacity, transmission and distribution capacity, and ancillary services<sup>17</sup>.

The study confirmed that there is no existing tool that integrates all the topics and calculations needed to value DERs accurately.

There may be scope for considering the development of such analytical approaches in Australia. Early efforts are considering data intensive approaches that could be adopted to provide a robust method for calculating and signalling value of DER to networks in Australia and this could be used as a basis for providing initial information to participants as more confidence was gained with the approaches.

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<sup>17</sup> Straten Report citing: Methods for Analyzing the Benefits and Costs of Distributed Photovoltaic Generation to the U.S. Electric Utility System. Tech. no. NREL/TP-6A20-62447. NREL, Sept. 2014. Web. <<http://www.nrel.gov/docs/fy14osti/62447.pdf>>.



## Future networks

Advanced network operations and optimisation in a high-DER future will require significantly enhanced capacity than has been required historically. Initial work has been carried out to implement some of these using the analytical capability provided by intelligent network and analytics available from smart meter technologies. Significant advances have also been made in the development of much more accurate forecasting, developing techniques for addressing the substantial increase in the very dynamic and volatile nature of load behaviour and the challenges that this creates at all levels for developing robust forecasts of energy generation and demand for the future.

### Intelligent network development

The need to develop basic intelligent network infrastructure is not considered to any great extent in any of the International Reports as it was not in the scope of activities they were requested to cover. In addition, some of these developments have already occurred in some US jurisdictions, most notably California, and are assumed to be in place to facilitate the platform development considered in the scope of this work.

However, the development of intelligent network infrastructure and advanced analytical and monitoring and control techniques remains an important consideration in developing the future arrangements contemplated in the Roadmap. The development of these capabilities is a key enabler of DER markets and has been addressed more fully in other Roadmap program work packages, so it is not included in the scope for this Report.

It is relevant for the longer-term consideration of platform and markets to the extent that many of these more sophisticated developments rely on the intelligent network infrastructure being in place, or well developed to provide appropriate control and data supports for market operations and DER coordination. This is currently being developed by a number of the Australian network businesses, with each at varying stages of development.

The key point to be noted is that there will be some period of time before these facilities will be consistently and fully implemented across the Australian distribution network businesses. This may impact on the timing of the development of the more sophisticated markets and network operational functionality discussed in this report and in the International Reports, which assume the functionality as a prerequisite for the future.

## Future network planning

The development of significant DER hosting capacity and trading requires a change in the way network businesses plan for the future. It introduces a significant amount of complexity since there will be literally many millions of supply points that have the capacity to provide an infeed to the distribution networks, while in addition demand response capability can mean that there is substantially greater uncertainty in predicting and understanding the loading that results from traditional connections.

The fundamental requirement for the network businesses to plan for their networks to operate safely, reliably and securely for a wide range of operating conditions is unchanged. There is substantially greater complexity at a number of levels, with the DER making the network operation more complex with the potential for a degradation in performance because of its presence. On the other hand, it may provide additional flexibility in meeting network and customer requirements through judicious use of the DER.

Therefore, the key focus for planning the network in the short term, with DER in a strong growth period is as follows:

- **Facilitating the connection of DER** while retaining the performance and quality of supplies to existing customers, with a key focus on simplifying the process and reducing the timescales for the process;
- **Modernising the network** to incorporate intelligent network capability including the provision of remote monitoring and control equipment, use of conditioning monitoring assessments for major plant and equipment;
- **Collection of system data and the use of analytics** to inform planning decisions, including the need for replacement and scheduling of maintenance cycles for existing equipment;
- **Assessing the potential for DER to increase the capacity** of the existing network, or to meet the needs of the connection of new DER; and
- **Considering the use of new DER to increase network capacity** as a cost effective and lower risk option than primary network augmentation;

Some work of a similar nature has progressed (to different stages) in network businesses throughout Australia, and these steps are considered to be early and necessary development or the Roadmap.

Integrated planning for the distribution system is essential in the future, both to fully accommodate the connection of DER into the system without it compromising the overall



system performance or the quality of supply, while also taking account of its potential to defer or replace network investment, and provide other operational benefits.

The planning process will need to become increasingly sophisticated to deal with the flexibility, uncertainty and variability of network operation in a high DER future. There will need to be a change in focus from relatively simple linear analysis of the capability of the system to meet peak demand imposed on it by relatively well behaved and predictable peak customer loads to efficiently managing a diverse set of resources within the constraints imposed by the technical limits of the networks.

The following detailed components are required for integrated network planning in the future:

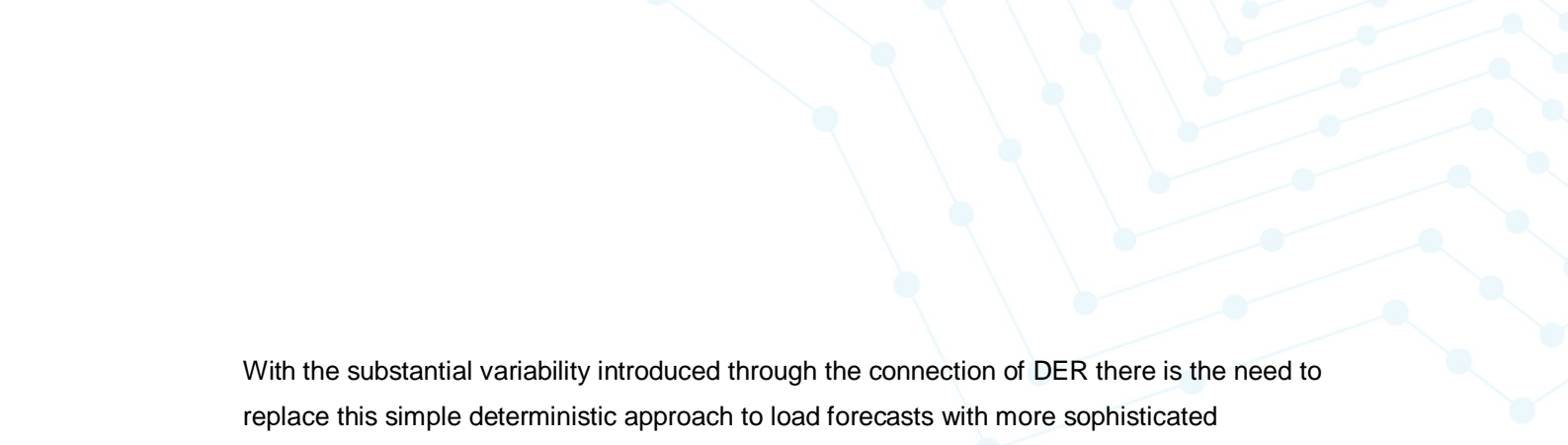
- Sophisticated approaches for accurate energy and demand forecasting for all levels of the network;
- Efficient connection processes, including hosting analysis to identify preferred locations for DER and streamline the administrative processes;
- Integrated transmission and distribution planning with DER forecasts;
- Scenario based probabilistic distribution planning,
- DER locational value planning,
- Transparent provision of system information, both static data and operational data.

At a more detailed level there are some key technology approaches that will be employed to achieve the above. This includes load flow analysis, stability and short circuit analysis, short and long term demand and DER forecasting using detailed historical databases, hosting capacity analysis, locational value analysis, connection studies for new customers and DER, BCA screening, estimation of capital upgrades, and providing a connection portal for information.

### **Load forecasting**

The first key change to traditional approaches that will be required is in load forecasting.

Traditionally load forecasts for network planning purposes has been based on stable long term forecasts developed using extrapolations for each supply point demand informed by an understanding of previous growth rates, impacted by a forecast of key economic demand drivers and augmented by local knowledge of any major change proposed in the future. There were well established approaches based on typical supply diversity at the connection point to determine the forecast demand requirements to assess the required network capacity into the future, with daily and monthly energy curves developed from historical consumption patterns, to assess the risk and duration of supply shortfall.



With the substantial variability introduced through the connection of DER there is the need to replace this simple deterministic approach to load forecasts with more sophisticated probabilistic and scenario based approaches, that deal with alternative DER development options in the longer-term future, and deal with implications of volatility in load forecasts.

The forecasting of load will require a similar level of granularity and precision, using systems that can account for customer behaviours impacting demand at a more granular level. For example, in addition to temperature, ambient humidity levels can affect how customers adjust thermostat settings – and these behaviours may vary with geography and customer demographics.

The other major change in load forecasts is the timeframes over which it is important to have accurate forecasts. In addition to the longer-term forecasts which have been used for network planning there is now an increased focus on shorter term operational forecasts. These will be increasingly important since there will be short-term network control alternatives to manage network operations that has never previously been available and which can dramatically improve the efficiency and safety of operating the network within current network limits.

The approach already taken in Australia by several network businesses is based on a bottom-up approach which involves significant use of data at the customer and even appliance level to build up load forecasts based on more detailed demographic information and much finer understanding of the historical loading at individual connection points, now available from smart meter information for example. This scenario based approach is proving more accurate for load forecasting at all levels. The International Reports point to the need for developing more sophisticated forecasting approaches, but Australia appears to be well positioned in this regard as it has already at an advanced stage of development.

### **Hosting capacity analysis**

The rapid development of DER seeking connection to the network results in challenges in ensuring that it can be connected efficiently and can be accommodated within the capability of the existing network. There have frequently been constraints that have either complicated the analysis of whether the DER can be accommodated at a particular location, and the connection processes are sometimes delayed while detailed investigations have been carried out as to whether or not the DER can be accommodated, or what specifications it must comply with.

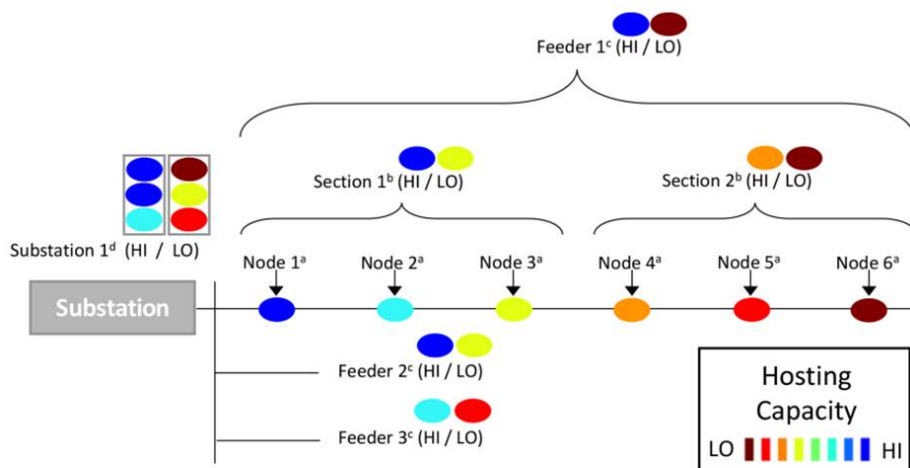
In some cases, the connection has been denied because of inherent limitations in the ability of the network to support the DER at that point. Enhanced data availability and transparency will improve connection processes, enabling DER providers and customers to understand local

network topology while enabling networks to better accommodate DER by better managing and coordinating local network assets (including DER).

In the future, with a strong customer delivery focus, these extended timeframes and denial of connection will be increasingly viewed as unsatisfactory and network planning processes must be developed to facilitate rapid and efficient connection processes, and deliver overall benefits from the connection of DER.

An approach that has been developed and is starting to be adopted in the US, and also Australia, is “hosting capacity analysis”. This is technical analysis that is carried out by the network businesses to show the maximum amount of DER that can be integrated for each location on the existing distribution grid while maintaining the performance of the network and quality of supply based on quantifiable factors including thermal, voltage control, power quality and relay protection limits.

The intention of this analysis is to indicate to prospective DER providers and customers where they can readily connect to the network. The knowledge that DER can be accommodated at that point in the network allows the network businesses to simplify the connection processes. A relatively simple analysis approach can be used to achieve this, but additional sophistication can be developed with time and experience.



<sup>a</sup> Node Hosting Capacity is dependent on DER at other nodes. That shown above is based on DER only at the specified Node.

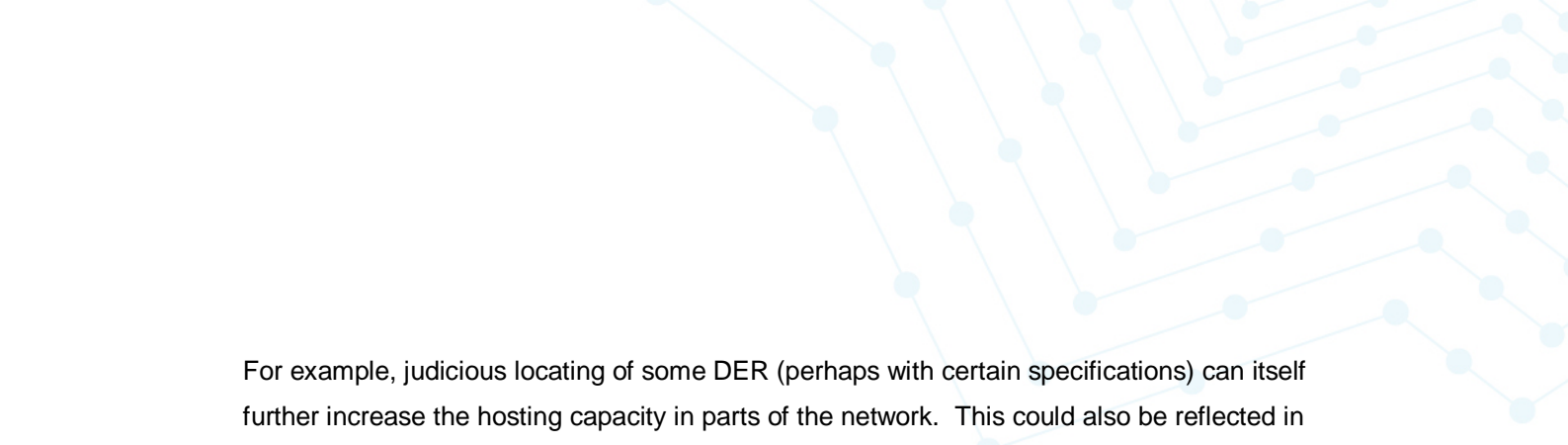
<sup>b</sup> Section Hosting Capacity is the HI/LO range in Node Hosting Capacity on that section.

<sup>c</sup> Feeder Hosting Capacity is the HI/LO range in Node Hosting Capacity on the feeder.

<sup>d</sup> Substation Hosting Capacity is the HI/LO range representing the summation of HI and LO Feeder Hosting Capacities.

Figure 4: Example of hosting analysis (Newport Consulting adapted from EPRI)<sup>18</sup>

<sup>18</sup> Staff, The Integrated Grid: A Benefit-Cost Framework, EPRI, 2015, and T. Lindl, et al., Integrated Distribution Planning Concept Report, Interstate Renewable Energy Council, Inc. and Sandia National Laboratory, 2013.



For example, judicious locating of some DER (perhaps with certain specifications) can itself further increase the hosting capacity in parts of the network. This could also be reflected in the outcomes of hosting capacity analysis that identified preferential locations based on the potential flow on impacts if DER was located at a certain point. This approach flows into a later alternative which is also being developed by utilities in the US for “heat map” analysis where a colour coded (or similar differentiated approach) is used to indicate the most favourable locations for inclusion of DER.

### Future DER forecasting

DER forecasting will need to further develop to improve the consideration of longer term supply demand balance at the distribution level which is necessary to provide assurance of future supply security. DER forecasting needs to be granular and also deal with aggregated transmission impacts where there is large penetration. It will need to be developed on a number of timeframes to assist in providing better operational information to allow the ISO and the transmission operators to more accurately reflect its impact on the transmission system operations, including consideration in the pre-dispatch processes as well as being well prepared for short term loading changes.

A more integrated transmission and distribution planning approach which is incorporated into long-term demand forecasting will be required. An iterative approach that starts with recognising and utilising the role that customer and merchant DERs will play in reducing and/or meeting resource adequacy, will need to be increasingly developed.

Operational and short term forecasting of DER is based primarily on detailed weather forecasts, since weather influences both the loads and the generation (in the case of solar and wind-based DER). Therefore, enhanced DER forecasting relies on improved forecasting of weather at a granular level and its implications for demand and supply.

Forecasting intermittent DER such as wind and PV-based resources is highly dependent on the ability to obtain accurate forecasts of wind and cloud cover, and to analyse its impacts. The overall goal is to increase both the precision as well as the granularity of these forecasts. In terms of granularity, forecasts of wind speed and cloud cover will need to be based on increasingly small time intervals – from current one-hour intervals to 15- or 5-minute intervals to allow effective management of grid operations in local areas. To facilitate this, forecasts will also need to factor in increased geographic granularity since regional-level forecasts will not properly account for the exact location of DER and variations in microclimates.

### International forecasting experience

The following summarises the experience to date in the US in developing improved forecasting approaches.

#### California

Ten year DER projections and load forecasts have been developed with hosting analysis down to the feeder level using various levels of sophistication depending on the level of DER penetration envisaged. There is a requirement for more integrated planning between utilities, and this has now commenced.

#### New York

New York has been using more sophisticated bottom up forecasting with DER. Initial hosting analysis has been carried out and information presented with a standard cost/benefit analysis for DER for identified benefit categories being used to encourage DER development in suitable locations. Some trial projects have been initiated to test these approaches.

The utilities in New York followed a phased approach for the first round of hosting capacity analysis. The utilities in New York are at different state of readiness in terms of available topological models, availability of profiles etc. and these capabilities will be developed in a phased approach consistent with Figure 5.

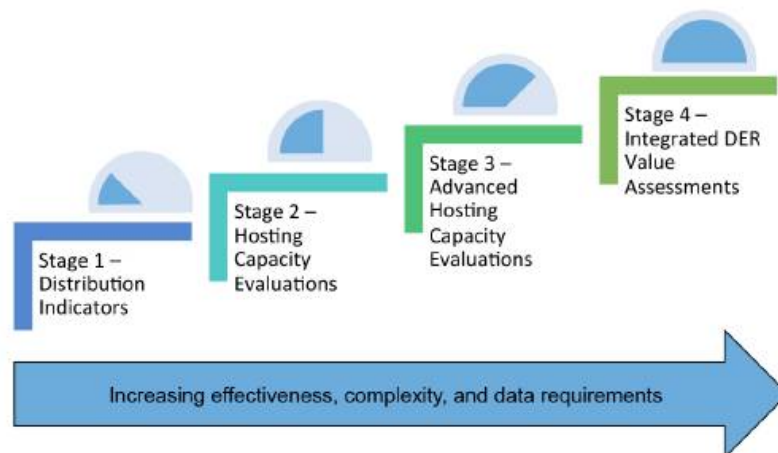


Figure 5: Phased implementation plan New York (Newport)<sup>19</sup>

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<sup>19</sup> Citing “Defining a Roadmap for Successful Implementation of a Hosting Capacity Method for New York State”, EPRI, Palo, Alto: 2016: 3002008848, p5.

Texas

Due to the relatively low penetration of DER in Texas there are limited changes to planning processes. Consideration is given to the impact of additional DER participation in existing markets, but with no change to planning processes.

Hawaii


Some baseline studies have been carried out but only a very preliminary focus at this stage.

