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Retail Electricity Tariff Design to Incentivise Efficient Consumer Behaviour

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Abstract

Customer choice is starting to drive developments in the Australian National Electricity Market (NEM), and accelerate the transition towards a more decentralised and cleaner electricity industry. However, retail electricity market arrangements may be impeding this transition, with reviews in 2016 and 2017 prompted by concerns of lack of competition and genuine consumer choice. This paper will explore whether new electricity tariff structures could better incentivise economically efficient consumer behaviour around distributed generation such as PV, battery storage and other demand-side options.

Whilst consumers are already actively investing in these options, present retail arrangements arguably do a poor job of aligning private returns from such investments with overall economic outcomes of the electricity industry as a whole. This concern, along with new opportunities for consumer response enabled by the development of advanced metering and control capabilities has led to a shift in approaches to retail tariffs in many jurisdictions around the world, from fixed price offers for residential customers, towards more dynamic electricity pricing that better reflects the underlying, time and location varying, costs and benefits of electricity service provision.

In this paper, outcomes of a real-time pricing (RTP) tariff, based on an approach recently implemented in Spain, are explored for retail customers in the NSW Ausgrid network area. The impacts of the new dynamic tariff on different customer types, the extent to which it might result in customer bill savings, and incentivise changes in electricity demand profiles via load shifting, are all assessed. This study suggests that consumers are likely to have lower bills on an RTP tariff, and that as the consumer capacity to respond to dynamic pricing increases, for instance with the uptake of new technologies, consumers may play a more significant role in managing both system and local network demand. However, there are important limitations to such tariff approaches and broader, more systemic, changes to retail market arrangements appear to still be required in order to appropriately facilitate energy consumers in deploying distributed energy options.

1. Introduction

The Australian Energy Market Commission (AEMC) has deemed retail competition to be effective in most states of the National Electricity Market (NEM) (AEMC, 2016a). However, Australia's 'competitive' retail markets are highly concentrated, dominated by a few large vertically integrated players, and have not delivered lower prices for consumers, meaningfully differentiated products or innovative services (MacGill and Smith, 2017; Wood et al., 2017). In March 2017 the Australian Competition and Consumer Commission (ACCC) responded to these concerns by launching an inquiry into the competitiveness of retail electricity prices.

The ACCC's preliminary report released in September 2017, found that a lack of understanding and confidence, and a low level of control on the part of consumers, are all barriers to consumer engagement in the retail market. At the same time, however, the retail sector is undergoing a disruptive transformation driven by increasing consumer investments in distributed energy (DE) resources (with rooftop PV penetrations continuing to rise (AEMO, 2016)), the growing availability of energy management systems and technologies and, importantly, the emergence of new customer attitudes (AEMC, 2016b). Electricity prices in Australia are expected to increase further over the 2018/19 period due to rising wholesale electricity prices (AEMC, 2016a), which will likely continue to drive already significant consumer investment in DE technologies. In effect, a growing number of consumers are actively bypassing conventional retail 'competition' arrangements in the NEM, a phenomenon which has prompted the AEMC to conduct a review into Distribution Market Models, examining regulatory and market-based frameworks to incentivise the efficient integration of DE resources (AEMC, 2016b).

This paper aims to contribute to our understanding of what appropriate retail market arrangements might look like in a world of growing DE options. In particular, it explores whether retail tariffs can deliver price signals to consumers that not only optimise their own energy investments and energy usage decisions, but also maximise net benefits for the electricity industry. Innovative Spanish retail electricity tariff offers are explored as examples of potential new electricity tariff pricing structures.

European retail electricity markets have been undergoing significant systemic changes in recent years, enabled by the widespread installation of smart-meters, regulatory reform, and greater innovation from retailers seeking to maintain competitive advantage (Capgemini, 2015). This has included more cost-reflective retail electricity tariff designs and greater efforts to facilitate demand response. In 2014, the regulated flat rate tariff in Spain was replaced with a real-time pricing (RTP) tariff, known as the voluntary price for small consumers (VPSC) (CNMC, 2016), [1] representing one of the more innovative examples of European tariff reform. Given world leading uptake of distributed PV in Australia, which looks likely to be followed by other distributed technologies such as storage and advanced metering, the extent to which tariffs can engage consumers by providing effective price incentives, providing them opportunities to reduce their bills and manage their own risk, is highly relevant to the present debate regarding future NEM arrangements.

In order to assess whether an RTP tariff pricing structure could incentivise consumers to act in the interest of the electricity industry as a whole, a new residential electricity tariff based on

[1] By the end of 2015, nearly 48% of entitled customers were on this tariff (CNMC, 2016).

the VPSC is applied to NSW consumer load profiles, and bill outcomes both with and without price-based demand response are compared to the outcomes under existing Tier 1 retailer fixed and TOU tariff offers.

