

Designing DERtopia

**How do we get to a decentralised,
democratic grid from here?**

Total Environment Centre discussion paper
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Key message

With the boom in rooftop solar and other distributed energy resources (DER), the opportunity exists to change the dominant paradigm of centralised control of the energy system to one based on local resources and democratic governance — but this opportunity must be recognised and acted on quickly to prevent new energy being stuck in the old model. “Grid architecture” is the discourse through which this challenge is explored.

This discussion paper¹ is intended to lay out a vision, in the context of Australia's national electricity market (NEM), for a “bottom up” grid architecture suitable for a high distributed energy resources (DER) system, and to begin a conversation around a process for its development.² The intended audience is stakeholders engaged in NEM reform processes. We hope, through them, to assist the conversation around future market design by presenting a viable alternative grid architecture model which we believe better satisfies user preferences and decarbonisation efforts than the current paradigm.



But first, a word of caution. Discussions around grid architecture can quickly become very technical. Given the purpose of this paper, it is more important to initiate a conversation grounded in the lived experience and expressed interests of energy users than to haggle over detailed design considerations.

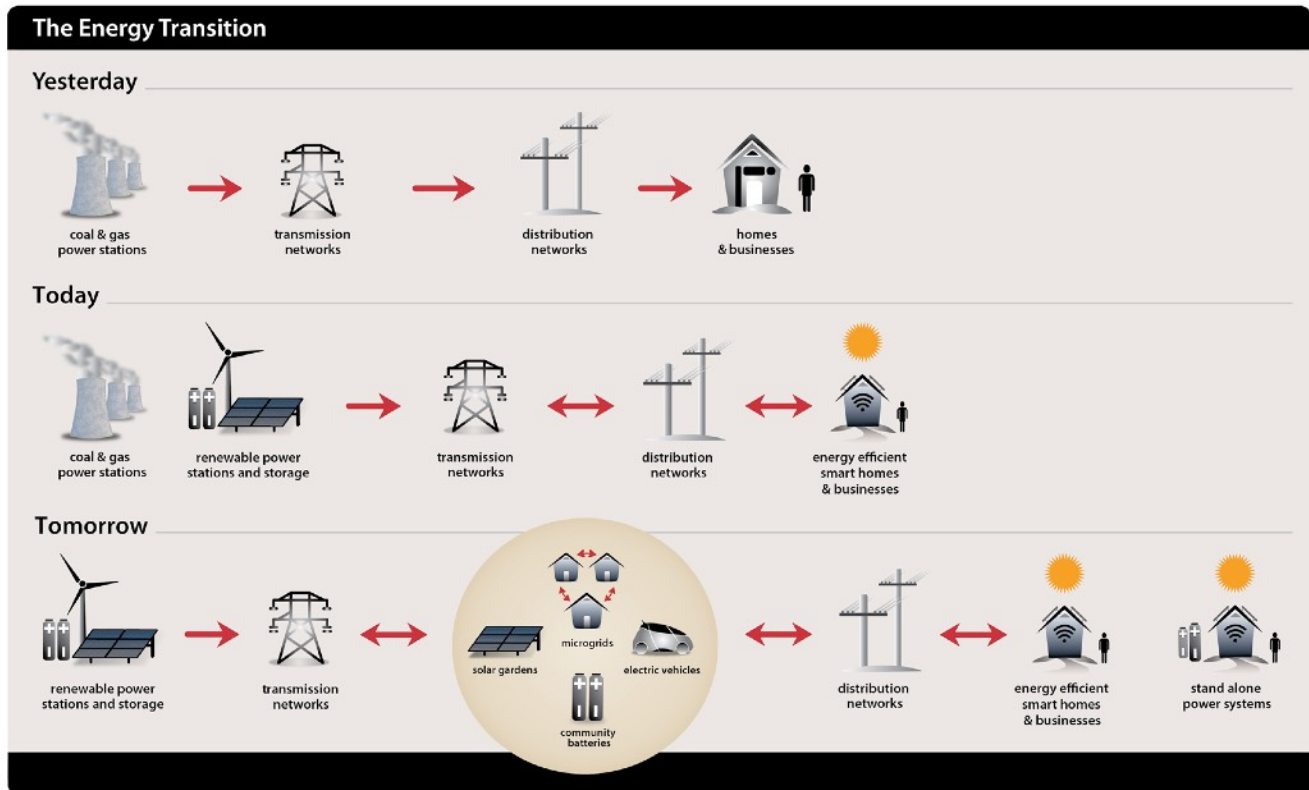
What are distributed energy resources?

By DER we refer not only to solar, batteries and electric vehicles (EVs) but anything that customers connected to distribution networks can do to at least partly manage their demand as well as supply. It also includes actions in front of the meter by networks themselves (such as community scale batteries) and by other parties (such as solar gardens). We would also include stand alone power systems (SAPS). Whether mid-scale generators connected to the distribution network constitute DER is debatable, since they generally lack behind the meter loads and respond to similar market signals as large-scale generators connected to the transmission network.

¹ A draft of this discussion paper was circulated to stakeholders in April 2021. Many thanks to everyone who provided comments feedback, especially Wendy Miller and Dr Gabrielle Kuiper. Naturally, the views expressed herein and any remaining errors are the author's responsibility.

² Noting that the focus herein is on the creation of distribution level markets, rather than, say, regulatory reforms to assist aggregators to participate in wholesale level markets.

That's what the [democratic grid] architecture is meant to do: manage complexity, speed decarbonization, and enhance local resilience. It moves responsibility for DERs into the hands of those closest to them and builds the grid from the bottom up, making every community a partner in the great fight against climate change.³



Background

There are a number of concurrent and intersecting dimensions to the once-in-a-century transformation commonly known as the energy transition:⁴

- From fossil-fuelled to renewable generation.
- From a one-way to a multi-directional⁵ supply chain.
- From centralised to decentralised control.
- From "dumb" analogue to "smart" digital or automated visibility and control systems including artificial intelligence (AI) and the internet of things (IoT).
- From supply following variable demand to demand responding to variable supply.
- The "electrification of everything" including not only energy supply but also transport, gas and manufacturing.

This paper is primarily concerned with the first three of these dimensions. Governments and market bodies are mostly on board with the transition from fossil fuelled to renewable generation. On the whole they are trying to achieve this transition through the historic paradigm of a centralised system: that is, with power and control being centralised alongside the supply chain as was developed over the past century.

³ David Roberts, [Renewable energy threatens to overwhelm the grid. Here's how it can adapt](#), Vox, 11 November 2019.

⁴ From the German *Energiewende*.

⁵ ie, down, up and across the supply chain.

However, the suitability of centralised-dominant paradigm in a system which is literally no longer solely centralised must be vigorously examined.

