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16 February 2024

Mr Daniel Westerman
Chief Executive Officer
Australian Energy Market Operator (AEMO)
Sent via email: ISP@AEMO.com.au

Dear Mr Westerman,

Draft 2024 Integrated System Plan (ISP) for the National Electricity Market (NEM)

Endeavour Energy appreciates the opportunity to provide feedback on AEMO's Draft 2024 ISP. We are aligned with AEMO's initiative in establishing a clear and consistent pathway for market participants to undertake the urgent action needed to transition the NEM to renewable generation for the benefit of all energy customers.

As is the case across the NEM, we are observing and enabling a rapid and continued uptake of decentralised and decarbonised generation by our customers. As at 30 June 2023, 250,000 (or 22%) of our customers owned CER assets, predominately rooftop solar, with increasing numbers of EVs and home or business energy storage devices. We also support 300,000 demand response hot-water systems. We expect 402,000 additional CER assets over 2024-29 and a further 1.7 million from 2029 to 2040. Last year, rooftop solar in our network supported 2 TWh of energy which equated to 11% of our overall energy delivered. This context offers insight into the enormous and growing potential of coordinated CER assets to the energy system transition and security, which the ISP has rightly identified.

Our ambition and organisational focus actively supports the energy choices of our customers and the transition of the Australian economy to renewable generation. To do this, we have been improving network visibility of CER, while developing price signals and connection policies for export hosting. We have invested in cost-effective solutions to improve export hosting and power quality and we are leading several innovative trials to maximise the value of the network for customers. This includes our industry leading Off Peak Plus project, subject to the first Regulatory Sandbox Trial Waiver in the NEM, implementation of Flexible Exports, rolling out several community batteries and establishing the Bawley Point & Kioloa Community Microgrid & VPP, a first for New South Wales.

It is critical that Distribution Network Service Providers (DNSPs) take these actions to deliver the energy transition quickly and cost effectively for customers whilst providing the appropriate controls for grid security and certainty.

We do believe DNSPs can offer more to accelerate the transition and address the growing NEM-wide reliability gaps identified in the 2023 Electricity Statement of Opportunities report[1]

[1] AEMO, 2023 Electricity Statement of Opportunities, August 2023, p. 3

and the concerns expressed in the NSW Electricity Reliability and Safety Check-Up[2] on the pace and ambition of the NSW transition.

Our investors form part of the ACE Energy consortium, recently selected by EnergyCo to be the Network Operator for the Central-West Orana Renewable Energy Zone (CWO REZ), the first of its kind in NSW. In addition to supporting Transmission REZs, we believe there is ample opportunity for Endeavour Energy, and other DNSPs, to unlock more renewable generation faster and at a lower cost to customers through existing, repurposed, distribution networks.

Our preliminary assessment of opportunities across our network area indicates the potential for at least 3-4 GW of additional renewable capacity in our existing grid, generating over 5 TWh annually, at low incremental cost[3]. Additionally, these potentially local distribution style REZs could more actively support local communities and establish a social licence through utilising CER via a combination of solar and wind across rural land; Commercial & Industrial (C&I) and residential rooftop solar supported by investments in storage, network upgrades and flexible demand.

Encouragingly, the Draft ISP recognises the increasing need for customer and DNSP involvement in the energy transition compared to the 2022 ISP with a 30% increase in distributed solar generation and 77% of storage needs in the NEM via orchestrated CER by 2050. On the latter, we recommend further work is undertaken on the orchestration sensitivities given the significance of this assumption. We also recommend AEMO considers the role of distribution as broader than CER orchestration, which remains of critical and increasing importance. In particular, further consideration should be given for the potential of Distribution REZs to connect renewable generation, at scale, to existing networks quickly and with minimal additional investment.

We are committed to supporting AEMO to identify options to address the urgent need for investment in generation, firming and transmission infrastructure highlighted in the Draft ISP[4] and welcome the continual engagement we have with AEMO. In Appendix A, we provide further details on opportunities where Endeavour Energy can continue to offer support to AEMO, including:

- Greater consideration of the benefits of a customer led transition including through distribution REZ's, flexibility services and increased transparency of network hosting opportunities;
- The increasing growth and opportunities for flexible loads, afforded by the increasing proliferation of data centres; and
- Further testing and behavioural impacts of EV consumption patterns.

I would welcome the opportunity to discuss our submission further with you and can be contacted on 0401 912 675. Alternatively, please contact Patrick Duffy, Manager Regulatory Transformation & Policy via email at Patrick.Duffy@endeavourenergy.com.au

Yours sincerely

Colin Crisafulli, General Manager Customer Future Grid

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[2] Marsden Jacob Associates, NSW Electricity Supply and Reliability Check Up – Prepared for NSW Treasury, 4 August 2023, pp. 9-11

[3] Through analysis, we estimate the ability to unlock these renewables through storage at around half the cost per GW compared to REZ or transmission actionable project scenarios.