The structure of the rest of this paper is as follows. Section 2 provides a review of retail electricity tariff structures, and experiences with consumer response to dynamic pricing. An RTP tariff and a load shifting model are derived in Section 3. Finally, in Sections 4 and 5, the extent to which the new tariffs might result in total customer bill savings, and incentivise changes in electricity demand, peak load shifting and network peak reduction are assessed.

2. Literature Review

The true cost of supplying electricity, mainly comprised of wholesale electricity purchase costs and network transmission and distribution costs, is dependent on time and location. Prices in wholesale electricity markets are determined by the marginal cost of generating electricity, which, while somewhat volatile, tend to be higher during high demand periods and when low operating cost renewable energy is not available. At these times, the most expensive generators must be dispatched to meet demand, and there are opportunities to exercise market power. In energy only markets such as the NEM, times of tight supply demand balance can see very high spot prices restricted only by the Market Ceiling Price. In purchasing energy from the wholesale market and on-selling it to consumers, retailers face some risk associated with price uncertainty and costs associated with managing risk e.g., through financial hedging products. The cost incurred by network operators to transport electricity and distribute it to customers is mainly driven by the cost of investing in capacity sufficient to meet projected peak demand, which occurs at different times in different parts of the network. For small energy consumers these costs, along with a range of more minor metering, environmental policy costs, retail margins and any sales taxes, are passed on through bundled retail electricity tariffs. In the short-term, an efficient price signal would incentivise the consumer to reduce consumption at times of high wholesale prices or high levels of local network congestion, while efficient long-term price signals would incentivise appropriate consumer energy investment decisions and energy consumption behaviour.

2.1. Retail Electricity Tariff Structures

Historically, simple flat rate tariff structures were seen as appropriate given low-cost metering technologies, the limited ability of consumers to respond to prices and a view of electricity as an essential service that justified cross-subsidies. As a result, there has been considerable smearing of the time-varying cost of supplying electricity in the price signal received by residential consumers. More recently, alternative tariff structures, such as time-of-use (TOU), critical peak pricing (CPP) (sometimes termed dynamic peak pricing) and real-time pricing (RTP) have been introduced or trialled to better reflect the temporal distribution of underlying costs and therefore drive more efficient investment in and operation of energy equipment by consumers.

TOU tariffs allocate a higher price to pre-defined ‘peak’, ’shoulder’, and ‘off-peak’ time-periods (hours of the day), which reflect different wholesale and network costs at different times of the day, and between working days and weekends. CPP is most commonly used to reduce network peak loads to defer network augmentation, and involves charging consumers a substantially higher rate during ‘peak events’, signalled in advance to consumers, and lower rates during the rest of the year. RTP consists of dynamically passing through electricity prices that reflect the wholesale price of electricity, to consumers. In practice, as seen in Spain, this has often been the average hourly price communicated one day in advance (ACER and CEER, 2016).

In theory, more cost-reflective tariffs allow the rational consumer to more accurately value electricity services and respond to prices in a way that minimises their costs. In practice, end-user decision-making concerning when and how to use electricity does not always maximise economic gain, since there are technological and psychological factors that limit the uptake of and response to cost-reflective tariffs (Stenner et al., 2015). These factors are important determinants of whether cost reflective pricing will deliver an overall benefit to consumers or broader benefit to the electricity industry as a whole.

2.2. Consumer Responses to Dynamic Pricing

In the near term, voluntary uptake of dynamic tariffs in Australia is expected to be only 5% – 10% of households (Stenner et al., 2015). Consumers prefer traditional flat rate tariffs partly due to a general aversion to decision-making (Stenner et al., 2015), which is heightened by the complexity of the retail electricity market and a lack of understanding of the underlying costs of electricity service provision.

To achieve higher levels of dynamic tariff uptake, risk-reducing strategies (such as offering money-back guarantees or free automation devices) may need to be offered to consumers (Stenner et al., 2015). Nevertheless, there are significant upfront costs associated with enabling consumer price response, including the cognitive information cost of understanding complex tariffs (Ito, 2014), interval meter purchase and installation cost, and the cost of acquiring hardware and software for appliance automation and control.

The effectiveness of cost-reflective tariffs depends on how residential consumers change their electricity consumption behaviour in response to electricity prices. Consumers may respond to high price events, that is perform demand response, through either load shifting or energy conservation. In NSW, the results of residential customer variable pricing trials indicated average peak demand reductions of around 25% (Strengers, 2010).

