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Distributed Energy Resources and the Australian NEM – a good match?

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Abstract

This paper aims to revisit the way that distributed energy resources (DERs) interact with the present structures of the Australian National Electricity Market (NEM), and consider opportunities to improve the interface between centralized and distributed resource operation and investment. The NEM was established with the stated aim of facilitating efficient operation of and investment in electricity systems across the Eastern Australian States through more competitive, market oriented arrangements. It was, however, designed at a time when DERs did not have a significant impact on the electricity system.

Distributed photovoltaic (PV) and battery storage systems, among other DER technologies such as ‘smart’ building management systems and appliances, may represent welcome new sources of competition in wholesale and retail markets, yet it is unclear whether present NEM arrangements provide a coherent or comprehensive interface between utility scale and decentralized end-user decision making. For example, utility scale PV systems reside within a wholesale market that requires them to participate in scheduling and provides dynamic pricing of both energy and ancillary services. By contrast, residential PV systems sit within retail market arrangements that utilize net metering of household demand and generation, and provide effectively fixed volumetric tariffs. The two markets do interact, of course - household PV systems can in aggregate influence wholesale prices by reducing the overall supply of energy provided by that market. And wholesale prices do eventually impact on residential tariffs that drive the case for residential PV uptake. However, this interaction would seem to lack coherence and comprehensiveness.

These factors already appear to be impacting market and customer outcomes at the current deployment of approximately 5GW of rooftop PV. Some forecasts predict that the system will need to support up to 19 GW in the coming two decades. This raises important questions around whether incentives from the NEM’s wholesale and retail structures are facilitating efficient investment and operation in this space and, if not, what might be done.

In this paper, existing NEM wholesale and retail market arrangements are examined in the context of growing DER penetrations, to provide a preliminary assessment of whether they provide a suitable framework for coordinating efficient operational dispatch and investment across both utility scale and distributed energy options, and energy consumer decision making more generally. A number of key challenges are identified in present arrangements, and possible opportunities to improve key aspects of them are presented.

1. Introduction

Distributed energy resources (DERs), such as rooftop photovoltaic (PV) are becoming a major feature of Australia's electricity industry, while emerging technologies such as battery energy systems also hold great promise. This raises questions as to the appropriateness of current industry arrangements to facilitate such options. These industry arrangements are themselves the result of a process of two decades of electricity industry restructuring, based around changing views on how best to deliver desired industry outcomes.

The aim in managing essential infrastructure such as the electricity industry should be to maximise net public benefit. Over the past two decades, Australia's electricity industry has largely transitioned from being government owned and centrally planned, towards arrangements with a greater role for competitive market arrangements in wholesale and retail sectors and economic regulation of monopoly elements of industry, alongside increased privatisation of assets. A key role of these markets is then to establish appropriate prices to incentivise private, self-interested parties to collectively provide publically beneficial outcomes.

There has been considerable work over the past two decades reflecting on how well or badly market approaches, and specifically Australian National Electricity Market (NEM) arrangements, have coordinated traditional utility scale generation operation and investment decision making challenges. Now, the rise of DERs poses the additional question of whether the NEM can appropriately coordinate such decision making across both utility-scale options and the growing number of DER technologies and opportunities, towards maximising net public benefit. The NEM was, after all, originally designed at a time when there was virtually no grid integrated PV in Australia and little conception of the potential of DERs more generally.

This paper aims to briefly examine the structures and effectiveness of the NEM's present market mechanisms for managing traditional utility scale decision making, investigate how DERs may interact with these arrangements, and consider what improvements might be made to improve industry outcomes.

It is important to note that the concept of public benefit is subjective and requires consideration of monetary, social and environmental impacts. In the NEM, the concept has been effectively defined in law under the national electricity objectives or NEO, ("National Electricity (NSW) Law," 1997), "to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers" with respect to "price, quality, safety, reliability and security of supply."

DERs clearly add to the complexity of achieving this objective. For example, it is unclear whether centralised or decentralised renewables might deliver more public benefit, and under what circumstances. Furthermore, DERs create new options for the consumers whom the industry is intended to serve. Arguably, consumers are best placed to determine their own long-term interests, and they have demonstrated clear interest in DERs. However, this interest and consequent deployment of some DERs has occurred within market arrangements that were not designed with such a purpose in mind.