[4] AEMO, Draft 2024 Integrated System Plan for the National Electricity Market, 15 December 2023, p. 6

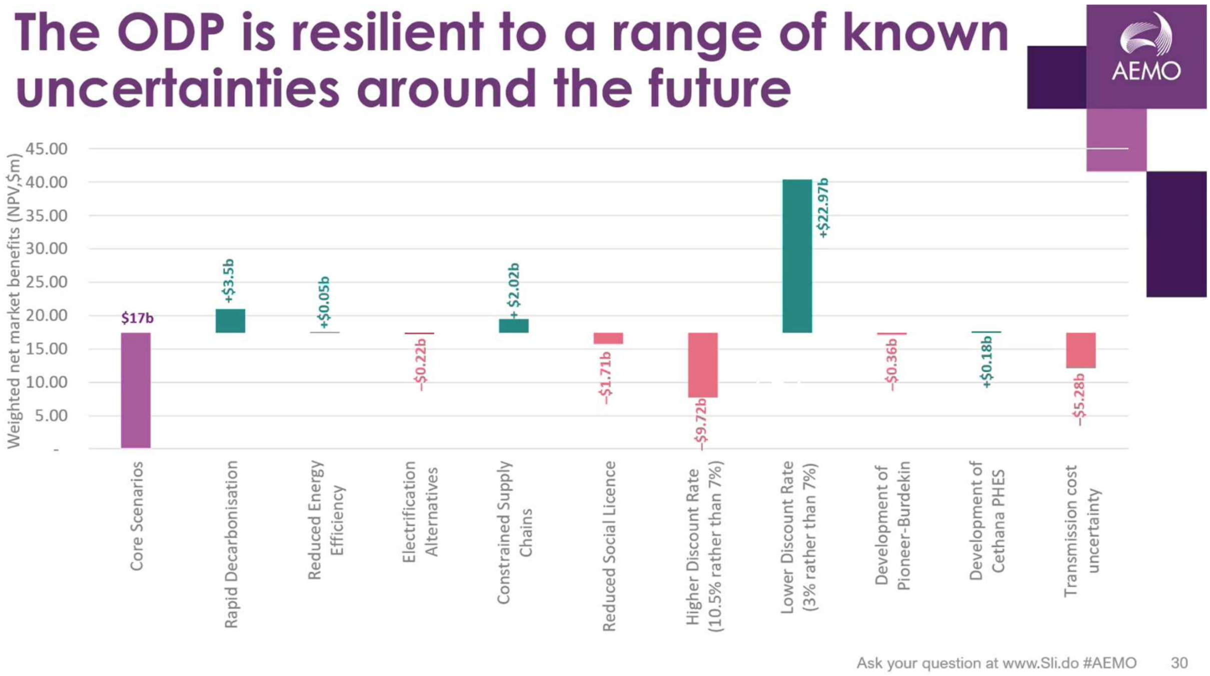
Appendix A: Detailed response

Greater consideration of the benefits of a customer led transition

CER orchestration

We consider that the Draft ISP and optimal development path (ODP) is comprehensive in its consideration of the energy transition and the transmission / ISP project pipeline. Extending this analysis into the distribution network presents an opportunity for refining and improving the ODP further. As pictured below, the ODP is well tested against a range of sensitivities.

Figure 1: ODP sensitivity testing



However, we suggest the ODP should be further tested against distribution network related contingencies. Notably, the Draft ISP anticipates a significant level of CER orchestration to manage the expected increase in rooftop solar capacity to 72 GW by 2050 along with 34 GW of residential and commercial batteries and up to 97% EV ownership[5]. We therefore agree with AEMO's observation that[6]:

> *These forecasts highlight the high value of solutions in which resources owned by consumers, such as residential electricity generation and storage devices, and increased demand flexibility, can help meet power system needs. With a high level of consumer participation and coordination of consumer energy assets and demand to help meet power system needs, the need for utility-scale solutions would be much lower.*

This is why several networks are trialling flexible demand related initiatives and it is a focus of ongoing policy reforms and strategic priority for ARENA[7]. On the former, we consider investing in energy storage will be of critical importance to achieving the ISP targets. In addition to storage, we have been trialling dynamic operating envelopes since 2021 and expect to launch our Flexible Connections Project to offer flexible exports to CER customers this year.

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[5] AEMO, Draft 2024 Integrated System Plan for the National Electricity Market, 15 December 2023, p. 47

[6] AEMO, 2023 Electricity Statement of Opportunities, August 2023, p. 4

[7] Australian Renewable Energy Agency (ARENA), Strategic priorities: optimize the transition to renewable electricity, accessed 29 January 2024, https://arena.gov.au/about/strategic-priorities/strategic-priorities-optimising-the-transition-to-renewable-electricity/

Whilst we are taking the necessary steps to build our capabilities there are a number of contingencies that could impact the pace and effectiveness of CER orchestration. These include:

- **Visibility:** delayed Basic Power Quality Data (PQD) will not be sufficient to implement dynamic voltage control and dynamic operating envelopes, which are critical to managing and maximising hosting capacity and instead require real-time and extensive data access. The contestable metering framework has not provided cost-effective or timely access to the data required to unlock the benefits of smart metering. Addressing this issue will be a key enabler to orchestration of CER.

