MDAG – Price Discovery with a 100% Renewables Wholesale Market

Prospects for the uptake of demand-side flexibility in the New Zealand wholesale electricity market under 100% renewables.

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Contents

[1] The author is grateful for the comments received from IPAG and MDAG members, Electricity Authority staff, and especially acknowledges the review, feedback and insights provided by MDAG member Dr Andrew Kerr.

2 The importance of DSF

1.1 There have been hopes for an increase in the demand-side's involvement in energy markets since the 1970s, when significant research programmes on demand-side responses were commenced following the two oil crises. Similar hopes were embedded in the wholesale market design exercise in New Zealand in the 1990s where demand side responsiveness was expected "to have increased significantly" by the time the generation market was fully competitive2. Indeed, the expectation of demand-side response was central to the concept of reliability in the new deregulated electricity models adopted worldwide where it was expected that "well-functioning markets [would be]…always "reliable" because the lights only go out if a customer wants them to, given the price."3 Some market designers expected that "adequate attention to demand response would remove the need for capacity markets, installed capacity requirements, price caps and other holdovers from regulation"4.

1.2 In reality, the most significant contribution of the demand side to electricity market outcomes has come about as a result of energy efficiency[5], rather than dynamic customer involvement[6].

1.3 With the removal of flexible, dispatchable fossil-fuelled plant (coal, gas) and increasing passive and active engagement by consumers with the market, dynamic use of consumption is increasingly being seen as having a viable role in the dispatch and pricing in high renewables markets. Along with grid-connected energy storage systems (hydro reservoirs, batteries, hydrogen) wholesale price-induced changes in consumption has the potential to absorb a component of weather-induced volatility of renewables-based generation. The effect: to stabilise wholesale spot prices (energy and ancillary services), especially when supply resources are close to being exhausted and corresponding wholesale prices are high. Similarly, demand side market participation may forestall the use of non-price demand rationing (and administrative pricing) in scarcity situations.

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[2] "Managing 'Dry-Year' Risk in a Fully Competitive Market: Issues and Option", Report for Officials Committee on Energy Policy, John Culy, NZIER, May 1995, p24. A footnote to this statement explained: "It is important not to underestimate the level of "demand side" response that is capable in the New Zealand market. There is a substantial level of back up generation which could be used in a crisis provided spot prices were high enough and presumably some of the major electricity intensive users (accounting for around 30% of consumption) may be prepared to shut down, or significantly reduce consumption, if spot prices went high enough (say, 50c to 100c/kWh) for a reasonable period."

[3] See Fraser, H (2001), *The Importance of an Active Demand side in the Electricity Industry*, Electricity Journal, Vol 14, Issue 9, pp52-73.

[4] Hunt, S. (2002), Making Competition Work in Electricity, Wiley, p76

[5] Batstone, S., Reeve, D., "Trends in Residential Electricity Consumption", 5 August 2014.

[6] An extensive literature exists which debates reasons over the years – see Lund et al (2015), "*Review of energy system flexibility measures to enable high levels of variable renewable electricity*", Renewable and Sustainable Energy Reviews 45. Some of these barriers are captured in this paper as they remain relevant today.

1.4 These system benefits are reflected in the international literature. Joskow (2019)[7] cites the work of Imelda *et al* (2018)[8], based on the Hawaii system, which shows that dynamic retail pricing[9] yields a 2.4%-4.6% reduction in power expenditures in a fossil-fuel environment, but an 8.5%-24.3% improvement in a system heavily dependent on renewable generation. Joskow concludes:

1.5 "This makes intuitive sense. In a system where the short run marginal cost of generation fluctuates a lot from hour to hour and day to day, the welfare cost of flat per kWh rates is much higher than in a system where the short run marginal cost of production does not vary very much. This is the case because with flat retail prices the average gap between retail price and marginal generation cost is much larger in a system with widely time-varying short run marginal costs than in a system where short run marginal costs do not vary very much. In their analysis, Imelda et. al. (2018) find that the demand-side responses induced by variable prices reflecting intermittency and associated variations in spot prices and short run marginal costs significantly reduces the costs of meeting a 100% renewables goal. Of course, the benefits depend heavily on the assumptions about consumers' demand elasticities and more generally, their attention to and responsiveness to variable pricing." [10]

1.6 Joskow's conclusion reinforces that demand side participation is not necessarily *essential* to achieving very high renewables, but, in many situations, will be a more beneficial approach in achieving high renewables than using only supply-side measures. These benefits may arise through lower costs, lower market volatility, and/or improving the social or political acceptability of prices discovered through wholesale markets, especially during periods of tight supply-demand margins.

1.7 All price-based demand response – irrespective of whether it is signalled to, or triggered by, the wholesale market or not – will have some effect on market outcomes in a 100% renewable world. Energy efficiency, fuel switching, and embedded behaviours of conservation are valuable: these actions often have the long-term effect of changing the shape of the load profile (usually reducing peaks) which has an obvious impact on dispatch. However, the focus of this paper is to focus on more dynamic, controllable responses at the consumer end of the supply chain, which we refer to here as "demand side flexibility" (DSF)", and our focus is in the impact on wholesale market outcomes. We adopt IPAG's recommendation of OFGEM's definition of flexibility as being "*modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system*."[11] IPAG's wider consideration of flexibility also invokes the concept of controllability as being commensurate with service provision to the energy system.

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[7] Joskow (2019), "*Challenges for Wholesale Electricity Markets with Intermittent Renewable Generation as Scale*", Working Paper, MIT Center for Energy and Environmental Policy Research, January 2019

[8] Imelda, Fripps and Roberts (2018), "*Variable Pricing and the Cost of Renewable Energy*", Working Paper 24712, National Bureau of Economic Research

[9] See comments later about Joskow's broader views on dynamic pricing and retail tariffs.

[10] Ibid., page 48

[11] OFGEM, as cited in "Draft IPAG review of the Transpower Demand Response Programme", 8 July 2021.

1.8 Notwithstanding that choice of definition, we are also attracted to the definition of demand response adopted Geske *et al* (2017)[12]:

> *"We interpret DR as a technology that reduces [sic] consumer's effort of participating in real-time electricity markets, thereby inducing load shifting and introducing demand elasticity."*

1.9 While this definition is potentially restrictive for our analysis here, it highlights the relevance of the customer's cost of participation, defined in terms of effort.

1.10 Flexibility, including on the demand side, is now a popular term in the discussion about increasing intermittent renewables, more distributed energy resources, and the role of distribution system operators. It risks becoming a loose term with multiple interpretations. To be clear, we use it here to describe the ability to change, via direct control, consumption (at the meter). The ability to direct a specific increase or decrease in net consumption at a point in time and space (for whatever reason) is only one form of DSF – the ability to control behind-the-meter inverter settings can help with voltage management. However, at this point, we do not consider that a wholesale market action.

3 Potential sources of demand-side flexibility

1.11 We primarily consider the following primary sources of DSF:

(i) Smart controls on home and business energy consuming devices (including EV charging) that allow users to actively manage consumption in response to an external signals that reflect wholesale market prices;

(ii) Battery storage systems installed on a customer's premises[13];

(iii) Behind-the-meter generation[14], e.g., wind or solar[15], enabled through smart inverters.

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[12] Geske, J., Green, R., Chen, Q., Wang, Y., 2017, *Smart demand management: Storing energy or storing consumption – It is not the same!*, Conference Paper, June 2017.

[13] We have not considered broader examples of merchant energy storage systems directly connected to the distribution network or grid. This is a judgment call, but we expect this might bias us away from a number of the issues raised here, since, presumably, such investments would be undertaken by a party focused purely on the energy trading benefits, rather than a "demand-side" customer who is consuming energy for reasons unrelated to the electricity market.

[14] Behind-the-meter diesel generators have been referenced in a small number of publications reviewed, mostly as a reflection of the status quo. We have not reviewed this in any detail, as – presumably – in a 100% renewable world these would be limited to off-grid/disconnection situations rather than contributing to wholesale market outcomes.