The fundamental issue is whether the NEM can deliver on its intended purpose. If pricing is to work as a mechanism for enhancing social benefit, pricing theory says that all participants need exposure to relevant prices. This in turn, raises questions around whether the NEM establishes appropriate price signals and presents these to relevant decision makers including market participants considering DER options.

This paper therefore examines whether the NEM currently functions as such a platform for market based operational and investment decision making and particularly if it may be capable of continuing to function efficiently given the forecast rapid uptake of DERs (AEMO, 2016). It is divided into three Sections representing three key types of decisions that the NEM is required to coordinate - operational dispatch and scheduling, generation investment, and delivering energy as a product to customers. By examining the mechanisms currently used to coordinate these decisions, the impact of DERs on the objectives of the relevant market framework can be considered. In each Section, a brief overview will be followed by an examination of how the problem has been approached by policymakers, some discussion around its effectiveness, and then some preliminary thoughts around the potential impact of DERs.

While network investment and operation arrangements also have a critical role to play in maximising net public benefit of the electricity industry, as well as presenting key opportunities and challenges for DERs, these have not been included in the scope of this paper, which focuses on the NEM's wholesale and retail market arrangements and DER integration mechanisms.

2. Operational Dispatch and Scheduling

The aim of operational decision-making should be to maximize net benefits to electricity consumers from decisions associated with existing electricity industry assets. Traditionally, this translates into the problem of dispatching and scheduling utility generation (and network) assets in a way that maximizes long-term public benefit. The set of generators chosen for dispatch influences the cost of energy due to their varied technical capabilities as well as operational and maintenance costs.

For market based dispatch, pricing theory suggests that efficient operation requires both efficient spot prices (based on short run marginal costs) and future prices (based on opportunity costs associated with the impact of inter-temporal links between past, present and future decisions) (R. J. Kaye & Outhred, 1989). For efficient market operation, these prices must be established for all locations in the network to reflect the different cost of supplying energy. Additionally, incentives are required to maintain power quality and reliability in the system. In the NEM, the extent to which spot prices are determined by SRMC is questionable at times, while future pricing for dispatch is limited by the absence of a technical day-ahead market. Instead, market participants are required to manage their particular inter-temporal links through the market offer strategy. The Australian Energy Market Operator (AEMO) does provide a range projections of future market status to assist participants in this. Notably for DERs, however, such pricing is not seen in any regard in present retail market arrangements.

2.1. Historical Response and Effectiveness

The NEM wholesale market mechanism was first implemented in 1997 and by 2005 encompassed NSW, VIC, QLD, SA and TAS (KPMG, 2013). Before this period, electricity assets were centralised, state-run entities with dispatch largely managed by States' respective electricity commissions. (Clarke, 1986). State-based systems helped to build the electricity industry in Australia and oversaw the electrification of the majority of the nation. In the 1980s however, questions were raised around over-investment in these systems, with estimated annual lost opportunity costs in the hundreds of millions of dollars in NSW alone (Owen, 2009, p. 570). This led to discussion around new investment mechanisms, with some jurisdictions working hard to create frameworks for controlling investment and others seeing an opportunity for restructuring. Proponents of restructuring favoured a market mechanism (Hilmer, 1993, pp. 215-238). The centralised generation system was broken up during the 1990s based on the assumptions that conditions for competition could be created in wholesale markets (Owen, 2009, p. 570), that a wholesale market could be organised for real-time trade (Owen, 2009, p. 570) and that competition could reduce the price of generation (Abbott, 2006, p. 445).

There exist a number of analyses that have been broadly positive about the NEM wholesale market (Outhred, 2000), (Moran & Sood, 2013). It is noted that prices have tended to be competitive with those observed internationally (Wolak, 2000) and generators across the NEM have also been broadly more labour efficient. There has, however, been little comparison of prices before and after liberalisation. Indeed, international studies have found that prices do not always decrease following spot market introduction (Nagayama, 2007). More generally, there is the question of whether lower prices would actually reflect improved public outcomes – unpriced environmental externalities are a relevant example of this issue. There are also opportunities for participants to exercise market power due to the limited participant pools, network flow constraints and the lack of storage (Outhred, 2000). This has been an issue in some markets, especially Queensland (Tamaschke, Docwra, & Stillman, 2005). The 'missing money' phenomenon whereby spot prices appear to be below long run marginal cost (LRMC) of supply has also been well documented (Simshauser, 2014) yet there appear to be few examples of supply shortfalls (Moran & Sood, 2013) that would be expected to result from low revenue opportunities.

