Inquiry into the current circumstances, and the future need and potential for dispatchable energy generation and storage capability in Australia.

Terms of Reference, items b and h:
issues related to system integration, connection, and grid transmission requirements and
other relevant matters, including reference to international examples

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Summary of the submission

This submission speaks to the economics behind the integration of grid-scale storage into the National Electricity Market (NEM). First it notes that the terms of reference of this inquiry make no mention of a *market* for electricity supply and for the the supply of storage services. This omission stands out in light of the fact that almost all electricity is produced by private operators, and that all electricity (except for WA and the NT) is traded on the National Electricity Market (NEM). This is important in that the incentives to deploy and invest in storage are provided by market signals to private operators. Which signals the market sends depends on the organisation of that market, that is, on market design (bidding and clearing rules), on competition policy and on regulation.

However the public discourse largely ignores incentives. Indeed, much of the work to date is either concerned with engineering aspects (for example, AEMO) or high-level consultation without much regard for economic analysis (as does the ESB). This submission attracts the attention of Committee Members to the fact that the market is for us to organise for it to serve us; that this work remains to be done. It is not enough to spur investment in new technologies; these new assets must be harnessed to deliver services. At present, "market design" (a field that recently received the Nobel Prize in Economics) is used as a slogan; designing a market is in fact real work to do.

Currently *neither* the market design *nor* the industrial organisation of the market are favourable to effective investment in, and deployment of, grid-scale storage. These are the focus of this submission, which reflects the work that is partly underway at Monash University to design the correct incentives for investment and for the use of storage.

Electricity storage on large scale is nothing short of revolutionary; it is the perfect, and very timely, complement to intermittently available renewable energy generation (VRE). While full of promise, it also entails plenty of challenges. By its very nature, storage allows for the use of extremely complex dynamic strategies in buying and selling energy, which market rules must account for. In particular, there is a distinct risk of market manipulation, which can be very costly to Australian consumers, and poorly perceived by voters. Dispatching storage units in the energy market must also be amended to account for this new behaviour. Storage is likely to play a critical role in ancillary services, old (FCAS) and new (synthetic inertia). Finally, unlike conventional generators, storage presents no significant returns to scale, which may offer an opportunity for enhanced competition in the energy market. However, this requires the competition authority to be watchful of attempts to engage in anti-competitive practices, and may need specific intervention and prohibitions to curb some practices.

Addressing these questions is essential to the successful deployment of storage across the NEM. The issues raised herein arise irrespective of technology nor cost; they are borne out of *incentives*. Understanding these incentives is essential to design an effective market, and takes some work that remains to be done.

Background

Until recently electricity was one of the very few commodities that could not be stored. In addition, the physical constraints of electricity transport required a precise balancing of supply and demand at all times. Taken together, these two facts implied that electricity had to be produced for immediate consumption; therefore *i*) the organisation of the energy market and *ii*) trading strategies were both quite simple. In particular, broadly speaking, the time horizon was immediate. This simplicity made for simple market rules, which could afford to be myopic. With a broad brush, at present AEMO collects bids from generators every five minutes and arranges them in increasing order from the cheapest to the most expensive one. The market clears where this supply curve meets demand, which delivers the clearing price, and the process repeats itself. Generators, whose price does not exceed the clearing price, are dispatched.

This immediacy of supply precludes many forms of manipulation based on delay and arbitrage. It also makes it very difficult to use intermittent, renewable energy (VRE), which cannot be committed in advance – unlike thermal generators that are exactly controlled. For this reason, VRE is said to be unscheduled, or not dispatchable; it cannot be relied on.

Delay, or the intertemporal shift of electricity consumption that storage affords, is the primary benefit of storage. Excess power supply from wind farms, solar farms or rooftop solar installations, can be put to better use at a later time, when consumers need it most and consequently are willing to pay more for it. Thus storage is the device the power industry needs to harness intermittent power supply, which produces when it can, and deliver services to consumers when they actually need them – not just when they are plentiful. Not only can storage help in solving the time delay between production and consumption, it can also turn non-dispatchable energy into dispatchable, or firm, power. Storage makes VRE reliable, and therefore more valuable.

