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Integrating distributed energy resources in the electricity grid

Energy EVP discussion paper

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Executive Summary

The energy transition is moving ahead rapidly.

The energy transition is moving ahead rapidly. We are entering what the Australian Energy Market Operator (AEMO) CEO, Daniel Westerman, has described as "uncharted territory."[1] Distributed energy resources (DER) are playing a central role in transforming the grid. Australians have embraced rooftop solar at double the rate of any other nation. Key technologies, such as smart inverters and batteries, are enabling a fundamental shift in what is possible. DER are changing consumers' behaviour from passive participation in the grid to active contribution. Consumers have shown that they will take up new technologies if they can see the benefit.

Even as recently as the development of the AEMO 2020 Integrated Systems Plan, the sector was not certain that these technologies could be grid-forming or provide system services. However, we now have the technology, and the task is integrating all this at the system level. Effectively and efficiently integrating DER will require this fleet to be active and co-optimised within the wider energy system, not just accommodated. We need the right operational architecture, incentives, and roles and responsibilities to facilitate a highly decentralised power system. The complexity of the task is exacerbated by the fact that for a period we will have parallel paths: maintaining and augmenting the capabilities of the current system, while designing and implementing the future system.

The AEMO Draft 2022 Integrated System Plan is the clearest path to clean, reliable and affordable power that we have seen to date. The task is massive and will require a national effort to complete in the timeframes needed to reduce emissions and take advantage of the market and employment opportunities it affords. There are significant challenges: new transmission networks will require planning, investment and social capital. Bringing new generators onto the grid will require further connections reform. The development and coordination of technical standards needs a forward-looking and coherent approach. Market reforms need to be proactive and clearly focused on enabling the transition for community benefit and investor confidence.

The biggest issue is the accumulation of passive devices, which is having an increasingly large aggregate impact on the power system. New challenges to the system include the performance of DER in regard to fluctuations in the power system and disturbance withstand requirements, how visible their output is to system operators, and whether they can respond to instructions from system operators to adjust their output. In contrast to large-scale generation, most distributed photovoltaics (DPV) generation cannot currently be curtailed by distributed network service providers (DNSPs) or AEMO, even under extreme abnormal system conditions. Demand management will be a critical aspect of the transition. Significant increases in the number of electric vehicles and energy-efficient buildings will exacerbate these challenges but will also increase opportunities.

Who makes the investment for the energy transition and who benefits is fundamental to market reform. Australians have embraced rooftop solar, showing that individuals are willing to pay to reduce their reliance on the grid. DER is providing new options and choices for individual consumers and communities, and this requires a restructure of the electricity market.

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1 Australian Energy Market Operator (AEMO), *AEMO CEO Daniel Westerman's CEDA keynote address: 'A view from the control room'* [media release], AEMO, 14 July 2021, accessed 26 October 2021. https://aemo.com.au/en/newsroom/news-updates/the-view-from-the-control-room

DER technical standards enable participation, protect consumers and ensure interoperability. However, there is currently no single point of leadership in their development and integration. Leadership, coordination and quality control are critical. Whatever governance and structure are agreed, they need to be transparent, timely, agile and forward-looking.

The lack of people with necessary skills, particularly engineering skills, is both critical and concerning. Infrastructure Australia is forecasting an unprecedented wave in public infrastructure projects over the next five years, for which we do not have the skilled workers, especially engineers. We need to understand the current energy workforce and implement a plan that enables the energy transition.

Requirements for engineers are also growing. As well as being technical experts, engineers must also exhibit teamwork, digital literacy, and interpersonal skills. They need to be able to apply systems thinking, build social licence, and apply sustainability principles. But this challenge is also a chance to encourage young people into a dynamic, community-focused career.

DER integration is complex, with many stakeholders. It cannot be the responsibility of any one organisation. This discussion paper is intended to stimulate a conversation about what is possible, and how Engineers Australia should engage with it.

1. Introduction to the external voice project

1.1 The external voice project

Engineers Australia's Strategy 2020–23 seeks to strengthen the engineering profession's contribution to public life and to be recognised for doing so. The External Voice Project (EVP) is an exciting new initiative for delivering on this Board priority.

Engineers Australia's strength is its established system for contributing authoritative technical perspectives to public policy debates. The EVP will help to unlock that value and integrate technical and engineering design perspectives into complex public policy discourses and decisions.

The EVP will build the engineering profession's reputation for impact in public policy by demonstrating that engineering is a profession that is both technically competent and socially engaged. It will do this by applying engineering thinking and a leadership agenda that builds alliances with community decision-makers on critical and engineering-intensive social matters.

The EVP will focus on four workstreams. These have been selected because they are complex public issues with broadscale community demands for action, and engineering is vital to their success:

- climate change
- energy
- infrastructure
- technology and industry.

With each workstream, Engineers Australia will engage extensively with members and will develop new models for bringing non-member engineers and allied professions into our work. Collaboration is an overarching component of the EVP, with discussion papers used to focus debate.

Advocacy to government and the community is a vital element. Engineers Australia will publish a series of directions papers to present a considered view on the future for each issue explored as part of the EVP.

1.2 EVP energy workstream

During consultations with Engineers Australia members, the following topics were identified as important to the energy workstream:

- energy governance and the engineering voice
- the energy/power transition
- energy reliability and security
- skills supply and demand
- energy efficiency
- transport – electrification and hydrogen

- transmission infrastructure
- storage
- power system services
- information and data analytics
- technical standards
- reducing reliance on oil and gas, and decarbonisation of oil and gas
- community participation in the grid
- industrial energy use and low-carbon materials
- clean hydrogen (and ammonia)
- offshore wind as an energy source
- innovation and research agenda
- bioenergy
- other energy sources such as tidal, wave, and small modular reactors
- market reforms.

The certainty of climate change and the potentially massive consequences of not acting or acting too late drive the urgency of the transformation process facing Australia. The need to radically reduce emissions and enhance the resilience of physical energy assets and systems underlines much of the transition process. This is the critical decade. Actions and investments taken between now and 2030 will determine how successful the transformation will be. Secure, reliable and affordable energy is a key driver of economic prosperity and is essential to ensuring high living standards. Unfortunately, energy is a controversial policy area that has been overly politicised, to the detriment of the community, the environment and the economy.

A discussion paper, Energy Governance and the Engineering Voice, was published by Engineers Australia in November 2021 and reflected stakeholders' input and a response to these issues.

This, the second paper in the series, is focused on another critical issue in the energy transition: integrating distributed energy resources into the electricity grid. It is a broad view of the situation in Australia and is designed to prompt thought and discussion on how Engineers Australia should engage with these issues. These stakeholder perspectives will progress the development of Engineers Australia's strategies and actions to strengthen the identity and influence of the profession for the benefit of the community.

2. An introduction to distributed energy resources

2.1 Distributed Energy Resources in Australia

Distributed Energy Resources (DER) are transforming the power system. Australians have embraced rooftop solar at double the rate of any other nation, and at 10 times the world average.[2] The Australian Energy Market Commission (AEMC) reports that between 2.6 and 3 million households already have solar panels, which supply around 14GW of capacity. The AEMC expects a further 3 million households to install rooftop solar in the next decade.[3] Consumers have installed more than 33,000 small-scale batteries since 2014.[4] The Australian Energy Regulator (AER) says around 20% of consumers in the National Electricity Market (NEM) at least partly meet their needs from rooftop solar and sell excess electricity back to the grid.[5] By 2050, AEMC expects 45% of electricity to come from DER. The Australian Renewable Energy Authority (ARENA) forecasts over 40% of energy consumers will use DER by 2027, growing to 60% by 2050.[6] Ensuring that DER can be integrated effectively and efficiently into the grid is vital for the energy transition and for community support to move towards 100% renewable generation.

DER are changing from being a passive participant in the electricity system, such as a simple rooftop solar installation, to being an active participant using smart inverters and battery storage in sophisticated energy management systems that can adjust in response to signals from the grid. In this paper, DER are considered to be any device that uses, generates or stores electricity, including rooftop solar, batteries and electric vehicles (EVs), and the technology used to manage them, such as smart inverters. To realise this potential, DER will need to be reliable, resilient, and operate in real time. The challenge for the system is that it will need to integrate more and more DER devices and manage more complex interactions both behind-the-meter and in the distribution network. This challenge will increase as we move from a lot of distributed photovoltaics (DPV) to increased DPV plus electric vehicles (EVs), demand response, storage, virtual power plants (VPP) and myriad forms of coordination and management.

DER are an opportunity for consumers to participate in the supply of electricity while at the same time providing services that aid grid security and stability. However, consumers will only take up these devices if they provide them a benefit.

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2 Australian Energy Market Operator (AEMO), *AEMO CEO Daniel Westerman's CEDA keynote address: 'A view from the control room'* [media release], AEMO, 14 July 2021, accessed 26 October 2021. https://aemo.com.au/en/newsroom/news-updates/the-view-from-the-control-room

3 Australian Energy Market Commission (AEMC), *Opening up Renewable Energy for Everyone*, AEMC, Australian Government, n.d., p. 4, accessed 27 October 2021. https://www.aemc.gov.au/sites/default/files/2021-05/Printable%20guide%20-%20Opening%20up%20renewable%20energy.pdf

4 Australian Energy Market Commission (AEMC), *Governance of distributed energy resources technical standards, Consultation paper*, AEMC, Australian Government,2021, p. 3, accessed 27 October 2021. https://www.aemc.gov.au/rule-changes/governance-distributed-energy-resources-technical-standards

5 Australian Energy Regulator (AER), *State of the Energy Market 2020'* AER, Australian Government, 2020, p.39, accessed 27 October 2021. https://www.aer.gov.au/publications/state-of-the-energy-market-reports/state-of-the-energy-market-2020

6 Australian Energy Market Commission (AEMC), *Opening up Renewable Energy for Everyone'* AEMC, Australian Government, n.d., p. 7, accessed 27 October 2021. https://www.aemc.gov.au/sites/default/files/2021-05/Printable%20guide%20-%20Opening%20up%20renewable%20energy.pdf

DER present a challenge to system stability. The existing network was not designed for a two-way flow of energy. Today, power flows from uncontrolled DPV at household level. With higher penetration levels of DPV, power will flow into parts of the higher voltage sub-transmission and transmission networks. This will require new techniques and services to manage the system. The significant majority of the DPV fleet is currently passive, meaning that it is uncontrollable and invisible to the system operator (behind-the-meter and unmonitored in real time). The passive nature of the majority of the DPV fleet in the NEM today is beginning to pose challenges to both the distribution network and bulk power system operation. We currently have the opportunity to address this by integrating DER to make them an active, optimised part of the system, aligned with consumer incentives, rather than simply accommodating them.