[15] We note that some analyses exclude the control of solar from a definition of DSF, on the assumption that the fuel source is not reliable enough to allow the technology to be "controllable". We believe it should be considered: Technology exists today (via smart inverters) to control solar PV. As outlined in *Updating the Regulatory Settings for Distribution Businesses*, the EA highlight how excess solar PV can cause power quality issues on the network. In such situations, being able to reduce the output of behind-the-meter generation (via smart inverters) through control systems may be valuable and is technically feasible.

1.12 Our interest for this analysis is in DSF that can respond to wholesale market signals (energy and ancillary services). We recognise that this purpose is not independent of other uses (for example, network management or emergency load shedding) for a number of reasons:

(i) Wholesale market uses for DSF may compete with other uses. This is really a question for optimal deployment of DSF ("value stacking"). In an ideal world, all uses of DSF would be explicitly valued (priced), and the DSF would be deployed to the customer's maximum value usage given the alignment of their objectives and the terms of use (eg frequency and term of requirement[16]). In addition to commercial trade-offs, there may be policy or regulatory priorities for some load management, such as is the case currently for hot water control, where primacy of use is for managing grid emergencies[17].

(ii) Some existing, or future, DSF may be contracted for non-wholesale uses due to e.g., the ownership of the control systems (e.g., ripple control systems of hot water[18]) and this may conflict with wholesale market uses.

(iii) A key driver of the uptake of DSF will be the magnitude of the total benefit received by the potential DSF investor, and this will be a function of all its potential uses, not just wholesale market value streams.

1.13 These three issues are the subject of the Electricity Authority's current consultation on regulatory settings for distributors[19], but we highlight them here as potential factors affecting the uptake of DSF.

4 The roles that demand-side flexibility can play in the wholesale market

1.14 There are different roles for DSF in a wholesale market like New Zealand's. These include:

(i) **Short-term shifting of consumption between time periods**: This largely relates to the storage of energy either through thermal inertia in heating and cooling (refrigerators, space and water heating), or in stationary or EV batteries. It can also arise in commercial and industrial settings from short term interruptions in production processes. Generally speaking, these sources of DSF simply shift consumption forward or back[20] by a few hours (although EV batteries may provide shifting over a number of days for some users), as the service (heating,

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[16] For example, if DSF has been contracted to defer a network investment it may not be able to provide services in other markets over the contracted period.

[17] Here we make value stacking sound easy, but it is by no means trivial, as the uses may vary temporally and spatially, and some of the key decision factors are uncertain at the time decisions are made about deployment. We also note that, even in the simple scenario of hot water, the 9th August 2021 event demonstrated that the competing uses of HWC by distributors was a factor, where some HWC had been exhausted prior to the grid emergency. See "Investigation into electricity supply interruptions of 9 August 2021", MBIE.

[18] Although see later discussion where we consider how the DDA enables at least retailers to use a distributors load management systems

[19] *Updating the regulatory settings for distribution networks*, Electricity Authority, Discussion paper, July 2021

[20] Although with some forms of demand shifting involving appliances on thermostats, e.g., hot water control, the rebound in demand when control finishes can be larger than the load reduced.

cooling, or transport) will eventually be required[21]. This DSF will be useful to manage short-term volatility.

(ii) **Reduction of demand for a range of periods (days, weeks, months):** This is where consumption is permanently sacrificed. Generally, this is much more difficult to procure (as the customer experiences a permanent reduction in service) but it is potentially more valuable to a 100% renewable system. While it is possible that some discretionary household consumption could be conserved in an extended high price environment (as sought in e.g., official conservation campaigns), we expect this is more likely to come from industrial processes which are able to absorb interruptions to production for prolonged periods. That said, we expect this will be restricted to a small number of operations.

(iii) **Increase in demand during low-price periods**: For the majority of demand, we wouldn't expect to see opportunities for consumers to "over-consume" when electricity was very cheap, such as when there was a surplus of renewable electricity. However, there may be enterprises connected to flexible supply chains which can flex up when power is cheap, as well as down. In most cases, this is a form of storage, except that the storage is in the form of an end product, rather than electricity or fuel.

1.15 In addition to the moderation of wholesale market volatility, DSF that can be formally bid into the wholesale market has an important price-signalling value. As explained by the Electricity Authority in a Real-time Pricing paper:

> *"By bidding and offering, dispatch-lite participants reveal the value of their resources to the system operator's scheduling and pricing processes. That information* ***improves the granularity and accuracy of the demand and supply curves the system operator optimises in finding the least-cost dispatch solution****. Dispatch prices are therefore more efficient."*[22]

1.16 This signalling effect of DSF that is formally bid into the wholesale market is important to the resulting nature of price volatility that is experienced by market participants, as it creates "shape" in the demand curve, potentially replacing the contribution that thermal offers currently make to the supply curve.

1.17 We also note that formal bidding of "willingness to pay" (WTP) demand bids into the wholesale market improves the social and political acceptability of prices, especially during periods of scarcity. It is far preferable to have prices set through voluntary demand reduction bids than through administratively set prices (usually referenced to an approximated value of lost load, or VoLL), and to maintain security of supply through price-

[21] We note a common misconception that demand-shifting is costless from the consumer's perspective (as long as they get the service they require at the point in time they require it). This ignores the fact that providing <u>firm</u> discretion to someone else over the use of energy-limited "storage" requires the customer to sacrifice the option to use the appliance in a way that they hadn't anticipated. This option will invariably have some non-zero value. Geske et al (2017) explore this idea further, including the non-equivalence of battery storage and demand-shifting, both from the consumer and the system's perspective.

[22] Remaining elements of real-time pricing, Consultation paper, Electricity Authority, March 2019, 3.53.

based reductions in demand, rather than non-price rationed involuntary curtailment (if their bid was enough to avoid the energy deficit[23]).

1.18 Wholesale market price discovery is not the only value stream for DSF – DSF has the potential to provide system security services via emergency load shedding, ancillary service markets, voltage support, deferring the need for transmission and distribution upgrades, and limit the consequences of network faults once they occur.

5 The "market" for DSF

1.19 Key questions[24] for a consumer regarding their ability to provide flexibility are:

(i) What flexibility do I have?

(ii) How complex and costly is enabling flexibility? Do the controls come embedded in an appliance or does it have to be retrofitted? What degree of active customer involvement is required?

(iii) How much flexibility and autonomy am I willing to give up? How does it impact my ability to get the service I require from the energy consuming devices?

(iv) How complicated is it to either use the flexibility to reduce the consumers consumption costs, or sell access to this DSF to a third party, and how much value can it get?

1.20 The potential third party users of DSF include retailers and purchasers of ancillary services (such as instantaneous reserves), and could include distributors. As raised by IPAG, a number of costs and complexities associated with procuring, monitoring, optimising and offering DSF can be reduced through "flexibility traders" – an intermediary that effectively sits between the buyers and sellers of DSF. Hence we also need to consider flexibility traders as potential purchasers.

1.21 As we will show below, in order to be purchasers of DSF, these buy-side entities also may need to make investments in capability, systems, and tariffs. Hence both sides of the market are making tradeoffs in terms of costs and benefits, and these tradeoffs are central to the growth of DSF.