- **Responsiveness:** compliance with inverter standards is another foundational requirement for CER orchestration. We note compliance rates, like the DER Register, are improving but remain below AEMO's target[8]. This is particularly challenging in NSW given its contestable connections framework. Addressing this issue will require action from jurisdictional regulators, CER manufacturers, installers and DNSPs.

- **Regulatory requirements:** the AER are currently consulting on an interim guideline for flexible export limits. The regulatory settings and incentives will impact the extent to which DNSPs offer these services and on what terms (e.g., apportionment methodology, consultation requirements, etc). It is important that a flexible regulatory approach is taken in the early stages of development and innovation amongst networks in order to test and refine multiple options.

- **Customer behaviour and acceptance:** the extent to which DNSPs and the industry more broadly can establish a social licence with customers will determine the extent to which customers accept and/or participate in CER orchestration. An industry wide effort will be required to educate and inform customers, particularly in support of tariffs, basic export limits and flexible export agreements.

Future ISPs would benefit from considering CER orchestration, providing recommendations on how to address issues like the above and testing sensitivities in developing the ODP. In our view, CER orchestration is such a critical input to the achievement of the ODP that it could be considered and managed as an actionable project in and of itself.

Distribution REZs

In addition to CER orchestration, the Draft ISP identifies the urgency of increasing renewable generation capacity to address the emerging risk of reliability gaps and shortfalls. Similar concerns were expressed in the NSW Electricity Reliability and Safety Check-Up[9]. Relatedly, the NSW Office of Energy and Climate Change (OECC) has commenced consultation on an Orderly Exit Management (OEM) Framework to manage the risk of early closure of thermal generators, by delaying closure (in full or in part) and providing for cost recovery.

As the NSW OECC notes:

> *While these projects are underway, building transmission infrastructure remains a key challenge due to the scale, complexity and risks of delay. The development of new network infrastructure can have a long time horizon (for example, 7 to 8 years). Furthermore, there are practical limits as to how much capacity and infrastructure can be put in place in a given timeframe. In addition, factors such as global competition for skills and resources, increased*

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[8] AEMO, Compliance of Distributed Energy Resources with Technical Settings: Update, December 2023, p. 3

[9] Marsden Jacob Associates, NSW Electricity Supply and Reliability Check Up – Prepared for NSW Treasury, 4 August 2023, pp. 9-11

cost estimates from prolonged COVID impacts and a challenging economic environment result in additional risks.

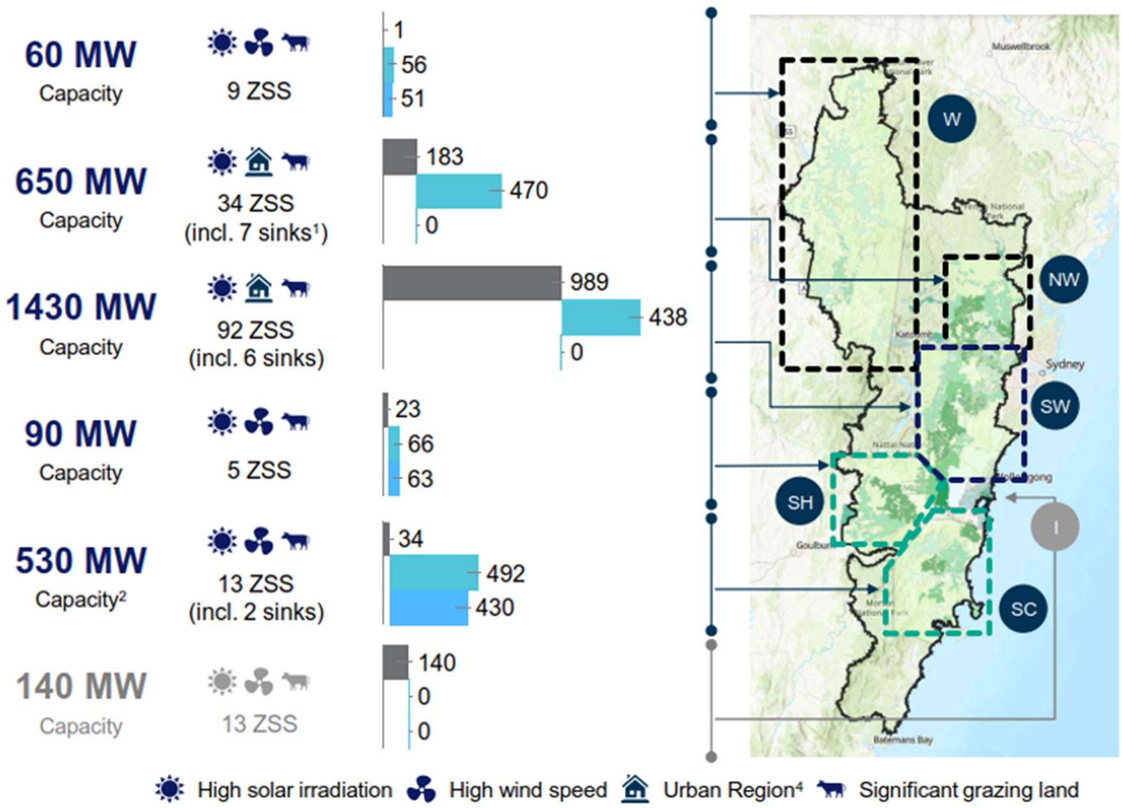
While Australian governments are united in their commitment to decarbonising our electricity grid, new energy infrastructure is taking longer to build, while the available runway to do so is compressed from existing thermal generators bringing forward their retirement dates.