There are broader structural issues that continue to impact on the NEM. The original design focus was certainly on wholesale arrangements, with questions around retail market structures seen as the unfinished business for later restructuring efforts. Full retail competition was introduced in stages after the formal start of the NEM. For residential and small business customers, metering is very simple (typically accumulation meters that are read only infrequently) and competition involves choosing between a range of offerings from different retailers. These offerings typically involve fixed and volumetric charges that are reset on a yearly or longer basis. Larger consumers have more sophisticated interval metering and tariffs that include Time-of-Use and peak demand charges. There is thus little demand-side participation (Outhred, 2004), which would require retail market innovation, especially around metering, but also tariff structures. Only a handful of consumers see real-time pricing and respond to changing wholesale market conditions.

2.2. Impact of Distributed Energy

DERs do not generally interact directly with the wholesale market. Instead, they are integrated within retail market arrangements. These arrangements can be very simplistic. For example, new residential PV systems have their generation output netted off against household load, hence effectively reducing purchases from the household's retailer, while excess 'exported' PV generation is assigned to this retailer who pays (or sometimes doesn't pay) a 'feed-in' tariff to the household, which is usually reflective of the average wholesale price. Most retail tariffs for households are still set as flat volumetric rates, although the deployment of interval metering is now seeing growing use of TOU and other tariff arrangements.

Regardless, almost no consumers including those deploying DERs have exposure to the wholesale spot market in real-time. DERs, conversely, do have impacts on wholesale markets. Models of the merit order impacts of rooftop PV, for instance, have suggested significant impacts on daytime prices (Gilmore, Vanderwaal, Rose, & Riesz, 2014).

Retail tariff arrangements also provide misaligned incentives for other forms of DERs such as battery systems and controllable loads. Certainly, flat volumetric tariffs provide no incentives to change load patterns or operate a battery system in ways that could assist in operational dispatch of the electricity industry.

DERs are thus seen as potentially able to influence wholesale spot prices to a growing extent, yet they are not directly exposed to these prices themselves. The current mechanism relies on the retail market to pass on price signals to DERs as dispatchable storage comes online.

2.3. DER Integration Solutions

There would seem to be a number of approaches for managing how high-penetration distributed renewables and other DERs might feasibly interact with the NEM. In Australia there are two primary integrations that have occurred, namely aggregation and demand reduction. There would exist more options with large-scale re-implementation of the principles and structure of the NEM.

2.3.1. Demand Reduction

Currently, the most common approach is to simply view DERs as a demand-reduction, with retailers losing sales volume, but possibly benefitting from reduced wholesale market exposure (e.g. during higher price periods) in the short-term. Incentives for customers to take up DERs, exist in opportunities to avoid retail tariffs through energy efficiency, or tariff arbitrage (e.g. by shifting loads across peak and off-peak times on a ToU tariffs, or maximising self consumption, rather than export of PV generation). For such a scenario to function in an economically efficient manner, more meaningful price signals would need to be passed on to DER operators. Such a situation would require an efficient, competitive retail market.

AEMO estimates that rooftop PV could account for up to 19 GW of generation (more than half of the total demand in the NEM) by the mid-2030s (AEMO, 2016), which would meet more than 50% of peak daytime demand (Gilmore et al., 2014). Market theory suggests that to maximise social benefit, real-time price signals must be provided to generators. However, these are not currently seen by DERs, and by 2030, it is likely that more than half of the NEM’s generation would not be participating in the wholesale electricity market, which undermines the fundamental basis of electricity restructuring, that spot electricity markets are the platform upon which electricity is bought and sold in real-time (Belyaev, 2011).