The wide variations seen in consumers' ability to reduce their peak demand in response to high prices (that is, the price elasticity of electricity demand) is influenced by weather, appliance holdings and demographics. Demand reduction in response to high price events tends to be higher in summer than in winter (Langmore and Dufty, 2004), and in climates that experience more extreme temperatures (Ito, 2015), with both of these phenomenon being largely due to consumers with air-conditioners being potentially more responsive to electricity prices. Consumer demographics and lifestyle are also factors, with lower income households exhibiting slightly larger price elasticities (Ito, 2015). Response to price is enhanced by providing transparent price and consumption information, communicated via in-home displays (IHDs) and text messages (Ito et al., 2017; Jessoe and Rapson, 2012), and by providing day-ahead notification of high price events (Jessoe and Rapson, 2012).

There are a variety of factors that influence the price elasticity of electricity demand, and hence the potential value of innovative tariffs for energy consumers and the electricity industry as a whole (Ito, 2014).

3. Methodology

Our study aims to assess the potential impacts of a real-time pricing tariff on residential consumer bills in the NEM and the potential for such a tariff to provide efficient price signals that appropriately incentivise changes in household consumption patterns. A new residential electricity tariff based on the Spanish VPSC is applied to NSW consumer load profiles, and bill outcomes both with and without a price-based demand response are compared to the outcomes under existing Tier 1 retailer fixed and TOU tariff offers.

3.1. Consumption Data

Half-hourly residential electricity consumption data from Ausgrid's Smart Grid Smart City (SGSC) project data set is used to calculate the impact of tariffs on consumer bills (Ausgrid and AEFI, 2014). Importantly, this trial, located in the greater Newcastle and Sydney areas, not only collected household half-hourly electricity demand data, but also information regarding household demographics, appliance holdings and the electricity demand characteristics. This information is used in our study to estimate the potential for demand response in the form of load shifting. The period from January 2013 to December 2013 was used for the analysis. The representative consumer for all the households analysed has an average yearly consumption of around 5640 kWh/year, which is consistent with the representative consumer's average yearly consumption of 5940 kWh/year used by the AEMC (AEMC, 2017).

3.2. RTP Tariff Design

The structure of the retail component of the RTP tariff tested in this study is based on the retail component of the Spanish VPSC. The hourly energy price is composed of the average hourly wholesale electricity price, an energy charge to cover market fees, retail costs and a retail margin (RED Electrica de Espana, 2017). The Spanish tariff is fixed one-day ahead and communicated to customers through an online portal to facilitate load shifting at times of forecast peak demand.

A building block approach was used to design an equivalent RTP tariff for Ausgrid customers, and the disaggregated components are shown in Table 1. Since this tariff is being compared to Tier 1 retail offers for the 2017/18 financial year, all the tariff components are based on projected 2017/18 financial year charges. The network and metering charges applied in this tariff are those for the Ausgrid residential TOU tariff for 2017/18. The environmental costs are based on projected 2017/18 costs from the literature. The retail component is considerably more complex, and Section 3.2.1 explains the assumptions made to account for the forward-looking nature of retail electricity tariffs when setting the retail cost.

Table 1. Component Disaggregation of the Designed RTP Tariff

Network Daily (Ausgrid, 2017)	44.35 (c/day)
Network Peak (Ausgrid, 2017)	25.2 (c/kWh)
Network Shoulder (Ausgrid, 2017)	4.15 (c/kWh)
Network Off-peak (Ausgrid, 2017)	1.99 (c/kWh)
Metering charge (Ausgrid, 2017)	**47.02 ($/year)**
LRET - LGC cost (Jacobs, 2017)	0.881 (c/kWh)
SRES - STC cost (Jacobs, 2017)	0.399 (c/kWh)
Climate Change Fund (Ausgrid, 2017)	0.47 (c/kWh)

Energy Saving Scheme (AEMC, 2016a)	0.23 (c/kWh)
Total environmental costs	**1.98 (c/kWh)**
Average hourly spot price (2016) (Creative Analytics, 2017)	0 to 1000 ($/MWh)
Fees for wholesale energy purchases (AEMO, 2017c)	0.41 ($/MWh)
Full Retail Contestability (AEMO, 2017c)	0.08 ($/MWh)
National Transmission Planning (AEMO, 2017c)	0.02 ($/MWh)
Energy Consumers Australia (AEMO, 2017c)	0.01 ($/MWh)
Ancillary Services costs (2016 – 17) (AEMO, 2017a)	0.35 ($/MWh)
Hedging costs - Premium on spot price (Section 3.2.1)	0%
Dummy variable – Spot price difference (Section 3.2.1)	29.8 ($/MWh)
Approximate total energy trading costs	**9.27 (c/kWh)**
Retail cost (IPART, 2013)	1.83 (c/kWh)
Net Retail margin (Section 3.2.1)	1.81 (c/kWh)
Gross retail margin	**3.64 (c/kWh)**

3.2.1. Retail Component

The retail component of the RTP tariff is composed of energy trading costs and the gross retail margin, which includes both the costs and profits accumulated during the provision of retailer services. There is significant complexity involved in projecting these costs for the 2017/18 financial year, and the assumptions involved in the design of this part of the tariff are explained further below. The RTP tariff was designed for the 2017/18 financial year to facilitate bill comparisons with current fixed and TOU tariff offers.