Endeavour Energy, and all DNSPs, must consider options to complement ISP investments and avoid potentially costly (albeit prudent) alternatives such as the OEM framework. The Draft ISP, or future iterations, would benefit from identifying additional renewable generation capacity that can be unlocked through projects to enhance the existing transmission and distribution network.

In addition to CER orchestration, our preliminary analysis suggests we can unlock additional renewable generation capacity that could contribute to the achievement of the ODP. Our priority is to utilise existing network to minimise the cost, time, and social impacts of introducing renewable generation capacity to maximise its value to customers. We are investigating several opportunities across our network to do so, potentially making use of the NSW Infrastructure Roadmap framework.

Specifically, we are assessing our network for the confluence of high CER penetration and/or the available land or roof space to host additional CER and network hosting capacity and/or the ability to increase hosting capacity through network enhancements as pictured below.

Figure 2: Endeavour Energy Distribution REZ Preliminary Opportunity Mapping



We will continue to investigate and scope these options and have commenced high-level costing work to determine a 'merit order' of potential HV and MV connections. Following this more detailed work on business models, funding mechanisms and regulatory settings will be required.

Below we outline the steps we are taking to improve hosting capacity information sharing in support of this opportunity. Noting that increasing small scale generation (relative to upstream ISP projects) will be dependent on our ability to harness and orchestrate generation exports so that they can be aggregated and operate as Virtual Power Plants and/or can be used by market participants to hedge/arbitrage.

As such, we consider storage on the network is critical to achieving this aim. Endeavour Energy, and other DNSPs, are well placed to locate, manage and operate storage in areas of greatest need to derive more value for customers. We therefore consider networks should be permitted and encouraged to install more battery storage[10].We also are supportive of creating incentives for third parties to invest in storage, particularly to increase co-location of storage with renewable generation.

Given the urgency of meeting renewable generation targets, we would welcome the opportunity to further our discussions with AEMO and other stakeholders on the opportunity of Distribution REZs with the aim of identifying locations that can be included in AEMO Services tender round 5 process and future ISP actionable project listings.

Digital hosting

A key step we have taken to support the development of Distribution REZs is establishing a consortium of industry leading proponents, Neara, ERM and Endeavour Energy, to create a Digital Hosting platform.

Our objective in doing so is to develop a NSW-wide network and generation hosting map that proponents can use to identify opportunities to select and connect renewable generation at the fastest pace and lowest cost. Specifically, the consortium is looking to deliver:

1. A network, land-use and generation map to identify where renewable generation siting can be optimised on the existing network, considering various parameters related to hosting capacity, consumer load, infrastructure, technical feasibility, social licence, and environment.

2. A recommendations paper, focusing on commercial and regulatory constraints that impact the speed and success of the renewable energy buildout.

We have already identified a shortlist of projects to help validate the platform, including:

- An unconstrained 200 MW opportunity to connect on-shore wind in the South Coast region (south of the Illawarra REZ) which can be upgraded to 400 MW with modest levels of investment or coincidence with local energy consumption.

- Several locational defined opportunities exist to connect up to 1.4 GW of rooftop generation on existing commercial and industrial precincts, with two ideal locations including the Eastern Creek and Guildford industrial precinct. This capacity can be further increased through the use of community and larger scale energy storage solutions of up to 1 GW on existing land.

- Opportunities for agrisolar, solar farms and the use of flood prone lands, particularly surrounding the Hawkesbury, with a total up to 1.5 GW.

In our view, this analysis and platform is aligned with the recommendations of the NSW Electricity Reliability and Safety Check-Up and key to facilitating the ODP through a combination of both network and commercially led investments. Our engagement with generators also suggests they are keen to access information on the HV capacity of distribution

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[10] In NSW, s192A of the Electricity Supply Act 1995 (NSW) permits for the making of regulations that provide for the construction and use of community-scale batteries larger than 30MW) by a range of parties including DNSPs.

networks to identify speedy and/or cost-effective renewable generation investment opportunities.

We note this project remains at the pilot stage and subject to Government approval and funding. If approved, the project would commence with Endeavour Energy's network before being expanded to NSW wide. We are keen to liaise with AEMO, Government and relevant stakeholders to further explore Distribution REZ opportunities and supporting actions such as Digital Hosting platforms. We consider this initiative can help inform future ISPs and support the achievement of the ODP, particularly if it culminates in the development of a NEM-wide, ISP-aligned digital hosting platform.