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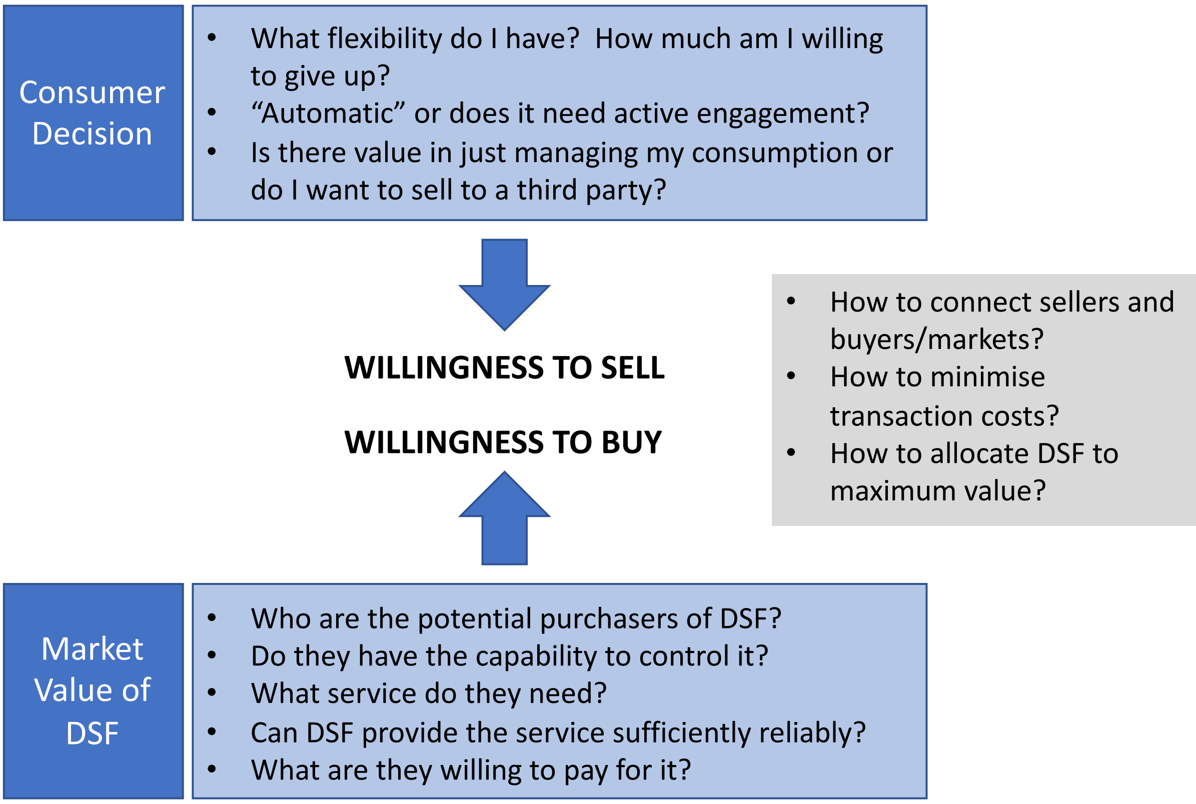
[23] The Authority has proposed to change the scarcity pricing arrangements as part of the Real Time Pricing project, which impacts situations of both energy scarcity and reserve scarcity. However, the point remains that demand response that is bid into the market could both avoid the need for administered pricing, as well as set the price thus providing a more efficient price signal.

[24] Despite referring to these factors as "key", we skate over many of the behavioural factors at play within this decision making system. Many of these behavioural factors are more comprehensively explored in the New Zealand context by the Energy Cultures work of the Otago Energy Research Centre. This work highlights how demand-side behaviours (including energy efficiency investments) are a result of "cultures" – a combination of norms, material culture and energy practices – that form in particular contexts (e.g., industries, households etc). See Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., Thorsnes, P., 2010. Energy cultures: a framework for understanding energy behaviours. Energy Policy 38,6120–6129.

1.22 Figure 1 – overview of DSF “market”.



1.23 The answers to the questions above, as illustrated in Figure 1, and the impediments that may exist in the answers, will differ between householders, small-medium enterprises, and large industrials. Richter and Pollitt (2018)[25] provide an excellent analysis of the heterogeneity of preferences amongst consumers for enabling smart energy technology options, highlighting that an assumption that all DSF providers are the same is deeply flawed, and that the types of services they wish to provide, or be provided, is quite diverse[26].

1.24 We would extend this argument to include third-party DSF purchasers. Their preferences for procuring and controlling DSF may relate to the “firmness” of the DSF bought, the speed of response, the time it is available, and the location (on the grid/network) where it is.

6 Decision Factors for DSF providers (electricity consumers)

6.1 Investing in, and enabling, flexibility

1.25 While there are many current and historical examples of consumers willing to monitor market outcomes and make discretionary choices about consumption changes, this is

[25] Richter, L. and Pollitt, M., 2018, *Which smart electricity service contracts will consumers accept? The demand for compensation in a platform market*, Energy Economics, vol. 72, pp 436-459.
[26] As discussed later, the authors go further to say that this likely results in a need for contract differentiation and customized contractual agreements. We are unconvinced by this, a topic we pick up later in the paper.

unlikely to be the pathway for significant DSF uptake, due to the effort required from the consumer. The evolution (and miniaturisation) of sensors, communications, software and learning algorithms now allows changes to consumption to be triggered by price automatically by algorithms embedded in a smart home "hub", or remotely by a third party, rather than requiring the consumer to be actively considering a response to a varying price. This is the new "prices to devices" paradigm.

1.26 For mass-market residential and commercial appliances (refrigerators, heating and cooling including hot water control, electric vehicle charging, and inverters for PV and battery installations) the "smarts" behind the controllability are increasingly embedded in these devices[27]. Smart appliances exist today that allow smart operation and remote control, but they are not yet mainstream. Customers may not even be aware that this is possible. Here, labelling and standards[28] may assist awareness and uptake.

1.27 There will often be fixed upfront costs to enable smart, third-party control of energy consuming and producing devices[29]. Reeve *et al* (2021)[30] quantify this for a selection of smart residential appliances, demonstrating how the commoditisation of appliances (and the in-built electronics) has driven the incremental cost of "smarts" (embedded in the cost of the appliance) down to relatively inexpensive levels. For more complex energy consuming equipment, where less commoditisation exists, the costs of investment in DSF are likely to be higher.

1.28 However, perhaps the biggest technological challenge for DSF-enabling technology is being able to embed rulesets to ensure the customer maintains an acceptable level of control over the energy consuming device, while leaving enough flexibility for a valuable market-driven modification of consumption. Richter and Pollitt (2018) suggest that smart automation of DSF is actually essential to its uptake, as the (relatively small number of) studies that have looked at consumer attitudes to the adoption of smart home appliances suggest that "*giving up high levels of flexibility and adapting everyday routines to fit in with electricity tariffs were regarded as difficult. Smart appliances that take over most of the work on the consumer side were therefore considered necessary*"[31].

[27] Retrofitting smart controls on existing appliances is possible, but we expect the additional costs (usually labour) will often outweigh the benefits for the consumer.

[28] We note that standards for smart controls in appliances, inverters and electric vehicle chargers are currently voluntary in NZ – see Section 5 of *Updating the Regulatory Settings for Distribution Networks*, Discussion Paper, Electricity Authority, July 2021. Australia has made demand response capability standards for particular appliances mandatory, requiring AC and hot water manufacturers offer AS4755-equipped appliances by 1 July 2023, swimming pool pump controllers by 1 July 2024, and EV chargers/ dischargers by 1 July 2026. We also note the potential for standards to play a strong role in increasing demand side participation was frequently highlighted in "Investigation into electricity supply interruptions of 9 August 2021", MBIE, p6, 31 and 42

[29] Agency issues - in respect of energy consumers who are not building owners – are well known as an impediment to energy efficiency and distributed generation investment. They may also be impediments to investment in smart appliances if those appliances are chattels to the leased/rented property.

[30] Reeve, Stevenson and Comendant (2021), *Cost-benefit analysis of distributed energy resources in New Zealand*, Report for Electricity Authority, Sapere Research Group, September 2021, p4

[31] Richter, L. and Pollitt, M., 2018, *Which smart electricity service contracts will consumers accept? The demand for compensation in a platform market*, Energy Economics, vol. 72, p438

1.29 For some sources of DSF, creating the rulesets that reflect the customer's desire to sacrifice flexibility and autonomy is relatively easy as the service provided is defined by a small number of parameters. For example, heating and cooling equipment can be expressed as a desired temperature and time of day. EV owners want to ensure that their vehicles are charged sufficiently to be used when needed, and usage may be based on routines. This becomes more complex in the commercial and industrial setting, as businesses with complex manufacturing processes will likely want tight control over when a particular part of the process is ceased or scaled back.