Until recently, energy was delivered from ever larger power stations over increasingly vast distances through sprawling tentacles of poles and wires to passive consumers, who had as little connection with their energy supply as they did with the slaughtering of packaged meat or the trawling of canned fish.

But the system changing fast, thanks primarily to the ongoing, world-leading boom in rooftop solar installations in Australia. As governments, market bodies and the incumbent industry continue to focus primarily on bulk system investments⁶ and wholesale market issues, they tend to treat the boom in DER as an ongoing series of technical problems to be solved or an externality to be shoehorned into the existing system and market model.

In the centralised model, DER “integration” is the dominant discourse. It implies the existence of a normative system into which the pesky newcomer must be assimilated, with the least disruption possible to the status quo. It is reminiscent of the arrival in the 1980s of what was then called “alternative” energy; but when renewables become mainstream or even dominant, they are no longer alternative, so this epithet gradually disappeared. Likewise for DER; as they become a bigger part of the system, the notion of integration should give way to another: adaptation at least; revolution at most.

DER is now a key actor in the energy system and is set to become more so in the near future, with projections that it could provide as much as half of the total system capacity as early as 2030.⁷

We must ground our response in today’s and the future system, rather than in a system that no longer exists. This paper lays out the case for a new supply paradigm congruent with a high DER system. The first step, however, is to change our orientation from the system or market to the user.

What do users want?

The NEM is expected to operate in the long-term interest of consumers (hereafter referred to as users, to reflect the fact that households and businesses are now generating, storing and trading as well as consuming energy). This is the core of the national electricity objective (NEO).⁸ This paper therefore takes a user, rather than system or market, perspective. That is, the system and market must work first and foremost for today’s and tomorrow’s users rather than for the industry or governments.

There is now a large body of research in which users express a desire for the energy system to provide affordable, reliable and clean energy.⁹ While these outcomes are generally accepted by the industry and market bodies, users also want the system — and their participation in it — to be fair or just; do not generally trust a now largely privatised and therefore profit-driven industry to act in their best interests; and as a result, many are also increasingly interested in opportunities to increase their choice, control and autonomy (or “energy sovereignty”).¹⁰

For instance, according to new research conducted by ANU on public concerns and consumer protection gaps for the network integration of DER,

Our findings reveal that householders have a whole range of concerns associated with emerging business models. Issues raised include data privacy, and skepticism that third party control of DER - V2G and VPPs - would be in consumer’s best interests. As with research into perceptions of demand response, the root of these concerns is that many householders feel that the energy sector’s interests are not in line with their own. Parties that were raised as untrustworthy, because of holding narrow interests in relation to profit maximisation, included both networks and retailers. Householders also felt a strong desire to control aspects of their energy use and technologies, which would often be in conflict with third party automation and control... Our research mirrors other social research in Australia that there are significant concerns about consumers about the way

⁶ Notably the \$27 billion in new transmission infrastructure in AEMO’s 2020 integrated system plan (ISP).

⁷ See A high DER system below.

⁸ While the current NEO excludes explicit reference to equity and environmental outcomes, they may be implied as relevant to the long-term interests of consumers.

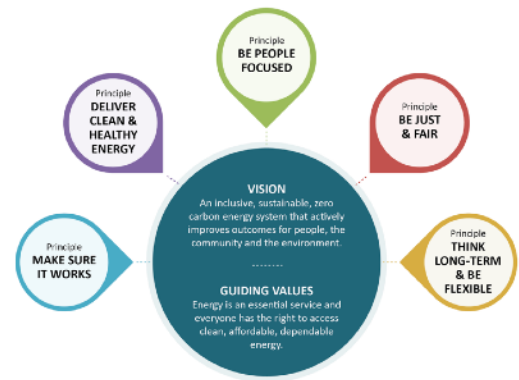
⁹ See, eg, A Future Energy Vision Consumer Expectations Research, Energy Consumers Australia Forethought Report – 2019; Strengers Y et al, Engaging households towards the Future Grid: an engagement strategy for the energy sector, Emerging Technologies Research Lab (Monash University) and Centre for Urban Research (RMIT University), Melbourne, 2019.

¹⁰ “Energy Sovereignty (ES) refers to political projects and visions towards a just generation, distribution and control of energy sources by organized and conscious communities, provided that these do not affect others negatively, and with respect for ecological cycles”: https://www.researchgate.net/publication/323614181_Energy_Sovereignty_a_tentative_definition.

the energy transition is unfolding. A concern that the industry is not accountable to consumers appears to be a key barrier to emerging business models.¹¹

As discussed later in this paper, where these opportunities are not seen to be provided by the industry, users are showing an increasing willingness to reduce their reliance on grid electricity by becoming more self-reliant. This has equity implications, as users without access to the same resources will effectively be forced to shoulder more of the burden of maintaining it.

These outcomes are well encapsulated in this schematic overview of the New Energy Compact (NEC), which was developed by TEC, ACOSS and Energy Consumers Australia with extensive stakeholder and user input.¹²



New Energy Compact – a people *centred* vision for the Australian energy system

3

A high DER system

Market operator AEMO's 2021 Draft IASR report projects that rooftop PV capacity could increase from ~13GW at present to 30GW by 2030, 40GW by 2035 and 50GW by 2040 under the sustainable growth (formerly step change) scenario (ie, about 50% of total system capacity).¹³ For the Post 2025 market design process the Energy Security Board (ESB) is assuming that DER are "likely to achieve 40 GW (~50%) of capacity by 2030".¹⁴ Likewise, recent modelling for AEMO predicts an exponential growth in distributed battery storage from less than 1GWh in 2020 to over 20GWh in 2030 and around 45GWh by 2040 under the step change scenario.¹⁵ In spite of persistent government inaction, a similar exponential growth in EV take-up is also likely in the same timeframe, with AEMO forecasting total EV fleet numbers to rise from several thousand today to over half a million in 2030 and five million in 2040.¹⁶ Given that past projections have repeatedly underestimated the take-up of rooftop solar, these projections may be conservative.

A high DER system can have considerable user benefits:

- *Lower cost:* while top-down, centralised models require or imply that multi-billion dollar spending is required on new large-scale generation, transmission and interconnection infrastructure to meet future demand and decarbonisation targets, a high DER system can largely make do with the existing distribution poles and wires.¹⁷ While a mix of centralised and decentralised generation and networks will always be required, especially for resilience, in time this could lead to the de-rating or decommissioning and repurposing of some transmission level resources.
- *Greater control and autonomy,* which is desired because of a lack of trust in the industry and increasing external interventions are limiting the use and value of DER, as well as to support users' environmental concerns and aspirations.
- *More choice and flexibility* through innovation, giving users more options about when and how to engage with the market (or not), especially in a rapidly changing technological environment.