The Australian Energy Market Operator (AEMO) must constantly balance supply and demand and do so with an increasingly large source of uncontrollable generation and performance. In 2016, AEMO issued six interventions to maintain grid stability. In 2020, that rose to 321.[7] These interventions were often due to variable generation displacing synchronous generators which needed to be online for stability. However, DER also play a role, and this will increase as DPV reduces minimum demand in the daytime and leads to curtailment.

The only real course of action is to continue developing new services, security capabilities and regulatory frameworks, and building social licence. The system needs to:

- continue to connect DER and support it
- develop DER capacity to support system stability
- ensure the benefits of DER flow to all consumers, whether they have DER themselves or not
- support the whole system to provide clean, reliable and cost-effective energy.

The power system will also need to manage increasing variability and uncertainty from climate events and cyber-attacks. Thankfully, with the right coordination, incentives, and management architecture in place, DER can be adaptive and scalable to deal with these issues.

Significant increases in the rollout of electric vehicle charging stations and energy-efficient buildings will also increase the importance of these issues.

Not for the first time in the energy transformation, it should be noted that the complexity of this task is enormous. Creating a new infrastructure with fit-for-purpose hardware, market rules, standards, communication tools and data exchange is not a task that any organisation or government can accomplish alone.

7 Australian Energy Market Operator (AEMO), *AEMO CEO Daniel Westerman's CEDA keynote address: 'A view from the control room'* [media release], AEMO, 14 July 2021, accessed 26 October 2021. available here https://aemo.com.au/en/newsroom/news-updates/the-view-from-the-control-room

2.2 Inverter-based resources

The NEM will increasingly rely on inverter-based resources (IBR). 'Smart inverters' are power electronic converters that can autonomously adjust their behaviour based on grid conditions. Adding storage such as batteries to solar panels and smart inverters gives an electricity supply even when the sun is not shining. The advanced software in smart inverters can perform specific grid-supportive functions. When aggregated and operating together at scale to form micro-grids and virtual power plants, these devices are a game changer for supplying clean, reliable and cost-effective energy.

The increasing use of DER will require a transition in system behaviour between inverter-based systems of variable distributed generation and synchronous generators. In future, energy will come from sources such as batteries, storage, wind at night via inverters, and from sources such as solar and wind during the day, also via inverters, with excess going to storage. The power system must operate securely under both systems and during transition periods.

During transition (at least until enough storage is available), there will be challenges.

- More energy from solar during the day will go into the grid than will be taken out, in the absence of EVs and other storage to absorb excess solar generation. This will reduce the demand for coal and gas generation during the day. There will then be a rapid shift to synchronous generation at night as solar drops off, assuming not enough has been stored during the day.
- Synchronisation will be harder, as frequency will no longer be a universal indication of system load.
- Local voltage control will become more complex, with uncontrolled local feed-in from solar, uncontrolled loads, and insufficient or uncontrolled storage. This will require monitoring and management.

The change is significant, and the risks are exacerbated by climate change increasing the frequency and magnitude of weather events, and potential cyber attacks as software-based solutions become more ubiquitous.

System strength, voltage control, frequency and black-start capacity all require new forms of management as the traditional options are retired. The key to a stable grid is consistent voltage and frequency. Too many inverters disconnecting from the system can cause instabilities, like voltage fluctuations, that lead to system failure. Grid-forming inverters continuously adjust using built-in control systems that can detect disturbances and respond accordingly.

While the mix of generation in the NEM is changing, the physics remains the same. Engineers Australia members consulted for this paper believe that IBR technology can answer many of the challenges facing the NEM today. However, as AEMO notes, "at present this potential is not demonstrated at the necessary scale, and focused engineering development is urgently needed to address the remaining issues and realise the promise of this technology."[8]

DER can both help maintain system security and provide other services, as well as allowing households to benefit from their contribution. AEMO has been working with stakeholders to identify ways in which DER can be deployed with the capability to ensure optimal performance that is affordable and delivers choice for consumers.

Some Engineers Australia members also see the energy transition enabled by modern power electronics as a chance to shift back from AC to DC systems, particularly with systems such as micro-grids and long-distance transmission.

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8 Australian Energy Market Operator (AEMO), *Application of Advanced Grid-scale Inverters in the NEM* AEMO, Australian Government, 2021, p. 4, accessed 2 November 2021. https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/application-of-advanced-grid-scale-inverters-in-the-nem.pdf

2.3 Batteries

AEMO expects installed storage, including batteries, to increase by 800% over the next twenty years, from 2,000MW to 16,000MW.[9] Batteries can be used either by individual consumers behind-the-meter or as community resources shared by many households. As battery technology improves and costs fall, the uptake of both large-scale and distributed batteries will grow. Residential batteries can store energy during the day and then release it in the evening or during interruptions, while grid-scale batteries can feed into the grid during disruptions. ARENA has launched a funding round to support the roll-out of grid-forming batteries enabled by grid-forming inverters. AEMO is keen to see these tested at scale in order to move towards 100% penetration with greater confidence.

The AEMC's Reliability Panel has found that 95.6% of supply issues are a result of problems with powerlines not power stations. Around half the cost of electricity is in transmission and distribution. Renewable generators are regulated to provide reliability mechanisms and many now use batteries to achieve this. Discoveries such as edge functionalised graphene that can be used in lithium-ion batteries is one demonstration of how battery technology is still improving in efficiency and falling in cost.

Battery electric vehicles could also play an important role as mobile storage in balancing supply and demand on the grid – if the demand management settings are handled correctly. The amount of energy stored in the average fully charged EV battery could power the average home for three days or more, but this will require vehicle-to-home (V2H) enabled vehicles and chargers.

It should also be noted that Australia has abundant deposits of the minerals, such as lithium, cobalt and nickel, needed to manufacture batteries. With more investment, Australia has the technology and engineering expertise to develop its battery manufacturing industry and ensure our sovereign capability in this sector. Studies have estimated Australia could go from a current industry of $1.3 billion and 6,000 jobs to $7.4 billion and 34,700 jobs.[10]

2.4 Circular economy

A Swedish company recently announced production of the first lithium-ion battery cell using recycled nickel, manganese and cobalt. Given the lifecycle of the many millions of batteries required, a more sustainable approach to battery production will be vital.

Companies are also starting to see the potential returns of recycling solar panels. Panel components can be separated manually, thermally and chemically to process nearly 100% of the solar panel. The aluminium, silicon, copper, silver and glass recovered can be used in the manufacture of new products.

A national recycling network and circular economy approach to renewables will be vital for the sustainability and credibility of the industry.

9 Australian Energy Market Operator (AEMO), *2020 ISP NEM Generation Outlook*, AEMO, Australian Government, 2020, accessed 26 October 2021. https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2020-integrated-system-plan-isp

10 Future Battery Industries CRC, *Future Charge: Building Australia's Battery Industries*, report prepared by Accenture, June 2021, p. 4, accessed 26 October 2021. https://fbicrc.com.au/publications/

2.5 Community participation in the grid

Smart inverters are a critical tool for micro-grids in rural and remote communities, particularly following natural disasters such as bushfires and storms. The falling costs of DER technology is giving communities new options, particularly those that struggle with expensive, polluting or unreliable power sources. King Island in Bass Strait is an example of where renewable generation and battery storage have replaced more than two-thirds of the local diesel generation that has traditionally supplied power on the island.

These areas are known as 'intentional islands' that can disconnect from the grid if certain criteria are met. Smart inverters can maintain power to keep important appliances and critical equipment functioning.

Virtual power plants are groups of DER that can be controlled collectively in real time to respond to grid conditions. Aggregating DER using smart inverters and advanced communications creates new options for rural and remote communities. Project Symphony in Western Australia is collecting 500 customers with more than 900 distributed energy resources to test the ability of the market operator and network companies to operate the system as a virtual power plant delivering grid services and reliable cost-effective power.

ARENA is administering the $50.4 million Regional Australia Microgrid Pilots Program to improve the resilience and reliability of electricity supply in regional communities, and to demonstrate solutions to technical, regulatory or commercial barriers to the deployment of microgrid technologies.

Community batteries allow households that cannot install solar, such as renters and apartment-dwellers, to draw from excess stored electricity. Typically, they can provide around 500kWH of storage, which can support up to 250 households. Community batteries can store and distribute electricity, allowing sharing. 'Solar gardens' or 'solar banks' may provide a solution for the 30% of people who either rent or live in apartments and who are often some of the most vulnerable in our community. This is a concept where people lease part of a community-owned resource and receive a credit on their electricity bill.

Australia is also seeing rooftop solar and grid-scale community projects funded by community/private partnerships driven by not-for-profit social enterprises and corporate social responsibility, and without any support from state or federal governments.

Consultation and creating social capital will be vital for the energy transition. Many consumers are sceptical of who will benefit and are concerned about the inequalities of any new system, particularly the idea that they are generating energy for profit. People will be far more likely to support new technologies if they feel they get a benefit, have a voice, understand the purpose, understand the cost, and that the technology contributes to the clean energy future.

2.5.1 Peer-to-peer trading

To realise the full potential of DER, households should have the ability to trade electricity either directly or indirectly via a marketplace. This complex marketplace could be managed by distributed ledger (blockchain) technology. AGL, a major Australian energy company, has been testing this idea in collaboration with ARENA in a virtual peer-to-peer trading model and found this to be a valid market, determining that both vendors and buyers would be better off than trading through a retailer.[11] While this is likely to start with households using batteries, it may also be facilitated by EVs and bi-directional charging. Power Ledger is another Australian company working in this space. These sorts of market reforms can drive consumer choice and innovation, as well as encourage uptake.