3.2.1.1. Wholesale Electricity Purchase Costs

Electricity industry costs are uncertain, and one role of the retailer is to manage consumers' exposure to wholesale price volatility. Hedging contracts generally allow the retailer to manage this risk (AEMC, 2016a), however under an RTP tariff, the wholesale price is passed onto consumers and so hedging costs are removed. In this tariff design, there was an assumption of perfect spot price foresight, and so historic 2016 30-minute spot price data was used (sourced from Creative Analytics, 2017). This reflects the potential for real-time consumer responses in the future, enabled by automated and remotely controlled appliances. The 2016 spot prices were then adjusted to reflect the forecast 2017/18 spot prices through the introduction of a dummy variable that accounts for the difference between the average spot prices in 2016 and those in 2017/18, based on available futures pricing data.[2] The dummy variable increased all 2016 spot prices by the difference in 2016 and 2017/18 averages. While demand response can reduce spot prices, the initial uptake of the RTP tariff is expected to be low (Stenner et al., 2015), and so the potential impact of residential demand response on spot prices has not been explored. However, if and as deployment increases, it will become more important to assess the impacts of demand response on spot prices. As for the ancillary services charges,[3] these are volatile and related to the retailer purchases, so average values are

[2] The yearly average spot price for 2016 is $59.03/MWh (Creative Analytics, 2017) and the predicted average spot price for the 2017/18 financial year is $88.83/MWh (AEMO, 2017b).

[3] A portion of the ancillary services costs is recovered from market customers (i.e., retailers). The customer recovery rate is determined for each region, and is the total customer recovery divided by the energy customers (AEMO, 2015). Average customer recovery rate for the NSW region for the year Sept 2016 – Sept 2017 was calculated using data from 'AS Recovery Summary File 2017' (week 36 to 52 of 2016 and week 1 to week 35 of 2017) (AEMO, 2017a).

used as estimates (Jacobs, 2017). Finally, trade-offs between cost-reflective pricing and equity concerns are reflected in the tariff design by imposing an upper limit of $1000/MWh (or $1/kWh) on the average spot price seen by consumers (Ausgrid, 2011).[4] This is to the detriment of retailers, that are liable for an additional $15,417, or $7.06 per customer per year, based on the analysis conducted (excluding hedging costs).

3.2.1.2. Gross Retail Margin

Since the gross retail margin component of Australian tariffs cannot be directly discerned due to the lack of information, it was estimated by disaggregating the 2017/18 financial year Tier 1 residential electricity tariff offers, subtracting all non-retail costs from the representative customer's total electricity bill, then comparing with the relevant literature (Jacobs, 2017; AEMC, 2017). Discounts of 10 – 15% provided by retailers were applied to all tariff calculations.[5] Net retail operating costs were approximated by the regulated retail cost allowance for NSW standing offers of $118 per year per customer (IPART, 2013).[6] Then a sensitivity analysis was conducted to determine a reasonable net retail margin, accounting for the fact that under an RTP tariff, the retailer is taking on less risk on behalf of the consumer, and so the retail margin should be lower for the RTP tariff. The selected gross retail margin charge of 3.64 c/kWh equates to an annual gross retail margin of $217 for the 5,640 kWh/year representative consumer. This value is within the appropriate range for residential customers (AEMC, 2017; AER, 2017b; Jacobs, 2017; State Government of Victoria, 2017; Wood et al., 2017).

3.3. Load Shifting Model

A load shifting model for residential households was developed to predict the price-based changes in consumption which may be incentivised by the designed RTP tariff. Although demand response due to both load shifting and energy conservation (achieved by installing energy efficient devices, for example) would occur, in order to simplify the modelling, it was assumed that all demand response was due to load shifting. This model attempted to differentiate between load that is fixed and load that is flexible. Flexible loads can be shifted without placing a significant amenity loss on the consumer (such as dishwashers, washing machines, clothes dryers, air conditioning and pool pumps). Household-specific electricity demand profiles were created based on percentiles that indicate the value below which a given percentage of electricity consumption readings fall for each time-period. Profiles were created for working week-days and weekend days, for each season. The resulting average electricity demand profile for households without gas appliances but with ducted air-conditioning is shown in Figure 1.

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[4] Spot prices can range from - $ 1000/MWh (market Price Floor (MPF)) to $ 14,200/MWh (market Price Cap (MPC)) (AEMC, 2017). The threshold value selected is based on results from CPP trials which showed that there is a threshold value above which a consumer's price elasticity of demand does not change.