¹¹ See, eg, Temby, Hugo., Ransan-Cooper, H. Draft report. New energy VOICES (Victorian Ombudsman Investigation of Consumer Experiences). Report commissioned by the Energy and Water Ombudsman Victoria, March 2021.

¹² https://www.acoss.org.au/wp-content/uploads/2020/02/NEC_Consultation-Draft-V.4-19022020-002-1.pdf.

¹³ AEMO, Draft 2021 Inputs, Assumptions and Scenarios Report, Figure 7, 62. In the sustainable growth scenario, [rapid] This DER uptake is driven by consumers seeking to take a greater degree of ownership over their consumption, choosing when and how to consume energy. This is also aided by continued technological advances that extend the strong uptake in DER technologies", 20.

¹⁴ See eg P2025 Demand Side Participation - Maturity Plan Workshop Slides.pdf, 22 February 2021, slide 16.

¹⁵ Green Energy Markets, Projections for distributed energy resources – solar PV and stationary energy battery systems: Report for AEMO. June 2020, Figure 1-3, 7.

¹⁶ AEMO, Draft 2021 Inputs, Assumptions and Scenarios Report, Figure 11, 66.

¹⁷ For instance, while the 2020 ISP proposed spending \$27B on transmission infrastructure by 2040, based on their current plans distribution networks are likely to spend around one-tenth of this amount to integrate DER. (This estimate is based on average AER-approved DER integration-related expenditure by distribution networks of around \$50 million each for the 2020 to 2025 period, extrapolated out to 2040.)

- *Less complexity*, where users seek to reduce their interactions with increasingly burdensome technical requirements and tariffs by becoming more self-reliant.¹⁸
- *More resilience/lower climate risk*: eg, where more local or dispersed generation and storage results in less reliance on poles and wires solutions, this can reduce the risk of blackouts and damage from severe weather events such as heatwaves, bushfires, cyclones and floods as well as decreasing the recovery time and cost.
- *Community benefits*, particularly in the case of community energy projects, which can lead to improved energy outcomes for communities, more local investment and employment, and increased engagement in energy services.¹⁹
- *Greater system security*: in some circumstances, DER can be the solution to, as well as, or instead of, the cause of network technical problems like overvoltage²⁰ and thermal constraints caused by net reverse flows.²¹

These benefits are attainable to varying degrees under current system and market arrangements, but (a) some are under threat as the market operator and networks ramp up their DER interventions to maintain system security, and (b) most would be likely to be accelerated under a decentralised paradigm. Of course, none is absolutely guaranteed merely by moving to a decentralised paradigm.

What is grid architecture?

“Grid architecture is the specialization of system architecture for electric power grids. As such, it includes not just information systems, but also industry, regulatory, and market structure; electric system structure and grid control framework; communications networks; data management structure; and many elements that exist outside the utility but that interact with the grid, such as buildings, merchant distributed energy resources (DER), and microgrids.”

JD Taft and A Becker-Dippmann, Grid Architecture, for US Department of Energy, 2015

Or, to put it another way, grid architecture is the visual representation of the relationships between the various levels or parties in the electricity supply chain.

A vision for a democratic grid

Beyond a future energy system in which DER are successfully technically integrated and managed into the existing system, the opportunity is emerging to transition to a system in which DER constitutes the primary or default source of supply for a majority of customers.²²

The vision²³ appropriate to this new paradigm might be summarised as: *an energy system which maximises the benefits of DER for users²⁴ to deliver a resilient, affordable and clean energy supply.*

This vision for DER could complement a corresponding vision for the bulk system, or be part of a vision for the whole system.

It could be achieved in part by developing a “bottom up” grid architecture model, which we call the “democratic grid,” which maximises the opportunities for control/autonomy, flexibility/innovation and sharing/trading by users and/or their agents within the system parameters. These opportunities could

¹⁸ Noting that in some circumstances DER can increase complexity — eg where tariff signals require behavioural responses, or where dynamic operating envelopes require smart inverters — although this complexity can be mitigated by the use of automation.

¹⁹ See, eg, <https://c4ce.net.au/aboutc4ce/what-is-community-energy/>

²⁰ Noting that solar exports do not cause but rather are one contributing factor to overvoltage issues, which according to one study are present even in areas without high solar penetration: see <https://prod-energycouncil.energy.slicedtech.com.au/lv-voltage-report>.

²¹ Eg, when smart inverters are deployed to correct overvoltage: see, eg, <https://www.uts.edu.au/sites/default/files/2019-10/Networks%20Renewed%20-%20public%20dissemination%20report%20October%202019.pdf>.

²² Residential users in particular, noting that they constitute 9 million of the 10 million customers in the NEM.

²³ This it's not intended to be a vision for the entire and your sister energy system, but could be part of a wider vision.

²⁴ Naturally this vision needs to be road-tested with energy sector stakeholders and users.

involve energy generation, storage and trading on both sides of the meter²⁵ (and via stand alone power systems or SAPS),²⁶ as well as flexible demand.

We are not suggesting that the adoption of the democratic grid model should be at the expense of economic efficiency — ie, that localisation should be pursued for its own sake. Rather, where regulatory reforms or infrastructure investments are planned, bottom-up solutions should be allowed to emerge where they best meet the needs of users, whether they be for energy sovereignty; low cost power; more choice, resilience or social equity; or a clean energy supply.

Grid architecture

The following discussion of grid architecture models is based on the understanding that there are four conceptual dimensions of the system — ie, flows of energy, money, data and control between different parties — with our focus being on the first two. The focus of this paper is also on the distribution level; no major changes are envisaged or required to the bulk supply system — ie, large scale generation, transmission networks, interconnections and the wholesale market.

Just as we distinguish between the engineering or physical system and the financial market overall, there are therefore two main dimensions to grid architecture at the distribution level: *system operation* (the role of distribution system operators or DSOs, responsible for distribution network security) and *market operation* (the role of distribution market operators or DMOs, responsible for market operations).

This distinction is important because it is not only possible but necessary to separate system and market operation functions.²⁷ There are useful summaries of the main roles and responsibilities of each in the 2020 WA DER roadmap²⁸ and the 2020 Open Energy Networks (OpEN) Position Paper.²⁹

At present, neither of these roles exists in these forms. Responsibility for distribution system security is shared between AEMO and DNSPs, while the only distribution level trading occurs via nascent P2P trading platforms such as Enosi and Power Ledger.³⁰ Indeed, we are not aware of a standalone DMO anywhere in the world.