Sophisticated market reforms would be needed to enable peer-to-peer trading of energy, and alternatives such as an access market also require further investigation.

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11 AGL Energy Limited, *Peer-to-peer Distributed Ledger Technology Assessment*, AGL, 2017, p.7, accessed 26 October 2021. https://arena.gov.au/knowledge-bank/peer-peer-distributed-ledger-technology-assessment/

3. Power system management and reliability

If not managed properly, distributed energy resources (DER) pose a significant challenge to system security through changes to frequency and voltage, as well as questions around the ability of DER to withstand disturbances.

The system will need to balance:

- daily fluctuation in demand, and differences in day and night cycles because of variable solar output, also known as the duck curve
- seasonal, month-by-month and week-by-week variations that are affected by sunshine hours and other weather conditions, and which will become less predictable with climate change
- cyclical conditions, such as periods of cloudy, windless days that occur on the eastern seaboard coinciding with increased winter heating demand.

Methods of balancing supply and demand on the grid include:

- coordination and management of DER
- energy storage such as batteries/pumped hydro systems or new solutions such as gravity energy storage, compression systems, kinetic energy recovery systems etc.
- synchronous condensers that can generate or absorb reactive power
- strong interconnection between states
- coal- and gas-generated electricity (while still available)
- demand management such as time-of-use tariffs, and demand response at a utility, community and household scale.

While the Australian Energy Market Operator (AEMO), manufacturers and the vast majority of Engineers Australia members consulted believe there is no technical reason why DER cannot be profitably integrated into the grid, this is still being tested and demonstrated at scale.

DER generation can only be integrated through additional investment in the distribution network. Each DER connection to a distribution system poses technical issues that must be addressed at the point of connection. However, a large volume of distributed connections must be dealt with differently to a small volume of large, localised connections.

The engineering challenges are substantial, particularly as DER penetration reaches a threshold which varies depending on the proposed point of connection:

- Distribution network service providers (DNSPs) will need to make additional investments to allow for two-way power flows without any direct way of signalling once local DER saturation is reached, whether due to equipment capacity, voltage regulation, fault levels or other power quality issues.
- Additional investments are increasingly inefficient. The cost impacts of local investment are felt across the entire distribution network cost model unless they are fully customer-funded.
- The distribution use of systems (DUOS) model means that customers who opt for inefficient capacity investments may drive up costs for other consumers due to avoided DUOS charges.
- Truly cost-reflective connection charges and time of use tariffs for DER may send the appropriate signals, but they will not be welcomed by consumers. This means cross-subsidisation of DER may persist, requiring appropriate regulatory change. This could reduce asset utilisation and drive up electricity prices.
- Cohesive planning needs to be undertaken to optimise the value of consumer-led capacity investments. Virtual power plants (VPPs) are one approach, but they do not necessarily make inefficient investments efficient, or make surplus capacity valuable.
- Similarly, electrification of personal transport poses significant challenges. If the point of connection and timing of charging/discharging vehicle batteries are not controlled or at least strongly influenced by a distribution network operator, it makes capacity planning and system operation/security impossible.

The rapid increase in DER requires consideration of distribution network regulatory frameworks and market models. It may also be helpful for the operators and regulators to provide more guidance on the best DER integration pathway for DNSPs.

Distributed energy resource management systems allow DER to be coordinated and managed by different parties for different uses, including:

- onsite coordination through home/building and facility energy management systems
- aggregator management through, for example, a VPP
- EV managed charging
- DNSP active management of a fleet of DER in their network.

DER will also contribute to the challenge of balancing the grid and the need to curtail generation at times when we have too much and intermittency when we have too little. AEMO modelling is indicating that, at a certain level, adding more storage is not economically efficient, and that installing sufficient variable energy to supply needs in winter and accepting some curtailment in summer may be the best way to proceed. The Integrated System Plan (ISP) is showing this could be 20% by 2050. A method of ensuring return on investment will be needed, particularly for those whose generation is part of the 20% curtailed.

Key activities to ensure DER can be integrated into the electricity network by building the operational architecture and associated roles and responsibilities for a highly decentralised power system include:

- DER demonstrations of technology (inverters and batteries, particularly at grid-scale)
- market reforms, demand response mechanisms
- community batteries and virtual power plants, micro-grids
- examination (testing) of how DER assets behave during disturbances
- data and visibility of DER asset specifications and locations
- development of standards such as AS4777 Inverter Requirements and AS4755 Demand Response to ensure performance, cybersecurity and interoperability.

Current examples of these kinds of activities in operation include:

- Project Energy Demand and Generation Exchange (EDGE) in north-east Victoria, which is developing a two-way market for DER[12]
- SAPN's Salisbury trial that connected 100 battery electrical storage systems and solar installations in Adelaide
- Ausgrid's community batteries at Beacon Hill and Bankstown
- a virtual power plant (VPP) in Victoria where 40 community batteries are allowing 3,000 households to collectively export, store and use energy generated by the solar panels on their roofs
- Queensland's Energex PeakSmart air conditioning scheme exploring demand management.

3.1 Incentivising load and demand management

Having the technology for demand management makes it possible to create pricing, tariffs and other incentives for consumers to save money by drawing power at certain times of the day when generation is high, which will allow higher penetration of renewables. One example is time-of-day tariffs. These could take the form of low-cost off-peak rates during the middle of the day. Electric vehicles and smart buildings have significant potential for demand management. The current market uses a mix of time-of-use tariffs and peak usage tariffs to incentivise demand management, but ideally, once there is an excess of renewable generation installed, demand management incentives should not be needed as much.

The Flexibility Services Pilot in Western Australia has enlisted 250 businesses to modify their energy use and solar generation in return for financial recompense. This shifting of demand is particularly designed to test ways to navigate periods of high solar supply and low demand.

One Engineers Australia member has suggested that future tariffs should reflect the rate of energy supply (peak power), not quantity (consumption), as this will better reflect the real cost of providing electricity services.

Combining demand management with DER technologies and data analytics can have a significant impact on reducing energy consumption and maintaining a balanced grid, while at the same time reducing emissions.

12 Latest reporting available at Australian Energy Market Operator (AEMO), *Project Edge*, https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/project-edge accessed 2 November 2021.

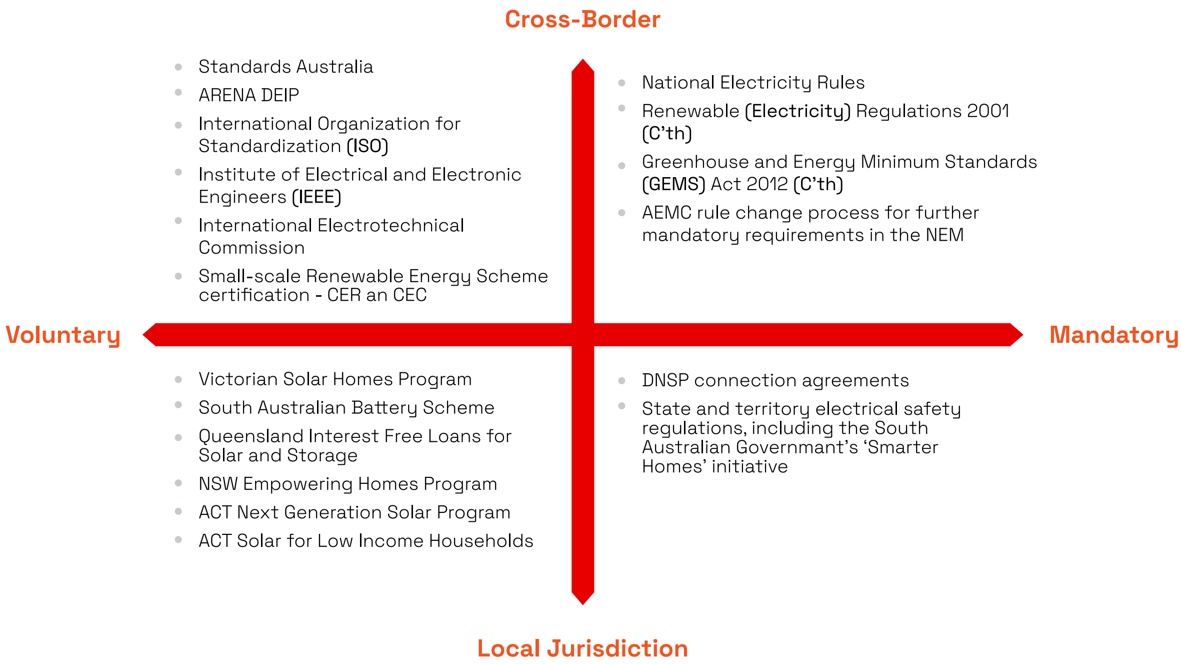
3.2 Development of technical standards

DER technical standards enable customer participation, protect consumers, and at the same time support system security and distribution network management.

There is currently no single point of leadership in the development and integration of DER technical standards. The Energy Security Board (ESB) proposed a DER Standards Governance Committee to take responsibility for guiding this work. The Committee is currently considering whether standards should be developed in-house, through the Distributed Energy Integration Program (see below), Standards Australia, by adopting international standards, or on a case-by-case basis. The ESB proposal received overwhelming support, but no structure for the governance of DER technical standards has been put in place. The danger of not resolving these issues is that it creates uncertainty and risks unnecessarily onerous requirements, and stakeholders will decide the process is not worth engaging with.

Figure 1, from the Australian Energy Market Commission (AEMC), indicates the complexity of the current arrangements. In addition, Engineers Australia members expressed the concern that the people involved in setting the rules are not always aware of the technical constraints of the various systems. (This is partly being addressed through dynamic operating envelopes – see section 4.1.2.)

Figure 1 – AEMC Overview of existing governance arrangements impacting DER technical standards[13]



The new inverter standard AS/NZ 4777.2:2020 Inverter Requirements has inclusions including voltage-reactive power control (Volt-Var) and voltage-active power control (Volt-Watt) functions enabled by default and configured by region. The standard also introduces the requirement to include ride-through performance to ensure the inverter stays connected to and synchronised with the system during system disturbances. It also includes electric vehicles.

13 Latest reporting available at Australian Energy Market Operator (AEMO), *Project Edge*, https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/project-edge accessed 2 November 2021.