## Network operations

### Technological functions for advanced network operation

Distribution network operations will similarly become more complex, but on the other hand will offer more solutions and opportunities for providing a more efficient and cost effective supply for customers, and allowing them flexibility and choice. Some of the key operational capabilities required to manage DER are:

- Remote control and automated control capability for distribution networks and connected equipment;
- A variety of communication facilities, but including high speed digital communications infrastructure to allow remote control and more sophisticated protection operation;
- Accurate sensing and measurement of real time system operation;
- A highly granular and dynamic distribution system model to allow an accurate representation of the overall system in the control centre environment with the ability to forecast future operation on a scenario basis, and identify preferred real time operational strategies;
- Structures, information and procedures to allow effective operation of the interface between transmission and distribution and establish secure operation across the entire network;
- Increased reliance on condition based monitoring for efficient asset management, including real time equipment monitoring and analysis, with alarm and protection responses to protect the equipment and ensure secure system operation;
- Sophisticated fault management, with the ability to implement automated switching of circuits and control of DER to minimise the impacts of network incidents on customers;
- Automated control to achieve improved power quality management, including improved volt/var performance;

- 
- Operational engineering and systems engineering approaches to maximise plant performance and availability; and
  - Real time optimisation of DER operation, consistent with any technical constraints and in accordance with commercial conditions to maximise the efficiency of the system, both for current and forecast operation.

These functions are supplemented by the following technical capability. Many of these already exist in some form in Australia, but the requirements to manage a high DER system will require sophisticated enhancements to many of these technical capabilities, and this is indicated where appropriate.

- Power state management;
- Flow control;
- Volt/VAR control and scheduling;
- Advanced customer metering;
- Meter data management;
- State estimation including optimal power flow to enhance operational efficiency;
- Flicker analysis and response;
- Asset monitoring sensors and analysis systems;
- Network configuration model and systems to interrogate “what if” analysis;
- Environmental sensing and response strategies;
- Cyber security to protect against extensive use of wide band communications and data disruption;
- Physical security to protect key individual asset and strategic network locations;
- Outage management procedures including treatment of vulnerable customers;
- Protection relay management with processes and or technical alternatives to ensure settings and protection actions remain up to date as systems configurations change rapidly with addition of DER;
- Processes for automatic islanding and reconnection of isolated parts of the network;
- Communication infrastructure management and network management capability;
- Customer information management systems; and

- Power Quality measurement and stabilisation.

A comprehensive future approach to providing effective network planning, management and operations will require the following components:

- **Perform distribution State Estimation** – to have the basic information base to provide a preview of the short-term future operation of the distribution network, and allow operational strategies to deal with possible future behaviour to be developed, including at a later stage, pre-dispatch schedules and assess the impact of differing generation and load profiles. A precondition for this capability is the development of an accurate and detailed distribution system model covering the extent of the network for which automatic or controlled operation is being implemented;
- **Remote monitoring and control:** - A number of components of intelligent network infrastructure is required to allow more sophisticated network operations, including automated operation. The basic requirements include the capability to have detailed monitoring and control at various levels within the distribution network. Significant investment will be required in SCADA capability throughout the distribution network, initially at least with remote access and later through automated control centre systems;
- **Facilitate Integrated Switching Management:** - an extension of the remote monitoring and control schemes with sophisticated automated central control capability to allow rapid reconfiguration of the network to manage its operation. This will have application both in managing contingencies and network outages, but also to allow higher levels of optimisation of DER resources by dynamically responding by maximising its utilisation within the dynamic constraints imposed by the network at all times;
- **Facilitate Reconfigurable Protection:** - Traditionally protection schemes have fixed settings that are set up on the protection relay devices to specify the conditions under which a protection operation is required. The settings must be applied to ensure the required operation for all of the anticipated operating conditions. Even with the relatively static operation of the networks in the past these settings have frequently involved a compromise, and the desired protection operation may not always be possible with a wide range of potential operating conditions, including significantly different connected equipment and two way flows. An emerging technology allows the use of reconfigurable protection where the settings, and even the specific equipment that is being protected can be dynamically modified in response to the prevailing operating conditions. This allows appropriate network protection responses to be achieved for a very diverse range of operating conditions that is likely to occur in a network with significant levels of DER, and



will greatly assist the provision of high levels of supply reliability and security in this future scenario.

- **Analyse Power Flow for real time control:** The central element of a sophisticated network optimisation capability is the central IT system that develops the optimal dispatch outcomes for all controllable elements (including and perhaps predominantly DER in this context) to optimise the performance of the integrated system. The key capability for this is the optimisation algorithm which can act on the data presented to optimise performance using all the controls available, in a very similar way to the system dispatch engine for the wholesale market.

In addition to controlling individual or aggregated DER resources of all types, it may also allow controlled switching of the network to manage demand and loads, and reconfigure the network to optimise the overall performance. While conceptually the algorithms are well developed and understood based on knowledge of operation at the wholesale market level there are many added complexities, and a major initial challenge is the availability of sufficient data of the characteristics of the network to allow formation of an accurate model, and the access to real time information to drive it. As with the wholesale market the central part of the system involves load flow modelling, which is a well-established capability. However, in this context it is much more complex because of the scale of the information and data required, which is many orders of magnitude more than that for the wholesale market.

The major constraint for developing this capability is likely to be the provision of accurate system data for the entire network to be modelled. However, it would be feasible to develop this capability progressively, commencing with more critical parts of the network where optimisation is important to reduce costs or ensure that the network can continue to operate reliably with the potential for network constraints, but avoiding augmentation.

- **Volt/VAR Optimisation:** - One of the shorter-term challenges that is already evident in parts of the distribution network where there is already a high level of installed DER is the difficulties associated with voltage control. This has been exacerbated because generally PV has been installed without the ability to control its reactive power output through four quadrant inverter operation. While this capability can be provided, it was not originally specified as the equipment would cost more, leading to higher installations costs, and operation on the four-quadrant mode to provide reactive power reduces the level of active power that is produced and hence the direct benefit to the owner. Ensuring satisfactory voltage control is a key challenge for high DER networks, with the only alternative being higher cost network investment options, or the restriction on further DER connection. Optimised and automated volt/VAR control is effective in maximising the output from all

the DERs within an area, and is a prime example of where a market for reactive power services that allows DER owners to recover the costs of providing this service to compensate for their revenue loss in the “energy market” provides an overall society benefit.

- **Micro-grid Management:** - It is anticipated that the future power system will involve a variety of network structures, including a range of “loosely” connected microgrids. These microgrids are themselves part of a distribution network, but will generally be separately or independently managed, such that the only interaction being at the interface with the main distribution network. Depending on the nature of the microgrid it may provide a highly variable flow at the point of connection which will need to be managed as part of the integrated distribution network, and which will have the potential to significantly impact on its optimisation. There may be various options for integrating this point of connection; including:
  - No visibility of the interface, including no real-time information or short term information on the demand profile;
  - Real time information at the interface but no forecasts;
  - Real time information at the interface with short term forecasts provided by the microgrid operator based on its own SCADA information; and
  - Access to internal real time information internal to the microgrid (on a disaggregated device basis), including forecasts at various levels.

This diversity of information and control capability means that a variety of approaches will need to be developed to ensure that the distribution network can be optimised with the functionality that is available from the microgrid. In addition to the variety of options for data, there is a similar potential for control, as follows:

- No control by the native distribution network possible;
- The ability for the native distribution network to define the desired flow at the interface, and allowing the microgrid manager to operate to this level; and
- The ability to exercise control at a more disaggregated level, perhaps on selected individual DER devices within the microgrid.

Each of these options would be subject to specific commercial arrangements reflecting the market arrangement that are in place.

## ISO/Distribution interface functional considerations

The introduction of significant amounts of DER throughout the distribution networks has changed the way the transmission network and the wholesale electricity market must be operated. Growing DER penetration has resulted in a high level of volatility at the interface between the transmission network and the distribution network, rather than the traditional relatively predictable one way flows.

It is not at all clear that exporting this volatility from the distribution network to the transmission system or the wholesale market is effective in allowing it to be managed. The experience in Europe and the US indicates that it compromises efficiency, and there is considerable debate regarding the preferred approach for dealing with it, especially as the participation of DER increases further.

From the transmission operations perspective, the DER represents millions of individual supply points which are currently invisible and unpredictable to the transmission system operator or ISO. This results in very significant challenges for transmission operations as the generation connected within the distribution networks is rapidly increasing. It is making the operation of the transmission networks and the wholesale electricity market much more complex as there can be sudden and unpredictable changes within a localised area of the distribution networks because of somewhat intermittent, random and difficult-to-predict changes in cloud cover or wind, for example.

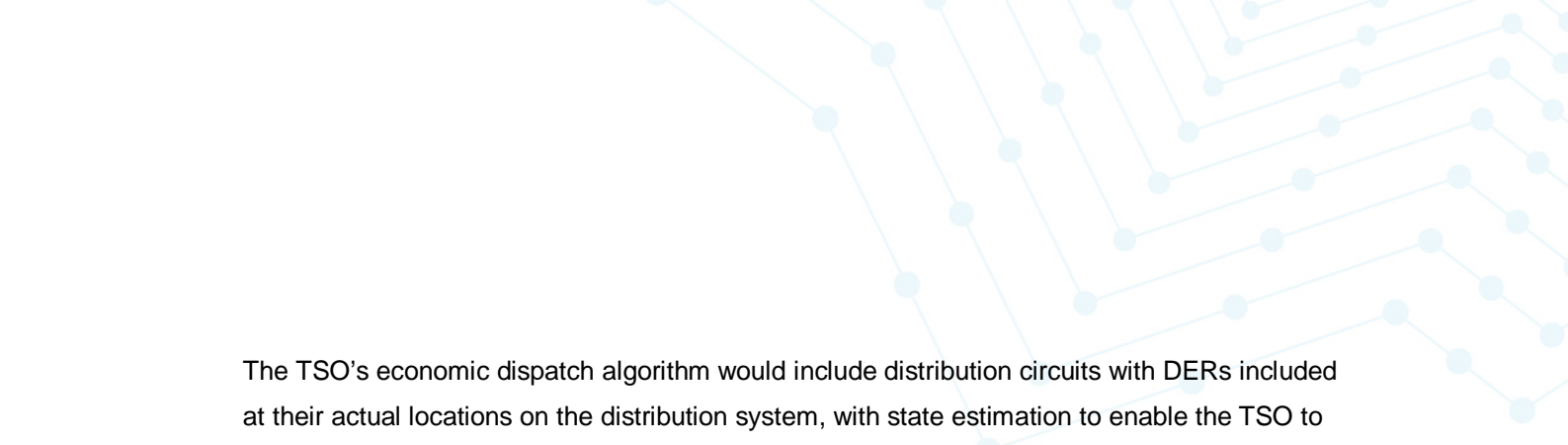
The ISO and TSOs in several jurisdictions are considering the preferred method for dealing with this emerging challenge, including AEMO in Australia. The Newport report considers this issue in some detail in a section that deals with the scope of the role of distribution and transmission system operations and the necessary interfaces between them.

At present the preference is being given to a decentralised operating paradigm, but this is not the only possible approach. It is clear from US experience that the electricity system must be operated holistically, with a high level of communication between distribution networks and bulk supply points critical to ensuring efficient and secure system operations.

Three possible approaches have been considered in the US for achieving the required level of integrated system operations. These are as follows:

### Total Transmission System Operations

In this approach the Transmission System Operator (TSO) or Independent System Operator (ISO) would operate the entire power system including the distribution networks. This would include performing economic dispatch, including DERs down to a relatively low size threshold.



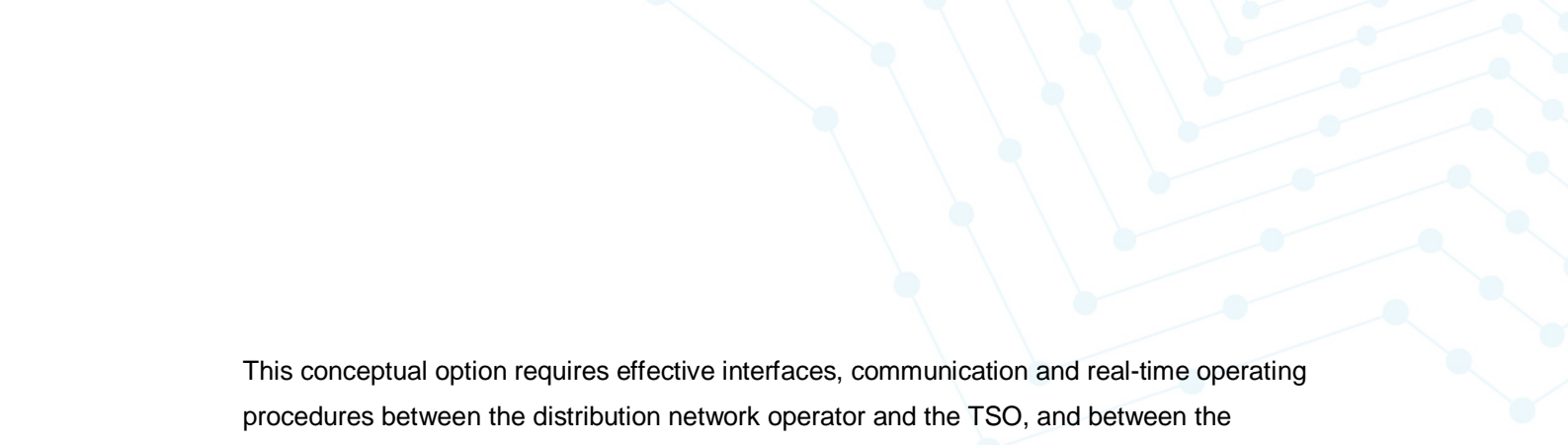
The TSO's economic dispatch algorithm would include distribution circuits with DERs included at their actual locations on the distribution system, with state estimation to enable the TSO to take account of distribution system impacts in determining its optimal dispatch. In this model, the distribution network operator's responsibilities would be restricted to switching and providing responses to TSO directions.

In the US this model is increasingly being viewed as not effective technically, and is not considered efficient, as it is too complex from an operational process perspective. It increases the complexity for DER that may be able to provide benefits to the local distribution network, and if this was to occur there is the potential for serious inconsistencies arising in coordinating the DER to meet the differing requirements at different network levels, especially those at the localised level. Also, implementation of a Total TSO model presents incredibly data complexity for the TSO/ISO who would have to manage millions of data points across the entire network from bulk supply to decentralised individual customers and devices. Some question whether the benefit of having a single TSO is outweighed by the technical and informational complexity this concept introduces.

### **Distribution Managed Interface**

In this approach the distribution network operator would operate local distribution networks and manage the point of connection to the transmission system, and would be responsible for coordinating DER participation in wholesale markets. The distribution network is also able to procure distribution-level grid services from many of the same wholesale market-participating DERs. Thus, the distribution network operator is responsible for physical coordination of the activities of the DERs that are contracted to provide services, and will utilise them to manage the distribution system, and in addition will facilitate any responses to TSO dispatch instructions for DER that is contracted, available or mandated to provide transmission or wholesale market services.

With this model the TSO's responsibility remains at the bulk power system, and the economic dispatch algorithm stops at the interface with the distribution network where the DERs are assumed to be located for dispatch purposes. There is no requirement to model distribution circuits and the actual location of DER participating in the wholesale market dispatch. There may be some DER located within the distribution networks that operates directly in the wholesale market, and this would require the TSO to have telemetry and can exercise dispatch control over these wholesale market-participating DER. The TSO has no visibility of distribution circuits and system conditions or the impacts its dispatches of DERs may have on distribution system conditions.



This conceptual option requires effective interfaces, communication and real-time operating procedures between the distribution network operator and the TSO, and between the distribution network operator and the DER providers in the distribution network operator's local area to ensure that all levels of network operations are managed in an integrated manner.

### **Oversight of DER by Distribution Network Operator**

With this approach the distribution network operator has a high level of control and has the sole responsibility for managing the interface between its distribution network and the connection point with the transmission network. It would carry out all control and scheduling requirements for DERs that participate directly in the wholesale market, and would provide the forecasts for the interface, and establish the DER schedule to meet any TSO specifications.

The distribution network would arrange the aggregation of all DERs within its area to meet the diverse requirements of the wholesale market, as well as managing any concurrent needs for efficient operation of the distribution networks.

Upon receiving a TSO dispatch instruction, the distribution network operator would determine which DERs in the area are able to respond most economically with manageable impact on the distribution system. Under this paradigm the transmission system operator (TSO) would see a single virtual resource at each transmission-distribution interface and would not have, and would not require, visibility for individual DER or aggregated DER below the interface. This is not unlike the existing operational paradigm between the balancing authorities for the interconnected transmission system in the US which primarily focusses on interchanges between balancing authority areas.

The distribution network operator would balance supply and demand within a local distribution area, relying on energy imports or exports at the transmission interface. Similarly, the market operator deals with only one aggregated resource at each interface, includes them in its economic dispatch, and leaves it to the distribution network operator to dispatch these resources via the range of options that are available to them from the services they have contracted with DER, with wholesale market contracts, or through services provided to them by third party providers or aggregators.

This concept requires a high degree of control by distribution network operators, and while this is feasible in some US jurisdictions where networks have a highly centralised role in the vertically aggregated electricity system, it does raise several challenges in the highly disaggregated Australian market. Despite this complexity though, the challenge of orchestrating millions of DERs across the local distribution network to ensure efficient network operations remains a critical one to address in an efficient and coordinated manner.

### **International considerations**

The analysis carried out within the US is focusing on the decentralised layered optimisation structure as the preferred option, as outlined in the third alternative discussed above (Oversight of DER by Distribution Network Operator). This model allows functional separation of the bulk power system operation from the distribution network, with clear specification and rules for the interfaces that are required between them. System optimisation only requires visibility to the interface points with adjacent layers, which is a common and relatively well understood approach for optimising very large systems.

This model represents a substantial simplification of the operational relationships between distribution network operators, bulk power system operators and DER providers. For this reason and the beneficial business model implications for the distribution utilities, it is an attractive approach. Discussions in the U.S. have identified a likely evolutionary implementation over the 2020-2030 period.

This initial scope of responsibilities, including those described under the second model (Distribution Managed Interface), could represent a first step in the development process, and these capabilities are expected to be required in several states including California and New York, perhaps by around 2025.