However, the emergence of local microgrids and VPPs as well as P2P, alongside the potential for flexible demand and other network services, are raising the issue of whether these new ways of trading energy can be accommodated into the existing market structure, or require the creation of either a single distribution level market (ie, a DMO) or multiple distribution trading platforms (DTPs).

Given the cumbersome and costly implications of adapting the wholesale market to accommodate, say, P2P trading, there is a general recognition in the Australian context that either a DMO or a common software interface for multiple DTPs will be required. Given that neither of these will not have direct access to the market operator (unless AEMO is the DMO), one or more DSO/s will also be required to ensure that distribution markets operate safely and reliably within the physical parameters of distribution networks.

In the context of the NEM, it is generally accepted that DNSPs (rather than AEMO or independent third parties) are best placed to perform the role of the DSO for their regions, although there has been some debate about the extent of AEMO's role in guaranteeing distribution system security (more on this below).

More contentious has been the DMO debate. The main issue is whether or not there needs to be a single DMO; and if so, whether this role should be performed by AEMO, DNSPs or a third party. In TEC's view,³¹

²⁵ In this paper, meter is taken to mean not only traditional connection point NMI's but other digital means of monitoring and controlling energy and value flows onsite and between users, traders and DSOs.

²⁶ SAPS are by definition not grid-connected, but can still be considered DER, especially since they can be provided by networks as an alternative to grid supply – eg, to improve bushfire resilience.

²⁷ Ie, unlike (our understanding of) the OpEN modelling, it is not necessary or even helpful to distinguish primarily between DMO/AEMO- and DSO/DNSP-weighted models. The first step is to understand which functions should be performed by the DMO/s and DSO/s; the second is to determine which organisation is best placed to perform these functions.

²⁸ WVA Energy Transformation Taskforce, Issues Paper - DER Roadmap: Distributed Energy Resources Orchestration Roles and Responsibilities, 2020.

²⁹ Open Energy Networks Project: Energy Networks Australia Position Paper, 2020, 26-27.

³⁰ The aggregation of household battery storage in VPPs for arbitraging uses distribution level assets, but the trading occurs in the wholesale and FCAS markets.

³¹ Supported by other energy consumer advocacy organisations which participated in the OpEN project.

strong case has not been made for the need for a single DMO to be set up in the short to medium term (rendering moot the question of who runs it).

The table below instead introduces a third concept, distribution trading platforms (DTP). Even a single DMO would require a trading platform, but it is also possible that multiple trading platforms could be established without the need for a central DMO, at least in the short to medium term, and especially if multiple trading platforms were able to talk to each other (ie, be interoperable) — and more importantly, to the DSO (to ensure trading occurs within system limits) and AEMO (where aggregated DER is dispatched into the wholesale and FCAS markets).³²

There are at least three potential trading functions for DTPs:

- Energy arbitraging for local trading — eg, P2P.
- Network services — eg, flexible demand and community scale batteries to reduce peak constraints.
- Essential system services — eg, FCAS.

This variety of trading functions could theoretically take place on separate trading platforms using a common interoperability standard or API to enable them to interact with the DSO in relation to operating envelopes to ensure that distribution networks continue to operate safely and securely.³³

Summary of functions		
DSO (and)	DMO (and/or)	DTP (or NOM)
Distribution system operator (and)	Distribution market operator (and/or)	Distribution trading platform/s or Network optimisation markets
<ul style="list-style-type: none"> • Dynamic system operation: plan, manage and optimise distribution system to ensure it is operating within its technical limits to maintain reliability — eg, • Receive bulk system dynamic operating constraints and conveying these to aggregators via DMO or DTP • Detect and convey distribution system dynamic operating constraints to DMO or DTP • Dynamic network pricing — eg, using tariffs to help balance user supply and demand • Flexible access services — provide network access services to customers including trading network capacity. • System services — provide new services and support to users to maximise the value of network assets and capabilities 	<ul style="list-style-type: none"> • Administer single distribution trading platform to enable access for aggregators to market trading for energy, capacity and ESS (such as voltage and frequency control) • Operate and manage the platform to ensure that participants meet AEMO registration requirements and provide information transparency, dispatch reconciliation and market settlement • Interface with the DSO to ensure distribution network issues are resolved in a co-ordinated manner 	<ul style="list-style-type: none"> • Common API or interoperability standard for decentralised third parties to trade energy and services on the distribution network via multiple trading platforms or marketplaces — eg, for <ul style="list-style-type: none"> • P2P • Community energy • Community scale batteries • Flexibility services • Common API or interoperability standard for aggregators to bid customer resources into bulk system markets via multiple trading platforms or marketplaces — eg, for VPPs to trade energy and system services (ESS) created by DER • Trading platform owner/operators interface with the DSO to ensure distribution network issues are resolved in a co-ordinated manner

A parade of models

The idea that the Australian energy sector needed to concern itself with different models of its overall design or architecture was probably first explored through the 2015-16 ENA/CSIRO network

³² Noting that other new markets may emerge at the bulk system or distribution level.

³³ The NTR lays out a number of basic architectural principles which should be implemented to create a NOM (or DTP): see NTR key concepts report, 80–81.

transformation roadmap (NTR) process.³⁴ The NTR key concepts report proposed the creation of “Network Optimisation Markets (NOM) [to] provide a technology neutral mechanism for procuring distributed energy resources network optimisation services where and when needed.”³⁵ This sounds like a potential future distribution level energy market, but the report distinguishes between the two. Our interpretation is that the NOM is the digital platform that would support one or more potential future distribution level trading platform/s.³⁶ In any case, the idea and terminology of NOMs has not caught on.

The later ENA/AEMO open energy networks (OpEN) process built on a similar process undertaken in the UK.³⁷ OpEN included a cost benefit analysis (CBA) for four potential models (summarised in the table below) — all of which, unfortunately in our view, conflated system and market operation roles and responsibilities. The fourth (hybrid) model was introduced midway through the process, essentially as a compromise between the AEMO-dominated single integrated platform (SIP) and the DNSP-dominated two-step tier (TST). The CBA concluded that the IDSO model would be the most expensive, while the other three were not significantly different with regard to financial costs and benefits.

The OpEN collaboration disintegrated in early 2020, but the conversation around grid architecture models resurfaced in mid-2020 in the ESB’s two sided market (2SM) workstream of the post 2025 market design (P2025) process. While not limited to distribution level markets or explicitly addressing grid architecture models, the ESB’s April 2020 2SM paper for COAG implied some design choices — eg, by referring to AEMO as *the* (only) power system operator³⁸ and the proposition that aggregated DER may be required to be scheduled to bid into the wholesale market,³⁹ as well as the absence of any detailed discussion around possible distribution level alternatives such as peer-to-peer and local energy trading.