The Institute of Electrical and Electronic Engineers (IEEE) is developing a suite of smart grid standards, IEEE2030, which provide a framework to enable interoperability of power, telecommunications, and IT systems, such as IEEE 2030.5-2018 – IEEE Standard for Smart Energy Profile Application Protocol. The International Electrotechnical Commission is trying to do something similar, at least for telecommunications. Other examples of relevant standards include AS/NZS 4755 Demand Response and AS/NZS 5033:2021 Installation and Safety Requirements for Photovoltaic (PV) Arrays.

Whatever approach is taken to standards development, it needs to be transparent, timely, agile and provide coordination and quality control. The process needs to be cognisant of the flow-on effects that can impact safety and testing compliance. AEMO's Engineering Framework Initial Roadmap and Integrated Systems Plan rely on visibility and monitoring data from DER. The energy transition is moving quickly, and the development of technical standards needs to reflect a cogent vision for the future.

Engineers Australia has members on the Standards Australia Council, as well as hundreds of members engaged in the technical committees that develop standards.

3.3 Transmission networks and REZs

Though not directly related to DER, investment in the transmission network is vital to enable the whole system to work. The National Electricity Market (NEM) transmission network was developed to take electricity from large coal-fired power stations to cities and significant regional areas. The future grid is likely to see both more localised sourcing of electricity and more that has been transmitted from a distance. DER can play a significant role in reducing the need to transmit power by providing local storage solutions. However, while DER can ameliorate the need for some expenditure on transmission and distribution networks, augmentation of the transmission network is still vital for a flexible, reliable system. The continental scale of energy supply and demand in Australia is challenging, but it also provides an opportunity to even out the variable nature of renewable generation, as well as seasonal variations, by moving power north–south, and taking advantage of time differences east–west. A more interconnected grid will improve resilience by connecting diverse sources of energy to lower prices and improving energy security.

Renewable energy zones (REZs) are areas where there is good generation potential from solar, wind or hydro resources. The main advantage of an REZ is to focus the planning, development and operation of renewables and transmission. The New South Wales Government recently officially established Australia's first REZ of at least 3GW at Central-West Orana, centred on Dubbo. Industrial energy users that co-locate energy generation with use are likely to enjoy a competitive advantage.

Most state governments are investing in transmission infrastructure, which often invests in regional communities. However, planning and investment in the transmission network takes time to deliver. Transmission projects identified in the AEMO ISP need a national commitment to deliver in a timely fashion.

New high-power transmission lines often cross farmland. The rules around compensation are out of date and need attention. Reforms are required to support people whose land and houses the infrastructure crosses, and to encourage the social capital needed to ensure public support. Wherever possible, development should protect good agricultural land or co-locate if that provides benefits for both. Farmers are paying attention to these issues. NSW Farmers has formed an Energy Transition Working Group to look at the opportunities and challenges afforded by these developments. Social licence for transmission projects is critical and cannot be assumed. Detailed assessments of community impacts and direct engagement are required.

3.4 Telecommunications network

Growing use of the Internet of Things, cloud computing, machine learning, and data analytics is a vital enabler for establishing the communication and control architecture for a highly decentralised power system. It will reduce costs and emissions by allowing real-time data monitoring, load shifting, advanced reporting, emission monitoring, advanced metering, and market access.

However, increasing the extent to which businesses and consumers in the power sector rely on information technology infrastructure also poses some challenges. For example, with DER monitored and managed by information technology (IT) via telecommunications, communication errors and delays can result in instabilities in control systems (especially when there are nonlinearities or constraints in the system).

Cybersecurity is paramount to system reliability. Updates to standards such as AS4777.2 Inverter Requirements have incorporated new measures to counter cybersecurity threats. However, there is still significant room for improvement.

Larger energy generators and transmitters could benefit from having their own internal isolated telecommunications and IT networks for security and control reasons, although this would add cost and complexity.

Nevertheless, a distributed system is, in principle, more reliable than a centralised system, in that one part may go down but the rest will survive (as with the internet). Future energy systems should therefore be designed as a network of generators and loads connected via the grid to reap the benefits of cooperation in shared infrastructure, but still be able to provide critical services if/when/while islanded from the network.

The market must also be regarded as part of the energy system and be designed with consideration for the physical limits of the energy system. For example, if automated traders operate within a transactional energy system, then system nonlinearities and delays in communicating and making transactions could result in market instabilities, which could cause significant adverse impacts to energy infrastructure. This is another reason to consider other market options for renewable energy, such as an access market.

Question for further discussion:

01. What does Australia need to do to have the IT infrastructure to enact the new power system?

02. What else can Australia do to counter the threat of cybersecurity breaches?

03. Engineers Australia members play a significant role in the development of standards generally, but should we play a more active and coordinated role in the development of technical standards for distributed energy resources?

4. Current programs and activities

The opportunities and challenges of DER are not lost on the agencies tasked with managing, regulating and operating the network.

It is a rapidly evolving and complex area of work, with many different agencies and stakeholders. With the pace of change, complexity and number of activities, it is important for Engineers Australia to consider its role in supporting a successful energy transition in regard to DER.

4.1 The Distributed Energy Integration Program

The Distributed Energy Integration Program (DEIP) is a joint initiative led by the Australian Renewable Energy Agency (ARENA) and includes market authorities, industry, peak bodies and consumer associations. Its purpose is to support information exchange and reform on distributed energy.

4.1.1 State of DER Technology Integration Study

The State of DER Technology Integration Study is developing a functional framework to identify the capabilities needed, including summaries of 50 key DER projects and how they relate to each other, answering questions such as:

- What capabilities can DER bring to the power system?
- How do DER assets communicate and integrate?
- What data, modelling and analysis are needed to understand and maximise benefits?
- What market and network services can DER deliver?

4.1.2 Dynamic operating envelopes

The development and testing of dynamic operating envelopes (DOEs) will be critical. A DOE is the dynamic performance of DER that can be accommodated before physical or operational limits of a distribution network are breached. A dynamic operating envelope essentially provides upper and lower bounds on the import or export of power in a time interval for either individual DER assets or a connection point.

4.1.3 Interoperability Steering Committee

One of the critical workflows in the DEIP is the Interoperability Steering Committee (ISC). The ISC supports the development and implementation of DER technical standards, with a focus on the ability of different systems to use and exchange data effectively (interoperability). It recently published the Common Smart Inverter Profile (CSIP) Australia implementation guide.

The next steps for the ISC include:

- working with Standards Australia to publish CSIP as a Standards Australia Handbook
- publishing a testing guide to allow stakeholders to validate conformance to CSIP

- engaging with the Institute of Electrical and Electronic Engineers (IEEE) to update IEEE2030.5 to accommodate Australian extensions
- integrating electric vehicle interoperability
- through the Cyber Working Group, engaging with key federal and state government departments/agencies
- developing a DER cybersecurity no-regrets technical workplan.

4.2 Australian Energy Market Operator (AEMO)

The power system must have both operability and technical attributes. Effective power system modelling is critical to understanding how the overall system will work. This requires accurate data in both real time and modelling of the future. Firmness is the ability of a resource to confirm its availability to generate electricity. Flexibility is the ability to respond to both expected and unexpected changes in supply and demand. With increasing distributed photovoltaics (DPV), which isn't controllable, it is preferable if DER owners are incentivised to behave in a way that aligns with the needs of the system, such as backing off the solar, turning the pool pump on or charging the EV in the middle of the day to soak up all that excess solar energy.

It is also much easier if all the resources in the system are visible to the market operator, hence the need for a register of DER assets, which was implemented in March 2020. However, the DER register is just a list of the DER installed and details such as its size and location. It does not provide real-time visibility. While this helps AEMO to better predict what the DER might do at any given time, it also reinforces the need for agreed performance standards, for which the principles and guidelines are defined in the National Electricity Rules (NER).

The accumulation of passive devices is having an increasingly large aggregate impact on the power system. The passive operation of DPV systems is characterised by three main attributes:

01. **Performance:** how they respond to fluctuations in the power system. DPV generation is not subject to the same grid support and disturbance withstand requirements as large-scale generation.

02. **Visibility:** given their location behind-the-meter, generation from most of the DPV fleet today is not visible in real time to distributed network service providers (DNSPs) or AEMO.

03. **Controllability:** in contrast to large-scale generation, most DPV generation cannot currently be curtailed by DNSPs or AEMO, even under extreme abnormal system conditions.

As penetrations of passive DPV continue to increase and become significant at the regional level, the impacts include:

- an increasingly large component of generation that is not currently subject to the same disturbance withstand requirements as utility-scale generation
- a reduction in the daytime system load contributing to:
  - → *reducing availability of stable load blocks necessary for the effective operation of emergency mechanisms, such as frequency control schemes and system restart*
  - → *reducing system demand, potentially to the point of insufficient load to support minimum synchronous generation levels necessary for system strength, inertia, frequency control, and other services required for system security*
  - → *reducing load at transmission network connection points serving locations with high DPV generation, introducing voltage control challenges in the daytime*
- an increasingly large source of variable generation, resulting in increasing ramps associated with daily diurnal solar profile at the regional level, and faster, less predictable ramps in significant PV clusters at the sub-regional level due to cloud movements
- an increasingly large source of generation that cannot be curtailed, resulting in a less dispatchable power system.

Due to South Australia's relatively high DPV penetration and low load base, the passive nature of DPV is already affecting the state's bulk system operation. Under current DPV uptake projections, these issues will also be increasingly prevalent in other NEM regions by 2025.

4.2.1 DER Operations workstream

AEMO's DER Operations workstream[14] addresses the operational impacts of increasing levels of DER penetrating the electricity grid. Its objectives are to ensure the operational systems are in place to maintain energy system security with regard to:

- understanding how distributed resources behave during disturbances. AEMO has been collecting and analysing data from a wide range of sources to understand DER behaviour in response to power system disturbances. This work is being conducted in collaboration with ARENA, Solar Analytics, Wattwatchers, the University of New South Wales, ElectraNet, TasNetworks and Energy Queensland
- developing models of DER and load behaviour to better represent the behaviour of DER and load during disturbances
- managing emerging system security challenges related to DER integration into AEMO's operations analysis
- adapting under-frequency load shedding at times of low demand.

