Modelling the Interaction of Prosumage Adoption and Retail Tariffs within a Transitioning NEM

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The National Electricity Market (NEM) is currently undergoing significant and simultaneous transformations at the utility- and customer-scales [1]. Electricity retailers are exposed to changes in wholesale costs and future customer demand, especially as the cost effectiveness of PV and battery energy storage systems continue to improve for residential customers [2], [3]. Retailers however remain in a position of influence, as retail tariff structures, and their range of retail offerings affect customer expectations by defining the financial incentives available to these behind-the-meter PV battery systems [4], [5]. At present with the large amount of rooftop PV-only systems [6], customers act as *prosumers* that can only *pro*duce and con*sume* energy. As the costs of battery systems decrease, a mainstream shift towards rooftop PV plus battery systems would fundamentally change how customers interact with the grid. This would allow them to act as *prosumagers* that can determine how and when to store and dispatch their own energy storage and provides increased flexibility for customers to shift demand in response to retail tariffs. With retailers having to recover electricity supply chain costs, any changes in utility-scale generation and storage portfolios would also have a direct impact on costs, affecting future retail tariffs that may influence further PV battery prosumage adoption and the subsequent shape of customer demand. This creates a relationship between a transitioning NEM at the utility-scale and growing prosumage at the customer-scale, with the retailer residing in between and influencing how customers may respond. Retail tariffs therefore have the potential to enable the operation of prosumage assets to better respond to (or ignore) the wholesale market dynamics, but at what cost? Virtual Power Plants (VPPs) and Neighbourhood-Scale Batteries (NSBs) offer retailers new pathways to actively operate customer PV and/or battery assets, while also being dependent on there being sufficient behind-the-meter capacity to make the business model viable. This study presents a modelling framework that evaluates the capability of VPPs and NSBs (and more traditional retail tariffs) to influence prosumage adoption while managing the costs to supply energy to these customers. This information may assist decision and policy makers to better understand the retail tariffs conditions that may improve participation of prosumage customers in a transitioning NEM.

Establishing this relationship between a transitioning NEM and future prosumage requires an integrated modelling framework (Figure 1) that captures capacity expansion at both the utility- and customer-scales. This research focuses on the development of an open-source multi-model framework that soft-links a 'least-cost utility-scale investment, dispatch and network augmentation model' called *MURIEL* [7], [8] with a dynamic 'customer-scale PV battery investment and dispatch model' called *Electroscape* [3], [9]. Assuming competitive generation and retail markets, this modelling approach estimates how different retail tariff structures/offers may impact future retailer revenue margins as utility-scale portfolios and customer energy assets change. This approach creates an opportunity for researchers and analysts to compare the trajectory of different retail offerings, from flat and temporal import/export tariffs to VPP aggregators and virtual battery subscriptions using a NSB.

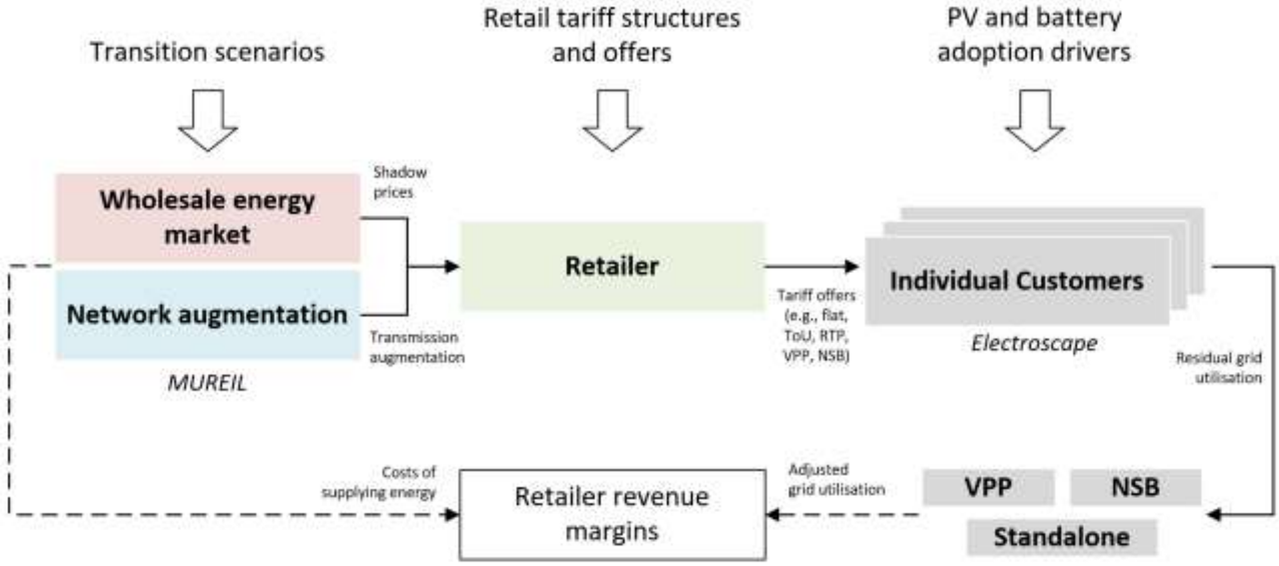

Figure 1. Oveview of the combined modelling framework.