Table 3. Roles and responsibilities as defined in the OpEN distribution market frameworks

Frameworks	Distribution Market Operator	Distribution System Operator
Single Integrate Platform (SIP)	AEMO	AEMO DNSP maintain assets
Two-Step Tier (TST)	DNSP *Could be third party	DNSP
Independent Distribution System Operator (IDSO)	Third party	Third party DNSP maintains assets
Hybrid	AEMO *Could be third party	DNSP

The consideration of alternative grid architecture models became explicit in the ESB’s January 2021 directions paper, as follows:

- **The No Platform Model:** this is baselined from our systems and processes today - i.e., essentially a point-to-point architecture between all actors with no shared capabilities beyond what are in use today (e.g., the Market Settlement and Transfer Solutions system, ‘MSATS’).
- **DSO weighted model:** this model weighs more functions and responsibilities towards the DNSPs acting as a DSO, which would involve some but relatively minor shared capabilities.
- **DMO weighted model:** this model weighs more functions and responsibilities towards AEMO, which would involve a greater proportion of shared capabilities.

³⁴ While there are international precedents, especially in New York and the UK, significant differences in jurisdictional regulatory regimes make it impractical to detail herein the lessons from those processes; but see, eg, Gabrielle Kuiper, *The future of electricity distribution networks*, Churchill Fellowship project report, 2019, 30–34: <https://www.churchilltrust.com.au/project/to-investigate-the-regulation-of-clean-smart-customer-centric-energy-networks/>

³⁵ ENA and CSIRO, *NTR key concepts report*, 2016, 78. These NOMs would be supported by “Advanced Network Optimisation (ANO) technological functions at the distribution level...” The NTR also “distinguishes the systemic application of advanced new tools for this purpose as Advanced Network Optimisation (ANO)” rather than the more commonly used term DSO. For more detail, see CSIRO and Energy Networks Australia, *ENTR Synthesis Report: Future Market Platforms and Network Optimisation*, 2017.

³⁶ This may be similar to the DTP concept outlined in the table above.

³⁷ <https://www.energynetworks.org/creating-tomorrows-networks/open-networks>

³⁸ ESB, *Two-sided markets - ESB COAG Paper - Consultation copy*, 9.

³⁹ *Ibid*, Ch. 4.

- **Aggregator weighted model:** this model weighs most functions towards the retailer / aggregator, and with some minor shared capabilities.⁴⁰

Since that time, the ESB has indicated to other stakeholders that it would not be choosing a preferred model,⁴¹ but would pursue “no regrets” options around short-term issues such as minimum demand, while leaving detailed consideration of market design options to the proposed two year “maturity plan” process which “sets out a process to work through a technology uplift out to 2030.”⁴²

Recently, ENA has begun developing its own DSO model (with Ausgrid) to outline the roles and responsibilities of DNSPs in managing DER, while also clarifying that in their preferred model DNSPs would not be responsible for distribution level market operations.

Other DSO/DMO models are also being developed through trials such as Project EDGE, an ARENA-funded collaboration which “will see AEMO partner with network AusNet Services and Mondo to coordinate the development of a replicable model for trading of electricity and grid services from DER that can be expanded across the... NEM.”⁴³ The grid architecture model in Project EDGE is intended to be a hybrid of the two-step tiered and single integrated platform framework models from OpEN.⁴⁴

The user perspective

A group of longstanding small consumer advocates was brought into OpEN late in the process and invited to respond to the four models. We concluded that

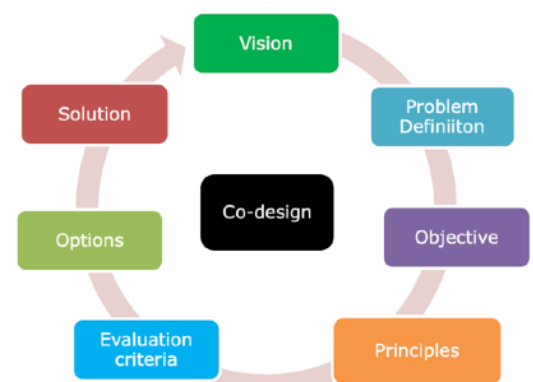
...the OpEN process had not demonstrated conclusively that the early implementation of any distribution system operator/distribution market operator (DSO/ DMO) model is necessary to leverage tools [such as appropriate pricing instruments] and to coordinate DER optimisation within distribution network limits...

The group also agreed that any market framework to optimise DER should aspire to achieving consumer objectives or outcomes. These include:

- responsive, just and fair services for consumers
- an alignment of consumer incentives with system requirements
- the availability of information and tools to assist consumers to make informed decisions
reliable and secure transactions
- positive environmental and social outcomes
- costs being borne by the beneficiaries.⁴⁵

A broader range of consumer advocates has also been critical of some aspects of the two sided markets (2SM) and DER integration workstreams of the ESB’s Post 2025 market design process,⁴⁶ primarily for two reasons: the lack of a logical and comprehensive decision-making process based on codesign principles; and the consequent tendency to focus on short term technical issues rather than a long-term, user-centred vision for a high DER system.

These concerns continue in light of the ESB’s recent interest in creating a three year “maturity plan” for DER integration, which continues to focus primarily on technical solutions to perceived short to medium term problems without the context of a clearly articulated and agreed-upon vision with milestones.⁴⁷ Consumer advocates have proposed a codesign process (applying the methodology on the right, from the NEC) intended to make grid architecture a central element of the Post 2025 process.



⁴⁰ ESB P2025 Market Design Directions Paper, 2021, 20.

⁴¹ I.e., before its mandate officially expires in June 2021.

⁴² Ibid, 81. It is not yet clear which organisation/s would be responsible for carriage of the maturity plan.

⁴³ <https://arena.gov.au/news/distributed-energy-marketplace-trial-giving-consumers-an-edge/>

⁴⁴ AEMO, Project EDGE, Lessons Learned Report #1, May 2021, 5.

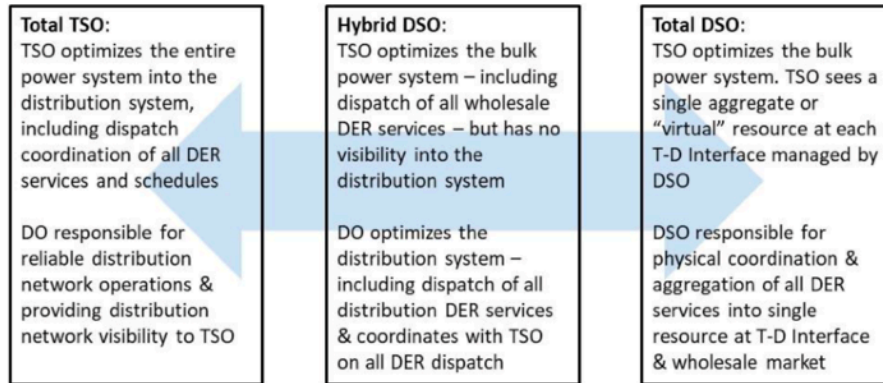
⁴⁵ Open Energy Networks Project: Energy Networks Australia Position Paper, 25.