Storage can deliver additional services that were hitherto impossible to supply, or not required. Congestion routinely arises on the network of the NEM, just like on a freeway, and leads to curtailment – typically, of VRE. Storage can absorb that energy and release it when congestion has subsided. The benefit is to optimise transmission investment, which need not meet peak generation capacity, for some of that capacity can be stored. With the increasing penetration of intermittent supply and the progressive retirement of large thermal generator, multiple grid-stability issues arise. Frequency control, in particular, becomes problematic as the physical inertia of the grid decreases. Storage can assist in rapid frequency control too. Thus, on multiple accounts, storage is the key complement to intermittent renewable generation.

Specifically, storage can

- allow for the intertemporal substitution of consumption, so that excess supply of cheap energy can be consumed at a more suitable time;
- be used in hybrid facilities (e.g. solar farm plus storage) to “firm” intermittent generation and turn it into dispatchable generation;
- arbitrage and smooth prices – prices may not be too high so that consumers do not get stung, but not too low so that producers refuse to sell;
- assist in congestion management on the network; at a congested node, a battery can act as a load, and release energy at a later time. Thus, it can also act as a complement to transmission, and therefore as a substitute for transmission investment.

- deliver essential frequency control services (fast frequency control and synthetic inertia).

The *problem* with storage is that this ability to delay and to be either a buyer (charging) or a seller (discharging) at any point in time makes for far more complicating trading strategies. In a market setting, where suppliers pursue their own private interests, this cannot be ignored. The operator of a storage unit may charge or discharge, depending on its current charge state and on its expectation of future prices; these are inherently dynamic strategies, for which the current, myopic market design is not adapted.[1] With tens or hundreds of batteries, this makes for a very complex problem (called a dynamic stochastic game), which the current market organisation and the current dispatch engine cannot handle. This point is largely neglected by AEMO and the ESB. It is extremely concerning because an inadequate organisation of the market will not deliver the correct incentives to market participants, and therefore the correct investments and services, and will be left open to manipulation. This is the point of the next section.

Identifying essential areas of work

In our work we have identified four essential areas that need significant scientific investigation: understanding storage behaviour and designing market rules for storage; clearing and dispatching a market with storage; new services with storage and understanding the industrial organization of a market with storage.

Area 1. Understanding storage and market design for storage

Storage behaves differently from standard generators and loads, and thus in many ways – starting with the fact it can be either at the same time, and which it chooses to be may depend on many factors (state of charge, current price, future prices, future volumes...). The first order of business is to better understand storage behaviour, especially when it comes to market manipulation. Karaduman (2020) is the only serious paper on the economics of storage, however it is short on market manipulation. It also takes as given the current market design, rather than designing a market for storage. With an understanding of storage behaviour, one must then design market rules that explicitly account for storage, the new strategies it can employ and its interaction with generators. These are dynamic strategies, and potentially collusive strategies. There is no reference on this yet, no experience that can dawn on; these are completely open questions.

Area 2. Clearing and dispatching a market with storage

Dispatching storage units that employ dynamic strategies cannot be achieved using the current dispatch engine (NEMDE), which is a linear programming engine – that is, a myopic algorithm. A new dispatch algorithm must be designed for this task, and a new numerical implementation must be created. This is essentially a problem of mathematics and computer science.

This too is an open question in that the problem on hand is potentially very large. The goal is not only to find a solution, but to compute a solution in a practical time so that it can be used robustly on a daily basis.

[1] At present the NEM clears and dispatches every 5 minutes, and forms no expectation about the future. With no batteries to dispatch this is perfectly fine, however not with storage.