14 More information can be found here: https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/operations

4.2.2 NEM Engineering Framework and stakeholder engagement

AEMO has been working with stakeholders (including Engineers Australia) since December 2020 to develop the NEM Engineering Framework, particularly the operational conditions and any gaps or missing activities the NEM may face in the future. This work has been closely linked with the work that the Australian Energy Market Commission (AEMC), DEIP and the Energy Security Board's (ESB) Post-2025 Reforms (see below) are conducting.

The Initial Roadmap released in December 2021 has identified over 300 gaps and questions, organised in 10 focus areas, that will be summarised in three sub-roadmaps. One of the three is the Integration Roadmap, which is particularly relevant to DER and considers four main areas:

01. **Visibility and understanding** – visibility of new and existing technology for planning and operational decision-making.

02. **Performance and capability** – device capability reflecting the changing role and nature of technologies in the power system.

03. **Coordination and management** – architecture to enable many new actors and increasing volume and complexity of data exchange.

04. **Enabling participation** – incentivising technology and consumer participation to provide system-level flexibility and services.

It should be noted that similar analysis and discussions are taking place in Western Australia and the Northern Territory, whose networks are not part of the NEM.

4.2.3 Draft 2022 Integrated System Plan (ISP)

In July of 2021, AEMO released its 2021 Inputs, Assumptions and Scenarios Report (IASR) for use in forecasting and planning studies and analysis, particularly to inform the 2022 Integrated Systems Plan (ISP) to provide an updated 20-year outlook for the National Electricity Market (NEM). The IASR modelled five scenarios using the parameters of decentralisation and underlying demand:[15]

01. Slow Change – challenging economic conditions following COVID-19, slower decarbonisation, consumers manage energy costs through investment in DER.

02. Steady Progress – driven by existing commitments and trends, technology cost reductions.

03. Net Zero 2050 – action through technology advancements, industrial electrification, electric vehicles.

04. Step Change – consumer-led transformation and coordinated economy-wide action, global policy commitments, increased digitalisation that helps consumers manage energy use, building efficiency, strong adoption of electric vehicles.

05. Hydrogen Superpower – social change, hydrogen presents opportunities both domestically and for export.

15 More information can be found here: https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/operations

The modelling was based on some key inputs and assumptions, including:

- higher-than-expected uptake of rooftop solar
- electrification and decarbonisation in residential, commercial, industrial and transport sectors, and new zero emissions/renewable energy export industries, particularly hydrogen export and green steel manufacturing
- continuing decline in the costs of inverter-based resources, while the costs of mature technologies remain flat
- implementation of Renewable Energy Zones (REZ)
- transmission augmentation costs.

Beyond 2025, AEMO has not identified any insurmountable reasons why the NEM cannot operate securely at 100% instantaneous wind and solar penetration, especially with ongoing technological advancement in Australia and worldwide.

AEMO released the Draft 2022 ISP in December 2021. While it focuses on the optimal build-out of large-scale generation, DER is considered on a scenario basis only. The Draft 2022 ISP is the clearest plan to date of how to best manage the energy transition to achieve reliable, clean and affordable energy. It includes a 30-year Optimal Development Path focused on the 10,000 kilometres of new transmission infrastructure that will be needed to enable clean energy.

The Step Change scenario (see section 4.2.2) is now considered the most likely by a significant majority of stakeholders. It requires a major increase in renewables and firming capacity.

The $12.5 billion, 10,000kms of transmission infrastructure will be critical. Actionable projects include:

- Marinus Link across Bass Strait - $3.5 billion
- Hume Link – $3.3 billion
- VNI West - $3 billion.

Stakeholder input and social licence will be vital, or these could become a significant barrier to transmission (and pumped hydro) construction.

The scale of the task also highlights the need for a comprehensive national action plan to ensure:

- we have the workforce to achieve this, engineers included
- a plan is in place for early closure of coal-fired generators to manage the process with the least amount of disruption, and for financial certainty
- the actions identified in the NEM Engineering Framework are supported
- further significant market reforms from the ESB and AEMC.

The energy transition has always been a huge task that will require a national effort to achieve in the timeframes required. The Draft 2022 ISP brings this into stark contrast.

4.3 Connections Reform Roadmap (CRR)

AEMO and the Clean Energy Council released the CRR in December 2021. One of the common complaints from new generators has been the slow, bureaucratic connections process that has sometimes delayed and undermined the value proposition of new developments. The CRR is a living document with non-binding recommendations that, by the authors' own admission, still requires further detailed work. However, given the scale of the task, the challenges of connecting new generators to the grid in the fastest clean energy transition in the world, and the need to provide investment certainty, this work is vital.

4.4 Energy Security Board (ESB) post-2025 market reforms

The state and federal energy ministers tasked the ESB with providing advice on a long-term fit-for-purpose national electricity market design.[16] The current market design does not value all essential system services. AEMO is increasingly having to make operational decisions to ensure the system remains secure. Integration of DER is a core workstream.

The post-2025 market reforms seek to build a grid where customers can continue to meet their primary household and business needs as energy users and use their assets to create value across the system for everyone.

The detailed technical, regulatory activities are set out in the DER Implementation Plan, which aims to:

- reward consumers for their flexible demand and generation, provide options for how they want to engage with the energy market, and provide a fit-for-purpose consumer protections framework
- support energy market innovation, allow for the integration of new business models, and provide a more efficient supply-and-demand balance
- allow networks to accommodate the continued uptake of DER and two-way flows and enable them to manage the network's security in a cost-effective way
- provide the system operator with the visibility and tools it needs to continue to operate a safe, secure and reliable system.

Stakeholders will be able to participate in the detailed design and implementation of the reforms through consultation and engagement mechanisms. Workshops were held in February and are also scheduled for April and May 2022. These are considering:

- interoperability policy framework
- development of technical standards and governance
- development of policy on electric vehicle charging standards and timing for their introduction
- development of DER cyber standards
- addressing system security challenges emerging from low system load conditions.[17]

16 More information can be found here: https://esb-post2025-market-design.aemc.gov.au/integration-of-distributed-energy-resources-der-and-flexible-demand

17 More information can be found here: https://esb-post2025-market-design.aemc.gov.au/integration-of-distributed-energy-resources-der-and-flexible-demand

One of the key decisions was around a capacity mechanism that would pay generators to be available to dispatch electricity depending on their ability to be fast and flexible. The capacity mechanism has raised issues around unintended consequences. Some market players and commentators were concerned that a capacity market sends the wrong signals around investment in clean energy and would unnecessarily prolong the life of coal-fired generators when these needs can be met by increased renewables and storage. Others saw it as a way of balancing competing needs and priorities to get the right energy mix in a complex transitioning market. The ESB and energy ministers have acknowledged that the capacity mechanism requires further work.

4.5 Australian Energy Market Commission (AEMC)

On 12 August 2021, the AEMC made a final determination on updates to the National Electricity Rules (NER) and National Energy Retail Rules to integrate DER more efficiently into the electricity grid.

The rule changes followed a nine-month process of working with stakeholders as part of ARENA's DEIP. The final rules have three key components:

01. Clear obligations on distribution businesses to support more DER connecting to the grid
02. Enabling distribution businesses to offer a range of options to encourage solar owners to limit solar waste, save money and benefit the grid
03. Strengthening customer protections and regulatory oversight by the Australian Energy Regulator (AER).

4.6 Australian Energy Regulator (AER)

The AER has released the Value of Distributed Energy Resources report produced by the CSIRO and CutlerMerz. The report recommends a methodology to determine the value of DER that can be used by networks in investment proposals to integrate DER into the grid. The purpose of the study is to deliver a simple and transparent methodology for assessing the value of DER unlocked by proposed network expenditures to increase DER hosting capacity.

In November 2021, the AER published its final Ring-fencing Guideline on 'ring-fencing' arrangements for DNSPs – concerning the network's ability to roll out community micro-grids and grid-scale batteries. The AER identified a concern that allowing DNSPs to actively engage in the battery market without appropriate controls risks the foreclosure of other players. This would not be in the long-term interest of consumers. The AER developed a streamlined waiver process to facilitate certain types of DNSP batteries, especially community-scale batteries, where they supply capacity to others. The AER will actively consider each waiver application to ensure that the criteria are met and monitor this on an ongoing basis through the annual compliance process. The AER considers that the approach strikes an appropriate balance in allowing DNSPs and third parties to explore the use and benefits of batteries, especially community-scale batteries.

4.7 Engineers Australia engagement

These are some potential roles for Engineers Australia:

01. Awareness-raising among our members with a call to get involved. As mentioned above, the AEMO Engineering Framework has identified 300 gaps and questions still to be resolved. The sector is working through these and AEMO needs and welcomes technical input from practising engineers. Engineers Australia made a submission to the Draft 2022 ISP.

02. Awareness-raising and creating the social capital with the wider community to overcome any concerns about what the energy transition will mean to them. Energy transition is not without political and social challenges. Renewables, transmission lines, blackouts and more have caused concern in the past. The scale and complexity of the energy transition means it is unlikely to all proceed smoothly, but engineers know we can overcome these challenges. Engineers Australia can play a role in providing easily digestible information and facts to inform the public of what is possible. Engineers Australia should be visible in this space.

03. Advocating for funding to perform the critical detailed engineering for testing new technology and systems.

04. Advocating for funding for research and development (R&D) and training. ARENA has had a great impact on the industry, but has never funded much R&D, and in recent years has focused on projects with commercial payback, like the Clean Energy Finance Corporation.

05. Advocating for market and regulatory reform to complement and enhance the work AEMO has been doing on the technical side.

06. Providing coordinated input to relevant technical standards – see question 3 above.

07. Providing research and advocacy around the supply and demand of power system engineers – see section 5.

08. Advocating for the importance of independent engineering advice and decisions – see discussion paper on Energy Governance and the Engineering Voice.

09. Engineers Australia is looking at creating an Area of Practice for Renewable Energy. Review whether other Areas of Practice are needed to reflect the reality of developing technology and the energy transition.

Questions for further discussion:

01. Given the volume and complexity of activities in DER, how should Engineers Australia engage with these activities and what priorities should our advocacy focus on?