⁴⁶ Now combined under the retro rubric of “demand side participation”.

⁴⁷ ESB, Post 2025 market design options paper, April 2021.

A US alternative

A group of esteemed power system engineers based on the US west coast has been at the forefront of developing the discipline of future power systems architecture (FPSA). In 2019 they provided an international review of system architectures for orchestration of DER for AEMO, prior to the publication of the 2020 Integrated System Plan (ISP). It included the following spectrum of models for DER coordination:⁴⁸



These models combine system and market operation roles (perhaps reflecting the more vertically integrated structure of US utilities), but are notable for raising the prospect of the wholesale market operator not having direct visibility of DER, instead relying on the DNSP as DSO to coordinate and aggregate DER services into a single resource at each interface with the transmission system.

The authors call the principle behind this approach “layered decomposition”, and explain that it “solves large-scale optimization problems by decomposing the problem multiple times into sub-problems that work in combination to solve the original problem.”⁴⁹ In simple terms, this means that AEMO, as market and bulk system operator, doesn't need to know what is going on behind the meter or in the local network, but the DNSP (as DSO) does.⁵⁰ The latter's job is to balance supply demand at the local level, and to ensure that no more or less energy is exported to, or imported from, the transmission system than necessary (as dynamically signalled by AEMO as the TSO).

The most radical implication of the “layered decentralized optimization” (LDO) model developed by Kristov, De Martini, and Taft (which in the Australian context we prefer to call the democratic grid)⁵¹ is that, in a high DER system such as the one emerging in the NEM, the old centralised supply chain is effectively flipped upside down. Users become increasingly responsible for their own supply, relying on the distribution system as backup; in turn, DNSPs rely on the bulk supply system for additional energy and security services.

The two points of connection between the three main levels of the grid – the user's meter and the transmission/distribution interface — then become like border crossings, places where supply/demand and value data as well as energy are exchanged. As summarised by Roberts,

The only point of communication and coordination between the transmission layer and the distribution layer beneath it would be at the TD interface (the substations). Everything below the TD interface would be managed and optimized by the DSO... The DSO would balance supply and demand within a local distribution area (LDA) using, to the extent possible, local DERs. It would then aggregate all remaining supply or demand into a single bid to wholesale markets (either a purchase or a power offer).⁵²

⁴⁸ Newport Consortium for AEMO, Coordination of Distributed Energy Resources; International System Architecture Insights for Future Market Design, 2018, 10, Figure ES-1. (T-D interface refers to the transmission – distribution interface, which in the NEM would be via bulk supply points or transmission nodes.)

⁴⁹ Ibid, 6.

⁵⁰ This is largely the case now, but is changing — eg, with AEMO directing DNSPs to shut down rooftop solar systems to maintain system security during minimum demand events (see below).

⁵¹ These authors distinguish between this new model and the old model which they call Grand Central Optimization (GCO): see Lorenzo Kristov; Paul De Martini; Jeffrey D. Taft, A Tale of Two Visions: Designing a Decentralized Transactive Electric System, IEEE Power and Energy Magazine May-June 2016, 63-69.

⁵² David Roberts, Renewable energy threatens to overwhelm the grid. Here's how it can adapt. Vox, 11 November 2019.

One of the key questions that arises in the LDO/democratic grid model is who would be responsible for distribution level markets, given the different ownership structure of the Australian system (ie, because DNSPs cannot buy and sell energy). We see no need at this stage for the creation of a single DMO role. Instead, the use of a common API or interoperability standard could allow multiple traders to offer services to DER users, with their operating envelopes being dynamically communicated by the DNSP as DSO. Aggregators could still bid generation and flexible demand into the wholesale market, as at present.

The graphics on page 17 are an initial attempt to apply this model to the NEM. The diagram at the top illustrates how it might work in terms of money and energy flows through the supply chain. The diagram at the bottom focuses more on the user experience, the services available and the importance of the interfaces (the customer meter and bulk supply points).

What difference would it make?

Current concerns about minimum demand are a case in point. According to the ESB,

Falling minimum demand levels, if not effectively managed, will lead to issues with managing voltage, system strength, and inertia. This will drive up costs and risk through increases in directions by AEMO and interventions in economic dispatch, and additional provision of services for system restart, increased ramping capacity, voltage management and system strength and inertia services.⁵³

AEMO's first intervention to correct this problem was to require SAPN to trip 12,000 residential PV systems for around 2 hours on Sunday, 14 March 2021 to stabilise the grid when operational demand fell below 400 MW.

Without arguing that such dramatic interventions may never be necessary, from a user perspective this should be the last, rather than the first, resort. The majority of those 12,000 customers were apparently unable to even self-consume solar energy at a time when many would have been at home. They were not given prior notice, so were not able to load shed or shift to reduce their reliance on grid consumption during that period. And they were not compensated for their contribution to system security. An estimated \$7,000 cost of lost feed-in-tariffs and additional retail charges was borne by solar owners for this event.⁵⁴

This is not a DER-friendly approach, and will only compound the lack of trust that many DER users already have that the system and the market are working in their interests. And we note that this intervention occurred "during a planned outage of circuits feeding the Heywood interconnector which links the state's grid with Victoria."⁵⁵ In other words, the problem was predictable, and if load shedding was required, why should the burden fall without notice on residential and C&I PV owners?

A bottom up perspective would begin by asking at what level of the system minimum demand actually creates problems, and where (noting, for example that SA is currently a unique case with high levels of VRE and being only connected to one other NEM region),⁵⁶ and then proceed to tailor technical and behavioural solutions to the appropriate level.⁵⁷ For instance, how can we soak up more solar energy (or neutralise its system security implications): first, onsite (behind the meter); second, on the local LV network; and third, on the HV network? This may result, say, in mandating or incentivising smarter inverters, load diversion devices and community-scale batteries as well as accelerating tariff reform, demand response programs (to temporarily increase demand) and the utilisation of dynamic operating envelopes. Indeed, dynamic operating envelopes a solution at the DNSP level should be able to address minimum demand when this is identified as a system security issue by AEMO.

It is also notable that alternative solutions such as voluntary generation shedding or voluntary increases in load were not trialled by AEMO. It will also be interesting to see what impact new tariffs such as SAPN's solar sponge will have on minimum demand. An approach that considers users, including PV owners, as partners in the electricity system is much needed.