Integrated assessment of utility- and customer-scale models

The overall assessment framework (Figure 1) begins by determining changes in wholesale energy and supply costs. Using *MUREIL*, various transition scenarios (e.g., business-as-usual, net-zero generation and consumption) are evaluated to determine the least-cost utility-scale investment and dispatch portfolios, along with the required transmission network augmentation. As each portfolio contains the generation and storage capacities of each technology type and how they are dispatched, shadow prices are used to reflect hourly changes in an energy-only wholesale market (e.g., [9], [10]). Combined with the costs of transmission network augmentation, *MUREIL* provides the means to estimate future wholesale electricity and transmission network costs under different NEM transition scenarios.

These costs components from *MUREIL* provide the foundation to estimate prices of future retail tariffs with respect to current prices. Changes to flat retail tariffs can be approximated using the average of future shadow dispatch prices. Time-of-Use (ToU) tariffs may be approximated using the average hourly value of generation and network charges. Feed-in Tariffs (FiT) may be approximated using the average market value of solar PV generation. Real Time Pricing (RTP) would equate to the shadow price plus network charges. This range of tariff structures and their future prices provide the cost signals necessary to simulate the adoption of PV battery systems by residential customers.

The *Electroscape* model optimises the dispatch and investment sizing of PV battery systems to minimise a customer's electricity bill. It is an iterative model that considers past investments in PV battery capacity and is based on discounted cash flows (i.e., Net Present Value). This allows the model to optimise the dispatch with respect to time-varying import and export tariffs, which allows customer grid imports and exports to reflect ToU tariffs. This allows *Electroscape* to simulate prosumage adoption for a single customer under wide variety of tariff structures and future electricity price trajectories. By using real household load profiles as an input, a representation of prosumage PV and battery adoption across the household sector may also be simulated.

Under VPP aggregation (Figure 2), a flat reduction in monthly bills is provided in exchange for access to customer batteries (e.g., [11]), which would result in lower upfront battery costs. As the *Electroscape* model determines the operation of customer batteries to maximise bill savings, it also quantifies the aggregate spare storage capacity (per hour) available across the set of households. This spare storage capacity may be used as a capacity constrained VPP battery, which time-shifts aggregate household load to further reduce a retailer's exposure to wholesale electricity prices (derived from *MUREIL*) and network charges.

Under a virtual battery subscription model, households do not install a battery behind-the-meter, but rather pay a monthly subscription fee for capacity in a NSB (e.g., [12]). Compared to the VPP, the

NSB utilises all of its storage capacity to arbitrage energy and network charges, but credits customer electricity bills as if they had access to their own battery. To reduce further modelling complexity, ancillary grid services currently remain outside the research scope.