1.30 In the commercial and industrial sector, beyond water heating, HVAC, and EV charging, the integration of smart controls is likely to be the subject of more complex and customised sensor and control technology and require a greater degree of attention and resourcing. Further, they potentially face fewer opportunities than residential consumers to increase their DSF technological capability[32] by "default" through the natural life-cycling of highly commoditised energy-consuming equipment (as is the case for refrigerators and heat-pumps for residential settings). This will increase the cost and organisational effort required to enable flexibility, as few commercial and industrial plants would have had demand response designed into them.

1.31 There are industrial consumers whose processes are baseload, highly complex and interconnected, and are connected to tight supply and demand chains for the product they produce. While these consumers face the same technological challenges as the commercial sector as discussed above, they are often more likely to have dedicated energy management personnel who can potentially manage the interface with the wholesale electricity market. The proportion of their underlying costs that is represented by electricity will motivate a degree of specialised attention that is not affordable for a small-medium commercial enterprise. This improves the affordability of participation. However, flexibility in electricity consumption (and thus operation of the plant) will have upstream (storage of production inputs) and downstream (warehousing of product, and demand-driven provision of products, typically to international markets) implications; the commercial tradeoffs for different degrees of flexibility will vary from participant to participant. We also note that, beyond the pure commercial, there are behavioural elements, where the focus of such firms will still largely be centred on stable provision of their product, rather than introducing the complexity associated with responding to wholesale market behaviour.

1.32 The most well-known example of optimised industrial demand response in New Zealand was Norske Skog Tasman, part of a significant global optimisation of Norske Skog's portfolio of pulp and paper plants[33]. There were significant resources committed by Norske Skog to building this capability. While the nature of the process did lend itself to some degree of flexibility, the Norske Skog Tasman plant was also a master class in value stacking (discussed later) – the interruptible component of their load was:

[32] Although increased use of, e.g., variable speed drives has been one such evolution which has incorporated higher degrees of power electronics.

[33] This optimisation work driven by University of Auckland's Professor Andy Philpott and Norske's Graeme Everett, which earned them a finalist placing in the prestigious INFORMS Franz Edelman Award.

(i) offered in to the reserves market,

(ii) used to avoid coincident peak transmission charges

(iii) used to curtail load at times of high spot prices, especially during dry years, reinforcing the incentives provided through a CfD supply contract (as opposed to FPVV).

Norske Skog was the only plant to have registered as a "dispatch capable load station" in the New Zealand market[34].

1.33 For most demand shifting opportunities, either thermal inertia or battery storage prevents any interruption to the service. However, use of DSF that results in demand curtailment, or even demand shifting in a commercial environment that interrupts a continuous process (e.g., a production line) will likely be more disruptive and therefore costly. While this could be incentivised by reducing the consumer's exposure to very high prices, the consumer may still need:

(i) A certain amount of notice that interruption may be imminent; and

(ii) The ability to opt out of responding, should circumstances make it difficult.

1.34 As outlined above, the potential for DSF to not only respond to, but also set prices in the wholesale market, is significant in a 100% renewables world. While opting out at a late stage is relatively straightforward if the consumer is simply responding to observed wholesale prices, under the current market rules, opting out may have compliance issues.

1.35 In the current market, demand side participants can set wholesale prices by becoming "dispatch capable load stations" (DCLS) and formally bidding into the wholesale market and being dispatched by the System Operator. DCLS stations can formally participate through price bids in the wholesale market, as opposed to monitoring price and responding "off market", and thus not indicating a wholesale price for the response. However, they face a similar monitoring and compliance regime as that faced by wholesale market generators. Only one industrial participant has ever registered as a DCLS in the New Zealand market.

1.36 The EA's proposed "dispatch lite" product, which forms part of the Real Time Pricing project, will allow smaller DSF providers (and embedded generators) to formally bid their ability to respond into the wholesale market under a much less onerous regime, that is expected to be implemented in the first quarter of 2023:

(i) A simplified approval process by the system operator (still under development)

(ii) Similar obligations for gate closure (30 minutes prior to trading period)

(iii) Receiving dispatch notifications through a web-based service

[34] DCLS stations can formally participate through bids in the wholesale market, as opposed to monitoring price and responding "off market", and thus not indicating a wholesale price for the response.

(iv) The ability to formally[35] opt out of dispatch instructions once received, although this will, along with compliance with dispatch instructions when staying "in", be monitored on a monthly basis (compliance criteria yet to be determined)

(v) The ability to change a bid without a bona fide

1.37 The Authority has been clear in their belief that the main driver of participating in dispatch-lite would be the benefit of participation in the price-setting process. Along with real-time pricing, which ensures that the price in real time that any demand-side response is responding to will apply to final purchases, this is a major step forward and removal of an impediment to an important type of participation in wholesale markets for smaller DSF providers. Further, the ability of third parties to aggregate a number of DSF providers should allow a more actuarial approach to performance, compared to a single DSF owner.

1.38 There is a risk, though, that – if successful – large quantities of DSF offered through the low-compliance dispatch-lite scheme may create material and unforecastable market disruption if opt-outs were exercised. In such situations, we may see the System Operator seek tighter compliance.

1.39 Enel-X reported on a real-life situation where they were able to provide 90% of their dispatch obligation despite a number of their largest DSF owners not being able to perform. This was possible due to a significant scale and diversity of DSF sites and sizes.

1.40 One might question whether the System Operator would be comfortable if large bids made through the "dispatch-lite" approach only achieved 90% (or worse) compliance with their bid. Anecdotally, we understand from international experience that uncertain compliance by demand-side bids has led system operators to be more conservative in dispatch decision making to allow for non-performance.

1.41 Even a lower compliance and simplified approach to bidding into the wholesale market requires a DSF participant to contemplate bid quantities and price, and then monitor dispatch instructions and consider compliance. This is only likely to occur in DSF owners or agents/intermediaries who are of a sufficient scale to warrant dedicated resources to wholesale market participation. It is highly unlikely that residential DSF owners would contemplate direct participation.

1.42 We expect therefore that, as a result of dispatch-lite, or just improvements in technology, that some existing commercial and industrial operations will, in the future, decide the tradeoff between cost, complexity and the benefits of DSF is worthwhile. However, it is perhaps more likely that increases in industrial demand response will come about as a result of new types of industrial and manufacturing plant entering the market partially motivated (commercially) by energy flexibility. We are seeing this emerge through Meridian and Contact's investigation of "Southern Green Hydrogen", a large-scale flexible hydrogen plant

[35] When declining dispatch instructions, participants will have to follow a correct process. Simply ignoring them would be a breach of the Code (*Implementing spot market settlement on real-time pricing: Decision*, Electricity Authority, June 2019. 5.36)

in Southland[36]. Similar investigations of new plant capable of DSF are being made in other industrial sectors, with Contact Energy announcing aspirations to achieve 100MW of flexible demand by FY2024[37] through their subsidiary Simply Energy. Contact recently announced that Simply is working with a digital infrastructure company to locate a 10MW data centre with demand flexibility technology in the South Island[38].

6.2 Getting value from flexibility – minimising consumption costs

1.43 The degree to which a consumer expects to benefit from being flexible in their consumption will be a key component in their decision to invest in enabling flexibility. There are two primary ways in which this benefit can be realised – through minimising their own consumption costs or selling their flexibility to a third party.

1.44 The first potential DSF value stream for the owner is to minimise their own electricity consumption costs. This may be something they self-provide (via a smart home hub in a residential setting, through to a team of energy management personnel at a larger commercial or industrial plant) or a service provided by a third party (retailer or flexibility trader[39]).