Treating the output of energy storage DERs as a demand reduction also means they would not receive price signals that would lead them to optimally dispatch their resources into the network. Thus competition will not serve to reduce wholesale electricity prices or will not be present in the first place (Belyaev, 2011). These outcomes would thus run counter to the national electricity objective which aims to ‘promote efficient investment operation and use of electricity services for the long term interests of consumers’ ("National Electricity (NSW) Law," 1997).

2.3.2. Aggregation

Another emerging model for integration of DERs into the wholesale market involves aggregation of a number of or other DERs, such as distributed PV systems, battery systems or large controllable loads that could also be aggregated to sufficient scale that they could participate in the utility-scale mechanisms of the NEM, perhaps as combined generator/loads (AEMC, 2012). This provides a means for coordination of both utility-scale and aggregated DER resources within the same market. There could be some valuable market outcomes from such aggregation – for example 'in a market that is closer to scarcity it may be possible to use storage strategically to exacerbate extreme price spikes' (Gilmore et al., 2014, p. 53).

There are however, questions of the likely efficacy, efficiency and costs of coordinating very large numbers of small resources, and the potential for market aggregators themselves to obtain problematic levels of market power. As aggregators are likely to emerge from the existing retailers, competition in the aggregation space may first require more effective competition in the retail market. The extent to which such competition exists is subject to controversy but it is clear that the NEM's retail markets currently have high levels of market concentration (AER, 2015).

2.4. Conclusion

Aggregation may offer a solution for integrating DERs into the market if price signals can be effectively and efficiently passed to DERs via suitable retailer and aggregator arrangements. If price signals are not passed via the wholesale-retail market coupling, efficient market outcomes within the NEM may not be possible. Successful integration of DERs with the NEM thus relies heavily on an efficient retail market to pass on price signals. Retail market competition is explored in section 4.2.

3. Generation Investment

Generators have historically been large, centralised plants on the multi-megawatt or gigawatt scale, with high upfront costs and multi-year deployment timeframes. The national electricity objective requires security and stability of electrical supply ("National Electricity (NSW) Law," 1997), implying that supply and demand should be balanced by adequate generation capacity. Wholesale markets based on SRMC alone have been shown to lack the information necessary to create efficient price signals for investment (R. J. Kaye & Outhred, 1989). This is know as the 'resource adequacy' problem, which can be defined as "the ability of deregulated energy-only power markets to deliver investments to meet demand in a timely manner" (Simshauser, 2010). As Simshauser (2010) writes, "consumers face the risk that power project proponents will mis-time investments, leading to transient price shocks and load shedding during the period spanning the lag in investment." The answer to this problem for the NEM has focussed on the formation of derivative markets to incorporate opportunity cost and other inter-temporal considerations (R. Kaye, Outhred, & Bannister, 1990).

3.1. Historical Response and Effectiveness

For much of the 20th century, generation investments were centrally planned and executed by states, based on demand forecasting (Abbott, 2006, p. 445). This resulted in several cases of what has appeared to be over-investment in capacity, notably during periods where traditionally high and consistent demand growth did not continue. The high costs of such overinvestment were a catalyst in the 1990s towards liberalization of Australia's electricity networks (Owen, 2009). After restructuring, investment in generation capacity is now meant to be left up to the market. The key assumption in liberalisation was that the promise of future revenue to be gained in the electricity wholesale market would ensure the adequate expansion of generation capacities (Belyaev, 2011, Chester, 2006).

Market risk is seen as a major barrier to financing: “once effective price competition is established in generation, the commercial risks of power-station investment, and therefore the generators' cost of capital, will be markedly increased, and this could have implications for long-term supply security” (Outhred, 1998, p. 16). Derivatives or futures contracts help to manage market risk in wholesale pools. Associated forward or derivative products have thus been used as an additional incentive layer that can allow investors to lock in prices for generation assets and de-risk investments (R. Kaye et al., 1990). If the price of electricity futures exceeds the LRMC of an additional generator, investors can sell futures and de-risk the output of a new plant (Outhred, 1998).