Growth in data centres

The Draft ISP and future iterations would benefit from expressly forecasting load growth from data centres and the associated impacts of this on renewable generation capacity requirements and system security and stability. This follows a recommendation from a 2021 CSIRO report highlighting the importance of AEMO investigating data centres further:

> *A review of the literature concerning data centres highlights the uncertainty surrounding this subject: uncertainty in estimates of how much energy is currently consumed by data centres and how much connected capacity is utilised, uncertainty concerning the extent that any current trends can be maintained, and wide-ranging estimates of future energy consumption and demand utilisation of connected capacity. Decision making concerning data centres is not well served by existing objective measures of actual data centre energy consumption and demand, and differences in methodologies, assumptions and data sources have resulted in a wide range of divergent projections for the future impact of the sector.*

And:

> *The data centre industry is rapidly developing, but what is not well understood are the magnitude and drivers of current energy consumption and demand utilisation of connected capacity, and, equally important, the likely magnitude and drivers of future energy consumption and demand. Absolute energy consumption is not the only concern. Growth in the size, number and nature of data centres has the potential to have localised effects that go beyond the impact of data centres on electricity consumption that is often cited at the level of 1% energy consumption. For instance, in Ireland and Northern Ireland, the creation and expansion of data centres will be a key driver of significant increase in future electricity demand and may cause up to 29% of overall demand in that region by 2028 (EirGrid and SONI, 2019).*

We support these observations and note forecast growth in data centres has increased rapidly since this report was developed. The CSIRO report cited market analysis suggesting Sydney alone could experience data centre energy peak loads ranging from 639 MW to over 1,400 MW from currently planned or under construction projects.

As noted by CBRE[11], there is strong growth in data centres with the rapid growth hyperscalers, artificial intelligence and cloud and edge computing, along with other modern technologies such as streaming, gaming and self-driving cars. This growth however has been inhibited by a worldwide shortage in available data centre supply mainly due to a lack of power supply. Despite this, global spending on the construction of data centres is forecast to reach $49 billion by 2030[12]:

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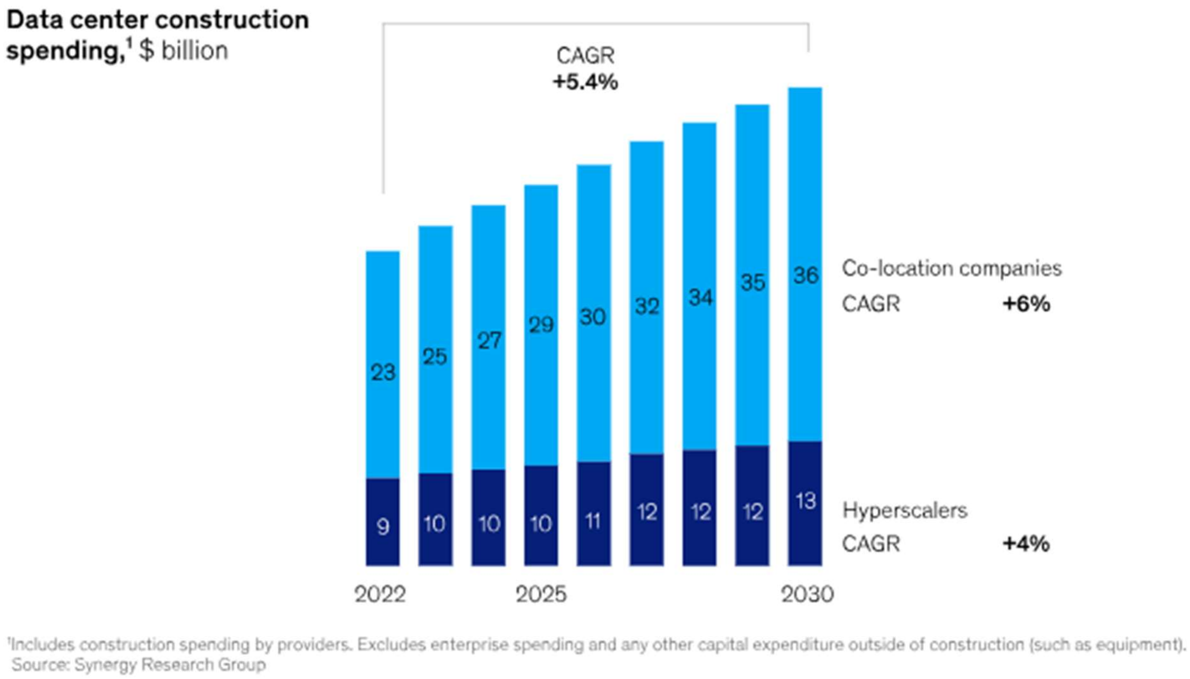
[11] CBRE, Global Data Center Trends 2023, accessed: 1 February 2023, https://www.cbre.com/insights/reports/global-data-center-trends-2023

[12] McKinsey & Company (2023), Investing in the rising data center economy, accessed: 1 February 2024, https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/investing-in-the-rising-data-center-economy

Figure 3: Projected data centre construction spending 2022-2030



At our local network level, we are observing similar exponential growth patterns. As of December 2023, we have data centres totalling 0.6 GW in connected load capacity from 16 different customers. This has increased significantly in recent years with 19 applications totalling 2.6 GW in 2023 .In addition to the applications, in December 2023, there were 18 additional enquiries totalling a further 2.7GW of connected load. If realised, we expect data centres alone to reach a peak demand of 5.9 GW, representing over 250% of our total network demand today. Key regions of interest from Data Centre proponents include Aerotropolis and South West Priority Growth Areas where industrial land supply continues to develop. Strong ties to the NEM in this region are likely required to support efficient outcomes in the long term for data centre proponents.