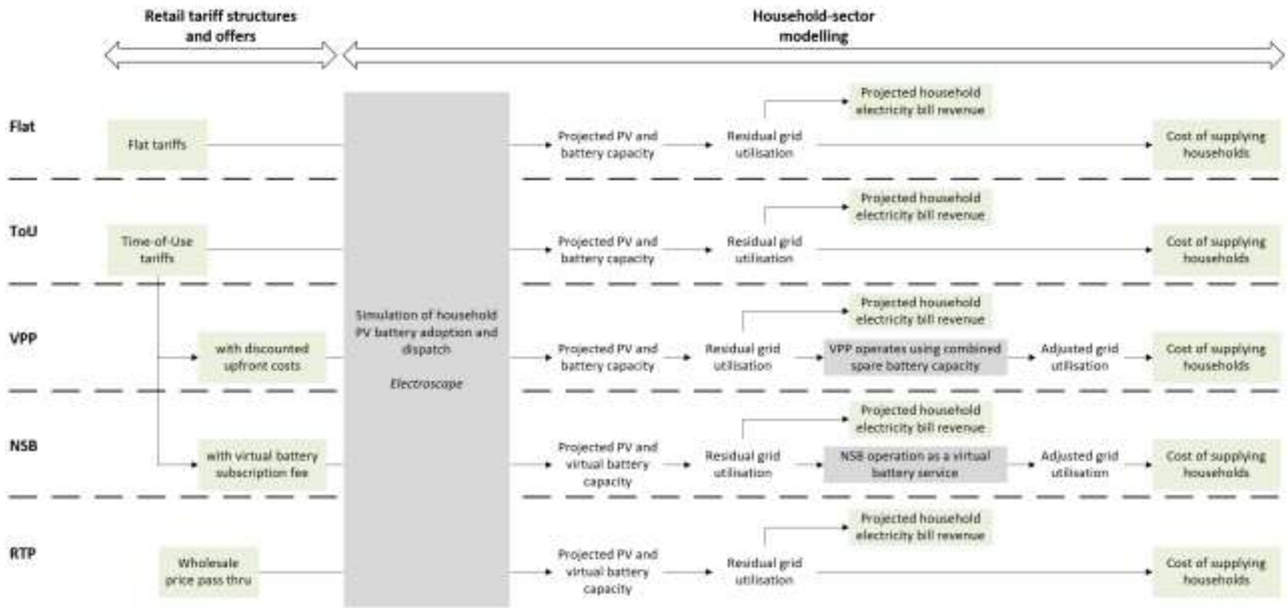

Figure 2. Modelling the influence of different retail tariff offers.

An important consideration for retailers is the impact on their revenue margins (i.e., the gap between the revenues from projected household electricity bills and the cost of supply to these households). As Electroscape determines the expected grid utilisation profile for each household, their electricity bills can be derived, while the costs of supply reflect the transition results from MUREIL. This allows the annual retailer revenue margins to be calculated for each of the five retail tariff offerings (Flat, ToU, RTP, VPP and NSB). By analysing how the annual revenue margins change over time and under different NEM transition scenarios (Figure 3), the robustness (or fragility) of each retail tariff offering and its revenue trade-offs over the short- and long-term may be subsequently evaluated.

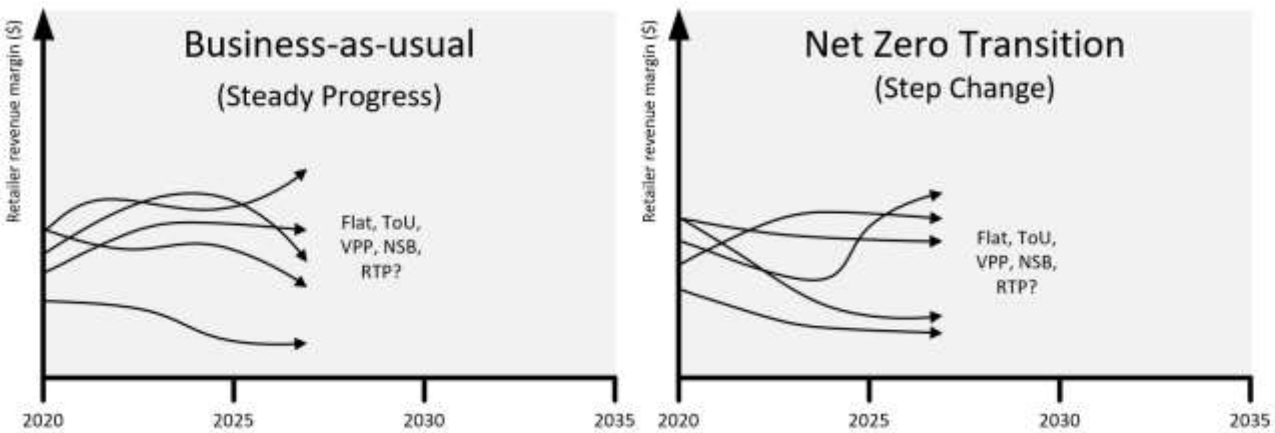

Figure 3. An illustrative example of the impact of the NEM transition and retail tariff offerings on future retailer revenue margins.

Conclusion

This modelling approach can provide decision and policymakers with the context to better understand the degree to which different retail offerings may improve the alignment between the operation of prosumage households and the wholesale market, while also considering how retailers may be incentivised to offer these tariffs. This may lead retailers to set the foundations to encourage prosumage households to transition away from flat time-invariant tariffs, and towards a broader range of time-varying tariffs, including those that provide active demand shifting (i.e., VPP, NSB). As retailers are capable of setting expectations of prosumage adoption, they play a critical role in the energy transition. The development of this research framework can then be used to further explore how climate and energy policies at the retail level (e.g., capital subsidies, regulated requirements, solar export charges) may accelerate the transition of the power sector to renewable energy at both the customer- and utility-scales.

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