1.45 This, of course, requires the consumer to be on a time-varying tariff, and the impact on wholesale market outcomes will depend on the degree to which the owner's tariff reflects the underlying pattern of wholesale prices. Retail tariffs are a combination of a retail energy price, and network charges, and there is a spectrum of tariff structures which reward shifting consumption.

1.46 Most mass market residential tariffs are currently "flat" pricing structures and will provide little reward for load shifting, and primarily reward conservation and efficiency. Efficient distribution prices will reward shifting consumption away from network peaks if it helps defer network upgrades[40], insofar as they are reflected in the retail tariff. If wholesale prices are correlated with network peaks[41], this may also result in a response which moderates high prices in the wholesale market.

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[36] https://contact.co.nz/aboutus/media-centre/2021/09/26/huge-interest-in-southland-green-hydrogen-project

[37] https://contact.co.nz/-/media/contact/mediacentre/presentations/investor-presentation---capital-markets-day-2021.ashx?la=en

[38] https://contact.co.nz/aboutus/media-centre/2021/08/30/contact-energy-to-supply-flexible-renewable-electricity

[39] Here we are referring to a service provided by the third party purely focused on minimising the household or businesses consumption costs, rather than wider service offerings where the third party can also use it to manage their own wholesale market exposure. The latter is considered in the next section.

[40] The Electricity Authority has been strongly encouraging distribution businesses to move towards "efficient pricing". In essence, this would see consumers charged for network access using a price structure that sees higher variable-like charges to signalling where and when demand reductions will support deferral of future network expenditure. These structures aim to incentivise the regular shifting of discretionary load away from network peaks. This is positive from a wholesale market perspective if high spot prices were likely to occur over the same period.

[41] However, some predictions are that short-term spot volatility in a 100% renewables world will be far more driven by the weather than by the load profile. Depending on the relative values of these competing uses of

1.47 There are a number of electric vehicle charging tariffs available which have both network and energy price components providing incentives to charge an electric vehicle off peak. Time-of-use tariffs reflecting wholesale market price *patterns* are prevalent in larger commercial and industrial segments. Finally, some retailers do offer spot-related tariffs to all customer segments, which would reward the DSF owner for demand changes at times of high spot prices.

1.48 Some large industrials directly connected to the grid face the wholesale price. The NZ market has seen large industrial processes (eg pulp and paper mills, aluminium smelters, and even gas consumers such as Methanex) respond to prolonged periods of high prices and/or participate in reserve markets (see below).

1.49 According to one report provided to MDAG, the value of Meridian and Contact's Southern Green Hydrogen plant (from an electricity perspective) included a $12/MWh "flexibility premium" reflecting its ability to change consumption when market conditions require, although caveated its potential flexibility as being partly in the hands of the purchasers of hydrogen with whom contracts are eventually struck[42].

1.50 However, at a mass market level (residential and small commercial), the uptake of dynamic spot-related tariffs is low and, as we argue later, likely to remain a limited segment of the market[43]. As we proceed towards 100%RE, and the ability to provide predictable spot market price patterns erodes, the opportunity to sell flexibility to a third party may become more attractive.

6.3 Getting value from flexibility - selling flexibility to a third party.

1.51 The lack of (in the case of flat tariffs) payoff, or at least level and uncertainty of payoff (in the case of spot tariffs), to a DSF owner from reducing their own consumption costs may not, for the reasons outlined above, be enough to incentivise consumers to expend the time and cost required to investigate and enable controllable flexibility, even if it is largely controlled through smart technologies. There are other wholesale market value streams[44] available for DSF which could be accessed by the customer through third parties which could increase the value available to the customer:

DSF reducing flexible load (in response to a market price event) just prior to a network congestion period may mean it can't be available to manage network congestion (e.g., if it is an energy storage device – heating or EV battery).

[42] *Problem Definition: "Lumpiness" with 100% Renewables*, report for MDAG, Nevill Gluyas, Jarden, October 2021, p8.

[43] In deference to Flick, we note that, as of today, over 20,000 customers elect to receive a spot related tariff, and this may very well increase in the future. But, as argued later, we question what proportion of customers in the market will be willing to be exposed to the type of volatility expected under a high-renewable world, especially in the context of an energy-only market.

[44] We reinforce that we are focused on wholesale market value streams for this work. There are other value streams, e.g., providing control to a party who may be deemed a beneficiary of a transmission investment, or a distribution business to manage congestion or outages.

(i) Providing control of the flexibility to a party with a larger wholesale market exposure – purchaser or generator[45] - who can use it in a wider range of situations to manage their own wholesale market exposure, or profit from inter-temporal arbitrage; or

(ii) Providing control to a flexibility trader[46] or platform which may on-sell a portfolio of flexibility to parties in (i), or sell directly into ancillary service markets (e.g., instantaneous reserves); or

(iii) Providing DSF as a service to ancillary service markets e.g., frequency keeping or instantaneous reserves, individually or via the intermediaries in (i) and (ii) above, or potentially distributors.

1.52 For consumers who wish to retain a retailer for the purchase of electricity, and employ the services of a separate flexibility trader that enables DSF, multiple trading relationships[47] would have to be permitted. Alternatively, flexibility traders may choose to integrate a retail operation into their business model.

1.53 When providing control of flexibility to a third party, the tariff structures and agreements will have to allow the consumer to specify their underlying service needs and preferences. Some agreements might be relatively simple where their preferences can be simply expressed (minimum/maximum water or air temperatures, or charge status of a vehicle at particular times), more complex arrangements may have to consider[48]:

(i) the duration and frequency of events that will involve the use of the flexibility,

(ii) daily and annual limits on usage,

(iii) amount of notice given of flexibility usage[49],

(iv) any consequences of non-performance, and/or

(v) ability to opt out or modify participation to suit household or business preferences.

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[45] Generators who are contracted may see value in DSF to manager their contractual exposures during planned or unplanned outages, insofar as they can obtain access to sufficient DSF to reduce the wholesale price,

[46] Sometimes referred to as “aggregators” or more generalised as “platform markets” (see Richter and Pollitt (2018)), which effectively fulfil the same purpose, in international literature. These are entities who obtain access to a number of consumers who are willing to provide flexibility, and use the aggregate capability to offer DSF services to other parties (e.g., distributors or retailers) or directly into the wholesale market (assuming they have contracted for a wholesale market exposure). IPAG provide a taxonomy of flexibility trading, but we note here that internationally these can include both aggregators of consumer technology, and vendors or owners of technology (e.g., solar/battery systems) that then combine them to create “virtual power plants”.

[47] Multiple trading relationships is the term assigned to the ability for a consumer (ICP) to have more than one “trader” assigned to it. Currently the consumer can have only one trader (i.e., a single retailer). Ara Ake, on behalf of the Electricity Authority, is running a national trial of multiple trading relationships currently.

[48] Enel-X, presentation to IPAG, October 2021

[49] This may be addressable through improved wholesale market forecasting (specifically the System Operators medium-term load forecast (MTLF)). We recommend that improvements to the MTLF are pursued to improve the participation of DSF owners.

1.54 In addition, agreements will have to be clear how the benefits will get shared with the DSF owner - through fixed and variable components (including availability and/or event fees) and, if required, reasonable baselining mechanisms to determine what flexibility was provided (as well as any other performance criteria required).

7 Decision Factors for DSF users (third parties)

7.1 Investing in, and enabling, DSF contracting arrangements

1.55 It goes without saying that, for a consumer to be able to sell some of their flexibility to a third party, there must be such organisations who are both incentivised to use DSF (as above), and have the ability to control and optimise the customer's flexible load. The most obvious example is the retailer, who currently manages the volatile (true) wholesale market cost of a customer's requirements on their behalf. Access to DSF – even if just shifting consumption by a few hours – has the potential to lower the volume-weighted purchase cost for the retailer. However, as discussed in paragraph 1.51, there are other parties that may be able to provide this service to the customer.