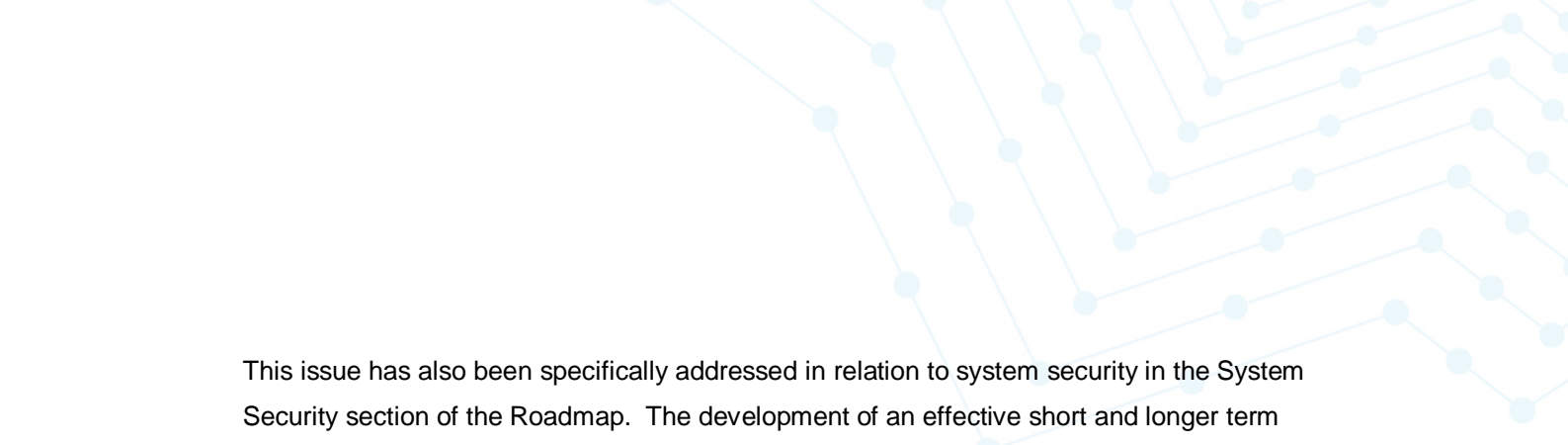
### **Emergence of a Distribution level energy market**

Additionally, over the 2020-2030 period it is anticipated that energy transactions will increase across the distribution network between retailers or aggregators and as supply for the bulk power system.

The more sophisticated distribution network operator model (Oversight of DER by Distribution Network Operator) has the potential for significant synergies with the possible development of an energy market at the customer or distribution level, and in due course may take on many of the characteristics of a local market operator at the distribution level.

### **Conclusions for Australia**

Determining the best way to manage the interface between the transmission and distribution networks with increasing penetration of DER will need to be addressed in Australia. This is becoming urgent as the growth in penetration of DER continues to be rapid and given Australia's power system is smaller than the US, potentially increasing its susceptibility to lower security of operation arising from unpredictable changes at the T/D interface accompanied by rapid changes in output from the transmission connected renewable generation sources.



This issue has also been specifically addressed in relation to system security in the System Security section of the Roadmap. The development of an effective short and longer term approach for dealing effectively with the interface between the transmission and distribution networks is a key challenge for ensuring the security of the transformed electricity sector in Australia.

As identified in the US and other countries, it is essential as a starting point that distribution network operators have visibility of the physical operation of DER if it is being used within the bulk supply market. The physical coordination of DER schedules and dispatch by AEMO and DER providers needs to be known by the distribution network operators to ensure that it can be accommodated efficiently over the distribution network. On the other hand, AEMO needs much more accurate information and forecasts of the likely loading at each connection point, including an estimate of changes to allow it to effectively operate the transmission system.

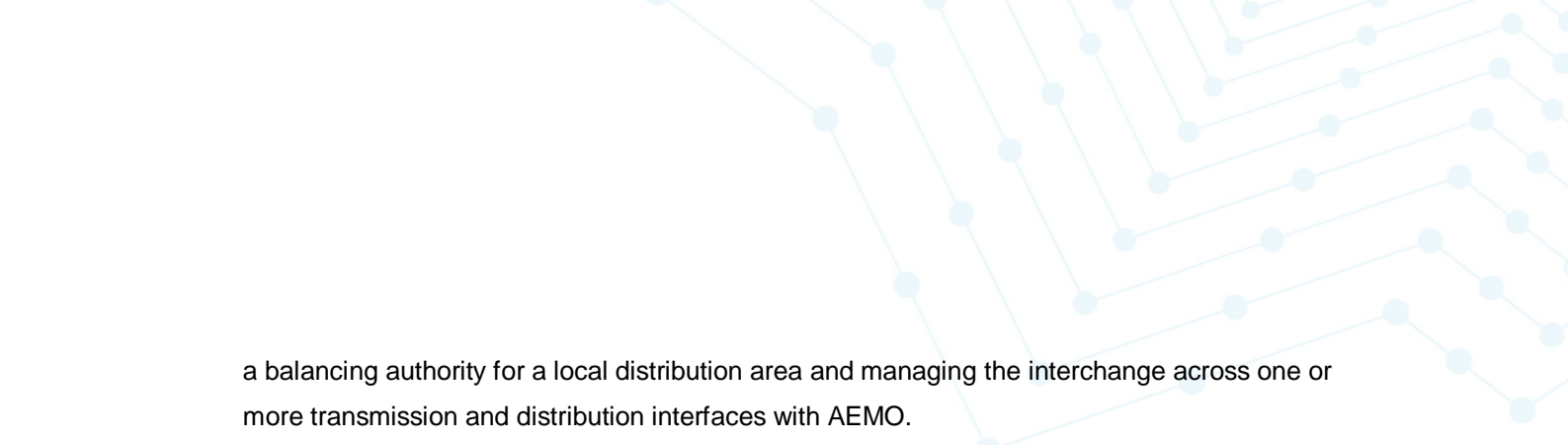
This capability could be developed on a collaborative basis as a starting point to address the need to coordinate physical schedules and dispatches of DER between AEMO, DNSPs and DER providers to ensure reliable grid operations.

The implications for scheduling, real-time optimal dispatch and other relevant market operations will be an increasing challenge, as the scale of DER penetration and potential market participants is very large. At this scale, it will be imperative to have already developed the approach for the physical coordination of the bulk power system with distribution operators consistent with the coordination approach outlined here. However, it will also be important to consider the implications on the AEMO market structure as well. For example, the ability to effectively compute real-time optimal dispatch with one to two orders of magnitude larger number of resources will be a very significant challenge. In this timeframe there might also be consideration of a distribution level energy market adding further complexity to optimal network operational processes.

Spot market transactions at scale would likely lead to a more dynamic management of constraints through re-dispatch of distributed resources. Also, the scale of potentially over 40% of premises with a combined total of around 32 GWh of distributed storage and 32 GW of distributed rooftop solar PV by 2027, delivering a wide range of DER provided bulk power, distribution grid services and bi-lateral distribution transactions will need more detailed consideration of the overall architecture to function efficiently<sup>20</sup>. The Australian power system may potentially require a layered optimisation, with the distribution network operator acting as

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<sup>20</sup> Enabling new services, better incentives, fairer rewards (Oct, 2016). Energeia for Energy Networks Association. Modelling applied in the Electricity Network Transformation Roadmap Concept Report (Dec, 2016).



a balancing authority for a local distribution area and managing the interchange across one or more transmission and distribution interfaces with AEMO.

It is expected that in Australia arrangements will evolve over the next decade and beyond in incremental and progressive steps in relation to the development of possible distribution level energy trading arrangements. However as noted above there is a shorter-term challenge that must be addressed relating to the interface between DER and the transmission networks, and the integration of increasing levels of renewable generation at the transmission level to ensure that there are robust approaches for ensuring system security on a sustainable basis using a well-planned process.

### **Network optimisation**

Networks have the potential to benefit significantly from DER services as it enables networks to optimise the performance of the network and maximise the penetration of DER to benefit all customers. Coordinated DER services can allow network businesses to; defer network augmentation; allow improved voltage control, including overcoming the voltage control issues that may arise from connection of increased penetrations of uncontrolled DER; allows for management of network constraints in real time by providing multiple sources of control that can manage the flow on components of the networks to ensure restrictive limits are met; provide for more efficient responses to network outages by further rapidly controlling flows on the network within post contingent limits; and is able to provide a frequency control management service to assist in both normal and abnormal system operation.

### **Changes required and challenges for networks**

Standards, skills and support systems all need development, including outage management, graphical information systems and reporting. There have been some advances but there remains a long way to go. The provision of detailed and accurate distribution system models is a major shortcoming.

These issues are difficult and may take up to a decade to resolve and these issues are address in separate Roadmap reports under Grid Transformation sections of the Roadmap program.





## Transition pathway

### DER Operations

One of the most revealing findings in relation to developing the operations of the networks and the power system to accommodate high levels of DER is the recommendation from Newport Consulting to consider a planned and measured approach to different operational approaches as the penetration of DER increases and as knowledge, experience and benefits are obtained from progressive implementation.

There are a variety of operational benefits likely to be achieved from DER, even within a localised area, but it may be necessary to encourage and nurture these during the initial time period and to be able to prove the value that can be derived without compromising the overall performance of the system. In other words, a stronger orchestration and control focus may be required for a period of time before it can be confidently left to market forces.

The integration of DER is expected to improve overall performance as the electricity system becomes subject to variable and two way flows, but this evolution is happening at different rates throughout all networks, depending in part on the specific demand drivers. Therefore, it must be recognised that a transition path will be desirable for implementing change, but that the speed and achievement of this transition can be expected to differ between networks.

Figure 6 taken from Newport demonstrates the potential staging of changes to network operation (and distribution network operation in particular) to implement the desired transition.

The key steps involved in this transition are as follows:

- **Stage 1 Grid modernization with low but growing levels of installed DER**

This stage sees an intelligent network developed and implemented with improved planning processes taking account of the possibility for DER to provide a lower cost option for meeting a future capacity need than traditional network augmentation approaches, and simple mechanisms to encourage this outcome. Preparations are being made for more advanced forecasting of future customer demand drivers incorporating DER and more advanced network modelling processes, including for example collection of accurate system data and network models to facilitate more accurate representation of the system in the future.

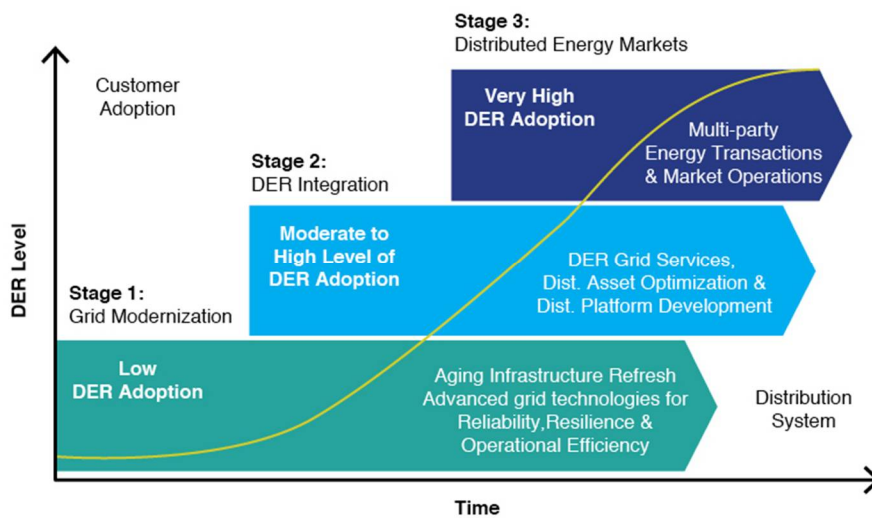


Figure 6: Transition of Network Operations to cater for DER (Newport)<sup>21</sup>

- **Stage 2 DER Integration – moderate to high levels of DER penetration.**

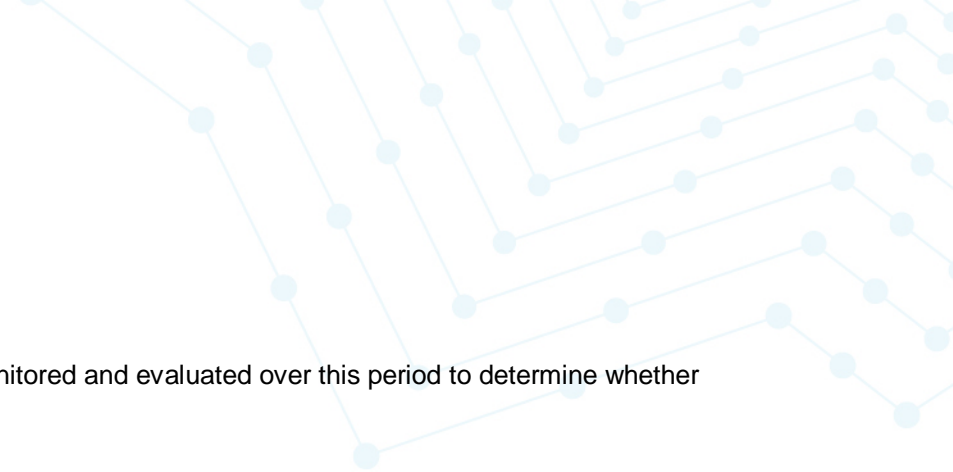
The next stage involves addressing detailed technical issues associated with DER integration requiring more advanced operational design (for example protection and voltage control) to enable efficient connection of growing penetrations of DER. The additional volume of DER provides scope for aggregation of DER to allow these to meet network needs reliably through DER services through commercial contracts with the networks.

This requires more flexible management of diverse resources potentially at wholesale and distribution level, with scheduled coordination between the Distribution and Transmission interface, with the ability to manage potential inconsistency between transmission and distribution needs (and possibly in other markets).

- **Stage 3 Distribution Level Energy markets – very high DER penetration**

This stage envisages the emergence of a Distribution Level Energy Market with the potential for many-to-many and peer-to-peer trading. It could cover energy exchange that does not conceptually require use of the transmission network. It is likely to be a longer-term development (perhaps more than a decade in the future) as there would be many changes to current operations required and the benefits would need to be proven. There are not currently many demand drivers for this extreme change, and its requirement would

<sup>21</sup> Used with permission: De Martini, Newport Consulting Group



need to be progressively monitored and evaluated over this period to determine whether this step is justified.

#### Concluding comments – possible subsequent developments

Network operations will become more challenging with the increasing level of dynamic behaviour at the distribution level and a sophisticated management platform is necessary to allow balancing and optimisation of the network utilising DER. This may be implemented as a network market function only (the extension of a Network Optimisation Market – NOM - to a digital Network Optimisation Market - dNOM - as an interim or final step in the third phase of the transition)<sup>22</sup>. The development of a dNOM would not include the distribution level energy trading noted above, but is still likely to require a transactive energy construct. This would similarly require later consideration as to whether or not it is justified.

This construct provides a foundation for further consideration of DER services and how a market for network level DER services might be developed.

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<sup>22</sup> The concept of a NOM and dNOM are covered in detail in this next section of this report.

## Markets for DER Services

The TCR report identifies four possible markets for DER services in an Australian electricity market structure re-architected for a high-DER future. This report focuses on the potential for DER to sell services into a Network Optimisation Market (NOM). The four possible markets for DER are further elaborated in the following sections:

### Wholesale electricity market

In the wholesale electric energy market (the NEM) regional reference prices are established at each regional node every half-hour. Customer DERs which participate in this market receive local spot energy prices at their connection point with their distribution network equal to the regional reference price for their region multiplied by the intra-regional loss factor applicable to that transmission network connection point serving their distribution connection point and the distribution system loss factor applicable to that distribution network connection point.

Additionally, there are existing markets for ancillary services with economic pricing, with the opportunity for DER to participate and extract economic value which is broadly representative of the market value of the specific ancillary service provided.

As has previously been identified there are specific instances where limited involvement of larger scale DER has been permitted in the wholesale markets in the US, including in some instances allowing them to bid their capacity into the market. Some additional market and pricing mechanisms have been introduced to allow the contribution of demand management options to be part of wholesale markets in particular.

Small DER has not generally been able to participate in the wholesale market, as most markets have invoked size restrictions, and there is no real ability for resources at this level to extract value from this market.

### Retail markets and services

There is the well-recognised ability for customer DERs connected at a lower level within the networks to achieve value from their arrangements with the retailer, even if this is only achieved through standard tariff arrangements. Currently, any connected DER is able to obtain a benefit from existing tariffs. However the benefit provided by the existing tariff may not be cost-reflective of the value that DER provides at each location and time interval. This is likely to be distortionary and inequitable unless specific new services and more cost-reflective pricing approaches have been employed.

In the future alternative retail arrangements may develop for smaller DERs, including from new energy services companies (other than the existing Electricity Retailers that currently operate

in Australia). These are likely to be developed in a very competitive and innovative environment with specifically tailored services that will enable participation to provide new services and receive economic rewards for a diverse range of DERs.

The establishment of appropriate open platforms will be a key enabler of the development of a more diverse range of innovative services that incorporate DER and this will be considered in more detail later in this report.

### **Distribution level energy market**

A distribution level energy market (as outlined in the section above) could facilitate the localised sale of energy and other services from DER, essentially ranging from a “peer to peer” trade to a “many to many” transactions as an energy product. This market would also be likely to evolve over time, but all the International Reports suggested that the development of a fully functioning distribution level energy market would most likely take a significant time to develop, probably well in excess of a decade.

There are many reasons for this lengthy development timescale. This includes both the complexity of the development, with very significant data requirements and sophisticated IT systems to support the pricing and clearing mechanisms that would be necessary.


Issues have also been raised in some jurisdictions regarding whether significant customer benefits would be generated to warrant the development, and it is not currently planned in any of the jurisdictions covered by the International Reports.

The key functions of a Distribution Level Energy Market would include:

- Settlement processes and procedures;
- DER portfolio managements;
- DER Aggregation to the wholesale electricity market;
- Market information sharing;
- Market oversight; and
- DER Sourcing.

The following are more detailed support tools and processes suitable for use in a Distribution Level Energy Market that would require development:

- Measurement and verification approaches;
- Confirmation and clearing mechanisms;
- Settlement;

- 
- Billing;
  - Optimisation;
  - Monetisation and valuation of DER;
  - Advanced pricing mechanisms likely involving real time and locational pricing;
  - Procurement;
  - Dynamic notifications;
  - Administration market participant rules;
  - Market surveillance for compliance with rules;
  - Portal design, operations and maintenance; and
  - Market security including cyber security.

The above list is extensive and involves significant development challenges and requirements. The experience from the development of the wholesale market indicates the extent of time and effort that would be involved in creating such a market, recognising that the complexity may be greater as the number of participants and transactions is orders of magnitude greater.

It also involves potentially much more sophisticated pricing mechanisms than has been employed in the National Electricity Market in Australia.

The establishment of distribution level markets involves not just traditional market functions, but also introduces new requirements for other infrastructure and systems. As an example, measurement and verification for DER services requires new information flows, and given the potential for multiple customer-facing platforms and the presence of energy services organisations like demand response aggregators and third party owners and operators of rooftop solar PV. These information flows can require communication and IT infrastructure not in existence at distribution network operators now. Therefore, establishing these market functions is not as simple as using frameworks based on bulk system market tools.

### **Network Optimisation Markets**

The network optimisation markets (NOM) and the digital network optimisation market (dNOM) are new markets that would allow the network businesses to procure DER services on a commercial basis to allow them to utilise the networks to optimise the overall outcomes of the combined DER penetrations and the network.

This is the most interesting of the markets from a network perspective, and as is now explored in subsequent sections of this Report and the Roadmap itself, the development of a NOM is

seen as a key development to allow the network businesses to unlock the full potential for DERs in Australia. Consequently, the NOM, and the possible later development of the dNOM are considered in more detail in the next sections of this document.

### Market development

The key activities recommended by TCR to be carried out for each of the market areas by TCR over the next decade (and beyond) are summarised below in Table 4.