[5] Discount rates are provided on the following energy price fact sheets: ORI402604MR (Origin Energy, 2017), ENE390950MR (Energy Australia, 2017a), ENE391091MR (Energy Australia, 2017b), AGL366956MR (AGL, 2017a) and AGL367089MR (AGL, 2017b).

[6] Net retail costs are the costs associated with administration (incl. customer service), customer acquisition and retention, and regulatory compliance (AEMC, 2017).

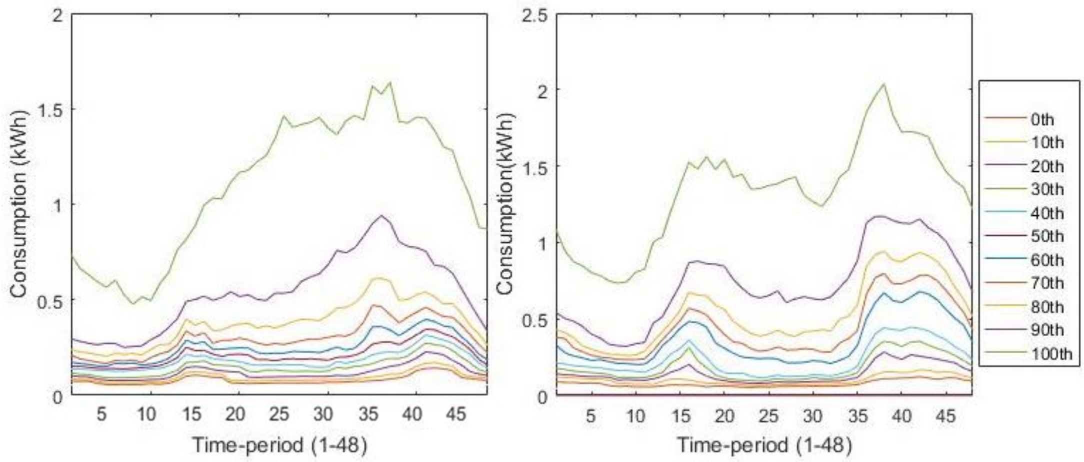

Figure 1. Average Profile for Households without Gas Appliances but with Ducted A/C for Weekdays in Summer (left) and in Winter (right)

The load shifting model looks one day-ahead and determines whether the three highest spot price periods that occur on that day are greater than $200/MWh, and if so, the model then determines whether the electricity consumption of that household is above the required consumption percentile (which depends on household appliance holdings) for iterations one to five. Successive iterations were undertaken to achieve a larger demand response, whilst accounting for limitations in household load shifting capabilities due to appliance holdings (as defined in Table 2). If these conditions are fulfilled, the load is shifted to one of the three lowest spot price periods on that same day. If there are no spot prices above $200/MWh, then demand response is activated for only one of the three highest spot price periods.

Table 2. Electricity Consumption Percentile Threshold Level

Household appliance holdings	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
No gas; A/C	60	50	40	30	20
No gas; no A/C	70	60	50	40	40
Gas heating/cooking; A/C	70	60	50	40	30
Gas heating/cooking; no A/C	70	60	50	40	40
Gas hot water/heating/cooking; A/C	70	60	50	50	40
Gas hot water/heating/cooking; no A/C	70	60	50	50	50

4. Results

4.1. Impacts of the Designed RTP Tariff on End-User Bills

The RTP tariff is the most competitive offer for the 5,640 kWh representative consumer. The estimated bills (for the 2017/18 financial year) for Tier 1 retailer offers, are compared with the designed RTP tariff in Figure 2. The single greatest component of all the tariffs was the retail component, which is composed of the wholesale electricity costs and the gross retail margin, and account for 27 – 31% and 12 – 25 % of the total bill, respectively. This was followed by the network component (31% – 40% of the total bill). As shown, these results are consistent with the ACCC estimated 2016-17 average revenue from NEM residential customers ($/customer) (Sims, 2017).