1.56 Just because they may benefit from accessing a customer's flexibility, it is not necessarily true that these third-party users of DSF will already have the capability, systems and tariffs/agreements in place in order to transact with customers who wish to provide DSF. Given the importance of technology and communications to DSF uptake, retailers and flexibility traders may have to build significant capability and systems in these areas.

1.57 Further, designing, piloting and integrating new tariffs into billing systems are nontrivial undertakings for existing retailers, let alone new flexibility traders. These tariffs are likely to have a number of "settings" in them, as they will need to incorporate preferences of the consumer, especially the degree to which they want to sacrifice autonomy and flexibility at any point in time (within the bounds that still provide value for the DSF user).

1.58 The large degree of heterogeneity Richter *et al* found in customer preferences (and thus benefit sharing) regarding smart energy services led the authors to conclude that this would like drive tariff proliferation in order to meet consumers' needs. They note that this direction of travel was counter to where the UK Competition and Markets Authority wanted to head[50].

1.59 While the idea of a single standard DSF contract or tariff offering may be a step too far, we are more hopeful that some of the variety in customer preferences can be accommodated via settings *within* a contract for DSF, rather than requiring individual contracts for every potential combination of preferences. Also, it is unlikely that retailers, distributors and flexibility traders will attempt to fully segment the market from day one, preferring to meet the needs of smaller market segments initially (such as early adopters). However, we have not researched this in any depth.

[50] Anecdotally, it also seems counter to the desired direction that New Zealand retailers have historically indicated in debates about the low fixed charge tariff and distributor tariffs.

1.60 While the investments in capability, systems and tariff development could be significant, there are potentially additional benefits available to third party DSF users. Through having greater capability, as well as access to wider markets for DSF, third parties could better perform the role of value-maximiser for DSF owners – i.e., always allocating flexibility to its highest value use ("value stacking").

1.61 Irrespective of who the third party is, invariably they will be an organisation with greater scale and capability than most consumers considering enabling DSF, and thus are able to leverage scale economies in respect of some of the costs and complexities of participation in DSF "markets". The role historically undertaken by electricity retailers in "shielding" the individual consumer from the complexity of wholesale trading, and spreading the fixed costs associated with participation across a large number of users, illustrates the importance of intermediaries in driving costs down.

1.62 The scale and scope economies and benefits discussed above should be shared with the consumer and thus improve DSF uptake. However, we are aware that the incentives to maximise the value of DSF faced by distributors and wholesale market participants are potentially limited, for different reasons:

(a) For a spot market participant with a physical purchase position, their portfolio position (including generation and financial contracts) in the market may only incentivise them to use DSF in a way that reduces their purchase volume, but not reduce the spot price[51].

(b) The Authority's *Updating the regulatory settings for distribution networks discussion paper* suggests distributors may be reluctant to competitively tender for DSF (in favour of in-house solutions), or simply prefer to use traditional network solutions and not want to use DSF at all[52].

1.63 We are not aware of any analysis (in the New Zealand context) which estimates the quantum of the benefit that would likely be experienced by each of these potential third parties (and how much is a wealth transfer effect versus actually lowering overall costs). Such an analysis would help the discussion of barriers, costs and benefits of DSF for these third parties.

1.64 In any case, we believe that any conclusion about who is the "right" counterparty for a customer wishing to sell their flexibility, or whether there even is a single right counterparty, would be premature at this stage.

1.65 What we do conclude, though, is that at this nascent stage of DSF markets electricity customers are not the only party considering the benefits and costs of enabling DSF. The potential third parties, to whom the customers may on-sell their flexibility, must also weigh

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[51] This is an argument often levelled only at vertically integrated generator retailers, we note that an independent retailer faces the same incentives if and when their (location-adjusted) contract position exceeds their purchase volume.

[52] We have not reviewed the robustness or materiality of the impediments to distributors using DSF cited in that study, as distributors' use of DSF is only indirectly related to wholesale market outcomes.

up the investment required to make a control-based tariff or contract available against the purchase cost or risk management benefits they might achieve through having control of some customers' load.

7.2 How should benefits get shared by third parties with DSF providers?

1.66 When using DSF to reduce their own consumption costs, customers will potentially face an uncertain stream of benefits, especially if their electricity tariff is spot-based. A third party DSF user may choose to absorb this volatility and provide a fixed payment to the consumer.

1.67 In the same way that financial derivatives de-risk investments in power stations, a fixed payment in return for the DSF user being able to use the flexibility at their discretion (subject to service standards) is, for a lot of consumers, likely to be preferable to a uncertain stream of future benefits.

1.68 Internationally, there are concerns regarding the efficiency of paying consumers to not consume[53]. We sympathise with these. However, a contract which provides a secure payment to a seller, in exchange for obtaining access to a variable revenue stream from using DSF, is an entirely appropriate way of contracting for DSF. This recognises that enabling flexibility often requires investment by the consumer – either a more advanced appliance (smart EV charger or smart refrigerator), or an investment in DSF-enabling control systems, sensors and, for large enough operations, capability.

1.69 In essence, the instantaneous reserve market provides an analogous situation where payment may be made for a reserve-providing plant to be available. There is no specific event payment other than the increase in wholesale market revenue for a generator, or reduction in wholesale cost for an interruptible load provider.

1.70 In the reserves market, the availability payment is still a volatile income stream for reserve providers, as the reserve market clears every half hour. DSF could be contracted in a much less time-granular way, closer to the HWC situation i.e., a monthly or annual payment for giving the third party access to the flexibility; plus any reduction in consumption costs – which may be zero if the consumer is on a flat retail tariff.

1.71 We note that customers need to understand that the magnitude of the payment is commensurate with the degree of "firmness" in the flexibility. Heating (space or water) that is not "on" cannot be turned off; the more that high prices are triggered by scarcity of *supply* (rather than peak demand), the greater the probability that power consuming devices will be at low levels of consumption when the flexibility is required; and many demand response options are time- or energy-limited (physically, or at the customer's request), and may be exhausted by the time a significant price event arises. In this respect the comparison between DSF and instantaneous reserves is different, as ancillary services have a very high

[53] See e.g., Hogan (2009) "*Providing Incentives for Efficient Demand Response*", prepared for Electric Power Supply Association

standard of performance required for compliance; hence the availability payment reflects that "firmness".

1.72 More generally, the varying degrees of firmness point to the nature of the pricing relationship between the customer and their retailer. Customers presently have both a stable retail tariff insulated from wholesale prices and provide no control over their discretionary consumption to their retailer (which faces the wholesale price on their behalf). Ideally, customers could select from a spectrum of relationships with their electricity service providers that could encompass scenarios such as:

(a) a retail tariff that *dynamically*[54] reflects wholesale market conditions, and make use of technology to manage their own consumption; or

(b) a semi-stable tariff that provides some control of their available flexibility to the retailer, who in turn manages their wholesale market purchase profile with the aggregate flexibility provided to them by their customers, sharing the benefits with the customer; or

(c) a relationship with both their retailer and a 'flexibility trader' (requiring multiple trading relationships to be permitted), which has control of their discretionary consumption, in turn selling this flexibility to wholesale market participants or directly into markets with few barriers to entry (eg., ancillary services) and sharing the benefits with the customer, or

(d) A fixed, but high, tariff that provides no flexibility or control to the retailer

1.73 Benefit sharing in (b) and (c) could be predictable for the customer either through a lower consumption tariff, or a separate fixed payment.