Time periods / Key Actions	Stage one (2017- 2022)	Stage two (2022 - 2027)	Stage three (2027 onward)
<b>NOM / dNOM</b>	<p><b>Develop Business Case</b> - size of market, DER participation in market, savings from DER participation, pilots as needed</p> <p><b>Develop Procurement Process, Platform and EBB</b> - standard products, standard contracts, compensation approaches, DMP functions, procurement rules</p>	NOM in effect*	dNOM in effect**
<b>Bulk Power - Ancillary Services Market</b>	<p><b>Develop Business Case</b> - size of market, DER participation in market, savings from DER participation, pilots as needed</p> <p><b>Develop Procurement Process, Platform and EBB</b> - standard products, standard contracts, compensation approaches, DMP functions, procurement rules</p>	Ancillary Services Market procurement of DER products and services in effect*	
<b>Distribution-level energy market</b>	<p><b>Develop capability to collect and use granular data</b> – distribution power flows, marginal losses, load data</p> <p><b>Develop Business Case</b> - size of market, DER participation in market, pilots to test concept</p> <p><b>Design Market Rules &amp; DMP</b> - standard products, DMP functions, explore potential to link to dNOM</p>	Distribution-level energy market in effect**	
<b>Bulk Power - Spot Energy Market</b>	Develop capability to provide spot prices at interface points with distribution system. Pilot calculation of DLMPs	DLMP prices calculated and used for transactions in the NOM, dNOM and Distribution-level energy market *	

Table 4: Promotion of DER in each market (As outlined by TCR)

## Markets and platforms for DER services

The central element of the Future Market Platforms and Network Optimisation section of *the Roadmap* is the consideration of the evolving market structures and platforms to facilitate and promote customer adoption and use of DER, and particularly the way in which they can best provide value adding services to improve network operations. The International Reports each gave very valuable perspectives on these aspects, drawing on their knowledge and experience from working in the US. Consequentially, the insights they have provided have been extremely valuable in allowing some approaches to be developed and milestones established for *the Roadmap* based on the evaluation and interpretation of this information.

Each of the International Reports has taken a slightly different approach to considering these future developments. This has strengthened the contribution by allowing alternative perspectives and approaches to be better understood. It has resulted however in additional challenges in this document when reporting on the various findings, and establishing a consistent direction.

Both TCR and Strategen have considered the development of economic approaches including various markets and platforms in considering how DER might be developed to achieve the best outcomes. They have both investigated the development of various forms of markets and platforms to accommodate this future, with a particular focus on the Network Optimisation Market (NOM) and digital Network Optimisation Market (dNOM), while also considering enabling platforms for DER and energy markets.

Newport Consulting has taken a stronger focus on functional relationships and system architecture to describe the possible evolution of the distribution sector to achieve the desired long-term benefits. They have provided detailed diagrams that explain key services and functions that will need to be developed and managed in transforming the industry in Australia. As previously stated, these alternative approaches are complementary, and the different perspectives provide additive insights to the overall issues being considered.

Newport have taken a functional approach to future market development, Strategen have taken a more markets focused approach while TCR, with expertise in valuation of DER and network requirements, have taken an economic valuation approach in their work. Combined these perspectives provide a comprehensive consideration of the challenges and options to develop markets for DER services, with a particular focus on network benefits, in Australia.

The following sections of this report therefore draw more heavily on some of the specific and more unique material included in each of the reports before trying to draw together the broad findings to inform the Roadmap program.



## Definitions and terms adopted

In addition to the different approaches adopted in considering future market and platform development there is also a slight difference in the terms adopted and the meanings attached to some of them. With that in mind the purpose of this section is to note the various terms and provide a brief definition of each, while also noting where there is a difference in interpretation.

### Network Optimisation Market (NOM)

The NOM is used by TCR and Strategen specifically to describe a relatively competitive environment in which network businesses procure DER services to meet network needs. The approach to this has been described in detail in this report, and may include for example simple contracting or bulletin board approaches. The NOM is intended to be more of a process-based acquisition of DER services for network optimisation (at least in the initial stages) rather than a dynamic market in the purest sense of the word. It is intended to be a simple approach with low transaction costs, but is only likely to be able to be accessed by large or aggregated fleets of DER resources.

Newport have not used this term but have described very similar approaches in their report, leading to the conclusion that this approach is generally embraced on a consistent basis by the International Reports.

### digital Network Optimisation Market (dNOM)

At the most basic level the dNOM is a digital extension of the NOM where network businesses procure DER services. It provides a more dynamic market that allows DER to interact and respond more interactively with networks and to provide them with services. As such it is more able to cope with a very large number of market participants and DER, and transaction costs for these smaller procurements should be lower than could be achieved for these with the more rudimentary forms of the NOM described above.

This would allow DER network-optimisation service procurement transactions to increase substantially in number, with standardised specifications and other key contract terms. The parties buying and selling DER network-optimisation services would rely on digital procedures for service matching and market clearing. In this sense a Strategen highlight that a dNOM platform would enable a dynamic marketplace for DER owners to trade their DER capability with minimal transaction costs, supported by clear price signals which incentivise optimal transmission and distribution network level operations.

Importantly, Strategen also notes that this platform could potentially support both a dNOM and other distribution-level markets that could emerge over time (see below for more information on how distribution level energy markets are defined).

TCR recommend that Australia should evaluate the merits of moving towards a more comprehensive distribution-level market for DER products and services operated on a single digital platform as the ultimate, long-term option, rather than having separate markets and market platforms for a dNOM and a distribution level energy market. Whether or not this is preferred it is recognised that there is a very considerable overlap between the dNOM and distribution level energy market concepts, as the mechanisms for determining and revealing prices on a locational and temporal basis would be the same, and metering and settlement processes would have a high degree of similarity.

It is accepted that this is a key point for further exploration in considering the transformation of the electricity sector in Australia. It is recognised that this issue may be resolved by the market itself, and if not, would be unlikely to manifest for some time.

#### **Distribution Level Energy Market (DEM)**

In addition to development of a NOM and potentially a dNOM, it is anticipated that a distribution level energy market may subsequently evolve to facilitate the sale and purchase of energy and other DER services between third parties connected together by the distribution network. Sales and purchases of energy would likely be influenced (either formally or informally) by the wholesale electricity market. The Distribution Level Energy Market (DEM) would be characterised by an increasingly large number of connected parties and potential transactions including many DER providers seeking an open market on which to trade.

It is likely to include both “peer to peer” trading and “many to many” transactions as energy products and more diverse services emerge in the future.

The TCR report states that increasingly sophisticated and dynamic price signals could enable and support the sale and purchase of DER core services across the wholesale electricity market, the wholesale ancillary services market, the network-optimisation market (NOM), and a distribution-level forward energy market. TCR posits that full implementation of price signals to support a more aligned marketplace will require significantly increased granularity in pricing and price discovery, which in turn should lead to improved economic efficiency in all of these specific markets, optimal system performance and value for all the trading customers. This highlights the potential overlaps between a DEM and a dNOM, as noted above, but it is important to note that TCR’s framework requires very granular, localised, dynamic based price mechanisms for different markets to be successfully aligned. It remains to be seen whether the technical

complexity inherent in the development of such price signals is practically achievable compared with other, less sophisticated market platforms and frameworks.

### **Distributed Energy Resource Management System (DERMS)**

A Distributed Energy Resources Management System (DERMS) may provide a technological means for centrally orchestrating fleets of DER where the DER owner has contracted dispatch rights in exchange for an agreed benefit from the network.

A DERMS is distinct from a NOM or dNOM market construct. It may however be implemented by network businesses and/or other market actors to provide the technical functionality to support a range of different markets, including a dNOM and/or a distribution level energy market. However, the operational complexities involved are also increased as the need to ensure that resources are operating in concert rather than in opposition must be considered.

Essentially a DERMS would provide a flexible basis to support the innovative development of DER products and services and facilitating their interaction with alternative markets, potentially including each of the four markets identified earlier, but allowing for development of others. It would therefore include a consolidated system with standard communications and data protocols that would allow devices to interact with it in a consistent and simple manner in whatever platform or market arrangement they would choose to be part of in the future.

The DERMS would manage and control DER operations to optimise multiple objectives simultaneously and/or to allow for changing optimisation priorities based upon operating conditions. With the increased penetration of energy storage devices and micro-grids and the growth in aggregated DER, more DER services are available and monetised, allowing for a broader optimisation that is more economically-based/driven.

The DERMS also has an operational role in that it would send prices, operating parameters, demand response schedules and other information to each DER that is involved in meeting the schedule. It also has a short and long-term forecasting role.

This concept is referred to by Newport and Stragen in a reasonably consistent manner. Among other things it is seen as a critical function to ensure that the sometimes contrary requirements are achieved in harmony, and that system security is not adversely impacted by competing demands. However, further consideration is required to explore how a DERMS could be applied, or may be required, within different network functional roles as identified in this report. This concept is explored further as a tool to support the emergence of market platforms later in the report.

## Markets for DER services to achieve network benefits

There are alternative market based approaches to procuring DER for network purposes. In the first instance a contract approach can be adopted which allows the networks to acquire and control services from DERs in return for the agreed commercial terms. A market could be developed (in early stages) that would utilise a bulletin board approach for posting details of requirements from network owners, or a competitive sourcing model may be used to select between alternative market offers.

California and New York have been active in developing distribution operational markets to enable DERs to provide services including distribution capacity deferral, steady-state voltage management, transient power quality, power system reliability, resiliency, and distribution line loss reduction. In these jurisdictions, the distribution utility is a logical buyer of these services, in order to meet the statutory obligations for a safe, reliable distribution network. Australian networks can likewise benefit from utilising DER capabilities to enhance or optimise network operations.

More sophisticated forms of markets may be developed to allow network businesses to procure or operate resources. In the longer term this could extend to a dNOM where a digital platform is used to automate and optimise use of the DER matching the need with the availability and providing the mechanism for market clearing.

## Network Optimisation Market

Each of the International Reports considers the development of a Network Optimisation Market (NOM). This recognises that one of the most valuable outcomes of DER optimisation will arise through the deferral or elimination of expensive and risky network investments. Given that vast numbers of DERs will be privately owned, a market construct is recognised as providing the mechanism for incentivising the participation of DERs through sharing the monetised benefits of such network efficiencies.

A NOM could take a number of different forms, and may also be subject to a staged development process. At one extreme, network optimisation can be achieved without a highly complex market, while on the other hand there is also the potential for a sophisticated option for implementing a digital and increasingly automated market.

While the concept of network optimisation using DER to replace network investment is well understood and administered, solutions can and have been readily implemented to achieve the technical and economic benefits possible from deferral, the extension to a market is more conceptual and has not been tested in practice. In particular, the successful development of a

competitive market assumes that there will be a large number of willing buyers and sellers, and at this time there is little experience within any jurisdictions to judge whether this is likely to be the case.

The NOM (or in later stages, a dNOM) would provide the platform that would allow participation from any of the DER or DER service providers (or Market Actors as depicted in the Figure below) that could interact with it (like any other market platform) to provide a service and receive the value for it, as depicted in Figure 7. It acts as the interface with the network services market, and may include interactions with other customer facing platforms. It is intended to provide the maximum flexibility for a range of market participants or their agents to engage on an economic basis where the true value is recognised and compensated.

It will be important that such a platform be sufficiently flexible to allow for the rapid evolution of the types of parties and processes that are expected to develop that would interact with this in the future.

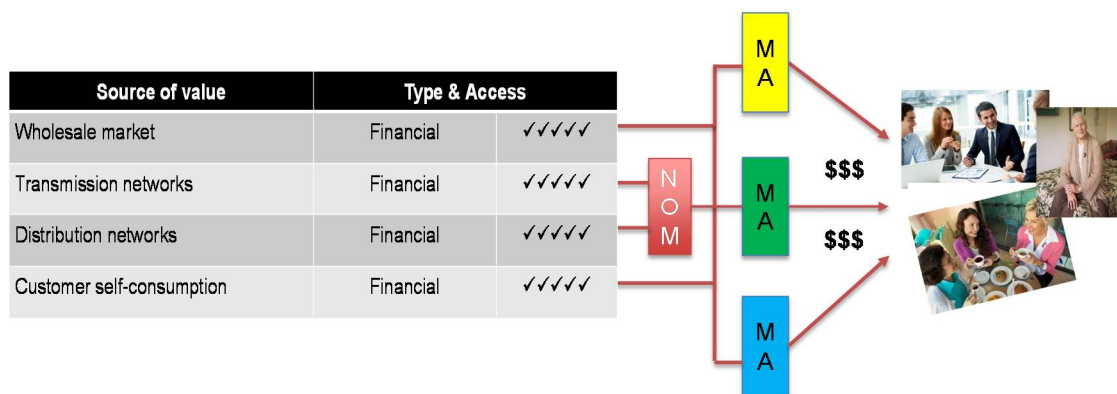



Figure 7: The NOM enables the valuation and monetisation of network benefits provided by DERs which may be bundled with other sources of value and presented to customers by various Market Actors.

### Benefits and value of a NOM

A preferred approach is again likely to involve a staged implementation approach, in which alternative simpler administrative processes are used initially to derive the key benefits that DER can provide for deferred network investment and evaluate the need for a more sophisticated market form based on the experience and outcomes. Alternatively, the development of more sophisticated approaches may be allowed to evolve as a natural logical market response to the increased interest and commitment that is shown at that stage by DER participants.



The technical aspects and the benefits achieved using DER to defer network investment has been discussed. There are a variety of administered approaches which can be used, including the requirement for network businesses to publicly and transparently investigate alternative non-network options when considering the need for network augmentation. This approach has natural restrictions in that they are confined to only specific circumstances and locations and these will generally be dictated by the needs of the distribution networks rather than being an open process that allows a broad range of DER to participate.

Market solutions provide a transparent customer focused basis for deployment of DER, which is an important element in developing preferred longer-term industry arrangements,

### **Steps for developing a NOM**

The following section summarises some of the essential steps and challenges that will be involved in developing increasingly sophisticated approaches to network optimisation.

An important first step, which is consistent with the requirement for an administered type approach is the need for the networks to make a considerable amount of information public regarding the need and characteristics of DER required by location and time interval. This would involve developing and publishing an estimate of the market size (including the location and duration), the locational value (based on the avoided costs of the network augmentation, or other network benefits), and the type of services that would be required to meet the specific needs.

The decision to promote a market would depend on the extent of the need, potentially both nationally and locally. While a significant global need might be established and judged sufficient to move to develop a functional market there is likely to be a requirement to deal with the potential consequences for specific locations where the market proves to be insufficiently deep or competitive.

The first step in a market development is likely to be a simple procurement mechanism. Care will be required with its development and simple and restricted approaches may be necessary initially so as not to discourage participation through unnecessary complexity. On the other hand, it is likely that ultimate solutions will need to be more sophisticated and ideally should build on rather than replace the earlier systems and participation that was initially established.

Even the simplest initial procurement systems will require some flexibility to deal with the different forms of DER, e.g. dispatchable and non-dispatchable, or those that can shift timing, but also have different opportunities in different markets.

A market assessment or more detailed investigation may be required to determine whether there is sufficient DER to warrant the development of a NOM. The presence of a large

number of DER in an area will not necessarily by itself indicate that a NOM will deliver the required benefits. Careful localised assessment of the network need and DER capabilities will be crucial to determining whether there is sufficient DERs for network optimisation, and if there are other markets or incentives provided for DERs they may offer better value. In this case the DER may not present themselves for a NOM, due to the lack of financial incentives, or the additional complexity of participation.

The potential for operation in multiple or alternative markets is complex, since there will be a variety of new modes of distribution network operation and it may not be trivial to determine the likely benefits of operating in any markets or under any of the simpler tariff regimes that may exist. The assessment will also be complicated because there is a timing dimension to many of the assessments, and they may need to be assessed as being most relevant in either the long-term or short-term. The value might also exist for short periods of time that are difficult to define. However, depending on the likelihood that the demands for services provided by a DER in both market will not coincide, it could be possible to allow firm operation of some DER in multiple markets.

### Requirements for a NOM

There are several foundational elements that need to be established to allow the successful development of a NOM. These include:

- **Transparency** will be critical in the formation of the NOM, and also for the development of other markets. Achieving this, however, may be difficult, especially initially where the new and changing modes of distribution operation will be flexible, complex and uncertain.
- It will be important for network businesses to make their **key planning assumptions, forecasts and planning and operational data available to DER participants** if they are going to be encouraged to become involved in a NOM. Unless this is successful a NOM may be difficult to implement or may take an extended period of time. (TCR).
- **Data management platforms will be important in the future to facilitate the development of a variety of markets**, and especially where a degree of forecasting and judgement regarding the future is necessary for a DER to commit to providing services over the timeframes required to allow them to provide sustained benefits to allow network deferral. (TCR)
- Transaction costs will be an important issue given the above complexity in the development of a more advanced market. These will need to be minimised to encourage participation in the NOM, initially by keeping the market development relatively simple, and ultimately perhaps through the implementation of an efficient digital platform.

### Staged implementation of a NOM

A reasonable conclusion is once again that the formation of a NOM is likely to be best staged. A potential development process could be as follows:

- **Network businesses could develop “heat maps”** to show the most beneficial places on their networks for connection of DER to assist participants identify the best locations for DER to avoid emerging network augmentation requirements. This information would be prioritised such that more accurate information is provided for the areas where the need is greatest. This information would ideally include an estimate of the value that the network would place on the service provided at each location, ultimately with sufficient certainty to provide an accurate assessment of the contract conditions which could be contemplated for a standard form service.
- Where there is an identified and time critical requirement for network augmentation to relieve a constraint the network owner could **carry out a competitive sourcing process that would enable it to select the lowest cost option for meeting the requirement**. In the event that there was no lower cost option than the most efficient network augmentation project to meet the need, then it would be proceeded with, otherwise the identified DER service/s would be contracted. This approach has been used for some time in Australia, initially at the transmission level, but more recently for larger distribution network expansion projects. Small-scale, localised non-network programs have also been explored but non-network needs are often addressed by larger scale DER or alternative energy products due to the complexity of aggregating smaller scale DER;
- **Simple procurement approaches could be developed** that would allow the DER that could be deployed to meet the needs determined by the network businesses to contract with them to provide a service. Standard form contracts would be in place and the value identified in the previous process would be used as the contract price. This process is only likely to be possible, at least initially, for relatively large DER due the nature of the procurement processes, but also because of the non-linear nature of the costs curve<sup>23</sup>. However, it could allow aggregators or other third party services providers, who may be contracting with individual DER for other reasons to participate in this early market.
- **These simple processes may evolve to more complex options with experience**, including **the addition of more complex services** (including time differentiation), use of

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<sup>23</sup>This arises because there will generally need to be a reasonable capacity of DER to allow the deferral of a network investment.



non-firm options and alternative diversified approaches to mitigating risk in assessing the capacity and value of DER services, and lower threshold levels for participation. There could be increasing levels of certainty attached to the value assessment and publication such that this represented a guaranteed offering, simplifying the assessment for the DER of the incentives for participation.

- The basic concept envisaged by this model is that a **DER service provider or aggregator would contract with the network operator to provide a specified service**, usually a defined level of capacity, for specified time periods and with a specified degree of certainty. The contract established with the network operator would allow it to utilise the service within the limits imposed by its specification (capacity, timing, performance including for example response characteristics and ramp rates) and receive compensation as outlined in the contract.
- **Aggregators or third party service providers should be encouraged to engage with this market at an early stage**, in order to allow innovation in developing options that are suitable for meeting network needs. It is likely to be the case that individual DER will have performance or service restrictions that will limit their suitability, or reduce their value to contribute to the identified, and often specialised network requirements on a standalone basis. However, they may be able to contribute as part of a combined service offering established by a third party, who may be able to use a combination of DERs with sophisticated controls that they develop to offer a service that has considerably more value than would be achieved even if the network owner could contract the resources separately. **It is always likely that commercial third party providers with access to a larger range of resources and more innovative approaches for addressing general market needs will be able to provide more advanced services and extract additional value from individual DERs** than could be achieved through stand-alone operation.
- Despite the limitations and restrictions noted under the previous dot point there may be further development of **a more sophisticated and low cost approach that does allow smaller DER to actively participate**, prior to the establishment of a fully digital platform envisage as the next stage. This may be especially relevant in the event that the extension to a full dNOM is not justified.