Area 3. New services with storage

Energy is not the only market in the NEM. There are Ancillary Markets, the main one being the Frequency Control Ancillary Service (FCAS) market. Frequency control is essential to grid stability; without it frequency deviations would damage equipment and cause blackouts. Conceptually, the solution is simple: rapidly inject or withdraw energy to correct the frequency. Like energy, frequency control is organised as a market, and suppliers are private entities. Storage, in particular batteries, are very well suited to this exercise, and possibly others.

Indeed, "synthetic inertia" is already identified as a new service that can be supplied by batteries to replace the physical inertia of the current power system. This physical inertia is provided by rotating generators, and thus decreases every time a thermal generators retires and is replaced by VRE. However, at present there is no sense in which we know how to *value* these services, which renders the organisation of a market impossible. Doing so first requires valuing inertia in order to elicit a demand for inertia services, and then devising a market design to supply synthetic inertia services. This market is obviously linked to the energy market, which generates new arbitrage opportunities. The principles and the methods that are used when dealing with synthetic inertia may be applied to other services, yet to be identified. At the risk of stating the obvious, it is not enough to utter the words "market design" for it to arise; it has to be carefully designed.

Area 4. Industrial organisation with storage

Because of large returns to scale, the electricity generation sector is highly concentrated: few generators are required to produce a lot of energy. The benefit of this concentration is that returns to scale can be exploited, which yields a low average cost; its cost is that generators routinely exercise their significant unilateral market power to raise prices significantly above the cost of production. To compound the problem, a small number of firms own these few, large generators.

Unlike conventional generators, most storage units, at the very least batteries, do *not* possess significant returns to scale, so there is no *social* benefit to large storage units nor to concentration; however the risk of exercising unilateral market power remains. That is, one should be wary of both *i*) large storage installations (including Snowy 2.0) and *ii*) the concentrated ownership of multiple battery installations. Andres-Cerzero and Fabra (2020) show that market power in storage leads to less efficient price arbitrage (less price smoothing) and inefficiently low investment levels in storage. They also warn that vertically integrated firms – owning generation plants and storage – behave even less competitively. In other words, while storage may be good to "firm" non-dispatchable energy, the details of the organisation of the market matter a great deal for its performance.

Furthermore, letting a single operator own multiple batteries, as well as batteries and other assets such as solar farms, may lead to market manipulation between batteries to the benefit of the generation unit. This is common in securities markets and even easier to orchestrate in the electricity market, where energy is completely anonymous.

Finally, because storage is also attractive to manage congestion on networks, it may be necessary to revisit the structural separation that currently exists between energy generation and energy transport. Without presuming of a solution, network service providers may have to be required to not own storage units but rather to contract with third parties. However now these third parties may control bottlenecks on a network and use it to create local monopolies on this network. A similar problem was encountered in the telecommunication industry, where most regulators elected to mandate access at a reasonable cost.

In closing, there is a tremendous amount of work to do in the industrial organisation of a nascent storage market, and competition policy is paramount.

Conclusion

This submission alerts Committee Members to the crucial importance of market design and competition policy in the sector of electricity storage, which is only emerging and in need of new rules. Irrespective of technology choices, which may be imported or developed in Australia, a proper organisation of the market is necessary for the investment in assets to deliver services to Australians at competitive rates and efficiently. It is not enough to deploy new technologies; they must be correctly harnessed to be effective. “Market design” means designing the rules of the market: participation, exclusion, clearing, price formation. It does not mean systematic intervention.

Much work remains to be done on market design. The cost of this work is trivial in comparison to the investments at stake, which makes it all the more compelling. All that it takes is resourcing the Australian Energy Market Commission (AEMC) correctly, compelling it to engage in this market design exercise, and resourcing the research entities (Universities mostly, but also CSIRO) to support the AEMC in this quest.

References

Andres-Cerezo, D. and Natalia Fabra (2020) “Storing Power: Market Structure Matters”, working paper, Universidad Carlos III

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