02. Should we be seeking representation on relevant bodies, for example the Interoperability Steering Committee, or are these better off with industry representatives?

03. Given the transformation of the energy sector and the multidisciplinary nature of power sector engineering, should Engineers Australia form an Energy Transition Community of Practice to bring together expertise to provide focus on these issues?

04. How should Engineers Australia assist in creating the public awareness and social capital needed to make the energy transition work e.g. public awareness campaigns, forums?

5. Energy engineering workforce

Engineering skills are critical to supporting prosperity in the modern economy.

Moving to a smarter grid, and the attendant underpinning infrastructure with upstream and downstream services, will require new skills and necessitates a rethink of workforce and training needs for power system engineers, electrical engineers and telecommunication engineers. Energy engineering draws from the same labour pool as mining and big infrastructure projects, which are expected to boom in the wake of the COVID-19 pandemic. Australia needs to understand the current energy workforce to be able to plan and provide the training and development required to enable the energy transition.

The key findings of the 2019 Engineers *Australia paper Australia's Engineering Capability: How the last ten years will influence the future* are still relevant[18]:

- Engineers are a small but critical segment of the labour market.
- The supply and demand of engineers must be understood in the context of economic growth and/or transition.
- New areas of practice mean engineering cannot be considered a homogenous discipline and it is important to understand the needs of individual sectors and locations.
- Skilled migration has fundamentally changed the nature of the engineering workforce and the migration program needs to refocus on employment outcomes.
- With talent harder to find, the industry needs to re-evaluate its value proposition in terms of wages, flexible conditions and development opportunities.
- The development of an engineer takes a decade: a four-year undergraduate degree (currently completed by around 25% of students in the minimum time) and five to seven years' experience before being considered competent for independent practice. Planning the domestic supply of engineers needs to account for this timeframe.

The June 2017 Independent Review into the Future Security of the National Electricity Market recommended that the (then) COAG Energy Council should facilitate the development of a national assessment of the future workforce requirements for the electricity sector to ensure a properly skilled workforce is available. This has not occurred.

18 Engineers Australia, *Australia's Engineering Capability: How the last ten years will influence the future*, Engineers Australia, 2019, accessed 20 December 2021. https://www.engineersaustralia.org.au/Government-And-Policy/Policy-Reports

5.1 Skills supply and demand

Infrastructure Australia is forecasting an unprecedented wave of public infrastructure projects over the next five years. It predicts that, at the peak, demand for skills will be 48% higher than supply, and that engineering is most at risk.[19] The category of 'engineering, scientist and architects' is one of the most volatile in their modelling. In the next two years, this category will call for an additional 20,000 full-time equivalent (FTE) jobs. Sharp rises are followed by a sharp drop in 2022 to 2025. It is estimated that approximately 19,500 FTE jobs will be shed in this period. Infrastructure Australia also anticipates that 40% of the workforce engaged in delivering infrastructure are set to retire over the next 15 years.[20] Without immediate attention, skill shortages may become a significant impediment to the realisation of the energy transition and the implementation of the AEMO 2022 Integrated Systems Plan.

Several data sources have identified an imbalance in skills supply and demand.

Engineers Australia research has identified:

- a shortage of experienced senior principal electrical engineers
- considerable uncertainty in economic activity arising from COVID-19
- while the media, industry and government report an engineering skills shortage, the nature of the skills shortage is an open question. For example:
  - → *salary surveys indicate wage growth is subdued, which in theory should not be the case in a skills shortage*
  - → *graduates report difficulties in finding work that develops their engineering qualification*
  - → *experienced migrant engineers struggle to find employment*
- the 2016 census shows approximately half of all engineering graduates were not working in engineering occupations
- no evidence was found that there is an insufficient number of Commonwealth Supported Places. Everyone who meets the entry requirements is enrolled, which suggests we have a shortage of experienced engineers, not of graduates
- there are reports of engineering skill shortages in other Organisation for Economic Co-operation and Development (OECD) countries that compete with Australia for skilled migration, such as the United Kingdom and the United States.

The National Skills Commission (NSC) maintains a Skills Priority List that includes a future demand rating. The NSC predicts several engineering areas that will see strong future demand, including electrical engineering.[21]

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19 Infrastructure Australia, *Infrastructure Market Capacity, Infrastructure Australia, Australian Government*, October 2021, p. 9, accessed 20 December 2021. https://www.infrastructureaustralia.gov.au/publications/2021-infrastructure-market-capacity-report

20 Infrastructure Australia, *Infrastructure Market Capacity, Infrastructure Australia, Australian Government*, October 2021, p. 29, accessed 20 December 2021. https://www.infrastructureaustralia.gov.au/publications/2021-infrastructure-market-capacity-report

21 National Skills Commission, *Skills Priority List*, National Skills Commission, Australian Government, June 2021, p. 4, accessed 20 October 2021. https://www.nationalskillscommission.gov.au/sites/default/files/2021-06/Skills%20Priority%20List%20Occupation%20List_0.pdf

Reliable, Affordable, Clean Energy for 2030 (RACE for 2030), an industry-focused Cooperative Research Centre tasked with improving the competitiveness, productivity and sustainability of Australian industries, found several engineering skill shortages:[22]

- cybersecurity/Internet of Things/software engineers
- EV infrastructure engineers
- grid engineers
- power system engineers/control engineers, renewable energy engineers.

More than 45% of respondents in RACE for 2030's survey indicated they expected the shortage to worsen over the next five years.

Hays, one of Australia's largest recruitment agencies, found several relevant engineering skills among the occupations in greatest demand:[23]

- Grid connection engineers/managers with project experience. Congestion and system strength issues are adding to this demand.
- Power system engineers with experience to connect renewable energy projects to the grid.
- Electrical engineers in renewables and research and development, and Clean Energy Council Accredited Electrical Engineers.
- Structural designers, in response to an increase in solar projects.

The Clean Energy Council's Clean Energy at Work report identified skills shortages in the renewable energy sector leading to delays and increased costs. There is a high demand for electrical and grid engineers in the sector and employers report these positions are difficult to recruit. Respondents reported this is due to the project-based nature of construction and installation jobs; remote locations; and the uncompetitive salaries on offer.[24] The report concludes that a review of the structure and relevance of training programs is needed.[25]

In large-scale renewable projects, over half of electrical engineer recruitments are unsuccessful, rising to 65% for grid engineers and 72% for supervisory control and data acquisition engineers. The most common reasons given were not enough experience in renewable energy (37%), salary (25%), and regional/remote location (19%). It was a similar story for small-scale solar.[26]

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22 J Rutovitz, D Visser, S Sharpe et al., *E3 Opportunity Assessment: Developing the future energy workforce*, RACE for 2030, 2021, p.56, accessed 27 October 2021. https://www.racefor2030.com.au/project/developing-the-future-energy-workforce/

23 N Deligiannis, *The most in-demand skills for 2021*, Hays website, n.d., accessed 20 October 2021. https://www.hays.com.au/blog/insights/skills-in-demand-2021

24 Clean Energy Council, *Clean Energy at Work*, Clean Energy Council, University of Technology Sydney Institute for Sustainable Futures, 2020, p.27, accessed 2 November 2021. https://www.cleanenergycouncil.org.au/resources/resources-hub/clean-energy-at-work

25 Clean Energy Council, *Clean Energy at Work*, Clean Energy Council, University of Technology Sydney Institute for Sustainable Futures, 2020, p.5, accessed 2 November 2021. https://www.cleanenergycouncil.org.au/resources/resources-hub/clean-energy-at-work

26 Clean Energy Council, *Clean Energy at Work*, Clean Energy Council, University of Technology Sydney Institute for Sustainable Futures, 2020, p.28-29, accessed 2 November 2021. https://www.cleanenergycouncil.org.au/resources/resources-hub/clean-energy-at-work

Consult Australia conducted a skill shortages survey in December 2020. Thirty-four firms participated, representing small, medium and large businesses. Electrical engineers were identified as one of the top three difficult-to-recruit occupations by a little over 15% of respondents. This compared to 33% for structural engineers, 39% for civil engineers, 15% for mechanical engineers and 3% for chemical engineers. These respondents reported that positions became harder to fill the more senior they were: 20% found it difficult to recruit graduates; 40% found early career and mid-level positions difficult to fill; and 80% found senior/principal positions difficult to fill. The most common key reasons given were a lack of applicants with the experience needed and a lack of applicants with the technical skills required. Eighty per cent of these businesses used employer-sponsored visas for electrical engineers.[27]

The 2012 Senate inquiry into shortages of engineers and related occupations is still relevant.[28] Unfortunately the committee's findings have predominantly not been addressed by government or industry, including its overall conclusions:

> *5.87 The engineering skills shortage in Australia can be attributed to a number of causes. One key stimulus is the departure during the 1990s of the public sectors from engineering training and the failure of industry to fill the gap. Graduate programs are thin on the ground, and graduate engineers are very employable in other sectors, which results in large numbers of engineering graduates choosing not to pursue engineering careers.*

> *5.89 While there may appear to be sufficient numbers of engineering graduates, many are compelled to opt out of engineering careers early on because industry tends to demand experienced engineers rather than new graduates. Others are lured by higher salaries in other sectors.*

> *5.90 International experience demonstrates that government investment in education and training will not be enough to address skills shortages, and that stronger partnerships between educational bodies and industry will 'encourage more effective use of existing skills'.*

One of the most significant findings of the inquiry was that the end of public-sector employment of engineers, particularly graduate programs and cadetships, was a significant cause of the skills shortage and that underutilisation of engineering graduates was a long-term, structural feature of the profession. This was echoed by many Engineers Australia members during consultations for this and other papers in the energy workstream.