⁵³ ESB P2025 Market Design Directions Paper, 65.

⁵⁴ From the RenewEconomy podcast — original source TBA.

⁵⁵ See eg <https://www.abc.net.au/news/2021-03-17/solar-panels-switched-off-in-sa-to-stabilise-grid/13256572>.

⁵⁶ Eg, voltage and fault current at a local level, frequency and inertia at a regional level.

⁵⁷ Also, the framing matters. Most of what is framed as minimum demand is not the result of any change to demand but the increase of solar generation, so it should be redefined as 'increased variation/variability/volatility of demand and supply' or 'the changing dynamics of demand and supply'. (Thanks to Craig Memery from PIAC for this insight.)

Counterfactuals

One way of understanding the pros and cons of the democratic grid is to consider what the future might look like without it. In this case, there are two obvious alternatives:

- *More of the same:* in the absence of any explicit grid architecture model being developed, and if the status quo continues, given the energy sovereignty issues discussed earlier it is likely that we will see greater behind the meter DER uptake and lower grid utilisation. This trend will likely accelerate as batteries become cheaper and the business case for exporting DER into the grid deteriorates, and as EVs with vehicle to home, grid or load (V2X) capability become common. Equity implications would arise by exacerbating the current emergence of a two class energy system, as non-DER owners with fewer choices are left to foot more of the bill for network expenditure.
- *Command and control:* in the event that a TSO-type centralised model is implemented to control DER, the flight from the grid is likely to be hastened, given the aversion of DER users to their investments being interfered with, especially by parties perceive to be motivated by profit rather than the public good. It is also likely to be exacerbated if AEMO and DNSPs continue to impose static export limits; if inverters are further controlled to assist system security; if DER exports are required to be scheduled; etc. In other words, DER users are going to need new reasons to stay connected, and external control and complex market interactions will undermine this endgame.

A bigger picture

While all such models present technical (engineering and ICT) and implementation cost challenges, the democratic grid model appears to be more congruent with the user expectations identified earlier than a centralised or TSO-dominant model. It might, for example, follow over time that:

- AEMO has no need to control (even indirectly), or even have visibility of, inverters and other DER, because this is the role of the DNSP as DSO.
- More opportunities arise for the local or regional trading of flexible demand and other energy services — eg, in P2P networks or between the members of community energy projects.
- DNSPs are encouraged or required to offer local use of system tariffs that stimulate the rollout of DER such as community scale batteries, since the democratic grid model implies a direct relationship between the extent of the system utilised and the appropriate tariff for its utilisation in both directions.
- Users are encouraged and incentivised, when installing solar and battery systems, to ensure that they are islandable in the event of blackouts, where the regulatory framework also recognises the resilience value of DER.⁵⁸
- Communities have the opportunity to “buy back” their local grids to function as isolated or islandable microgrids where they see an environmental, economic or social benefit in doing so.
- Some transmission assets are derated, with cost savings to users, as the utilisation of existing distribution network capacity and new SAPS increases.
- Users without active DER such as solar, batteries and EVs have more opportunities to benefit from them, as well as to trade their flexible demand, because of the emergence of multiple localised marketplaces unfettered by centralised control.

But this is just the beginning. The point of a democratic grid is not to enable or incentivise particular known products or services: it is to put literal and metaphorical power back into the hands of users by localising markets and services as much as possible, and then to get out of the way. How people and communities choose to respond will depend not only on their resources and ingenuity but also on the governance frameworks we put in place around this model. The intended outcome is beautifully summed up in this promotional video from P2P platform provider Enosi:

Clean low cost energy is a basic human need. What if... you get to decide where it comes from, and where the benefits flow. People and communities in control of their electricity and futures.⁵⁹

⁵⁸ Similarly, users might be incentivised to install grid-forming inverters.

⁵⁹ <https://enosi.energy/platform/>

Power and governance

The proposal to introduce multiple distribution trading platforms as an alternative to a single distribution market operator model should, from a user perspective, be voluntary (ie, opt-in). That is, anyone who wishes to retain their traditional contact with a single retailer should be free to do so. Depending on the type and degree of aggregation and automation involved, offering a service to, and/or buying a service from, a DTP trader need not entail a higher degree of direct awareness of system and market dynamics. The absence of dynamic involvement, however, requires a high degree of transparency regarding product/service disclosure on the part of traders and energy literacy on the part of users.

How users will interact with distribution level traders is a matter that requires more attention, perhaps as part of a broader discussion of options for the governance of grid architecture models for a high DER system, including the democratic grid. In other words, if we are replacing the top-down model of control/decision-making as well as top-down system and market operation, what are we going to replace it with? Our default position, in line with the above paragraph, is that the democratic model should, at least in the short to medium term, evolve and operate alongside the traditional top-down model. Thus, active users who want to do so should have the opportunity to be involved in decisions affecting their energy usage (eg, by joining local energy cooperatives),⁶⁰ while relatively passive or traditional users experience no change to their contractual or power relationship with traders, networks and market bodies.

Implications of the democratic grid

1. Onsite supply is the primary or default source, followed by the local LV and HV networks, and then by the bulk system. From this it follows that:
2. Onsite technologies should support islandable or standalone operation where necessary.
3. DNSPs are primarily responsible for distribution level system security.
4. The regulatory regime should support local energy trading as well as trading with wider markets.
5. The regulatory regime should recognise the resilience benefits of local energy (DER).
6. Users should have access to the resources necessary to be able to choose how they engage—directly or indirectly (via aggregators)—with the democratic grid.

Note: Wherever possible and at least in the short term, users should be able to choose between standard supply and a higher level of engagement through the emerging democratic grid.

Next steps

The short term impetus for this discussion paper is the ESB's P2025 market design process, with the grid architecture (roles and responsibilities) piece of the puzzle effectively being postponed to be dealt with in the DER maturity plan, the future of which is unclear. Nevertheless, discussions around grid architecture began before the P2025 process and will continue for years thereafter, so a broader discussion is worth having.

To date, the democratic grid model represents the application in principle to the NEM of a model developed in another context, albeit with widespread applicability.⁶¹ De Martini and Kristov have laid out what they call "a practical framework to consider DER growth and address its impacts in a logical sequence, in order to guide distribution system evolution with clear lines of sight to overarching regulatory and public policy objectives."⁶²

Within the context of their framework, there are some pieces of work specific to the Australian context which may also need to be undertaken:

- *Economic:*

⁶⁰ See, eg, https://en.wikipedia.org/wiki/Sustainable_Energy_Utility.

⁶¹ See, eg, De Martini and Kristov, DISTRIBUTION SYSTEMS IN A HIGH DISTRIBUTED ENERGY RESOURCES FUTURE: Planning, Market Design, Operation and Oversight, Berkeley Lab Report No. 2, 2015.