The Council of Australian Governments (COAG) energy market review has previously stated, however, that “the financial contracts market is extremely illiquid” (Council of Australian Governments. Energy Market Review., 2002, p. 9). While since 2002 further commoditization of electricity futures has occurred, studies show that 85% - 95%, of electricity futures are private contracts, reducing competition, limiting pricing information and presenting a barrier to entry (Anderson, Hu, & Winchester, 2007). For price signals to effectively stimulate demand-responsive investment, both sides of the market must be competitive; however at this point in time, both appear heavily concentrated.

Spot prices also do not appear to have been high enough to support continued operation of many generation assets, ostensibly due to weather events and renewable merit order impacts (Moran & Sood, 2013). This ‘missing money’ phenomenon has raised “questions of whether resource adequacy and a least-cost plant mix can be practically achieved in energy-only markets” (Simshauser, 2014).

For renewables, investment is further complicated by variable output. The difficulty of renewables to guarantee dispatch during key periods has introduced market risk and played a role in preventing the financing of further capacity despite adequate short-term price signals (Foster, 2013, p. 36).

3.2. Potential Impacts of Distributed Energy Resources

While DERs are making up ever more of Australia’s generation capacity, with 5GW installed (Parkinson, 2016) and up to 19 GW forecast, DER investment incentives would seem to be largely detached from the incentives of the electricity wholesale and futures markets at present. End-users have an inherently different approach to investment than wholesale energy firms due to differing market and policy-based incentives, and often very different and diverse investment objectives. The trade-off between centralised and decentralised renewables is not coherently addressed between these two differing sets of incentives.

Growth in rooftop PV capacity in Australia has over the past decade been supported by renewable portfolio schemes (Buckman & Diesendorf, 2010) and generous feed-in tariffs (Watt, Passey, & Johnston, 2011). Increasingly as the price of PV systems drop and these incentives are no longer available, the continuing popularity of PV is driven by customers offsetting high volumetric network tariffs. Rooftop PV investments have remained stable over recent years, at times exceeding centralised generation investment as shown in Figure 1.

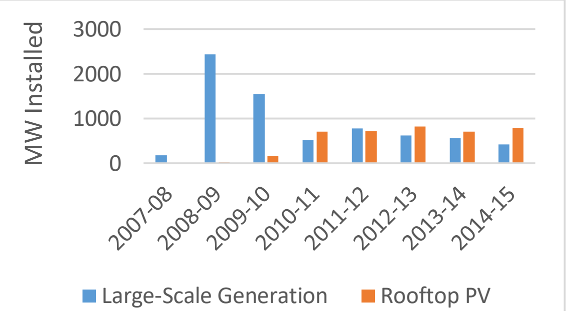

Figure 1: Large-Scale Generation and Rooftop PV Investment

An even greater opportunity to drive investment that improves public benefit lies on the demand side. For example, there exist many opportunities for efficient investment in smart loads that could reduce the need for generation investment, yet which have not been suitably deployed by energy users, In particular, controlled air conditioning (AC) loads have the potential to greatly reduce peak demand and hence the need for peaking generators. However, peak price signals from the wholesale market, which correlate with high demand, have not been passed on to consumers by existing retailers, hence they see little incentive to undertake this potentially highly valuable load management.

Perhaps even more important, energy users or their representatives also require the ability to manage the risks associated with end-use investment. Existing exchange-traded derivatives are designed for hedging large generators. The challenges of unsuitable products and lack of market access mean that DERs don't have access to similar arrangements.

3.3. DER Integration Solutions

Retailers offer solar feed-in tariffs in a competitive market that does provide some incentives for DER investment. It is possible that given the correct price signals in the wholesale and futures markets, retailers could pass on appropriate incentives.

In terms of securing investment opportunities for DERs, one possibility is that retailers provide financing for DERs. Retailers would then have the right to dispatch these assets in the market, taking advantage of incentives provided by spot and futures markets. This model has been used by SolarCity in the US. However, it may present equity concerns, as it requires further corporate finance and does not distribute the ownership of the resource among customers. It is also not clear the extent to which economies of scale may benefit this solution.

Energy storage systems may also allow aggregated DERs to interact with derivative products as they are less time-dependent and able to dispatch to recoup losses in times of high spot prices. However, even more complex arrangements with retailers or aggregators would be required.