27 Clean Energy Council, *Clean Energy at Work*, Clean Energy Council, University of Technology Sydney Institute for Sustainable Futures, 2020, p.28-29, accessed 2 November 2021. https://www.cleanenergycouncil.org.au/resources/resources-hub/clean-energy-at-work

28 Senate Education, Employment and Workplace Relations References Committee, The shortage of engineering and related employment skills, Senate Standing Committees on Education, Employment and Workplace Relations, Parliament of Australia, Australian Government, 2012, accessed 4 October 2021. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Education_Employment_and_Workplace_Relations/Completed_inquiries/2010-13/engineering/report/index

Engineering skill supply is cyclical. Australia experienced skill shortages in the late 1980s and during the mining boom in the early 2000s. Planning needs to account for these cycles and respond accordingly. Boom-and-bust cycles and unclear policy direction create uncertainty and deter many people from following a career in energy engineering. Infrastructure Australia cautions about drawing conclusions about the manageability of labour demand through peaks and troughs because it is difficult to source through diversion and upskilling alone. Also 'troughs' beyond 2022 are likely to be an artefact of the government budget forecast periods. Newer projects, although they are not captured, are likely to emerge in coming years.[29]

5.2 Relevance of education and training

The development of a professional engineer requires a four-year degree plus five to seven years' experience to be considered competent. In addition to the supply problems, many Engineers Australia members and industry stakeholders consulted felt there was a potential gap between university graduates' skills and the needs of industry. This was expressed in three ways:

01. The pace of change and the development of technology makes it difficult for university course content and laboratories to keep up. The API assisted with this work around 10 years ago, but that funding no longer exists.

02. The expectations on engineers are growing. As well as specific technical expertise, the modern engineer is expected to work in complex multidisciplinary teams, be digitally savvy, have good interpersonal skills and apply systems thinking. In addition, engineers will be expected to help develop social licence (trust), apply principles of sustainability to all their work, and engage directly with a broader range of stakeholders.

03. With the pace of change and expanding expectations, some members expressed concern that the basics are being neglected in some areas such as system control engineering.

Many members felt that, along with government, industry needs to take a more active role in providing training and real-world placements for university students, as well as traineeships and cadetships. The 2012 Senate inquiry into shortages of engineers and related occupations recommended that Commonwealth contractors should be encouraged through procurement requirements to provide graduate and cadetship programs.

Industry, quite rightly, wants to see a greater emphasis on practice in engineering education. There is a need for industry to look at how it trains and develops graduate engineers to build a pipeline for itself. Industry is uniquely placed to offer real-world experience through workplace learning, apprenticeships and technical trainers with up-to-date skills and knowledge of new equipment, tools and processes. Industry is also well placed to respond to the specific needs of a location and sector.

29 Infrastructure Australia, Infrastructure Market Capacity, Infrastructure Australia, Australian Government, October 2021, p. 48, accessed 20 December 2021. https://www.infrastructureaustralia.gov.au/publications/2021-infrastructure-market-capacity-report

A recent Engineers Australia survey of students on professional practice placements indicates:

- a need for greater coherence between theory and workplace practice.
- stronger partnerships and communication between institutions and industry.
- a need to re-position the perception of placements as rich learning experiences and the establishment of valuable connections and career opportunities.
- a need to consider placements across the curriculum with growing complexity as a student's knowledge develops.

The next step in this project is collecting the views of industry representatives.

Short courses, continuing professional development (CPD) and stacking micro-credentialing with flexible entry and exit pathways can be delivered in shorter timeframes. Rather than being seen as supplemental, these forms of training should become central to the energy transition.

A review of the structure and relevance of training programs, including for already qualified engineers, such as CPD and micro-credentialing, with particular emphasis on digital skills, could be helpful in making activities as relevant as possible. Greater collaboration between and within industry, vocational and university training bodies, and policymakers would result in courses that are relevant to industry needs with practical, problem-solving content.

The danger of not providing relevant and effective undergraduate and postgraduate training is a failure to deliver the clean energy transition the community expects, and could contribute to a perception that clean energy technologies do not work. As the role of an engineer changes, so too must the way they are educated, trained and developed.

5.3 Diversity is a solution

There is an increasing awareness that engineering needs to be a more socially engaged profession. A more inclusive industry may provide part of the solution and encourage young people to join, retain people considering their options or bring back people that have moved into other occupations.

The difficulty of retaining engineering graduates in engineering occupations is reflected by the Australian Council of Engineering Deans' 2019 engineering statistics, which showed that engineering was the field of study with the highest employer satisfaction rating, at 89.9%. Employers were particularly satisfied with the foundational, collaborative, technical and employability skills of engineering graduates.[30] The banking and finance sectors are interested and willing to pay for engineering graduates.

Australia has a number of untapped resources to bolster the engineering workforce. Addressing diversity is particularly relevant in Australia, where most engineers were born overseas, we have an engineering workforce that has the lowest percentage of women of all the STEM professions, and where we have trouble retaining graduates in the engineering workforce.

30 Australian Council of Engineering Deans, *Australian Engineering Higher Education Statistics 2009–2019*, Australian Council of Engineering Deans, 2020, accessed 15 November 2021. http://www.aced.edu.au/downloads/ACED%20Engineering%20Statistics%20Dec%202020_v2.pdf

Gender

Engineering has always been a male-dominated profession, with the current proportion of qualified female engineers at 13.6% in the 2016 census. The Office of the Chief Scientist estimates this is now around 15%. Engineering has the lowest percentage of women of all the STEM occupations. Women are underrepresented in all engineering university courses, but particularly so in electrical engineering, at 14%. In contrast, women make up over 40% of chemical and environmental engineers.[31] Undergraduate electronic and electrical engineering had 703 completions in 2018, comprising 644 men and 59 women.[32]

In the workforce, 7% of electrical engineers are female, compared to 12% of civil engineers and 32% of environmental engineers.[33] Gender equality data from the Workplace Gender Equality Agency indicates a pay gap of 22% compared to 14% across all industries.[34] Attracting more women will require specific strategies to overcome structural barriers.

In addition to the pay gap, the other issues that need to be addressed are:

- professional development opportunities
- sexual harassment
- workplace culture
- work/life balance
- flexible working conditions.

Increasing the participation of women in engineering will ensure that Australia is drawing on all available human resources. The lower participation in science and mathematics starts at primary school. Also, after the education years, the attrition of female engineers is higher than males and the issues identified above need urgent attention.

Overseas-born engineers

Infrastructure Australia has identified electrical engineers as one of the occupations where migration has a role to play in addressing capacity.[35] However, Engineers Australia believes supply could in part be addressed by accessing the existing pool of overseas-born engineers, who make up 58% of the engineering workforce but are significantly more likely to be unemployed or underemployed than Australian-born engineers.[36]

31 G Schaffer, 'Engineering gender equality', *Pursuit*, University of Melbourne, 14 March 2018, accessed 20 December 2021.https://pursuit.unimelb.edu.au/articles/engineering-gender-equality

32 A Kaspura, *Australia's Next Generation of Engineers: University Statistics for Engineering*, Institution of Engineers Australia, 2020, accessed 2 November 2021. https://www.engineersaustralia.org.au/Government-And-Policy/Statistics

33 The Association of Professional Engineers Australia, *Women in Engineering – an action plan for addressing the key drivers of attrition of women from the engineering workforce*, Professionals Australia, 2021, accessed 20 December 2021. http://www.professionalsaustralia.org.au/professional-women/wp-content/uploads/sites/48/2021/06/Women-in-Engineering-report.pdf

34 The Association of Professional Engineers Australia, *Women in Engineering – an action plan for addressing the key drivers of attrition of women from the engineering workforce*, Professionals Australia, 2021, p. 10, accessed 20 December 2021. http://www.professionalsaustralia.org.au/professional-women/wp-content/uploads/sites/48/2021/06/Women-in-Engineering-report.pdf

35 Infrastructure Australia, Infrastructure *Market Capacity*, Infrastructure Australia, Australian Government, 2021, p.10, accessed 20 December 2021. https://www.infrastructureaustralia.gov.au/publications/2021-infrastructure-market-capacity-report

36 J Romanis, *Barriers to employment for migrant engineers*, Institution of Engineers Australia, 2021, p. 6, accessed 2 November 2021 http://www.aced.edu.au/downloads/ACED%20Engineering%20Statistics%20Dec%202020_v2.pdf

In a 2021 report, Barriers to employment for migrant engineers, Engineers Australia identified six opportunities to address these issues:

01. Positioning migrant engineers as a collective talent pool and talking about the size of the opportunity for employers
02. Providing credible, trusted information on employment pathways for migrant engineers
03. Increasing local networks by developing networking and sponsorship programs/ opportunities for migrant engineers
04. Coordinating initiatives to build local knowledge and experience of migrant engineers
05. Assisting humanitarian visa holders with their credentials assessment
06. Making it easy for employers to access the talent pool.

Even in periods of low demand, skilled migration has still been necessary to meet demand. Skilled migration needs to focus on utilising these engineers in the workforce.

Aboriginal and Torres Strait Islander engineers

Aboriginal and/or Torres Strait Islander students enrol and graduate from engineering courses in very low numbers. In 2018, 61 students completed, comprising 53 male and 8 female. In 2019, they constituted less than 1% of students commencing bachelor's degrees. For example, the comparable figure for health is 3.4%. Completion numbers also indicate a high attrition rate, of around 40%.[37]

Creating a genuine engagement with Aboriginal and/or Torres Strait Islander communities has been identified as important. Reaching out to Aboriginal and/or Torres Strait Islander children in urban, rural and remote communities at a young age and putting forward positive role models would be valuable. Another important element would be to increase the relevance of Indigenous knowledge and world views by incorporating it into the mainstream curriculum.

In the workplace, we need more focus on incorporating Indigenous knowledge into engineering projects, such as land conservation and sustainability, as well as understanding and respect for Indigenous culture.

Engineers with a disability

Many engineers with a disability face challenges in both study and the workplace. This is often based on false assumptions about what they are capable of achieving. There are many successful engineers with a disability and many limitations can be overcome with reasonable adjustments to the work environment or the use of technological aids. The Engineers Australia community, Engineers with Disabilities Australia, reports that one in five Australians report having a disability. Reasonable adjustments to include people with a disability would encourage diversity, but also innovation and project outcomes.

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37 Australian Council of Engineering Deans, *Australian Engineering Higher Education Statistics 2009–2019*, Australian Council of Engineering Deans, 2020, accessed 15 November 2021. http://www.aced.edu.au/downloads/ACED%20Engineering%20Statistics%20Dec%202020_v2.pdf

Nonbinary gender inclusion

Gender dynamics can cause some people to feel they have to mask their true selves to fit in and succeed at work. Without social support the profession becomes unwelcoming. This can be extremely stressful and lead to some people deciding that they would rather leave the profession. There are some simple steps that can be taken such as gender expansive language and expanding the gender options in administrative systems.