The operation of a NOM requires digital monitoring and control capability, and most likely integration with a network optimisation algorithm to achieve optimal DER dispatch. It is, however, unlikely to involve sophisticated real-time response to incentives, or operation in a more dynamic market structure, both of which are characteristics of a digital Network Optimisation Market or dNOM, to be discussed in the following section.

## Digital Network Optimisation Market

dNOMs are intended to provide a scalable platform capable of enabling very large volumes of DERs to dynamically provide network services at low transaction costs. Ideally it would also enable the diverse, and at times competing, market signals to be harmonised so as to enable a level playing field for participating DER.

There appears to be a substantial overlap between a dNOM and a DEM, and one of the challenges is that there is no clear and unique definition of either. It is apparent from the descriptions and treatment in the International Reports that some consultants view these markets as being highly congruent. Whether that needs to be the case is an important detail that will require further attention in developing the future approaches in Australia. It is, however, clear that they are closely related, and it is likely that they both would coexist for a limited time before they would be amalgamated.

### Benefits of dNOM

The overarching benefit provided by a dNOM (or potentially by a distribution level energy market -DEM) is that it would allow for a platform at the distribution level that could operate or oversee a localised network-level market for DER services.

The additional benefits of dNOMs include:

- **Strengthens Flexibility & Resilience**

dNOMs enable transactive solutions that create distribution- level flexibility to adapt to operational circumstances in real time.

- **Reduced costs**

A large fraction of system costs is created due to what is generally a very small fraction of hours of critical operation on the load duration curve. Transactive solutions would allow a much broader range of resources to help meet that need, avoiding excess network infrastructure and peak generation resource costs, and optimising least cost dispatch based on a broader resource base.

- **Fairly Allocates Costs**

dNOMs render moot the ongoing cost allocation concerns over DERs. In a transactive market setting, participating customers always pay – and get paid – their fair share based on the impact they are having on the grid and the benefits they provide the grid.

- **Improves Consumer Choice:**

dNOMs enable the ultimate in consumer choice, because customers have the freedom to participate in the manner that suits them best, be it as “prosumers” and DER service providers, (or if combined with a DEM, on a peer-to-peer basis as prosumers or load customers, or on a peer-to-grid basis as load customers only). Further, not all customers must opt into a dNOM in order for the system to function properly. Traditional rate structures can still exist, and non-participating customers can still benefit from the system optimisation that results from a portion of customers dynamically responding to market signals and system conditions.

- **Encourages Network Participation:**

Establishing transparent mechanisms that value a more complete range of DER, demand response, and load modification activities as services will create incentives for grid participation and customer actions that are aligned with grid needs.

- **Reduces Grid Defection:**

Fully valuing the services that DER can provide, and providing additional choice to consumers as to whom they transact with reduces the incentive for customers to disconnect from the network.

- **Supports Carbon and Pollution Reduction Goals:**

Most DER are greenhouse gas free resources. Fully valuing DER services will result in more greenhouse gas free, resources being deployed, lowering the overall emissions profile of the electricity sector.


### **Potential Drawbacks to NOMs**

The benefits of a NOM or dNOM as the economic ‘glue’ that binds the grid together as the electricity system moves from a load following system to a prosumer demand responsive supply following system are clear. However, NOMs and dNOMs are “a complex answer” to a “complicated problem”, and can result in a radical departure from traditional price formation methodologies in the power sector and loss of control of regulators and traditional stakeholders over price formation.

Therefore, there are a number of considerations that must be fully evaluated including:

- **Market power and gaming:**

In any organised market, actors can aggregate sufficient market power individually or through collusion that can have a materially negative economic impact for market participants, and



there are a number of examples where energy markets have been subject to failures caused by market power and gaming. Market power is an important consideration at the formative stages of market development since it is very difficult to predict the potential for market power arising from different behaviours which short circuit protective mechanisms and take advantage of unclear requirements;

- **Implementation cost and complexity:**

Creation of a dNOM is highly complex and expensive, and there is a tremendous amount of physical infrastructure and software that needs to be deployed for a dNOM to function, such as smart meters, communications equipment, market platform software, DER management systems, and power electronics. The preferred approach to address this issue is through gradual evolution of systems as the benefits are proven;

- **Regulatory and policy influences:**

Regulations, legislation, historic market design and market products, and other physical and virtual barriers can heavily influence the price formation and conflict with ultimate successful implementation of transactive market structures.

- **Cybersecurity:**

Malicious hacking or access presents a potential threat to the security of the entire power system. IT system design architecture needs to have the appropriate protections in place to minimise this risk.

- **Market response:**

Self-scheduled market responses to price signals may not provide networks with the technical capability required to manage the system securely at all times. There is a high potential for unexpected responses including for example ringing, when there are high penetration rates of zero marginal cost resources that, in theory, may all respond in a similar manner to a broadly distributed price signal.

- **Consumer behaviour and the potential for backlash:**

Amongst a subset of early adopters, the concept of providing more control over energy costs and the ability for individuals to self-generate is appealing. However, it's unclear whether the general population – and particularly vulnerable communities – would understand and embrace a more dynamically priced energy system. On the other hand, managing price and ensuring reliability, beyond a certain point of DER penetration, necessitates a change towards a more dynamically capable system.

## Steps required to implement a dNOM

There is little or no precedent to consider the detailed approach to developing a dNOM. It may be expected to start with the more administrative process that is developed for the NOM.

There is also very considerable overlap with the development of a Distribution Level Energy Market (DEM). A dNOM could coexist with a Distribution Level Energy Market, however the International Consultant Reports indicate it may be cost-effective to have a single marketplace to support the operation of all distribution level markets for DER services.

Therefore, the following steps identified in the Strategen Report may be equally or at least partially applicable for the development of a dNOM and perhaps in conjunction with a Distribution Level Energy Market.

### **1 Establish a clear policy direction**

A clear policy direction is necessary to ensure that all participants are clear on the longer-term direction, and that this clarity of purpose can ensure that a detailed (albeit it potentially long term program) can be implemented successfully. For this to be possible a broad degree of stakeholder support is necessary.

### **2 Wholesale market design**

Implementing an appropriate market design at the wholesale level is necessary to ensure that price signals that are adopted at all market levels are consistent. This may represent a significant challenge in Australia where there has traditionally been a high level of opposition to moving towards the more economic and dynamic approaches to price signalling that is likely to be necessary, including for example proper temporal and locational pricing through locational marginal pricing in real time;

### **3 Appropriate Network Regulation**

It is highly unlikely that the existing cost and asset based network regulation frameworks will remain an appropriate mechanism for providing incentives for network businesses to operate efficiently in the future with the high potential for DER to offer alternative services on a more cost effective basis, or for network operators to provide a more dynamic and efficient network operations platform. Therefore, new regulatory revenue models should be trialled for network operators;

### **4 Open and transparent grid planning processes**

It will be necessary to develop open and transparent grid planning processes, not only to encourage network operators to incorporate DER as a preferred alternative to network investment, but to allow DER providers to assess the potential benefits of their resources.

This will enable DER providers or service providers to be proactive in seeking DER opportunities. It will require a high level of accuracy and transparency in the provision of network information and forecasts;

## 5 Locational benefits of DER

Establishing locational (not temporal) benefits of DER as the easier first step in identifying and making public the full economic value of DER will be desirable. This is an easier step than implementing dynamic temporal pricing, and hence is proposed much earlier<sup>24</sup>. This will allow DER providers to establish a clear understanding of the financial benefits that they are likely to achieve through provision of their services, but also to be in a position to assess the merits of the determined price, given that there is a degree of subjectivity in developing prices that reflect the avoided cost of network investment<sup>25</sup>.

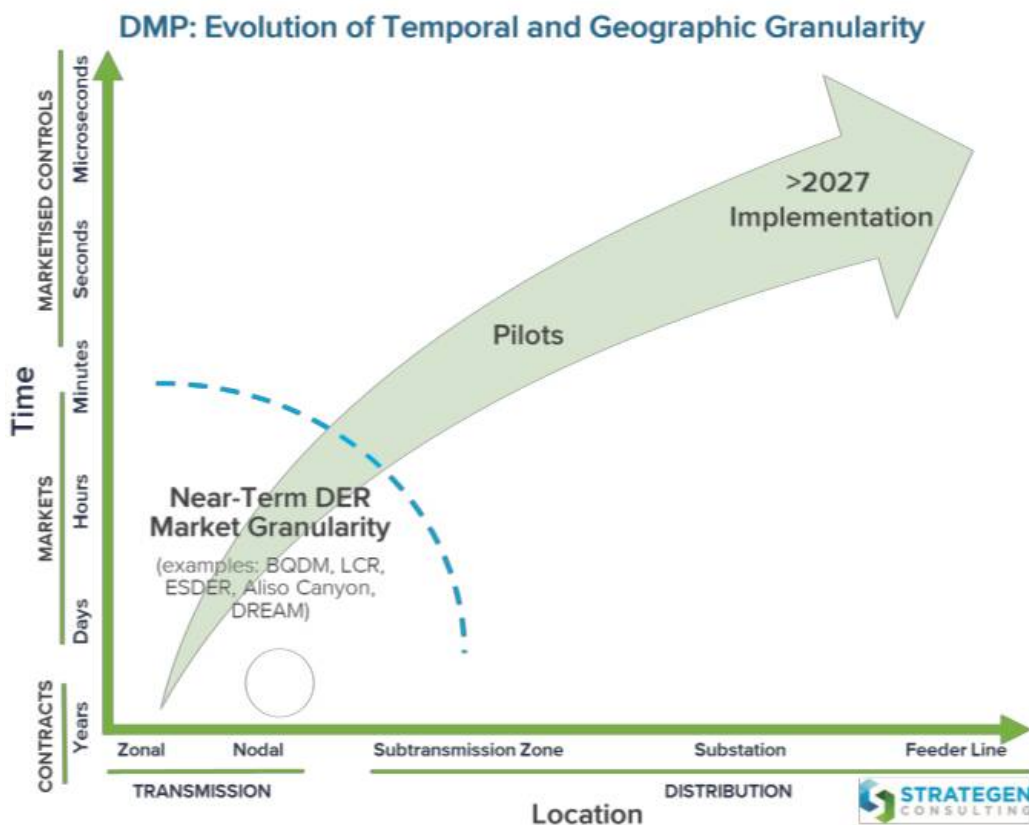


Figure 8: Evolution to more complex forms of network optimisation markets (Strategen)

<sup>24</sup> Note that throughout the International Reports attention is drawn to the fact that real time pricing is very challenging.

<sup>25</sup> Since it must be based on forecasts of future load, DER and generation developments.

## **6 Establish a protoNOM**

Establish a protoNOM involving networks contracting for DER for services on a commercial basis using the value method established for the previous step (allowing the DER provider to debate and negotiate according to their own assessments), and using a standard contract form to facilitate the process, clarify the risks and ensure that negotiation and implementation would not result in unreasonable delays to the connection of the DER. Since the value of the DER would reflect network deferral for this stage of development the pricing arrangements could be expected to be based on a fixed price subject to meeting qualification requirements to ensure that it actually provided the capacity required to justify the deferment.

## **7 Test and Implement dynamic NOM**

Test and implement NOM, probably initially as a day ahead market, as the most logical initial approach. It could be expected that the contracts would initially be for a relatively simple set of services, which would give the network operator some level of control over the scheduling and dispatch of acquired DER services at the times required. The forecasts could be established for the following day based on weather impacts for DER and the forecast demand to develop a predispatch profile which could be identified in advance, recognising that some operational requirements might result in modifications to these schedules during actual operation. The DER provider would be compensated based on the agreed price for provision of the service and settled based on actual delivery.

## **8 Pricing for other services**

As the experience is gained with the simpler approaches additional pricing approaches for specific and most important ancillary services, can be incorporated, initially through a simple off market incentive based mechanism that reflects the value of the services, including a temporal element. Over time and as the market conditions and availability allows introduce locational value to the DER provision.

## **DER Management**

DER management can be viewed as having three primary components: planning, operations, and markets (in the case where a market exists - Newport). Since DER interacts with the grid electrically, and in fact may be managed to supply services to the grid, DER management is inextricably linked to grid operations and grid control specifically. Where markets exist for DER, the coupling of DER to operations and to markets means that these markets will be coupled to operations as well. This is especially true if real time residual markets exist, but even the use of forward markets impacts grid operations directly and through planning.

## DER Management Platform

The key role of the DER management platform is to ensure that the most economic and flexible use of DER consistent with customer expectations for choice and control is at all time compatible with the safe, reliable and secure operation of the overall system.

A DER Management platform could be developed that would support the required technical functionality and incorporate it as part of the functionality provided to assist in facilitating and supporting a range of different markets, including a dNOM and a distribution level energy market. In addition to the technical functionality that is required to operate the power system efficiently and reliably the DER management platform will need to incorporate the mechanism to allow seamless interaction with DER at whatever level is appropriate for the overall stage of development of DER, for example whether it is through aggregation of DER resources provided by a third party or even ultimately resources at a relatively low level within the networks.

Essentially a DER management platform would provide a flexible basis to allow innovative development of products and services incorporating DER and facilitating their interaction with alternative markets, potentially including each of the four markets identified earlier, but allowing for development of others. It would therefore include a consolidated system with standard communications and data protocols that would allow devices to interact with it in a consistent and simple manner in whatever platform or market arrangement they would choose to be part of in the future.

### Functions of DER Management Platform

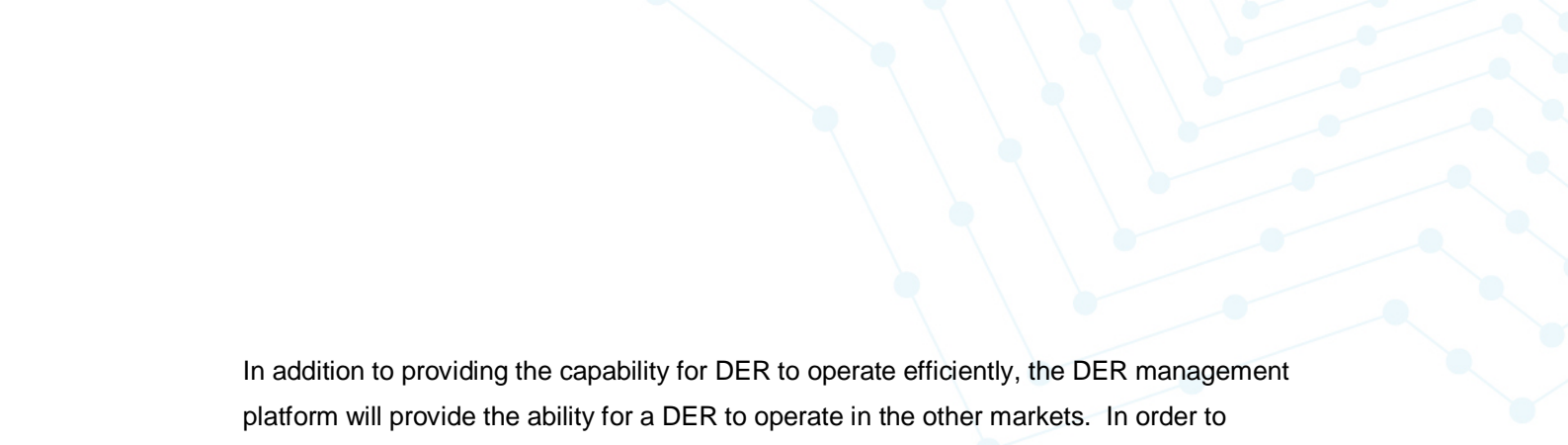
The following functionality would ultimately be required:

- **Provide interface for DER Status and Control:**

As described in the technical requirements, information on the status of DER is important for the management of the overall network, and the automated control of DER (as part of a commercial arrangement with the DER provider or an aggregator) to optimise the overall performance of the system will be a desirable feature of an efficient network operations. Whether or not a particular DER provider will choose to operate their DER in this manner it will be necessary for the platform to provide a consistent interface able to provide this capability in order to provide customers with the maximum flexibility and the potential for the system to achieve maximum efficiency.

- **Facilitate DER Market interaction:**





In addition to providing the capability for DER to operate efficiently, the DER management platform will provide the ability for a DER to operate in the other markets. In order to participate and achieve value from these markets it will be necessary for their output to be measured for settlements and depending on the services to be offered, it may be necessary to manage their contribution, either as an automated response to incentives generated by the particular market in which they operate, or by a service provider that is utilising their DER to provide a service.

- **Optimising the various DER output options:**

This is an extension of the capability for managing the overall performance of the network and optimising utilisation of the available DER to achieve maximum efficiency from its operation. However, the DER management platform potentially provides a basis for DER to operate in alternative markets, or to meet specific owners or service providers' objectives, that need to be factored into the operation of the overall system. Additionally, many of the DER resources have the capacity to operate in alternative markets, and there will be the need to provide a platform that automates or simplifies any decisions required regarding the preferred market in which to operate for a particular time. This may be quite a complex assessment that requires integrated forecasts and detail for the whole system.

- **Ability to support marginal locational pricing:**

Ultimately for the most efficient operation of the system accurate price signals will need to be presented to allow the most efficient customer and DER response. Ideally this could be expected to translate to the need to provide some form of locational marginal pricing at each point in the network to most accurately reflect this value, in other words prices that change dynamically with time, and are different for each location within the network to reflect the marginal cost of consumption at that location. The platform will need to be capable of informing and settling sophisticated forms of pricing, and potentially create the marginal prices in a form suitable for use in alternative markets.

- **Ability to support 3rd parties (e.g. retailers, DNOs, aggregators, etc.) interaction with both the platform and the end customer's resources:**

It is anticipated that there will be a number of different service providers seeking to utilise various DER by aggregation and additional value added services to deliver benefits for all connected customers operating in one, or in any of the other markets. In order to do this, they will need access to the individual DER, and it could be expected that all interaction between the third-party supplier and the individual DER would best be achieved on a consistent and standard basis through a common DER platform. This would allow maximum flexibility for the

third-party providers to operate most competitively, and not be constrained from changing their services as innovation develops, or alternatively would not prevent a DER seeking to offer services to another third-party provider if this was more competitive.

- **Ability to manage DER resources directly based on tariff and/or contractual limits:**

Direct control of DER resources through the DER platform would not generally be the preferred mode of operation, unless contracts were in place specifically providing for this as a service from the DER. Allowance will need to be made for extreme circumstances including unexpected system operating events where direct control is necessary, or is beneficial to the DER, for example to ensure that they do not violate a contractual obligation, a critical system constraint or do not operate in a regime which would result in very adverse outcomes because of the particular tariff arrangements that are in place for them. Therefore, the capacity and protocols will need to be established in which the DER Platform has the ability for direct control of DER when necessary.

It is important to note that the main intent of the DER is to provide a flexible platform that maximises the ability for DER to interact with the market and contribute to the optimal overall performance. It brings together the multi-faceted and complex needs of the power system by achieving this in the context of providing a safe and reliable electricity supply. At all times the system is operated in accordance with the technical requirements, using the available DER to achieve this in the most efficient manner. However, there are likely to be occasions when the needs for control of DER needs to interact and perhaps override pricing conditions to ensure that the grid remains stable and operable.