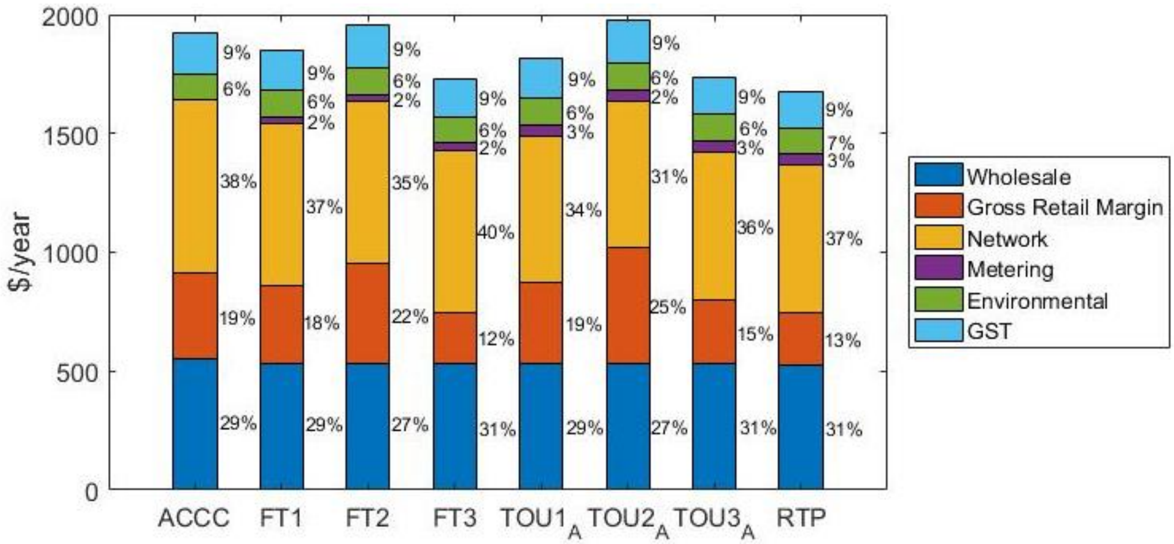

Figure 2. Electricity Bill Disaggregation: Flat Rate, TOU and RTP Bill Comparison for 5,640 kWh Representative Customer (projected for the 2017/18 Financial Year)[7]

[7] The Tier 1 tariff offers are; AGL Energy fixed and TOU tariffs (FT1 and TOU1), Energy Australia fixed and TOU tariffs (FT2 and TOU2), and Origin Energy fixed and TOU tariffs (FT3 and TOU3).

Households were identified as low, medium and high consumption based on whether their yearly electricity consumption was below 3020 kWh, between 3020 and 7355 kWh and above 7355 kWh. The median annual bills for low consumption, medium consumption and high consumption households on the Tier 1 tariff offers were $830, $1600 and $3020 respectively, whereas the median annual bills on the RTP tariff were $785, $1485 and $2730 respectively, meaning that for the median customer there is a financial incentive to opt into the RTP tariff – although there was significant variability for low consumption households moving from a flat tariff. Figure 3 displays the annual bills for households on Tier 1 tariff offers, the designed RTP tariff and the designed RTP tariff with the best-case (model iteration 5) load shifting (RTP + DR), grouped by consumption level. The savings (as a percentage of the total bill) that consumers may derive from switching from a Tier 1 tariff offer to the RTP tariff, and the savings from engaging in the best-case price-based load shifting (model iteration 5) whilst on the RTP tariff, are also shown. The saving acquired through load shifting appeared inconsequential to the savings derived from switching tariffs, with low, medium and high consumption household savings from load shifting amounting to $17 (2.2% of total bill), $39 (1.2% of total bill) and $69 (0.6% of total bill) respectively. Again, low consumption consumers received the greatest benefits relative to their total bill. Notably, although the RTP tariff has a more variable wholesale cost, the customer bill spread was smaller on the RTP tariff. Lastly, the yearly variability of the RTP tariff was investigated by comparing the yearly wholesale component for the 2013 to 2016 period. The maximum yearly variability (as a percentage of the wholesale component) was 52 – 60%, which occurred between 2015 and 2016 for the majority of households, reflecting the increase in wholesale prices of 48% between 2015 and 2016 (AEMO, 2017b).