3.4. Conclusions

There are clear opportunities for societally beneficial integration of DERs into Australia's electricity system. Issues with the design and operation of wholesale and futures markets provide barriers to efficient investment decisions, particularly as they relate to small consumers and DERs, which affects the degree to which capacity planning and deployment can be carried out appropriately by these distributed decision makers. There is currently no direct mechanism linking DERs with the wholesale and futures markets. The closest approximation is the market coupling via electricity retailers. The efficacy of market-based investment signals to maximise social benefit thus hinges on the competitiveness of the retail market, and a broader framing of this market beyond just choosing between retailers, to far higher retailer and end-user engagement, as considered in the next Section.

4. Energy as a Consumer Product / Service

Retail businesses provide a consumer-facing product that bundles electricity services from complex and volatile wholesale markets and regulated network businesses. The goal of electricity investment, operation and planning should be to maximise societal benefits. It was concluded from previous sections that for efficient integration of DERs into the NEM, appropriate price signals must be passed to prosumers via the retail market. Without competitive retail markets, the tenuous links between wholesale pools and DERs are seen to break down, resulting in inefficient price signals that run counter to the national electricity objectives.

4.1. Historical Response and Effectiveness

Retailers are regulated by the National Electricity Retail Law, with price deregulation in many states, following from the key assumption that competition for the benefit of consumers could be created in retail markets (Belyaev, 2011). “Margins will only stay low if consumers are believed to penalize inefficient suppliers by switching to competitors with lower margins” (Olsen, Johnsen, & Lewis, 2006). Competition can be seen as a proxy for market efficiency. Given the significant margins enjoyed by Australian electricity retailers, it is worth analysing how competitive retail markets in fact are.

Defeuilley (2009) sets out competition indicators for retail markets, namely the propensity of customers to ‘switch’ retailers, participant makeup, and the extent of innovation. The AEMC conducts reviews around customer activity (ie. switching) and outcomes, barriers to entry and exit, rivalry and whether prices are consistent with competition (AEMC, 2016). These indicators appear to offer mixed perspectives that highlight the difficulty in assessing competition in retail markets. We will briefly touch upon some of the potential difficulties.

On customer switching, an ‘active’ market and an ‘inactive’ market may have emerged in retail sectors, with ‘active’ participants benefiting from competition in a subset of the market and the ‘inactive’ segment shouldering higher rates that exceed costs. This suggests that switching rates in the ‘active’ segment may not be a strong indicator of competition, with evidence from international markets showing that switching has not resulted in price convergence (Defeuilley, 2009). A critique of this work however suggested that the number of ‘active’ participants has risen over time (Littlechild, 2009).

On concentration, the AEMC examined market share (domination) of the ‘big three’ energy companies: AGL, Origin and Energy Australia, on the basis that “industry concentration is associated with incumbent monopoly power” (Customer Utilities Advocacy Center, 2012). The Herfindahl-Hirschman index (HHI) is a common concentration measure and key indicator (AEMC, 2016). Based on criteria from the US department of Justice (2016), Victorian retail markets are seen to be ‘moderately concentrated’ with all other regions ‘highly concentrated.’ Thus no regions were found to be competitive under the HHI measure, yet this is a component of the metrics used by the AEMC to conclude that “competition continues to be effective in most jurisdictions.” Interestingly, Victoria has both the lowest HHI and highest switching rates. One would thus expect lower margins, eroded by competition. Victorian margins are however higher than in other states and increased following deregulation, an outcome not consistent with competition (ESC, 2013), and which raises further questions about the suitability of the indicators.

On innovation, Defeuilley (2009) contends that while developments such as tariff changes, software and monitoring products have emerged, “they neither do [sic?] involve a broad redefinition of retail market attributes nor challenge incumbents' business models by disqualifying their offers both technically and commercially." Thus far, the extent to which retail innovation can improve competition or reduce consumer's bills under current arrangements is unclear.

Aside from indicators of competition, structural issues in tariff design may prevent efficient markets from emerging. Simulations have shown that consumers must be exposed to real-time price signals in order for retail markets to operate efficiently (Joskow & Tirole, 2006). The lack of real-time pricing in retail electricity markets appears to contradict the standard model of efficient competitive markets (Borenstein & Holland, 2003). However, while increasing the share of customers on real time pricing has been shown to improve overall efficiency, incentivisation of capacity investments was not observed (Borenstein & Holland, 2003).