1.74 As cited earlier, Joskow (2019) argues that dynamic pricing (option (a) above) and DSF enables significant benefits in a high renewables world. However, we note that spot-linked residential tariffs can be problematic when prices rise significantly for households who do not have the ability to respond[55]. Mallapragada *et al* (2021)[56] cites the policy challenges with householders paying very high spot prices during times of scarcity. Acknowledging this, Joskow (2019) suggests the most pragmatic solution will be the increase in "*more stable partially hedged retail price structures….in return for rights to partially control*" their load, as intended by our option (b) and (c) above. This highlights that it doesn't require the customer to be exposed to the price, it just has to be a tradeoff between price stability and control.

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[54] As argued earlier, in a 100%RE world, this may not necessarily be achieved with a time-of-use tariff structure that sees higher retail prices during load peaks.

[55] See a recent example of this in Singapore – see https://www.straitstimes.com/singapore/households-on-wholesale-electricity-plan-see-power-bills-balloon-in-october

[56] Mallapragada, D., Junge, C., Wang, C., Pfeifenberger, H., Joskow, P., Schmalensee, R., 2021, *Electricity Price Distributions in Future Renewables-Dominant Power Grids and Policy Implications*, Working Paper, MIT Center for Energy and Environmental Policy Research, CEEPR WP 2021-017.

1.75 We also note that this discussion of the value of DSF highlights its relevance to risk management and hedging for wholesale electricity purchasers (retailers and direct-connect industrials). The liquidity of shape-related hedging products is low in New Zealand, and is a concern for some market participants as they contemplate the higher-volatility world of 100% renewables[57]. In particular:

(i) The discussion above about the availability payment structure is analogous to that of a cap contract, where a fixed, up-front payment is made in return for insulation against prices over a certain level. We note that many of the DSF "options" are energy limited, and would need to structured accordingly, in a way that differs from a pure cap. Notwithstanding that, an aggregator or large market participant may be able to monetise the flexibility as such.

(ii) Alternatively, the short-term shifting nature of some DSF may be able to be a source of liquidity for "superpeak"-type hedge products, which hedge only the morning and evening peak.

1.76 We are not aware of any comparative analysis of the benefits of DSF versus hedge contracts as risk management mechanisms for wholesale electricity purchasers.

7.3 An example of a successful third-party arrangement in NZ - ripple control of hot water

1.77 Ripple control of hot water (HWC) has been New Zealand's most significant demand management tool for over 60 years. It is almost exclusively a third-party only arrangement, since the control equipment[58] is owned by distributors, retailers and metering equipment providers.

1.78 It is a material form of DSF: there is reported to be 987MW of hot water cylinder load connected to ripple control nationally[59], although at peak times it is likely only 644MW of controllable load.[60] Collectively, this is nearly as large as the three in-service Huntly Rankine units.

1.79 HWC is an important part of load management in grid emergencies (as illustrated on 9th August 2021[61]), temporary network reconfigurations to manage outages or upgrades, and to manage network congestion. Some offer it into reserve markets.

1.80 Whether HWC should be used for other valuable purposes (e.g., managing a retailer's purchase exposure) has been a contentious issue for some time. For many years, the

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[57] See Batstone (2021), "*Wholesale risk management practice trends in the New Zealand electricity market, and prospects for a high renewables future*", Working paper for MDAG, October 2021.
[58] Either the ripple relay at the customer's site, or the older pilot wire system
[59] *Ripple Control of Hot Water in New Zealand*, Report for EECA, Power System Consultants, September 2020, p12
[60] Winter capacity margin – potential effect of possible changes to transmission pricing, Concept Consulting, February 2020, p9
[61] See "Investigation into electricity supply interruptions of 9 August 2021", MBIE

ownership of HWC prevented, in many situations, the use of HWC for managing spot market volatility. Today, the Default Distributor Agreement makes it clear that the service can be contracted to a retailer (as the counterparty to the DDA), noting that emergency load management has priority[62]. This is appropriate, given the sheer value of HWC control in these emergency situations.

1.81 As outlined earlier, the customer's experience of HWC has, generally, been an exemplar of simplicity. The relationship with the controlling organisation has allowed for choice of participation (albeit without a right to assign control to another party, unless the control system is replaced), a stable (fixed) availability payment via lower distribution prices, and an underlying service standard.

1.82 However, the current control systems do not rank alongside the types of smart devices we have discussed here. Ripple relays are relatively unsophisticated in that they don't provide information back to the controller as to whether the cylinder is currently in a heating mode, or what the temperature of the water is. Further, what the customer's hot-water use will be, and therefore what the heating requirement will be, is uncertain at any point in time. Hence, for the controlling entity, there is a degree of uncertainty about the resource available at any point in time (although relay owners have developed methods to obtain good estimates through experience).

1.83 The ripple control systems also can't discriminate between retailers. This has often prevented distributors from agreeing to provide HWC for managing a specific retailer's purchase risks, as activating the relays would likely reduce the sales quantity for all retailers with customers on the feeders targeted.

1.84 The transition of hot water control to smarter controls would either require a new "smart" control system to be retrofitted to the cylinder, or the complete replacement of the cylinder with an embedded smart control. Given the slow life-cycling of hot water cylinders relative to other appliances, and the likely costs of retrofitting, it may be some time before smart hot water control becomes mainstream.

1.85 While we agree that there is value in providing more choice to the customer as to which party they assign their hot water control to, and that flexibility could be applied to other uses, we are not aware of any analysis that has attempted to quantify, given the limitations of the current ripple technology, how material the net benefit would be if HWC was "optimised" across all potential value streams (including the impact on grid and network security).

[62] This is established in Schedule 8 of the Default Distributor Agreement, where the use of load management controlled by the distributor must be prioritised first to any grid emergency event, and second to parties other than the distributor for market participation purposes. We are aware that, prior to the DDA, some retailers were able to reach agreement with distributors regarding the use of HWC for spot market purposes

7.4 Ancillary Service Markets

1.86 Ancillary service markets are relevant to our consideration of "wholesale markets", at least in terms of instantaneous reserves which is co-optimised in the market dispatch algorithm along with energy.

1.87 For flexibility traders, instantaneous reserve markets are likely to be an easier market to access initially (assuming they can meet the service requirements), as it doesn't require the customer or third party to have a retail exposure in order to provide the service and obtain revenue. This appears to have been the case for early flexibility trader business model development in New Zealand.

1.88 Reeve *et al* (2021)[63] provides a commentary on the ability for distributed energy resources (DER) to access ancillary service markets in the New Zealand context. In fact, the authors argue that service performance of DER should improve, noting that:

(a) Smart grid communication and control should enable a continuous demand response to an under-frequency event, which is in contrast to the current binary response of interruptible load afforded by relay technology that trips load at a pre-defined frequency;

(b) It is technically feasible for currently installed DER to meet the technical requirements for frequency keeping, but the System Operator does not currently permit access below a certain size;

(c) The power electronics in DER systems can operate so quickly that they could provide a very quick response to any changes in frequency. This is technically ultrafast reserve but could be designed to simulate inertia. Therefore, some DER can assist with the potential inertia problem that is likely to arise in a 100% renewable world.

1.89 Further, the recent draft decision to amend Part 13 of the Code will allow battery storage systems (or, more generally, energy storage systems) to participate in the instantaneous reserves market. The Code change was motivated initially by the prospect of grid-scale battery installations. The Authority is further exploring the potential for smaller-scale distributed resources to provide services to ancillary markets in its "Future Security and Resilience" workstream.

1.90 Reeve *et al* also commented that, at least in the short term, cheaper inverters will prevent access to a number of ancillary service markets for DER generally (e.g., voltage support). AS/SNZ 4777.2:2020 (inverter requirements) is non-binding, despite the latest version including "*including revised set-points and limits, provisions for demand response and power quality response modes*." However, distributors effectively require adherence to 4777

[63] Reeve, Stevenson and Comendant (2021), *Cost-benefit analysis of distributed energy resources in New Zealand*, Report for Electricity Authority, Sapere Research Group, September 2021, p9-12. We note there is a large international literature on the potential for smart demand-side technologies to provide ancillary services, albeit mostly from the perspective of the system, rather than the customer (Richter and Pollitt (2018), Silva et al (2011))

through the list of approved inverters they allow for connection of DC equipment to the network.