We understand other networks across the NEM are experiencing similar growth in data centres which would make this one of the most significant drivers for demand growth in the NEM besides electrification and the take-up of EVs.

We consider data centres warrant additional consideration relative to ordinary commercial and industrial load growth due to this rapid growth and their uniqueness. Data centres typically have stable, predictable load patterns and operate on a 24/7 basis. However, they tend to ramp up their operations far quicker than other large energy users and have intense energy consumption needs, consuming 10 to 50 times the energy per floor space of a typical commercial office building[13], to cool the often thousands of servers they house, accounting for around 40% of their energy consumption.

However, higher computing power (power densities have doubled in recent years), space constraints and the challenges of global warming have stalled reductions in power usage effectiveness (PUE)[14].

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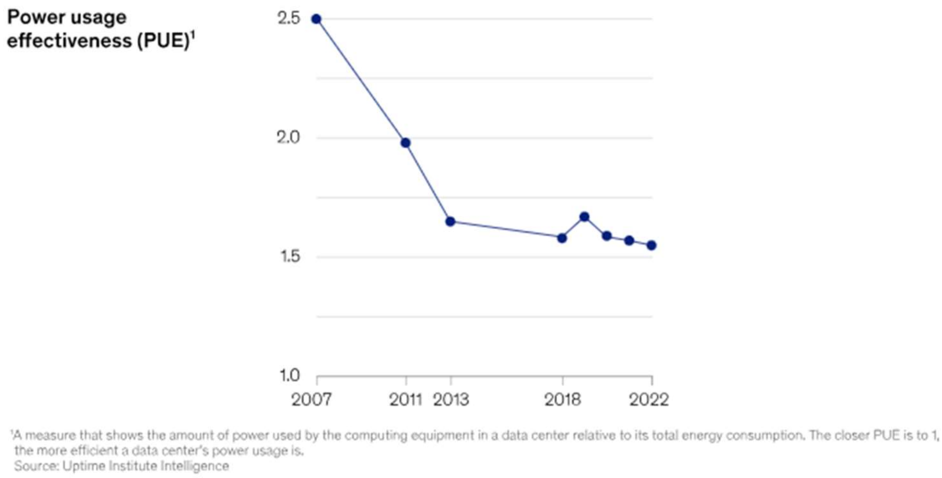
[13] Office of Energy Efficiency & Renewable Energy, United States Government, Data Centers and Services: Buildings, accessed: 1 February 2024, https://www.energy.gov/eere/buildings/data-centers-and-servers

[14] This refers to the amount of power the computing equipment in a data centre uses relative to its total energy consumption:

Figure 4: Data centre PUE trend 2007-2022



As per the data above, the average data centre size in our network area is trending upwards, upwards of 150MW. Similarly, CSIRO noted the scale of individual data centres is also rapidly increasing with 'hyperscale' facilities, with peaks well in excess of 100MW, proliferating globally[15].

Technological advancements are being explored to improve PUE as summarised by the Department of Climate Change, Energy, the Environment and Water[16]. It will be important to track the progress of these initiatives in order to forecast future data centre load requirements.

In addition, data centres have service level agreements (SLAs) that require a high level of reliability. This means that data centres often have full backup supply from diesel generation that is often under-utilised. Many data centres invest in power purchase agreements to offset their carbon footprint due to growing concerns around their carbon footprint. Energy storage solutions co-located with onsite generation (subject to available space) also present a preferable and sustainable alternative option to meet SLAs and reduce the environmental impact of data centres.

Given these characteristics, data centres can have a significant impact on system security and reliability. Depending on the circumstances, some data centres could provide significant load relief where they can vary the load and/or offer system support through under-utilised back-up supply. Incentivising the use of flexible scheduling and investing in storage has significant potential to smooth intermittent renewable generation.

For instance, Google have developed carbon-aware scheduling technology to shift computing tasks across time to maximise renewable energy utilisation[17]. Zheng et al (2020) highlighted the potential for data centres to significantly reduce curtailment of renewable generation at excess times (by up to 62% in California during the period examined) through load migration between data centres[18].

However, many data centres may be unwilling to provide this load relief or support. For instance, where they are constant loads without fault-ride through capabilities or have SLAs that dampen their incentives to offer system support services.