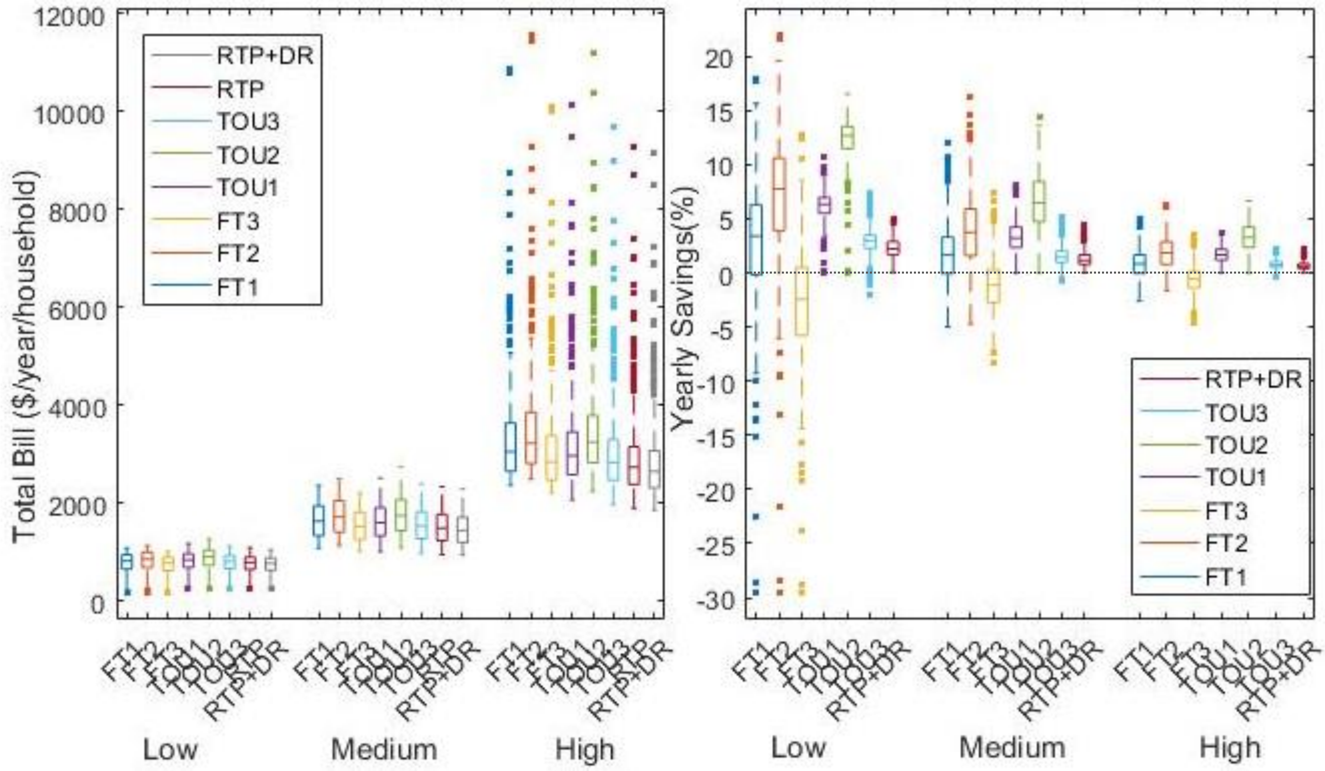

Figure 3. Yearly Bill (left) and Potential Customer Savings by Switching to the RTP Tariff (right) for Low, Medium and High Consumption Households

4.2. Impacts of the Designed RTP Tariff on Peak Demand and Network Peak Demand

The results indicate that the RTP tariff sends an effective price signal to reduce the NSW region's peak demand. For the summer 2012/2013 and the summer 2013/14 peak days (AER, 2017a), aggregate household load reductions of 65% – 80% (model iteration 1 to 5) and 60% – 75% (model iteration 1 to 5) occurred between approximately 2 and 5pm. While for the winter peak day (AER, 2017a), the morning peak was reduced by approximately 20% – 50%, and the winter evening peak was only reduced by approximately 15% (and was similar across all the iterations). In addition, the aggregate seasonal peak demand day and peak demand time for these households corresponded to the NSW peak demand days and times (reaching 4.7 MW (2012/13) and 3.8 MW (2013/14) in summer, and 4.0 MW (2013) in winter). Secondly, in terms of managing peak demand at the network substation level, the price-based demand response tended to occur during network shoulder (41%) and network peak (38%) time-periods. Load was primarily shifted to off-peak (87%) and shoulder (12%) network time-periods. The potential value of such demand reductions in reducing longer-term network costs are not factored into this study but represent a potential area of future work.

5. Discussion

As the penetration of renewable energy generation increases, spot prices are likely to become more volatile, and so demand response will also increase in value (Riesz, J. and Macgill, I., 2013). Residential consumer investments in distributed energy resources, such as automated appliances, rooftop PV, batteries and EVs, can in aggregate provide substantial demand response capabilities. Real-time pricing is a means to leverage residential demand response capabilities to incentivise effective load shifting, to minimise costs for the consumer and the electricity industry as a whole. Harnessing residential demand response is particularly important given the finding that residential heating and cooling loads drive peak demand in NSW, and that load shifting was able to significantly reduce peak demand and (to a lesser degree) local network congestion. Thus, since the designed RTP tariff is able to incentivise appropriate consumer demand response, the projected consumer savings and their implications for the voluntary uptake of RTP tariffs and the 'efficient' use of the RTP tariff price signals deserve further consideration.