4.2. Potential Impacts of Distributed Energy Resources

Market indicators provide mixed results for Australian electricity retail markets (as well as leaving wide room for interpretation). It is also clear that DERs will have an impact on the indicators.

Proper analysis of the impact of DERs on the retail market requires a degree of framing. One view may be that DERs are a source of competition within the retail market, as consumers face the choice of opting away from purchase of grid energy towards privately owned and operated devices. This choice would be dictated (in theory) by the relative cost of each method of energy supply; retail businesses are competing with DER installers and operators. Another view is that distributed energy presents an opportunity for some consumers to leave the retail market altogether. Another is that while DERs may reduce the profits of the retail sector, prosumers are still forced to engage with a retailer and thus DERs are simply changing the range of services that are demanded from retailers by a growing portion of the customer base. These frames make it easier to speculate on the impact of DERs on retail market competition.

DERs may either solidify retailer relationships or spark further switching via retail competition around tariffs. The introduction of DERs to retail contracts could create demand for longer-term agreements to guarantee returns on investment, conceivably reducing switching. Additionally, some new business models may deter switching. For example, retailers that provide DER financing may lock consumers into long contracts and impose penalties for premature removal. Alternatively, in higher-penetration scenarios, we may see enhanced switching as retailers compete to offer attractive retail tariffs to prosumers.

The concept of the retail market existing as two separate 'active' (switching, competitive) and 'inactive' (little switching, high tariffs) markets (Defeuilley, 2009) is one problem that may be somewhat resolved by high-penetration DERs if inactive customers are converted into prosumers with an additional financial interest in securing a more beneficial retail contract.

For the case of DERs viewed as a new entrant into the retail space, switching costs are high. DERs require significant upfront investment and have significant lead times in their construction. Additionally, they introduce new market and operational risk by adding further contractual (feed-in tariff) and weather-dependent variables for customers.

Market concentration may also be impacted by the emergence of high-penetration DERs. This analysis depends on the perspective from which DERs are seen in the electricity market. If DERs are envisaged as competitors to existing retail businesses, large-scale distribution of energy sources would be reducing the market concentration of the retail sector (at least on a per-kWh-consumed basis). Alternate conceptions of this scenario may conceive of aggregators or PV suppliers as single entities, potentially increasing measured concentration. The HHI index is the general measure of market concentration, though it is not clear how such an analysis may be carried out in a market with many thousands (or millions) of small aggregators that interact with incumbent utilities in a complex manner.

Academics have lamented a lack of opportunities for innovation in the retail market (Defeuilley, 2009), but DERs may present scope for disruption. The advent of DERs appears to fundamentally change the relationship between consumers and retail service providers and may present opportunities for business model innovation beyond simple contracting, advertising and business efficiency gains.

5. Conclusion

While NEM restructuring over the past two decades has succeeded in bringing market based competition to large-scale generation operation and investment, there would seem to have been much less success in strengthening competition at the retail level. This poses considerable challenges for effective and efficient DER integration into the NEM given its reliance on retail market arrangements. The break-down of the energy (non-network) component of the electricity sector into wholesale, derivative and retail markets was designed at a time when DERs were not expected to have a major impact. Over the last two decades, the proportion of DER generation capacity in the NEM has grown substantially, yet integration into existing markets has been ad-hoc, with more coherent and comprehensive change requiring a paradigm-shift away from a centralised model. This makes coupling DERs and existing markets a difficult economic design challenge.

Analysis of the dispatch and investment mechanisms for generators in the NEM appears to show that market mechanisms will only deliver efficient outcomes if price signals can be passed from the wholesale markets to DERs and their investors or operators. The mechanism for passing on price signals is the retail market. This mechanism relies on effective retail competition, which is difficult to assess, but certainly appears inadequate at present. It follows that if retail markets do not appear to be facilitating the effective integration of DERs with wholesale price signals, further exploration of methods for passing on these signals is required if the NEM is to continue to comply with the national electricity objective's aim of maximising societal benefit .

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