Engineers Australia is proud to be a founding partner of InterEngineer, a community designed to provide an avenue for LGBTQIA+ engineers and allies to communicate, network and advocate.

Neurodiversity

It is estimated that 10% of the population are neurodivergent and the real number could be twice that many.[38] Like the rest of the population, many engineers are neurodiverse with conditions such as Attention Deficit Hyperactivity Disorder (ADHD), Autistic Spectrum Disorder (ASD) and dyslexia. Neurodiverse people process information differently and have different strengths. In an information occupation like engineering, having people that think differently on your team is an advantage and may lead to the idea that others are looking for. Understanding the way neurodiverse people think and making simple adjustments to work to their strengths will lead to more successful projects and less people leaving the occupation.

Intersectional Analysis

Intersectionality is the idea that categories such as gender and ethnicity do not operate independently of one another. Looking at elements of diversity as separate issues will not address all the issues and ignores the compounding impacts of marginalisation. The experience of a woman with a disability may be completely different to those of other women. Using intersectionality as a framework to consider these issues will provide a better understanding of people's lived experiences by thinking about the cultural, structural and organisational barriers to participation in the engineering workforce. Intersectional thinking also allows us to consider that we are all intersectional in our advantages and disadvantages and that it can change depending on context.

Engineering problems are complex and getting more so. At the same time, engineering does not attract enough young people and loses too many along the way. The reasons are complex and interrelated. However, a workplace that values diversity and inclusion is more likely to attract and retain people.

5.4 Other considerations

Fossil fuel workforce

Given the high skill base of the fossil fuel workforce, and the increasing likelihood of substantially reduced global demand for fossil fuels over the coming decades, mapping the training needs of the fossil fuel workforce would support a 'just transition' and play a role in addressing skill shortages.

38 Diversity & inclusion, *Supporting neurodiversity in your engineering team*, Anna Granta, 27 April 2021, accessed 21 February 2022, https://leaddev.com/diversity-inclusion/supporting-neurodiversity-your-engineering-teams

Research, such as that conducted recently in Queensland, indicates that 80% of the tasks needed in a clean energy economy are already being performed. Creating growth in these industries, while it will cause structural changes, will not lessen the demand for many occupations, and for others may just require on-the job-training or short courses. Conversely, the report found that failing to coordinate the transition and adapting training systems would increase the costs and disruption to workers and businesses. Some workers may need support to enhance their skills, including electrical engineers.[39]

ANZSCO

The Australian and New Zealand Standard Classification of Occupations (ANZSCO) codes are too generic (e.g. Electrical Engineer) and are not reflective of the current or future energy sector, which makes analysis difficult. Other engineering roles are simply captured as 'Other Engineering Professionals'. ANZSCO codes relating to engineering in the energy sector should be updated to reflect the modern engineering workforce.

5.5 Engineers Australia current activities

Because of its accreditation program and other links, acting as a bridge between universities and industry is something Engineers Australia is uniquely well-placed to do. The energy and university sectors are both going through massive transformation. The engineering workforce needs to have knowledge of an increasingly wide range of areas. In the past, the Australian Power Institute (API) has worked to upgrade university labs and create contemporary teaching resources, but that funding no longer exists. Those teaching modules are now 10 years old, and universities do not have the resources to update them. Many people in the power industry, and Engineers Australia members, are concerned that we have a growing knowledge gap as a result.

Engineers Australia is very active in skills supply and demand, including:

- accrediting university courses
- assessing engineers' competency levels via the Chartered Engineer program and establishment of the National Engineering Register
- reviewing what it means to be competent in an Area of Practice
- researching demand signal data to feed back into university and possibly schools
- working with the Australian Government (Department of Education, Skills and Employment, and the National Skills Commission) to identify policy levers to encourage more students to study engineering
- providing training through Engineering Education Australia, who provided training to 5,133 engineers in 2020-21, incorporating a targeted graduate program, Emerging Leaders Program, micro-credentials, and working with businesses to structure their training and move their staff towards achieving Chartered status
- providing a national program of CPD, including conferences
- assessing the skills of overseas-trained engineers, enabling them to immigrate and contribute to the Australian economy

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39 Deloitte, *Powering the future: Skilling Queenslanders for the clean transformation*, Deloitte Access Economics, 2021, pp. 9-10, accessed 20 December 2021. https://www.climatecouncil.org.au/wp-content/uploads/2021/12/People-Powering-the-Future-report.pdf

- conducting research such as the Statistical Overview, engineering skills supply and demand, utilisation of overseas-born engineers, STEM etc.
- providing career services, including a job board, connecting students and graduates with employers, and providing mentoring for young engineers
- providing services to encourage the STEM pipeline through primary, secondary and tertiary education. See the STEM strategy here: https://www.engineersaustralia.org.au/STEM
- providing support through the Women in Engineering Group to guide our diversity agenda and provide a support network for female engineers
- providing support through the Indigenous Engineers Group to help create, develop and grow ideas and strategies for Aboriginal and/or Torres Strait Islander engineers around Australia.

5.6 Engineers Australia further engagement

Engineers Australia could further contribute to ensuring the demand for power system engineering can be met by:

- lobbying government to fund industry engagement in engineering education
- ensuring Engineers Australia's competency reviews and Chartered status keep pace with the modern demands of engineering practice
- working with government and training providers to ensure forthcoming engineers have the right skills to contribute to the clean energy transition
- engaging with industry and academia to develop a more thorough understanding of skills supply and demand and devising solutions for the short, medium and long term
- enhancing our role as a bridge between industry and academia, particularly around retraining, on-the-job training, and projects for the last year of undergraduate and master's degrees
- providing a CPD program that assists experienced engineers to transition into the renewables sector
- further promoting and lobbying for a greater emphasis on the importance of a diverse and inclusive workforce
- conducting further research such as the Statistical Overview (15th edition) to provide a more recent understanding of Australia's engineering profession data, including following the census in mid-2022
- commissioning quantitative research on the mismatch between supply and demand to gain further insights on the issue
- collaborating with other industry associations to provide a united front on solving the issue of boom-bust cycles, particularly for sectors such as construction
- continue advocating for changes to the skilled migration program, focusing on outcomes of migrant employment and bringing in 'in-demand skills' and not just qualifications
- targeting effort on increasing utilisation of recent graduates to retain them in the profession

- investigating what underpinning skills are lacking in graduates, if any
- initiating an ongoing discussion around the balance between electrical, electronic and systems engineering in both formal and on-the-job training to take into account the trans- and multidisciplinary nature of modern power engineering
- enhancing our work with school outreach with more resourcing and better coordination between all the stakeholders in this space
- continuing to promote and differentiate the 'E' in STEM, with specific emphasis on sustainability and social impact.

These are critical issues for the future of the energy transition. Having the market rules in place will be undermined without sufficient skilled engineers to plan and deliver projects on the ground. Government should work with industry, education providers and Engineers Australia to develop a detailed scope of future occupations and skill supply and demand. Sufficient engineering skills will be critical to realising the full benefits of the energy transition and the smart grid.

Questions for further discussion:

01. Given the role Engineers Australia already plays in developing engineering skills supply and demand, what else could we be doing and what programs should we be enhancing?

02. How can Engineers Australia support industry and government to better model the demand for engineers by sector over the next decade and beyond?

03. How can Engineers Australia work with industry, the tertiary sector and government to encourage more students into the STEM subjects and STEM-based careers?

04. What more can be done to retain graduates in the profession?

05. How can Engineers Australia collaborate with industry and government to increase the number of women in engineering?

06. What resources could be made available to both employers and skilled migrants to support employment in Australia?

07. With regard to energy sector skills, what priorities would you like to see Engineers Australia advocacy focused on in terms of both government and industry?

Conclusion

Distributed energy resources (DER) are transforming the power system. DER is changing from being a passive participant in the electricity system to being an active participant using sophisticated energy management systems that can adjust in response to signals from the grid. However, the majority of DER is currently passive, meaning that it is uncontrollable and invisible to the system operator (behind-the-meter and unmonitored in real time). This brings considerable challenges. The existing network was not designed for a two-way flow of energy. This will require new techniques and services to manage the system. While there are some lessons to be learnt from overseas practice, Australia is at the cutting edge of this aspect of the energy transition and many countries are watching how we manage it. It is a technical and regulatory challenge that will become even more difficult as DER penetration increases.

There is a considerable amount of thought, time and energy going into ensuring DER is integrated into the grid in a sustainable and reliable manner. All the market regulators, operators and funding agencies are looking at these issues. AEMO, ESB, AER, AEMC and ARENA are all working to understand what capabilities DER can and must bring to the power system, as well as how they communicate and integrate and ensure interoperability. AEMO is tasked with ensuring the operational systems are in place to maintain energy security with regard to how DER behaves during disturbances and can adapt at times of low demand. Modelling and analysis are critical. AEMC and AER are working to determine the market models that will allow DER to be integrated in a sustainable and equitable manner. The technology is moving so fast it is hard for the market operators and regulators to maintain pace. Despite best efforts, the pace and complexity of the transition could become overwhelming.

Multiple data points indicate we do not have the engineering workforce to deliver the energy transition. Having the technology and market rules in place will be undermined without sufficient skilled engineers to plan and deliver projects on the ground. Government should work with industry, education providers and Engineers Australia to develop a detailed scope of skills supply and demand. As the step-change transition develops, many members and industry players see a potential gap between tertiary education, professional development and industry needs. More needs to be done to ensure university courses keep pace with the needs of industry, and to ensure graduates are equipped to cope with new and expanded requirements. The skilled migration program should focus more on employment outcomes, and industry needs to work towards more inclusive workplaces that welcomes diversity. Sufficient engineering skills will be critical to realising the full benefits of the energy transition and the smart grid.

Engineers Australia is already very active on many of these issues, but certainly not all. We need to consider what unique role Engineers Australia can play, and where we should focus our resources and advocacy.

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Integrating distributed energy resources in the electricity grid

Energy EVP discussion paper