The designed RTP tariff is the most competitive when compared to the existing Tier 1 flat and TOU tariff offers, and the clear majority of customers will benefit from bill savings and greater bill predictability (since the bill spread is smallest for the RTP tariff). Future customer savings may vary since retail electricity tariff offers are dynamic, and as consumer uptake of RTP tariffs rises, retailers are likely to change their offerings. However, given the current consumer reticence to engage with the complexity of the retail electricity market and their resistance towards RTP pricing, the savings don not appear sufficient to incentivise customers in the current market environment to opt into this tariff. Exacerbating this issue is the finding that the additional savings to be derived from engaging in load shifting in response to high spot prices periods are minimal. However, the potential for price-based demand response to incentivise energy conservation (Ito, 2015; Ito et al., 2017; Jessoe and Rapson, 2012), as opposed to load shifting, was not accounted for, which means the savings calculated here are likely to be at the lower bound. Furthermore, our study did not consider the potential implications of other energy consumer options such as PV and battery energy storage. Nevertheless, consumers may require a greater incentive if they are expected to switch to this tariff and actively respond to hourly price signals. It is complex to predict whether price will be driven by high energy costs or network congestion, and price drivers and potential customer savings will require location specific analysis. In this study, the value of load shifting in terms of distribution level voltage regulation and the avoided network augmentation costs are not considered. Abdelmotteleb et al. (2017) discuss the design of efficient network charges to optimise the deployment and use of distributed energy resources, and there is scope for future work optimising RTP tariffs to maximise outcomes for both retailers and networks.

In general, the voluntary uptake of RTP tariffs can be improved if it is accompanied by a risk-reducing strategy, such as a money back-guarantee (Stenner et al., 2015), and optimal consumer response to the RTP tariff can be facilitated by providing daily feedback information regarding consumption and the electricity price schedule, ensuring clarity and transparency of information. As the automation of appliances increases and new customer-centred services offer to take on the burden of actioning demand response on behalf of consumers, demand response will become less restricted by human decision-making and the findings from behavioural economics studies discussed in the literature review. The high penetration rates of air-conditioners, increasing numbers of smart-meters and appliances that respond to automated control signals in Australian households, are playing a significant role in enabling customer responsiveness.

Another complicating factor is that, at present, residential retail electricity markets in the NEM are dominated by the 'Big Three' retailers (in truth 'gentailers'), which has resulted in limited innovation in electricity tariff design to-date (ACCC, 2017; AEMC, 2017; Wood et al., 2017; State Government of Victoria, 2017). Instead, price-based competition occurs based on discounts, and only a few smaller retailers, such as PowerShop and Mojo are offering more innovative offers. Current customer engagement is low in the retail market in terms of these conventional offerings, with not many consumers likely to switch tariffs, and so market pull for cost-reflective tariffs (that would place pressure on the dominant retailers) is unlikely (as discussed earlier, engagement through residential PV deployment is another story entirely). The ACCC is taking action to address transparency and affordability issues by improving customer understanding of retail electricity prices, and is working in conjunction with the government to decrease the number of customers that are on the worst retail offers (Sims 2017). However, additional regulatory intervention may be required to move customers onto more innovative and dynamic tariffs, such as the designed RTP tariff.

Regulators and consumer advocates often object to dynamic retail electricity tariffs that vary on an hourly basis because they require the customer to monitor hourly prices and then decide whether they want to reduce their demand (Wolak, 2011). However, the findings show that consumers were less susceptible to bill shock on the RTP tariff, and the cost of failing to perform demand response was minimal. Both of these findings indicate that the RTP tariff can provide consumer protection, an important consideration from the regulator's perspective, which should allow initial biases to be overcome. An alternative solution can also be provided by automation technologies, which allow risks around consumer willingness and ability to respond to the RTP tariff price signals to be overcome, meaning this concern may become more irrelevant in the future.

Regulators have an important role to play in facilitating the uptake of cost-reflective pricing and enabling demand response. Policy-makers do now appear to have a greater focus on the opportunities for demand response in the NEM, marked by recent funding to trial demand response on a large scale (ARENA and AEMO, 2017). This program includes a number of demand response efforts involving small energy consumers.[8] Politically, rebate programs are more acceptable than exposing consumers to volatile hourly pricing, since consumers will not be subjected to an obvious economic burden (Ito, 2015). Therefore, this type of incentive could compliment the RTP tariff, de-risking cost-reflective pricing from a consumer and regulator perspective, and also rewarding responsive consumers.

6. Conclusion

Retail electricity bills are the only means through which consumers receive an indication of the costs their energy services impose on the electricity industry. It is therefore essential that consumers start to receive better price signals so that their energy investment decisions can be improved, and so that problems arising from uncoordinated operation of distributed energy resources can be avoided. Dynamic pricing has a significant role to play in leveraging residential household demand response capabilities, which can assist in maintaining supply-demand balance, whilst also placing downward pressure on wholesale prices. However, it is likely that RTP tariffs such as that assessed in this study will not provide consumers with sufficient rewards for being responsive to price, and this will be the key to enabling large-scale residential demand response. The government has recently shown interest in promoting demand response, and it is recommended that the benefits of RTP tariffs are further

[8] Peak time rebates are offered to customers if they reduce their consumption during critical peak pricing events.

investigated. In particular, future work should explore whether such tariffs can assist end-users with PV and battery systems to engage effectively with the electricity industry.

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