1.91 While products such as the EA's proposed "dispatch-lite" will, at least initially, allow a degree of (notified) opting out at short notice, service performance requirements in ancillary markets are likely to be very high, where the consequences of non-compliance are more significant in terms of system security. Ancillary markets will require compliance that exceeds that in the proposed dispatch-lite regime for wholesale energy, especially around being able to opt out at relatively short notice.

8 What are the prospects for an increase in demand side flexibility?

1.92 While some proportion of households and businesses have always engaged in demand response, the ability for it to reach a mass-market level has been hampered by a range of factors, including a lack of expected value compared to the behavioural and financial cost of enabling flexibility.

1.93 The technological evolution of smart devices is potentially a game-changer here, in two particular ways:

(i) For household and businesses, the demand response control systems are embedded in the appliance, inverter or vehicle charger, rather than needing to be retrofitted; and

(ii) Advanced algorithms can be programmed to automatically respond to the price of electricity, in a way that minimises the impact on the level of service provided to the consumer.

1.94 Further, the potential volatility of wholesale prices in a post-thermal world is already incentivising the investigation of new types of industrial consumers to engineer their manufacturing systems around the potential value of demand response.

1.95 Our analysis above argues that, assuming they are aware of the opportunity that modern technology provides in terms of DSF, electricity customers will trade off:

(a) The overall effort (including financial outlays) required to enable automated and controllable demand flexibility, and

(b) The benefits they are likely to receive from using this flexibility, either from:

(i) A reduction in their own electricity consumption costs provided through a time-varying electricity tariff (which, for the purposes of wholesale price discovery, must be a spot tariff or approximate the pattern of spot prices in some way), or

(ii) On-selling some degree of control to a third party and receiving a share of the benefits they receive.

1.96 Ultimately, in a world of scarce time, attention, budgets and other resources, the net payoff to a consumer for enabling flexibility – even if it is positive – may not be sufficient to warrant them investing the effort. This is a complex assessment that involves a range of behavioural factors that are well beyond the scope of this analysis, and ultimately, up to the customer.

1.97 The extent to which enabling DSF can be made almost effortless for the consumer, e.g., embedded in, or piggybacking on, a purchase of a new appliance or signing up to a new retailer; as well as making the payoff predictable, will be key factors. These are relevant to larger consumers too, but the scale of potential benefits (in terms of arbitrage or reduced consumption costs) may warrant greater effort in establishing the capability.

1.98 The general theme of "ease of decision making" for the consumer leads us to believe that, at the mass market level[64], customers are most likely to enable DSF at the point of a decision regarding a major energy "appliance", e.g., a solar/battery system or electric vehicle purchase, or refitting a factory with a new HVAC system. Such purchases carry significant cost commitments (either as capital costs or annuities), will have a more significant impact on electricity bills, and the "smarts" are either built in or easily included in the purchase[65]. Hence the "energy consciousness" will be much higher than, say, the purchase of a new refrigerator or heatpump.

1.99 In order to provide wholesale market price discovery benefits, consumers opting to use DSF to manage their own consumption costs (option b(i) above) need, at the very least, a reasonable degree of exposure to the wholesale price (as is the case today for many large commercial and industrial consumers). Increasingly, pre-set time-of-use tariffs will struggle to capture the patterns of wholesale prices as intermittent generation increases. But we agree with Mallapragada et al (2021) and Joskow (2019) that widespread residential and small business (if not large commercial) exposure to the highly volatile pricing of a 100%RE world is unlikely to be politically, socially or economically tolerable.

1.100 Hence we have argued that the most likely path for DSF uptake results from consumers on-selling a degree of their autonomy to third parties (ie b(ii) above), in exchange for the third party sharing the benefits in some predictable way. However, these third parties face their own cost-benefit tradeoff, as we expect that significant investments in capability, systems and tariffs will be required to enable arrangements that providing some degree of control to the customer as to how much autonomy they hand over to the third party at any point in time. These investments will need to be made with some expectation of a reasonable scale of uptake.

1.101 As a result, there is a chicken-and-egg aspect to significant DSF uptake. It needs to be relatively easy for customers to access a tariff and share in the benefits, which requires retailers, distributors or flexibility traders to believe sufficiently in market uptake to have

[64] Residential and small commercial customers.
[65] We understand the additional cost of a smart (versus "dumb") EV charger in New Zealand is around $100, and declining.

invested in developing the capability and tariffs which will achieve the wholesale market benefits.

1.102 Given that the ability to achieve scale is critical to retailers, distributors and flexibility traders having the confidence to invest time and resources in development of DSF capability, this may mean that acceleration of DSF uptake, at least at the residential level, is closely related to the uptake of EVs and household batteries[66].

1.103 This intuition seems to be borne out internationally in terms of where DSF uptake is most significant, if the emergence of aggregators is any guide. While there are some markets where smart HVAC tariffs are available, in 2019 IRENA listed 5 "leading aggregators" around the world, four of which focused purely on behind the meter battery systems and/or electric vehicles[67].

1.104 Increases in commercial and industrial DSF is difficult to predict due to the complexity of production processes, but will likely benefit from standardised flexibility agreements and tariff structures, as well as the Authority's dispatch-lite product. However, it is perhaps more likely that increases in industrial demand response will come about as a result of new types of industrial and manufacturing plant entering the market partially motivated (commercially) by energy flexibility.

1.105 Hence, we should not be surprised that, today, there is no significant uptake of DSF in New Zealand at the mass market level. Smart appliances, electric vehicles and behind-the-meter batteries are not yet widespread, and third-party offerings for DSF (ie. beyond reducing one's own consumption costs) are still in their infancy. Put another way, the majority of customers who will provide DSF in a 100% renewable world have yet to purchase the appliances or vehicles that will make this possible.

1.106 Our central thesis of DSF uptake being linked to EVs and household batteries is only one scenario, albeit the one we believe is most likely. There are other plausible factors that could change the rate of its future emergence:

(i) We suspect general consumer awareness of the value of owning "smart" appliances (in the broadest sense) is still low. New types of appliance labelling could help here, as could mandatory standards for some appliances[68];

(ii) Part of this relates to the prevalence of retail tariffs that don't provide significant reward for shifting consumption, which could at least encourage

[66] We note the potential for existing ripple-controlled hot water to be included here – which we comment on earlier.

[67] We understand that the evolution of DSF and emergence of aggregators in the Australian NEM was largely driven by the enormous investment consumers (and the government) made in solar PV which caused network issues and triggered commensurate investment in (mostly residential) batteries. In Norway, while the acceleration of demand response products and tariffs occurred due to exceptionally high prices (see footnote 17) in 2021, control has been primarily focused on electric vehicles, which have a higher penetration in Norway than any other country in the world.

[68] We note the potential for standards to play a strong role in increasing demand side participation was frequently highlighted in "Investigation into electricity supply interruptions of 9 August 2021", MBIE, p6, 31 and 42

consumers today to think about the flexibility they have in their demand. Today, time-of-use tariffs will likely reflect the load-shape pattern of wholesale prices, and would provide some wholesale market benefit.

(iii) Similarly, changing the mindset of consumers to a world that asks consumers to trade off price level and stability with flexibility/controllability is likely to accelerate the control of load by parties with direct wholesale exposure;

(iv) We do not preclude some catalysing event which accelerates uptake – e.g., market events (such as that seen in Norway in 2021, albeit with a high prevalence of spot tariffs) or policy initiatives (e.g., triggered by 9th August) which spur a change in attitudes or desires for customers to adopt new technology or retailers to develop DSF tariff offerings;

(v) Provision of medium-term demand curtailment, where consumption is permanently reduced for a period of days or weeks, is likely to always be more challenging to procure than short term "shifting" DSF, which may not affect the level of service experienced by the customer at all.