### **Staging of DER management platform development**

The development of a DER Management Platform will be complex, and in line with the development and transformation of the network could be achieved through a staged process that implements development to match the priority and pace of the industry transformation. With this in mind the following represents a potential staging.

#### **STAGE 1:** Implementation of:

- demand management response capability;
- hosting analysis;
- storage integration;
- DER managed by platform automatically to maximise economic value;

- provide voltage control and ensure stability and forecasting and use of forecasts in setting up the system;

**STAGE 2:** Would involve further development but essentially building on the capability described in Stage 1 with additional functionality and complexity. This may involve:

- More optimisation with a much greater number of resources, and more complex optimisation algorithms. In essence, this would involve developing a short term forecast for the potential use of DER based on a larger range of DER at lower levels within the network, and developing a pre-dispatch schedule and later issuing signals to DER to optimise their operation;
- DER allowed to operate directly in a market, initially restricted to connection of large resources to the wholesale market through bids, with the platform facilitating this process;
- A retail energy market is active with nodal prices;
- DERM balances at a local level and integrates with the WEM.
- More sophisticated hosting analysis is undertaken including more advanced planning that would identify the form and location of DER or other efficient mechanisms for increasing current hosting capacity provide longer term benefits.

**STAGE 3:**

- The distribution network operator develops non-wires scenarios as alternatives for networks;
- Publishes information regarding the preferred locations for the establishment of DER and awaits responses from participants to the incentives;
- Forecast operation becomes close to real time also with geographical granularity;
- DER coordinates with sophisticated dNOM which essentially automates the process of optimised grid operations using lots of resources, information and control on an automated basis; and
- A full range of ancillary services is transacted through a dNOM with effective price signals.

It is worth noting some of the disparities with the above views compared to some of the other reports, particularly in relation to the timescales assumed for the development of a fully nodal spot price market at the distribution level. Most of the reports are much more cautious regarding the timescale for this development, and in fact whether it will ever be justified in its own right. Nevertheless, this is only one of the components where it is seen that future value can be achieved through implementation of a DER management platform.

## Aligning the International Reports


As has already been observed each of the International Reports examine the approach to future markets and platforms in a slightly different way.

One of the key questions from the perspective of the Roadmap is whether or not a dNOM can or should exist in isolation of or in conjunction with a more sophisticated distribution energy market. This is important because the network sector will have little or no control over this development, it is likely to be protracted, and if possible it would be desirable to pursue a standalone dNOM in the absence of any further development.

TCR consider the Distribution Energy Market (DEM) as the potential longer term extension of a NOM and dNOM if granular nodal prices are able to be implemented and introduced successfully. It is suggested that a dNOM could exist without the development of a DEM, but acknowledges that the most likely outcome in the longer term would be for both markets to emerge. The TCR Report appears to generally consider the development of a DEM (implemented through a digital market platform with granular nodal pricing) to be all encompassing and to provide all the functionality required to allow operation of the DER in an optimised manner from a network perspective. In other words, if a DEM was in place with nodal prices, then the dNOM would not essentially be a different mechanism, but an integrated part of this potentially more sophisticated market.

A further question arises as to whether the case could be made for this development. It would appear that the functionality for a dNOM is very similar to that for a DEM. An alternative perspective is that both would best be supported by the DMP, which essentially provides all the infrastructure, communications, information and IT systems to support any form of market. It provides the basis for the transactive energy systems which are the basis for a dNOM and the DEM. In other words, the significant decision to be taken would be the decision to implement a DMP, as this would represent the major cost, and could potentially facilitate both the DEM and/or dNOM at a relatively smaller incremental cost.

The Strategen and Newport reports have a stronger focus on the development of the DERMS; after the essential components of a NOM (not a dNOM) are achieved. This is seen as the functionally rich platform that would allow most of the capability necessary to optimise the use of DER, including more operational aspects such as the planning, system operation and market development and operation functions. This focus is possibly based on a stronger focus on the functional and operational requirements of networks, compared with TCR's focus of efficient nodal pricing operating across markets. Both views have merit and need to be considered carefully together.



The Newport report also addresses the future development more from an operational and structural perspective, rather than a detailed investigation of markets. It identifies the DERMS as a functionally rich, long term solution that would be required to achieve all of the benefits from the DER in a technically feasible manner (potentially from the viewpoint of networks playing a more central role in the orchestration of DERs). It also considers system architecture more completely than the TCR report for example. There is a degree of overlap between system architecture in Newport's description of the future requirements, and the treatment of the DMP in the TCR and Strategen reports.

Newport provides additional detail on the functions and relationships between the various entities that will need to be considered in the future. More consideration is given to system architecture and functional relationships in a subsequent section of this document.

## **Conclusions and issues arising from market development**

There are some conclusions that are drawn by each of the International Reports in relation to the development and use of markets to identify and deliver the value from the DER to participants:

### **Evolutionary development**

Markets are complex to establish and require significant development of data and supporting systems, as well as requiring changes to the way participants interact, as well as regulations. Therefore it is expected that the development of markets should be evolutionary, with successive developments taking place as the benefits from the previous implementations are proven, and the potential benefit from the subsequent change is clearer.

In relation to capturing network benefits this conclusion is particularly relevant. Complexity may not deliver benefits, particularly for example moving to fully nodal locational spot pricing. Additionally, it would seem logical to focus initially on the areas where greatest benefit can be achieved. Newport suggests that 80% of the benefit of DER in the US will be achieved through the deferral of network investment, and as a consequence the initial focus could be on ensuring that this benefit can be captured and rewarded, initially on a locational, geographically targeted basis. This is also desirable from the perspective that it is the simplest market mechanism to achieve, as it does not require the advanced forms of real time markets, at least in the first instance. These would be required for the shorter term operational benefits but their development could be staged as discussed above.

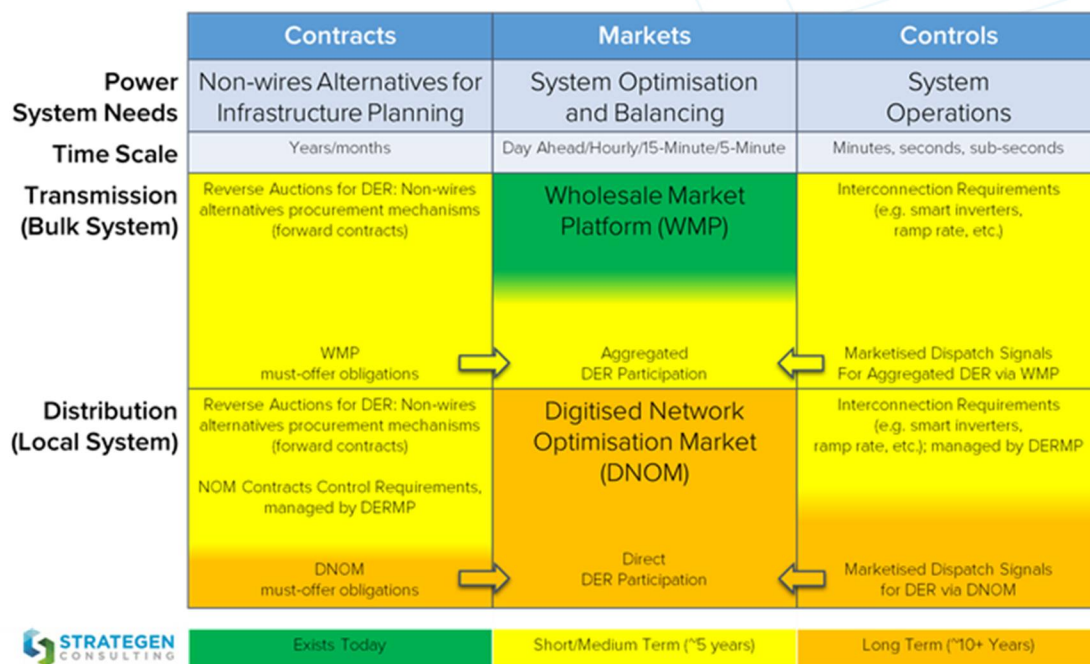


Figure 9: Evolution of optimisation and markets (Strategen)

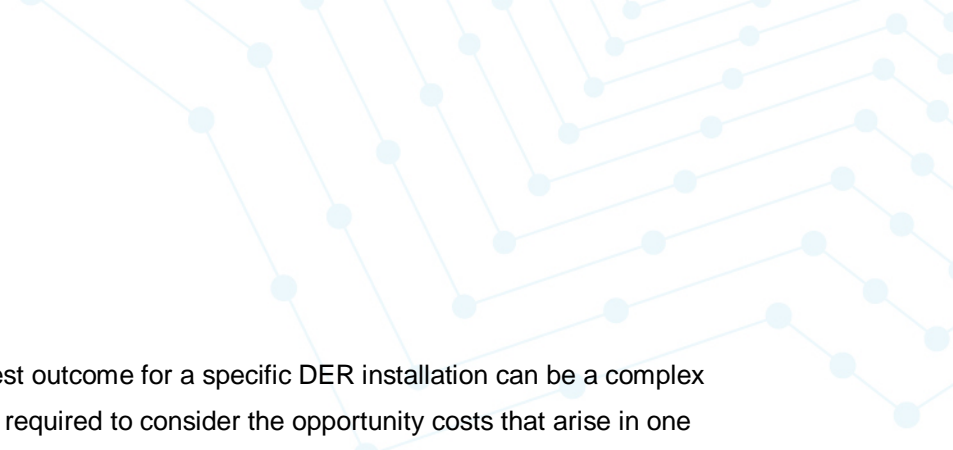
It is entirely possible that sophisticated market approaches to achieving the short run benefits may never be required, as 80% of the benefit delivered to the network by DER will probably be achieved with deferral, and simpler mechanisms may be adopted to achieve some of the short-run benefits.

Figure 9 outlines the approach taken by Strategen in considering a possible evolutionary approach to the future development of optimisation and platforms. This is similar to the views expressed by the other consultants for various aspects of the future development (including that proposed by Newport in Figure 5 for example).

### Different capability

There is a diverse range of DERs, and with further innovation, this could be further extended. Not all types DERs are suitable for providing services in all of the above markets, while DERs located at different points throughout the network may be unable to offer services in all markets.

On the other hand, there are a range of DERs that could offer services in multiple markets, and, in some cases, are capable of providing value in multiple markets at the same time. The most obvious example of this is any DER that provides energy as this can provide value in each of the above markets simultaneously (though this is dependent on market needs at any particular time). In some cases, the value is dictated by the guarantee of availability at a future time period.



This means that achieving the best outcome for a specific DER installation can be a complex optimisation task, with the owner required to consider the opportunity costs that arise in one market when determining which market it should be operated in. With a range of new services developing, this complexity is only expected to increase, pointing to the potential for more sophisticated market arrangements in the future to maximise the benefit achieved from single DER installations and from them collectively.

### **Operational needs**

The development of any market for DER must be cognisant of the importance of ensuring that it aligns with the operational needs of the distribution system. This is a common challenge in the development of wholesale electricity markets where the need to ensure that high levels of reliability and security are maintained is paramount in market design. Similarly, distribution markets need to align with operational needs, although these may be slightly different at the lower voltage levels.

Depending on the aspirations of the scope of the markets being developed they may need to provide satisfactory operating outcomes over a range of time scales, including processes for ensuring efficient development of long term infrastructure that allows operation of the system in the future. The spot market, including any ancillary services markets, will need to ensure that there is sufficient operational control and flexibility to support the safe, reliable and secure real time operations, in addition to the primary market role of ensuring that this operation is achieved in the most economically efficient manner possible.

The key point though is that the market should provide the most economic operation for the desired level of safety, reliability, security and performance.

# Electricity system architecture

## Definition of electricity system architecture

A system architecture is the conceptual model that defines the components, structure, behaviour, qualities, properties, and essential limits of a system. An architecture description is a formal representation of a system. It can be the direct precursor to design, or it may be the highest level technical view of the system in either as-is form or envisioned future form. A key difference between an architecture and a design is that an architecture allows multiple possible implementations, whereas a design allows only one.

System architectures consist of three types of elements: abstract (black box) components, structures, and externally visible properties.

In their reports Newport and Strategen focus on system architecture, and use it to identify the key future requirements, and particularly to make the point that there must be a focus on all intersecting and interacting activities of the new complex power system to achieve the desired customer, technical and commercial outcomes in a balanced way.

## Components

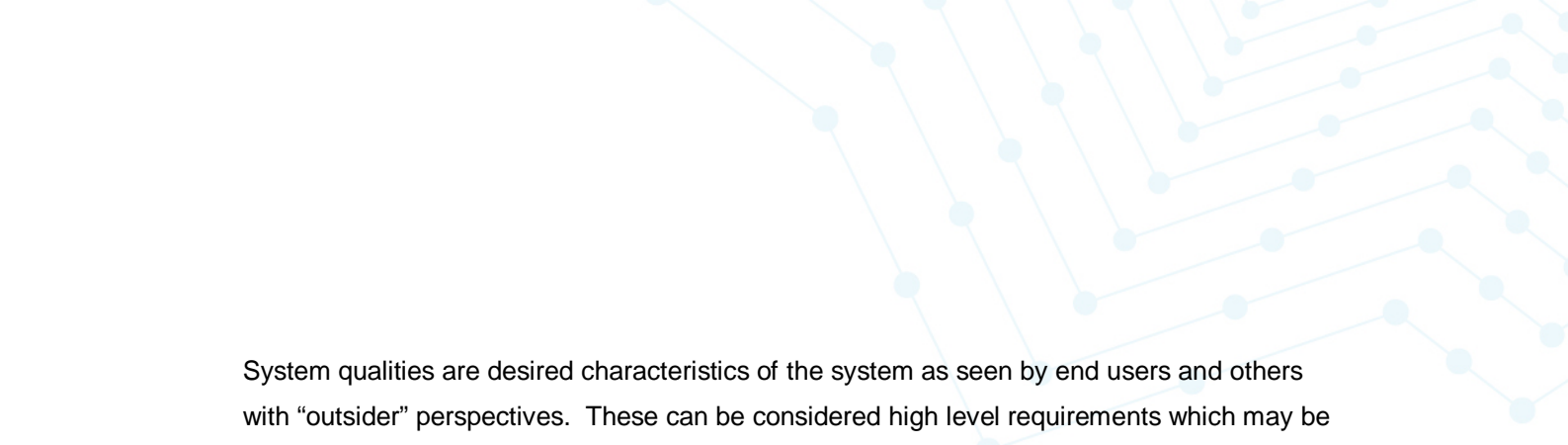
Components are the objects (devices, systems, organisations) that comprise the tangible aspects of a system. System architecture treats components from an external standpoint, meaning that the internal workings of a component are not of concern, and are not specified by architecture. Implementations are the domain of the component designers and must not be constrained any more than absolutely necessary. Components are defined in terms of function and externally visible properties.

Structure defines the relationships among components, including how they are connected, how they relate to each other, and how components act in groups. Structure itself has properties, and some of the goals of system architecture are to identify constraints inherent in legacy structure, determine minimal change in legacy structure to relieve constraints, and specification of new structures to enable advanced capabilities.

System architecture considers three levels of externally visible properties;

- the properties of the components;
- the properties of the structures, and;
- the properties of the system that arises from interconnecting components via structures.





System qualities are desired characteristics of the system as seen by end users and others with “outsider” perspectives. These can be considered high level requirements which may be expressed qualitatively or quantitatively. Generally, the number of qualities selected for a system is small, and one of the challenges is to choose a set that is comprehensive in nature and that have minimal overlap.

System properties are characteristics of the system as a whole as seen by “insiders” (developers, product providers, system integrators, owners, builders and operators of the system) that combine to provide the system qualities or enable them to be manifested. System properties emerge from system components and structures, each of which has its own set of properties. In practice, a complex system will have a large number of desired properties.

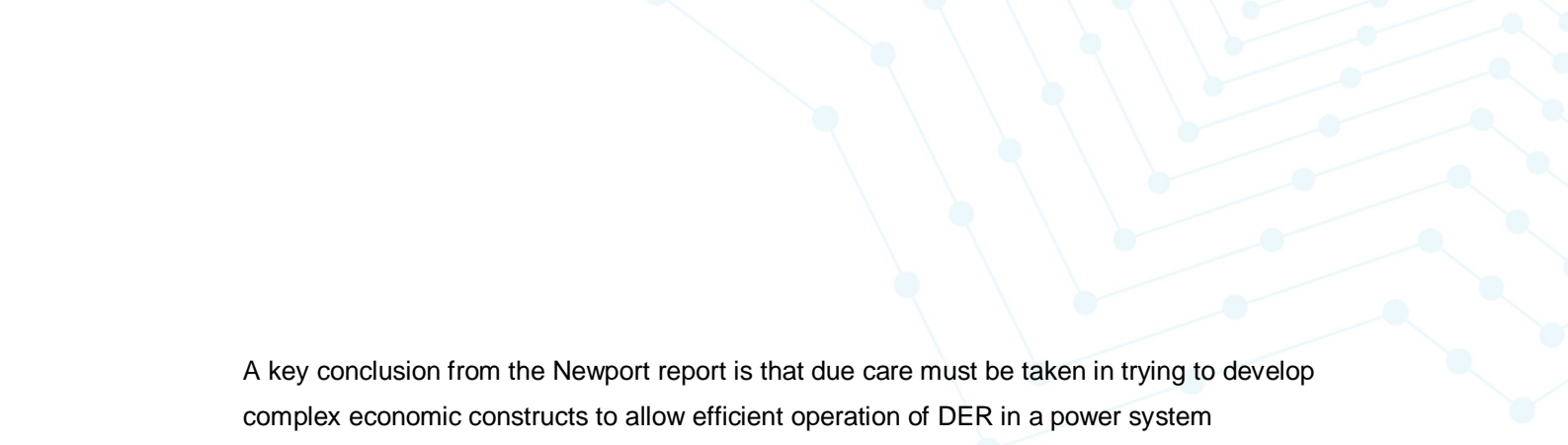
## Report findings

In their report Newport notes that Grid Architecture combines the disciplines of system architecture, software architecture, network theory, as well as control engineering and applies them to electric power grids. The structural aspects of grids are important because structure sets the essential bounds on system behaviour. Existing grids have inherited existing structures, some of which must be changed to enable new capabilities. The grid must be treated as a network of interconnected structures that includes electric circuit structure, industry structure, market and regulatory structure, information and communication system structure, control and coordination structures, and potentially the interactions with other industries and systems.

The primary purpose of developing a grid architecture is to manage the complexity and its most important outcome is the insight needed to make superior decisions about investment, planning, design, operation, and regulation of power grids. Grid Architecture provides the big picture view of the grid and defines the top level and large scale decisions needed before focusing on individual elements of the grid, such as the IT systems or control networks.

The Newport report notes the considerable technical complexity involved in power systems that is not really considered in the other reports, which take a more economic perspective on the development of markets. Newport notes that developing future arrangements for a DMP or DERMS involves more detailed consideration of the relationships between the parties and the challenges that will exist in the real world in emulating the ideal theoretical outcomes. It suggests that that arrangements may need to evolve as experience is gained and the need to integrate more DER and achieve more benefit from it emerges.