⁶² Ibid, 1-2.

- Modelling of the conditions under which it may be more financially viable for users to disconnect from the grid — eg, as battery prices and feed-in tariffs decline, so it makes more sense to store rather than export surplus generation to the extent that the value of retaining a grid connection may become marginal. This piece of work would give a good indication of the urgency of the need to shift to a bottom-up model.
- For AEMO's 2022 integrated system plan, review DER forecasts and model the likely uptake of different types of DER, their technical characteristics and consumer willingness to participate in external markets.
- A cost benefit analysis of the cost of meeting additional projected demand in 2030 or 2040 via a combination of centralised and decentralised resources. This piece of work would give a good indication of the economic advantages inherent in the shift to a bottom-up model.⁶³
- *Roles and responsibilities*: determining in detail which system and market functions are the responsibility of the DNSP/DSO, AEMO, traders/DTPs and users.⁶⁴
- *Technical*:
 - Basic engineering requirements for the democratic grid to function in bottom-up mode,⁶⁵ especially at the interfaces between levels in the context of the broader shift from a system based on synchronous generators to one based on grid forming inverters.⁶⁶
 - Basic ICT requirements for the development of DTPs, particularly the design of a common trading platform API.⁶⁷
- *User experience*: ground-truthing how well the model meets users' needs and expectations as it develops — paying particular attention to the equity implications for users without active DER.⁶⁸
- *Governance*: in line with the section above, there needs to be a discussion of options for the governance of grid architecture models for a high DER system, including the democratic grid — ie, how the power relationships that have evolved for a top-down model can be re-imagined for a bottom-up future grid.

Meanwhile, we note that the nascent ENA/Ausgrid DSO vision is largely compatible with a democratic grid, although some clarification is required in relation to the role of the DMO/s, which is part of the DSO vision but is not envisaged in a democratic grid.⁶⁹ It is also broadly consistent with the “nested layers” model included in the AEMC's 2019 ENERF review, although this model does not appear to have been developed further in the interim.⁷⁰

As it has arisen from consumer advocates rather than market bodies or the industry, the democratic grid requires the support of other stakeholders and a codesign process to progress.

Perhaps the most important thing in the short term is to do no harm – that is, to ensure that decisions made today do not preclude the emergence of a decentralised model either organically or by design in coming years.⁷¹ When combined with the other key themes in this paper, this suggests the following three key principles to encourage the emergence of a democratic grid:

⁶³ Noting that both large and small scale resources will still be required, this work would give an indication of the optimum mix of both.

⁶⁴ The ESB's post-2025 market design process said in 2020 it was looking at this, but it is unclear from more recent communications what will be produced on roles and responsibilities, given that apparently no architectural design/s will be chosen.

⁶⁵ In other words, how each level of the system can operate largely independently of the one above.

⁶⁶ That is, the transmission – distribution interface (bulk supply substations) and the distribution – user interface (meters and inverters). For instance, on the latter, most users are unaware of the technical requirements for solar and battery systems to operate in islanded mode, and few inverters currently have this capability.

⁶⁷ Noting that the NTR found that “the development of a NOM [DTP]...is a required step, whether or not there is a more advanced subsequent stage”, and is therefore “a no regrets action”: CSIRO and Energy Networks Australia 2017, Electricity Network Transformation Roadmap. Synthesis Report: Future Market Platforms and Network Optimisation, 14.

⁶⁸ This might involve, for instance, using a reference group of consumer advocates but also user focus groups to test the emerging model against the five principles of the NEC.

⁶⁹ We also note that Strategen is pursuing a Future Power System Architecture collaborative project with ARENA.

⁷⁰ AEMC, Integrating distributed energy resources for the grid of the future, Economic regulatory framework review, 2019, 139.

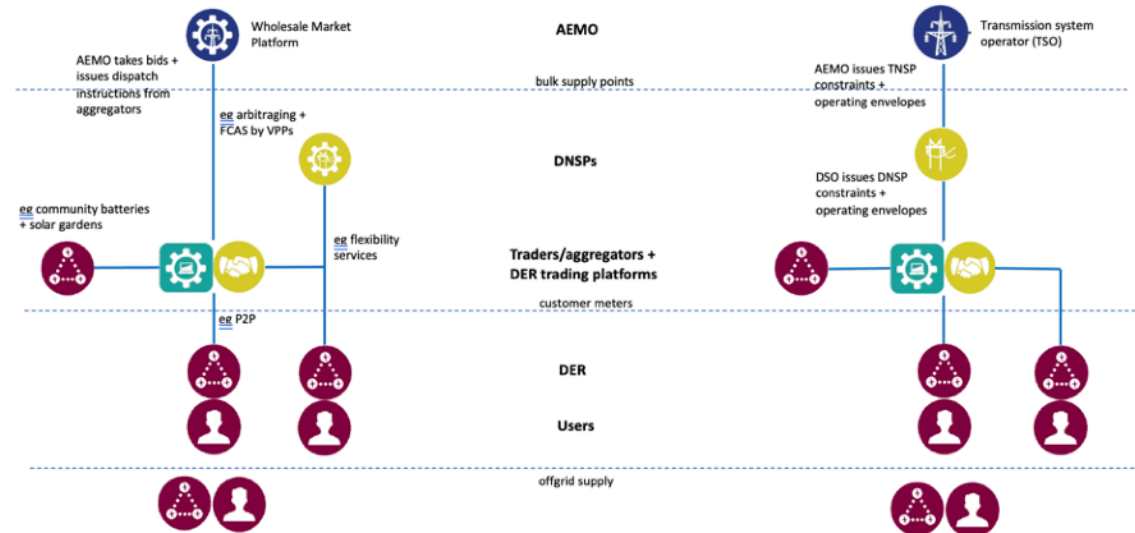
⁷¹ This is perhaps less straightforward than it sounds, since DSO and DMO options are being trialed at present which may become default solutions in the near future — eg, in Project EDGE (discussed earlier).



Democratic grid #1

Distribution market operator/s (DMO) roles and responsibilities

Distribution system operator (DSO) roles and responsibilities



Key features

- 4 level system (including offgrid systems) with interfaces at the meter and the T/D interface (bulk supply points).
- Separation of distribution system and market operator roles.
- DNSP is DSO.
- No need for single DMO: multiple distribution level trading platforms (eg for P2P and community energy trading) common software interface or API.
- No need for AEMO to see or control individual DER: DSO aggregates DER and supplies operating envelopes to traders and aggregators.
- DER can still be aggregated for dispatch into the wholesale market via VPPs in response to AEMO instructions.

Democratic grid #2