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[15] S. Lindsay, K. Cavanagh, and T. Lovasz, Data Centres and the Australian Energy Sector, National Energy Analytics Research (NEAR) Program, 31 May 2021, p. 9

[16] Department of Climate Change, Energy, the Environment and Water, Business equipment guides – Data centres, accessed: 1 February 2024, https://www.energy.gov.au/business/equipment-guides/data-centres

[17] A. Radovanovic, Our data centers now work harder when the sun shines and wind blows, 22 April 2020, accessed: 1 February 2024, https://blog.google/inside-google/infrastructure/data-centers-work-harder-sun-shines-wind-blows/

[18] J. Zheng, A. Chien, and S. Suh (2020), Mitigating Curtailment and Carbon Emissions through Load Migration between Data Centers, accessed online: 1 February 2024, https://www.sciencedirect.com/science/article/pii/S2542435120303470#fig4

As a result, we have seen examples of International regulators taking steps to more closely regard and regulate data centres. This ranges from the publication of best practice guide to energy-efficiency data centre designs (for example by the U.S Department of Energy[19]) to more direct regulation. For instance, in the case of Singapore, a moratorium was placed on data centre construction from 2019-2022 in order to develop resource efficiency, innovation and sustainability requirements[20]. Whilst the Commission for Regulation of Utilities (CRU) in Ireland established a criteria for the connection of data centres (to determine whether to connect and prioritise between applications) that requires networks to consider[21]:

- *The location of the data centre applicant with respect to whether they are within a constrained or unconstrained region of the electricity system.*

- *The ability of the data centre applicant to bring onsite dispatchable generation (and/or storage) equivalent to or greater than their demand, which meets appropriate availability and other technical requirements as may be specified by the relevant SO (System Operator), in order to support security of supply.*

- *The ability of the data centre applicant to provide flexibility in their demand by reducing consumption when requested to do so by the relevant SO in times of system constraint through the use of dispatchable on-site generation (and/or storage) which meets appropriate availability and other technical requirements as may be specified by the relevant SO, in order to support security of supply.*

- *The ability of the data centre applicant to provide flexibility in their demand by reducing consumption when requested to do so by the relevant SO, in times of system constraint, in order to support security of supply.*

We consider a proportionate and co-operative regulatory approach can be taken to integrating data centres in the NEM to support their growth whilst managing system security and reliability. However, it is clear that data centres represent a source of load growth well excess of organic population growth that is unique and being seriously regarded by energy regulators throughout the world.

We therefore recommend AEMO consider separately forecasting data centre load growth in future ISPs given the scale of their growth and potential system wide impacts. In addition to updating CSIRO's analysis, we note efforts have been made in academia to develop data centre load growth forecasting models[22] which may also be of use. We would welcome future opportunities to liaise with AEMO and/or other interested stakeholders on this matter further.

Robustness of EV charging assumptions

We note the Draft ISP contains an increase in the number of EVs compared previous ISPs. However, in addition to this forecast growth in EVs the Draft ISP contains a significant change in charging behaviour. That is, charging is largely non-coincident with the summer peak demand with an increase in daytime, standard power point (vs dedicated household chargers) and weekend charging.

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[19] U.S. Department of Energy, Federal Energy Management Program: Best Practices Guide for Energy-Efficient Data Center Design, March 2011, accessed: https://www.energy.gov/femp/articles/best-practices-guide-energy-efficient-data-center-design

[20] A. Ng et al, Ashurst, Lessons from Singapore Data Centres, 30 August 2023, accessed: https://www.ashurst.com/en/insights/lessons-from-singapore-data-centres/

[21] Commission for Regulation of Utilities (Ireland), CRU Direction to the System Operators related to Data Centre grid connection processing Decision Paper, 23 November 2021, p. 5

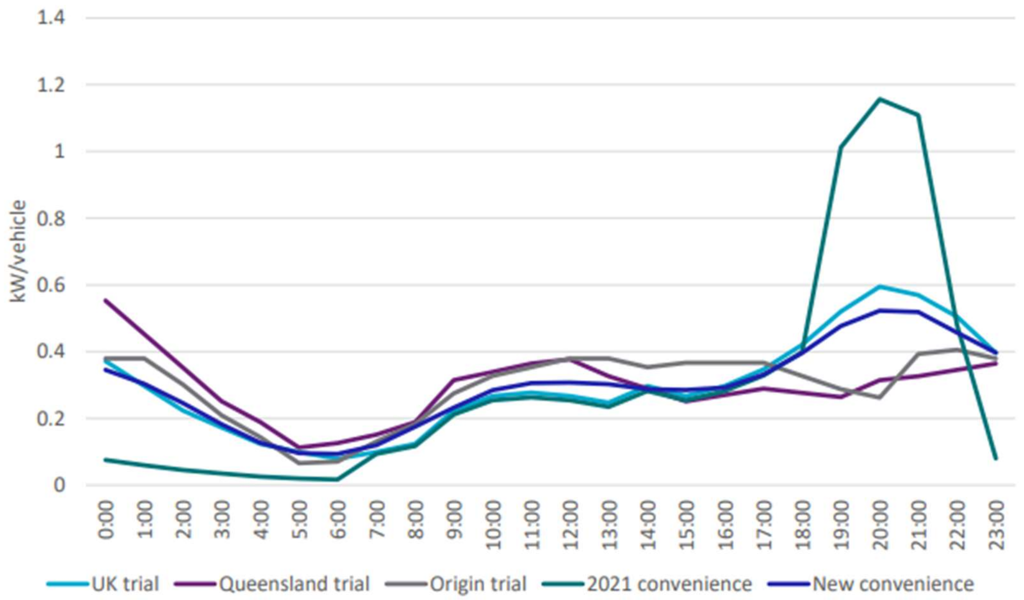
[22] For instance, Koot and Wijnhoven (2021) developed a system dynamic model for policy makers and researches to simulate data centre energy scenarios. (accessed: https://www.sciencedirect.com/science/article/pii/S0306261921003019)