It considers the evolution around the development of control functionality and the approaches that may be adopted for overall network control for the system.



A key conclusion from the Newport report is that due care must be taken in trying to develop complex economic constructs to allow efficient operation of DER in a power system environment. There are many practical complexities associated with ensuring secure and reliable operation of the power system that may be compromised by a poor system architecture, or an ideal market solution that then needs to have significant regulatory overlays to make it work.

Strategen has taken a more detailed approach to the consideration of System Architecture. They discuss architecture in the context of the foundation that must be addressed regardless of the final architecture, product selection, or implementation methodology. The most critical elements are:

- **Messaging structure and format;**

The messaging structure determines what information is available to IGMS components and what data is passed between them. The message structure will also influence the frequency and volume of message transactions between components. For example, messages with voltage information might be streamed between a SCADA front end processor and an operations console, while those same messages might be batched to a profiling or analytics application. Messages must have a specific structure to support the volume of data that will flow through the system within the latency that is required. Traditional API structures may rearrange the incoming data to match a given application's needs, but tend to add latency and processing overhead.

- **Grid connectivity model**

An accurate grid connectivity model from the substation down to the meter is foundational for safe and accurate operations, optimisation, and forecasting. This includes the phase(s) that customer equipment is attached to, the path that the equipment is supplied through, and the geo-physical location of the equipment. It also includes any customer owned devices that participate in the grid through any program (e.g. demand side management, storage, vehicle charging, distributed generation, etc.). The model must not only be accurate, but must also be temporally correct (i.e. showing changes in switch positions over time) and kept up to date with minimal latency. An additional aspect of the connectivity model is the need to have device and conductor characteristics available for each item on the path to the customer. The characteristics need to include static, dynamic, transient, and forecasting related modelling information, so that the system can support optimisation operations, restoration, and engineering.

- **Common storage for master data;**

The IGMS also requires a place to hold all of the master data. A common data store prevents the IGMS from needing to obtain key data elements from disparate systems of record. The added processing time, messaging latency, and other overhead associated with distributing data across multiple data owners would result in a system that is forever compromised in what it can do. Most days, when nothing is going wrong, this probably will not be an issue. It is really only on the days when there are cascading issues in the grid (e.g. major forest fire, mud slides, etc.) that the design compromises will have a major impact on the operation of the system. Unfortunately, those are the days when the performance of the system is most critical to the operator. It is not enough to have a messaging structure and a shared place to store master data.

- **Common data model;**

A common data model is also required. Many of the Apps on the IGMS platform will demand response data directly from the data store. To this end the actual data model in the data store has to be known and available. Effective data models have well considered relationships between the data elements that are optimised around application activities and performance requirements, not idealised storage principles such as third normal form. A common data model facilitates a consistent approach across applications.

- **Ubiquitous IP-based communication between systems and devices;**

IP-based communications between systems and devices allows the IGMS to use a wide variety of protocols and interaction. For example, a remote intelligent switch might use 61850 SCL and MMS for interaction with a SCADA front end processor, 61850/DNP3 Routable GOOSE for teaming with other switches, and DDS-based OpenFMB to obtain voltage, load, and generation data from nearby meters and inverters. IP communications must extend from the central domain, through the distributed domain, all the way to the edge. Using IP allows a single approach to addressing them, and provides an abstraction between application protocols and the underlying network technologies. This abstraction will be critical to allowing the independent evolution of the IGMS and the telecommunications infrastructure.

These items are “no regrets” items for the IGMS and the future. Regardless of the decisions on the physical implementation, getting these foundational elements correct will make a huge difference in the future operation of the grid and the hosting capacity for DER in the future.

## Industry Structure

### Determining industry structure

At a high level the following aspects are important when considering a preferred industry structure and supporting system architecture. Generally it is important to:

- Start with policy and user requirements;
- Account for emerging trends as nearly as possible; and
- Connect these issues to architectural elements in a systematic and measurable way

More specifically it is necessary to consider DER as a portfolio, and determine the capabilities, and the network services, that can be delivered by DER, and which will have value for the networks.

It is important to consider the impact of basic structure early. Industry structure (with its inherent association with organization roles and responsibilities) is the basic context in which to consider the changes to other structures (markets, control and coordination, communications).

Markets, system operations and controls cannot be treated separately as they are each interrelating parts of the spectrum that makes up the entire electricity system. It is important to understand how temporal and spatial granularity, DER-based value streams, and implementation capabilities impact the trade-offs for the specific functionality that resides in each element of the spectrum.

Structure has impact on the flow of information related to the physical system and information related to financial transactions. These information streams and the flow of dispatch and coordination information exist in consequence to these structures. It is vital to understand the impact of structure, and to specify the structures that best match the top-level policies and user needs. Not until this is achieved and increasingly more detailed refinement of structure determined can designs be developed with a high level of confidence by the responsible parties, be they policy makers, utilities, regulators, product and platform developers, or system integrators.

### Possible industry structure in Australia

The structure of the industry in Australia is also likely to require a measured transition process because of the timeframes and complexity involved. The physical operation of the grid is separate from the markets, but integration of the two is important and different communications required.

To assist in exploring integrated architecture required under different industry structures Newport provides two potential views of industry structure, building upon their experience in guiding U.S. based network transformation that may be helpful in guiding Australian evolution. These models are not provided as recommended or preferred structures but are instead intended to provide examples of the communications and integrated structures that are required in different industry structures. The intended point of these examples is to provide a practical but hypothetical illustration of the manner in which changes and communication infrastructure need to occur to implement structural transformation in the Australian context.

The initial model includes a structure that has DNSP as coordinating DER through to AEMO. The latter model includes a description of structure whereby DNSPs might operate local spot markets. The coordinating structures would apply regardless of how emerging distribution level markets were to operate.

Figure 10a and 10b below shows an industry structure diagram for the as-is and potential first phase evolution of the industry.

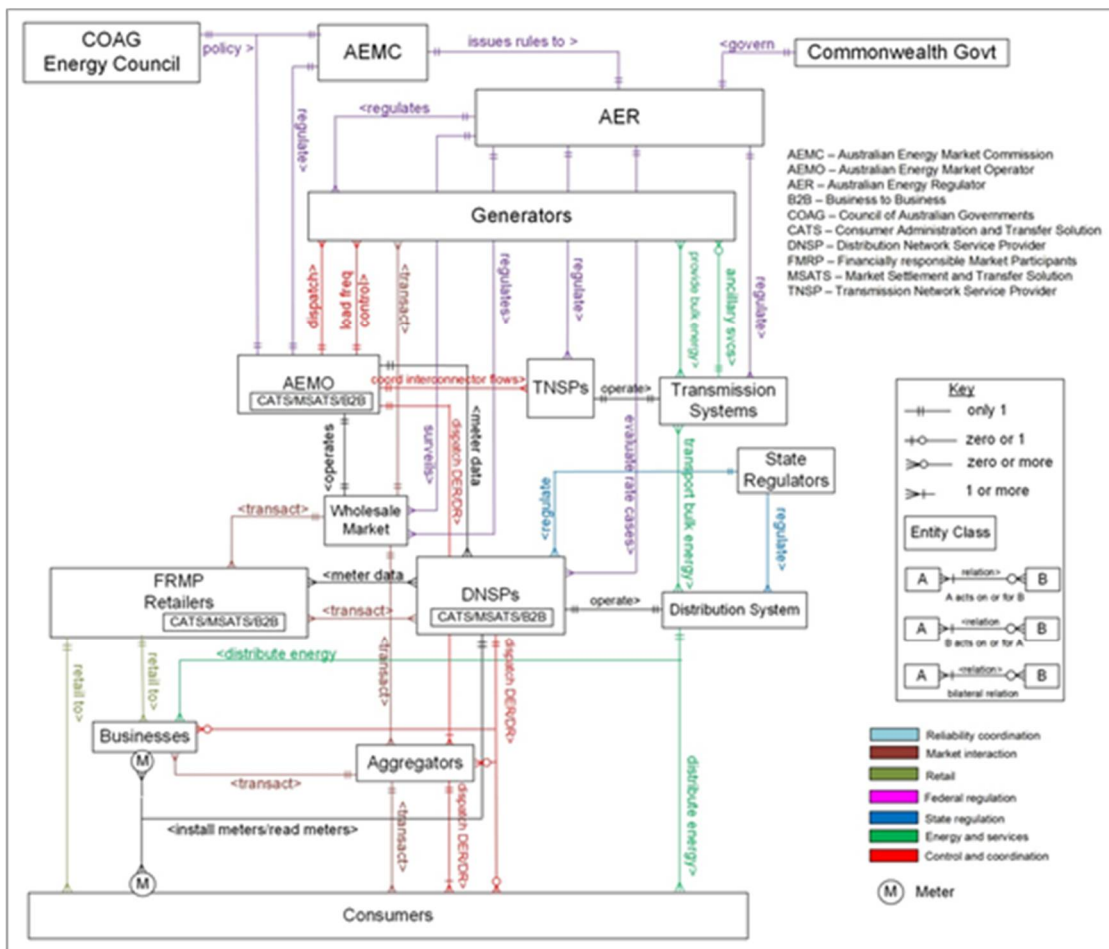


Figure 10a: Simplified As-Is Industry Structure diagram (Newport)

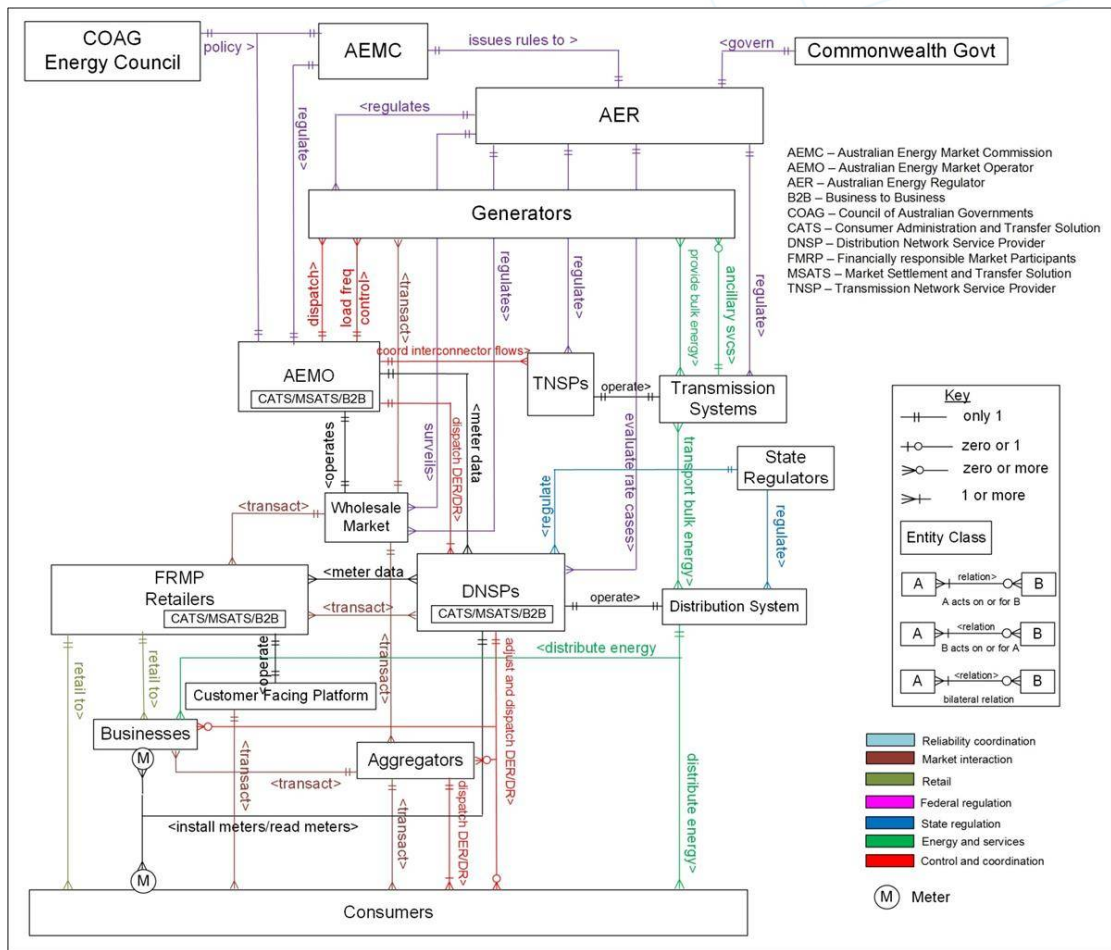


Figure 10b: Possible first stage of industry structure (Newport)

In this model (Figure 10b) DER operations are coordinated through the DNSPs. This avoids the need to consolidate distribution grid state and DER information to AEMO, thus avoiding a potential communication and information scaling problem. It also avoids direct connectivity from DER endpoints all the way to AEMO, which presents significant cybersecurity issues. This approach requires new communication frameworks and protocols between DNSPs, TNSPs and AEMO, and between DNSPs and the retailer/aggregators and a growing range of customer/prosumers. Figure 11 compares the coordination structure of the current model to the coordination structure for this potential model.

This structure eliminates potential distribution reliability issues by avoiding the direct association between DER and the wholesale market. Market structure has not been changed, so it is important to understand that physical coordination and financial coordination are no longer bound to the same structural model. Under Newport’s conceptual model, the Transmission system operator (TSO) still has telemetry and dispatch control over potentially tens of thousands of wholesale market-participating DER. However, the TSO has no visibility to distribution circuits

and system conditions while also only having limited information at best about the impacts its dispatches of DERs may have on distribution system conditions. This requires communication and real-time operating procedures between the distribution network operator (represented here by the DNSP which operates as what Newport would define as a Minimal Distribution System Operator - DSO) and the TSO, and between the distribution network operator (DNSP) and the DER providers/customers in the distribution network operator's local area.

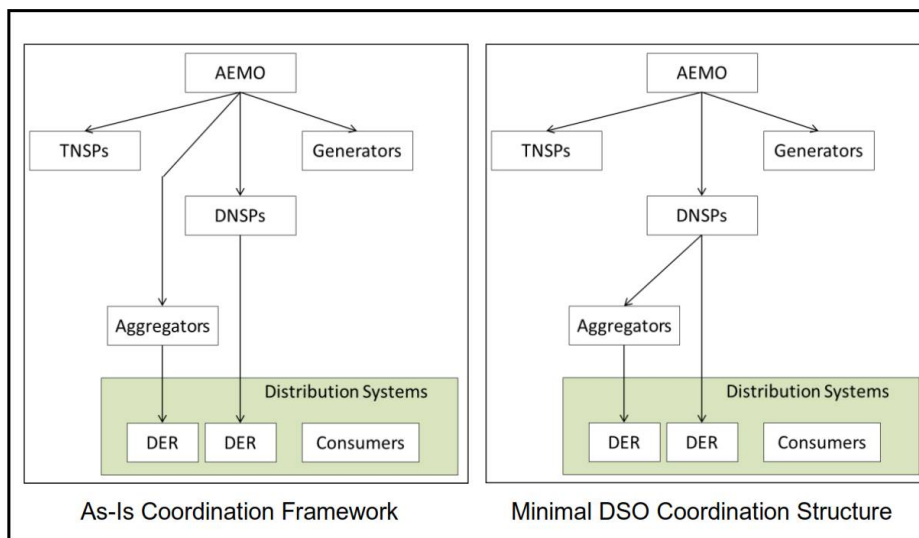


Figure 11: Minimal DSO Concept - Relationships between parties compared to the present (current on left) – Newport

Figure 12 (below) shows a subsequent potential stage of evolution where a layered market structure has been introduced. The wholesale market is the same, but new distribution level markets now accommodate DER on a local distribution service area basis. These markets facilitate local (distribution-level) bilateral energy transactions and also support dynamic trading of energy and DER services at the localised network level. In Newport's Total DSO model, the distribution network operator (DNSP) functions as the sole scheduling coordinator to submit a single bid/net schedule to the TSO at each T-D Interface reflecting the aggregation of all DERs within each network area.

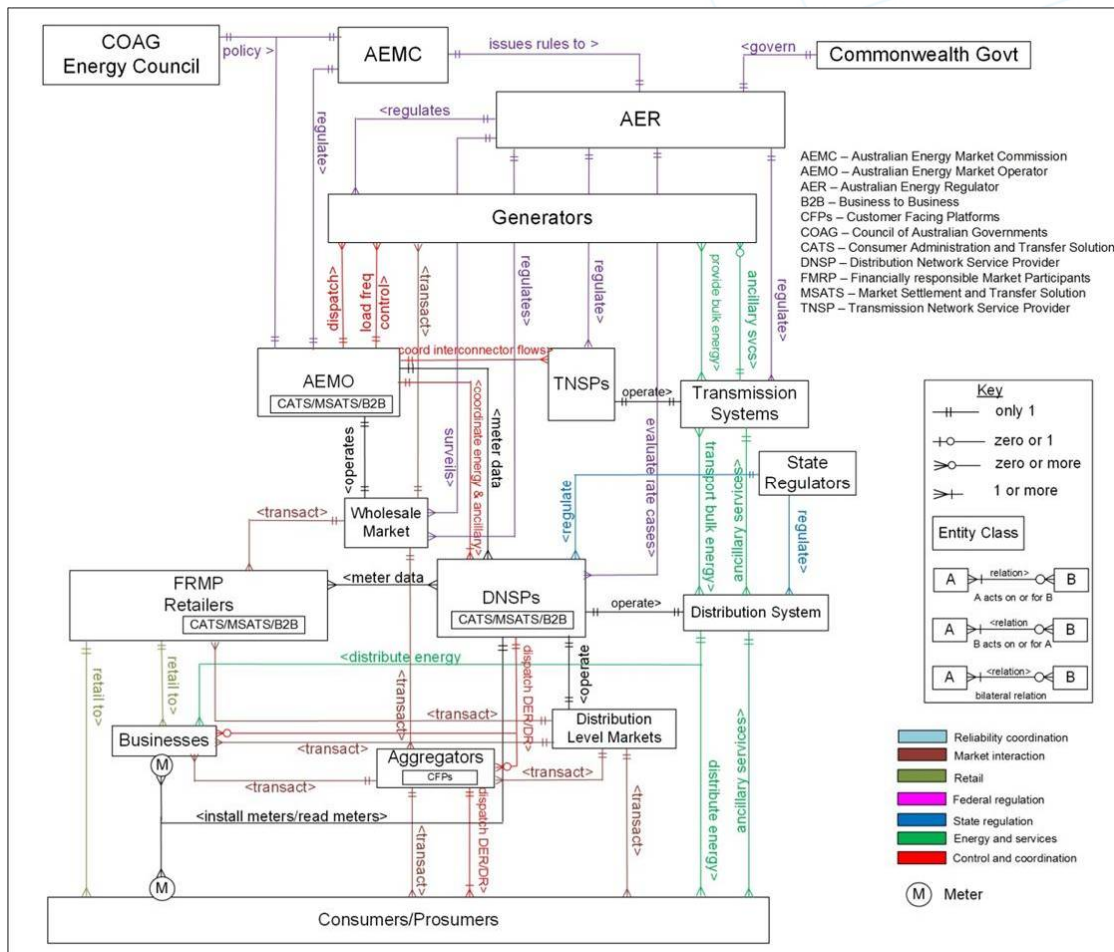


Figure 12: Layered approach to energy markets (Newport)

In this approach, optimisation at any given layer of the system only requires visibility to the interface points with the adjacent layers above and below. This is intended to reduce complexity associated with managing and having visibility to a growing range of DERs.