Table 1: Comparison of ISP EV growth and demand assumptions

NSW 2035	EV's	Consumption (GWh)	Demand (MW)	kWh / EV	kW / EV	kWh / day
ISP 2020 - Central	904,897	7,434	363	8,215	0.40	22.49
ISP 2022 - Step Change	2,416,197	20,691	1,430	8,563	0.59	23.45
ISP 2024 - Step Change	2,675,801	24,532	917	9,168	0.34	25.10

This change in behaviour is based on modelling conducted by CSIRO which draws on EV charging patterns from more recent trials[23]:

Figure 5: CSIRO EV trial charging behaviour



Such a change in behaviour would be a positive outcome if realised and result in the better utilisation of networks and improve solar hosting. However, we consider the ISP would benefit from further consideration of the veracity of these assumptions and the actions required to support their realisation. Relatedly, CSIRO notes it:

> *…gave consideration to the concern that trial data would represent early adopters who may not be a good guide to mainstream behaviour (once adoption reaches the mainstream). However, the trial data revealed that electric vehicle owners recruited into the trials were not particularly sophisticated in their charging behaviour, the majority relying on standard power points. Also, the trial participants use of home charging versus public charging appeared to be aligned to ratios seen in countries which have reached mainstream adoption.*

Notwithstanding this observation, we remain of the view there could be significant changes in mainstream behaviour once EV charging becomes more ubiquitous. For instance, Norway, which has the highest EV ownership per capita in the world, has experienced a shift in charging behaviour as EV take-up has increased. In 2019, the majority of customers (upwards of

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[23] P. Graham (CSIRO), Electric vehicle projections 2022 – Commissioned for AEMO's draft 2023 Input, Assumptions and Scenarios report, November 2022, p. 47

60%[24][25]) charged their EV using an ordinary or dedicated socket compared to home charging stations (ranging from 30-40%). As EV take-up continues, there has been a shift to more demand intensive home charging stations (77% by 2021[26]).

Relatedly, Henriksen et al (November 2021) examined EV charging behaviour in Norway to understand how it is integrated into people's lives and habits over time in accordance with domestication theory. Notably, this study[27]:

> *… revealed key domestication processes unfolding in the Norwegian energy transition as a consequence of the increasing numbers of EVs and corresponding grid peaks. The findings clearly indicate that users' motivations to use smart charging, such as fire-safety aspect of smart chargers, the joy and fun of using smart home technology, the practical and economic benefits, and the enhancement of physical comfort, can be as important than the economic rationale. Moreover, the findings indicated that the ways that different motivations for using smart home technology are articulated will have an impact on the potential for flexibility and grid optimization in the future.*

Whilst it is reasonable for AEMO to update its assumptions based on the latest available studies, it represents a significant change from previous ISPs that is reliant on single EV household studies. This requires further consideration as there remain international examples which support the assumptions contained in the 2021 projections. For instance, a study of Canadian EV charging behaviour found evidence of a residential EV charging duck curve and a marginal difference in the level of weekend versus weekday charging events[28].

We are therefore keen to understand further the factors that could influence customer charging behaviour and the steps networks and Government need to take to achieve an optimal outcome. In particular, identifying sensitivities associated with a fully EV reliant household, tariff settings, travel distance requirements, access to public charging infrastructure and customer responses to outages.

Relatedly, we note the Draft ISP is also informed by insights provided by enX on the risks associated with growing EV charging loads. This report is informed by the 2022 IASR and may require revision for the latest assumptions produced by enX.

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[24] H. Saele and I. Petersen, 2018 53rd International Universities Power Engineering Conference (UPEC), Electric vehicles in Norway and the potential for demand response, Figure 4, accessed: 1 February 2024, https://www.researchgate.net/publication/329651963_Electric_vehicles_in_Norway_and_the_potential_for_demand_response

[25] E. Figenbaum and S. Nordbakke, Institute of Transport Economics Norwegian Centre for Transport Research, Battery electric vehicle user experiences in Norway's maturing market, August 2019, Figure 5.6, p. 28

[26] A. Flataker et al, 2022 18th International Conference on the European Energy Market, Impact of home and destination charging on the geographical and temporal distribution of electric vehicle charging load, Table 1, accessed: 1 February 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3057599/EEM2022_home

[27] I. Henriksen et al (2021), Energy, Sustainability and Society, Electric vehicle charging and end-user motivation for flexibility: a case study from Norway, accessed: 1 February 2024, https://energsustainsoc.biomedcentral.com/articles/10.1186/s13705-021-00319-z

[28] T. Jonas, N. Daniels, and G. Macht (2023), Electric Vehicle User Behavior: An Analysis of Charging Station Utilization in Canada, accessed: 1 February 2024, https://www.mdpi.com/1996-1073/16/4/1592