Figure 13 subsequently illustrates both information flows (including control and coordination flows) and function allocations at the distribution level. This model indicates the need for a number of information flow paths, over both utility owned and non-utility-owned communication networks. A model of this type is useful for considering comparing possible structures for integrated communication, coordination and control.

The Newport work explores various control and communication structures which are possible in the future, including:

- conventional hub and spoke;
- layered hierarchical or laminar approach; or
- highly distributed communication and control structures.



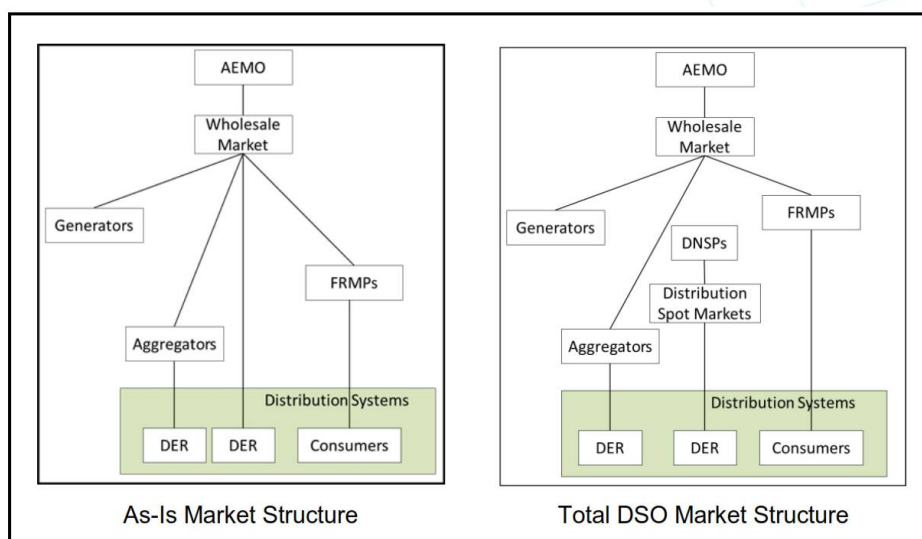


Figure 13: Coordination with longer term market arrangements (Newport)

As explored earlier in this report, considering how networks might orchestrate DER operations can aid in the efficient operation of networks and the broader electricity value chain, however, how this fits with Australia's existing disaggregated market structures requires further attention. These examples are intended to provide practical illustrations of the complexity and level of integration of communications and operations that are required to efficiently coordinate a growing fleet of DERs at the distribution level of the electricity system.



## Conclusions for *the Roadmap*

### International guidance

The International Reports provided three separate and very useful perspectives on the challenges facing the industry in accommodating a high DER future in Australia. They each provided a status of the considerations in other jurisdictions, primarily the US (but also to a slight degree in Europe), and an explanation of the directions being taken in the most relevant jurisdictions that are most advanced in dealing with this issue.

They each used their considerable experience and knowledge of the Australian system to identify the directional changes that might be appropriate in managing the change to a more dynamic future environment.

This provided a comprehensive basis for *the Roadmap* to draw specific shorter-term conclusions for establishing key milestones and actions for developing and implementing the appropriate platforms to enable the development of the best possible structures for 2027 and beyond.

One of the challenges in interpreting the International Reports is that they all used a slightly different terminology, and brought different knowledge, experiences and perspectives to bear on the issue. In this context it should not be construed that the term “challenge” as having a negative connotation, as to the contrary these different perspectives provided three detailed insights that has allowed a much more broader analysis of the possible future to be established with a much greater understanding of the potential challenges and issues to address once the implementation phase of *the Roadmap* commences.

It has not been possible, or indeed intended, to provide a complete distillation of all the material and nuances covered in the three International Reports. Rather the intent has been to draw out the key issues that have been instrumental in forming the key conclusions and recommendations included in the Roadmap, and most specifically supporting the key findings and milestones that have been proposed for Future Market Platforms and Network Optimisation, which are reproduced below.

## Key findings for Roadmap

### Finding one

Each of the International Reports pointed to the additional complexity in developing and operating the overall power system incorporating increasing levels of DER. There is a degree of complexity in enabling DER to connect at some locations in the network. Newport in particular highlighted the need to ensure that the various technical requirements needed to support reliability and security of supply are not forgotten in the desire to establish customer focused markets with a high degree of customer autonomy and flexibility.

This is not intended to infer that the requirements to ensure appropriate power system operation are inherently inconsistent with the development of markets, or the optimisation of the overall system to incorporate DER. Rather it signals the need to carefully consider the integration of the physical realities of power systems operations when developing energy market solutions for optimising the network.

These challenges have been recognised, and this report highlights that there are integrated solutions that can utilise the characteristics of DER, not only to facilitate connection of greater levels of DER than would otherwise not be possible, but also to alleviate some of the existing system constraints that would otherwise lead to costly network investment.

The important conclusion to be summarised from this is that an integrated planning and development process is required for the future efficient development of the power system alongside the innovation and DER development that will continually evolve. While the outcomes noted above are possible with a considered development that comprehends the various complexities and interactions this are unlikely to occur if there is too much focus on isolated development of one or other of the new features. This will also require new technology and innovation to best manage the complexity associated with the increased level of DER. Fortunately, these do exist, but will need to be developed further to address the specific issues raised in optimising the use and adoption of DER across networks.

The holistic and innovative approach will be essential for development of the distribution level markets of any form, since they are more complex in many ways than the development of the NEM.

**Finding 1: Integrating high levels of intermittent renewable energy and DERs markedly increases the complexity of network management and requires the holistic application of advanced technologies and tools to ensure stable and efficient operation.**

*The majority of Australians will continue to depend on the benefits provided by electricity transmission and distribution networks as they evolve to support a much wider range of energy sources. These core benefits include:*

- *sharing of energy resources, which provides customer value through network effects and economies of scale; and,*
- *enabling the natural diversity of millions of connected customer loads and generation to help instantaneously match supply and demand.*

*An increasing dependence on intermittent renewable energy sources and millions of DERs markedly increases the complexity of managing an electricity network. This requires the development of a new range of advanced planning, distributed intelligence and operational tools (section 10 of the Roadmap key concepts report). It also requires the holistic and systemic application of those tools to efficiently manage multi-directional electricity flows across the network while maintaining system stability.*

*The Roadmap distinguishes the systemic application of advanced new tools for this purpose as ANO (Advanced Network Operations). This avoids the lack of clarity that can arise by using the term Distribution System Operator (DSO) as it is defined in many different ways within the international literature. The Roadmap recognises that ANO technological functions will be increasingly necessary to ensure efficient management of Australian electricity networks that have high levels of renewable energy and DERs. It also recognises that many ANO functions may naturally arise as an extension of current utility functions.*

#### **Finding two**

Each of the reports provided significant evidence of the inherent capability of DERs to provide benefits for the networks, and discussed the broad range of services that they can provide, and the diversity of benefits that they can bring to improve the performance and operation of the networks. The diversity of the forms of DER, in terms of size, characteristics and locations means that ultimately greater benefits are possible through their coordinated or orchestrated use.

Additionally, the International Reports all noted that there are various ways of determining the value that DERs can provide. The most efficient outcomes are likely to be obtained if the DER providers can respond to value based, dynamic price signals that allow them to be compensated in accordance with this value. While careful consideration may need to be taken initially to ensure that markets are sufficiently competitive and liquid to achieve efficient outcomes, it is apparent that there are simple approaches that can be used to elicit sufficient DER services to progressively achieve improved levels of efficiency.

Each of the International Reports noted that the first steps for network businesses to achieve access to DER to improve overall performance could involve simple approaches to obtain access including procurement through contestable tendering processes or even regulated

procurement. This would be effective where such services could or avoid defer network investment and which could also provide access for a network to use in real time operations within the commercial conditions of a contract.

The networks will need to deploy sophisticated optimising algorithms to take advantage of the DER services that they have available. This will involve some system development activity which is outlined by Finding 2.

**Finding 2: The orchestration of DERs can provide valuable services that help optimise electricity network operation and provide customers with opportunities to participate in response to financial incentives.**

*Where well integrated, aggregated distributed energy resource sources can provide a cost-effective alternative to capital intensive network investments in specific locations. More advanced approaches to integrating distributed energy resources will also enable real time services to be provided that maximise the operational efficiency of the network.*

*Effective network and distributed energy resources co-optimisation involves customers allowing their privately owned distributed energy resources to provide an agreed service to the electricity network. This will generally be in the form of energy (or reactive power) at a time when the service can help reduce the costs or operational complexity of network operation. In most cases this will be automated either directly or through the customers' agent.*

*Methods for enabling network and distributed energy resources co-optimisation may include either the mandating of direct distributed energy resources control (perhaps as a condition of connection) or the network actively procuring it via market mechanisms. The market arrangements will initially be simple, perhaps involving a bilateral contract allowing manual control, or voluntary participant response. Arrangements may be between customers and networks directly and/or involving market actors specialising in distributed energy resources fleet management.*

*Where electricity networks are transformed to enable the orchestration of distributed energy resources, grid connected customers are likely to achieve the maximum benefits from their distributed energy resources investment by providing such services in return for the financial incentive.*

**Finding three**

Each of the International Reports identified the development of a Network Optimisation Market (or close variant) as an intermediate step in achieving a more automated and dynamic future market platform. There was some divergence in the anticipated and preferred long term outcomes, but they were equivocal as to whether a dNOM or a customer energy market would ultimately develop. Hence it was especially notable that not only was there general agreement

on the need to develop a NOM as an intermediate step, but there was also a high level of agreement on its general form and specification.

Each of the International Reports noted that a balanced set of objectives must be established to ensure that the required longer term outcome of improved efficiency and performance would be achieved for customer benefit. While the precise articulation of these varied slightly between the reports there was also a high degree of commonality between even the specific design features that were suggested as necessary, in part based on the experience gained in early consideration of approaches in the US. This leads to the conclusion that there is already a high degree of confidence relating to these features in a variety of different environments with different operating conditions that led directly to Finding 3.

**Finding 3: A range of market design features must be applied to ensure that customers, networks and society benefit from distributed energy resources orchestration.**

*The optimisation and orchestration of a decentralised and integrated electricity system involving millions of DERs will not just happen. Certain basic architectural principles must be implemented to create a NOM. For example, such a system must be:<sup>26</sup>*

- **Coordinated and self-optimising:** *The system must seamlessly enable distributed energy resources fleet 'orchestration' and self-optimisation at the customer level*
- **Technical and economic benefits:** *The system must enable the integration of DERs in a way that supports both power system reliability and economic efficiency*
- **Firmness of response:** *The system must be designed to ensure firmness of response from DERs at all critical times (with equivalent certainty to traditional network augmentation where it is relied on to avoid that expenditure)*
- **Non-discriminatory:** *The system must provide for non-discriminatory participation by qualified participants*
- **Transparent:** *The system must ensure the value of network optimisation opportunities is transparent and the benefits are received for actual distributed energy resources services provided*
- **Verifiable:** *The system must be observable and auditable at its interfaces*
- **Future proof:** *The system must be scalable, adaptable, and extensible across a number of devices, participants, and geographic extent*

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<sup>26</sup> Used with permission: Decision-Maker's Transactive Checklist, Gridwise Architecture Council, 2016

#### Finding four

One of the most common conclusions drawn throughout the International Reports on a variety of subject matters was the need for a staged process using small incremental steps, perhaps involving trials, but not progressing to a more advanced stage until there was clear operating experience and the benefits and suitability of the approach had been tested, with sufficient information provided to underpin progression to the next stage.

This progressive approach has been taken in all of the international examples cited. Even in New York where the initial approach was much more aggressive than elsewhere, the initial enthusiasm has been tempered by the realisation of both the complexity of the issues and the implications of an inappropriate development. This has always been the approach in California, where the experience of the 2000 Energy Crisis may have resulted in more measured approach to significant industry change.

The need for incremental change is both circumstantial and intentional. It is circumstantial because the development of DER continues such that it generally has not developed to the point where the largest benefits are yet possible. Thus, there is time available to develop the sophistication of the approaches in line with the rate of development and deployment of DER. This does mean however that it is important to establish a well-defined process now, rather than wait until significant levels of DER are implemented, and the lead time for measured development has been exhausted.

It is intentional because the risks of rapid and untested development are well understood. Even though there has been significant investigation carried out in a number of the jurisdictions studied in the International Reports it is patently clear that there is little or no actual operating experience in the development and operation of a successful Network Optimisation Market (NOM) in any environment that would allow this to be used as the basis for a detailed and advanced NOM specification. This leads to Finding 4:

**Finding 4: The form of the NOM must evolve to increasing levels of sophistication and scope as experience is gained and the approach is proven.**

*The conceptual benefits of co-optimised distributed energy resources and network functions have been investigated in several jurisdictions. However, there is only limited operating experience since there is significant lead time in developing the capability including the very significant amount of data that is required. Software algorithms and systems that utilise real time data are also essential ingredients of a fully operational approach to optimising the performance. There is also a trade-off between transaction costs and benefits of increasingly complex arrangements which need to be assessed progressively in the light of experience.*

*At the same time there are a range of essential functions that are extensions of the current distribution network responsibilities. These will provide the initial steps to unlock this value. Therefore, a staged approach is preferred, with successive development occurring when the benefits of the previous stage are identified and proven.*

#### **Finding five**

As noted previously, the International Reports all identified the need for a NOM, and were consistent in its form and to a significant extent the underlying detail of such markets.

They had similar perspectives on the long term development, but there were differences in their perspectives on whether there would be a separate dNOM or a Distribution Level Energy Market, and the precise relationship between them. But even with these longer term differences the NOM was seen as a key intermediate step in unlocking the value of DER, and depending on circumstances may be an end point in itself.

The International Reports were consistent in their perspective that development beyond a NOM was highly uncertain as it is possible that the benefits would not be sufficient to justify the costs and that further exploration of such post-NOM platforms is necessary.

The conclusion from this is that a NOM is a required step, whether or not there is a more advanced subsequent stage. Therefore finding 5 follows.

#### **Finding 5: The development of a NOM is a no regrets action.**

*There is an intrinsic relationship between a potential future distribution level energy market and the development of the NOM. This is because the same distributed energy resources can provide services and be compensated in both markets. While the ideal approach may be to develop consistent market arrangements for both purposes, this would require prejudging the future development of nascent energy markets and digital platforms. The development of NOM processes and structures represents a no-regrets approach which avoids unnecessary delays but would not foreclose the future potential for alternative market structures where they are justified.*



## 2017-27 Roadmap Milestones

*The Roadmap* outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions as outlined in Section 11 of the Electricity Network Transformation Roadmap Key Concepts Report (2016).

Importantly, it should be noted that the following Milestones are directly related to and dependent upon activities outlined earlier in Section 10, *Grid transformation* of the same report.

**Milestone 1:** By 2018, networks with very high distributed energy resources levels are implementing basic NOM functions to procure locational distributed energy resources services for network support, either directly from customers and/or through their agents.

There is a significant amount of preparatory work to develop the optimisation methodology and support it as required with distributed monitoring and control devices. Early consideration will be given to identifying beneficial locations and providing transparent information to participants about how they may contribute distributed energy resources capacity.


This will enable the development of a fleet of customer owned distributed energy resources that are orchestrated initially in a limited manner to defer network investment. The development will provide experience and facilitate an increased understanding of the commercial expectations of participants and the value provided through the distributed energy resources provision.

**Milestone 2:** By 2019, a basic set of ANO functions are performed where networks with very high distributed energy resources levels progressively implement advanced network planning tools, distributed grid intelligence and control and advanced network operation techniques.

This milestone introduces more sophisticated techniques for the utilisation of distributed energy resources. It is used as part of a coordinated and automated process for network management, for example, assisting in managing voltage excursions, responding to loading unbalance in real time or managing short term constraints, perhaps as part of an automated and intelligent control scheme to achieve integrated system operation.

This may involve initial trials using the fleet of distributed energy resources procured for the first milestone. Ultimately all new distributed energy resources would be procured with the expectation of being used with the more advanced functionality provided for this milestone.

**Milestone 3:** By 2020, collaborative projects demonstrating the integration of ANO functions and NOM procurements have validated direct and market based orchestration of DERs as a reliable non-network alternative.



There is enough distributed energy resources volume and utilisation in use, together with sufficient trials of advanced market procurement, to provide a clear demonstration that it has achieved its objectives.

This milestone implies that a rigorous review be undertaken to analyse the experience to date and would include technical assessments of the system optimisation algorithms and implementation, achievements of benefits, achievement of value by participants, and change in risk profile.

Ultimately the approach will be considered successful if it has met the needs of both networks and distributed energy resources providers.

**Milestone 4: By 2023, networks with very high distributed energy resources levels are performing an integrated set of ANO functions and NOM procurements as mainstream activities to ensure technical stability, economic efficiency and market animation.**

Based on the successful achievement of the preceding milestone, further measured development has occurred to embed ANO and NOM activities within mainstream network operations.

Based on benefit realisation over a sufficient period of time, this approach is considered to have been proven under all foreseeable circumstances as providing a technically stable and economically efficient means of integrating distributed energy resources into the network.

**Milestone 5: By 2027, a feasibility study, cost benefit analysis and conceptual design of a dNOM is complete**

Where there are clear economic benefits, there may be the potential to extend the scale of distributed energy resources participant involvement through the development of a dNOM. This could have the benefit of allowing smaller users to interact with a market for provision of their distributed energy resources. It could provide a more consistent and transparent basis for participation for all distributed energy resources providers.

However, it is also anticipated that there would be significant transaction costs. Additionally, there is the possibility towards the end of the NTR decade that consideration will have been given to the development of a distribution energy market, initiated by non-network stakeholders.

These, and other factors will fundamentally impact on whether or not the development of a dNOM will provide sufficient additional benefits to justify the costs. Furthermore, the evidence to support such a cost benefit analysis requires the active development of distributed energy resources markets and procurement of orchestration services by networks in the NOM as per the previous milestones.



## Concluding comments

The purpose of this report has been to draw on the knowledge and experience provided by three international consultants and documented in reports that were commissioned by CSIRO and CSIRO on behalf of Energy Networks Australia, as well as drawing upon broader Roadmap reports and source materials.

These reports have made a very valuable contribution to understanding the status of similar investigations in other jurisdictions, and the challenges that have emerged as DER has been employed in other jurisdictions.

Importantly the consultants who have authored the international reports each have first-hand knowledge and experience in dealing with these challenges and are involved in developing approaches in the more advanced and forward looking jurisdictions within the United States. As such their experience has been invaluable in developing approaches and planning investigations that need to be carried out in Australia as part of *the Roadmap* to ensure that Australia can be in a position to take the best advantage of the future, and to prepare fully for it.

Each of the consultants brought slightly different perspectives and background to the task, and this has meant immense value has been obtained, not only from those issues where consistency has been apparent, but also in interpreting the reasons for differences and utilising the different perspectives to identify the need for further analysis in the Australian context.

In addition to reporting on the information provided in the International Reports this report has made some interpretations and developed approaches to be further developed as the *Roadmap* unfolds.

However *the Roadmap* team expect to continue working closely with overseas experts as *the Roadmap* program progresses to ensure that we remain current with the latest thinking and employ it to maximum benefit in the Australian context.