QUANTIFYING DEMAND-SIDE FLEX

Current state and literature Review

ENERGY EFFICIENCY & CONSERVATION AUTHORITY
TE TARI TIAKI PŪNGAO

Jacobs
Challenging today.
Reinventing tomorrow.

Important note about this report

The sole purpose of this report and the associated services performed by Jacobs is to assess the quantity of demand-side flexibility available in the New Zealand Electricity Market in accordance with the scope of services set out in the contract between Jacobs and the Energy Efficiency and Conservation Authority ('the Client'). That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context. This project has been desktop-only and includes only factors that have been included in the scope due to time and budget limitations as agreed with the Client.

This report has been prepared on behalf of, and for the exclusive use of, the Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party

1. Foreword

This report is one of a suite of reports documenting research to quantify the potential of industrial demand-side flexibility (DSF) in the New Zealand Electricity Market (NZEM).

As the country moves towards a more sustainable and resilient energy future, understanding and harnessing the power of DSF becomes increasingly crucial. This study aimed to provide a detailed assessment of the current landscape, potential, and pathways for implementing DSF across various sectors of the New Zealand economy.

The primary objectives of this research were to:

- Evaluate the current state of demand response in New Zealand through a thorough literature review and stakeholder engagement.
- Quantify the potential for DSF across different sectors and regions of the country.
- Identify barriers and enablers for DSF implementation.
- Develop recommendations for unlocking the full potential of DSF in New Zealand.

To achieve these objectives, our research team employed a multi-faceted approach, combining data analysis, modeling, and stakeholder input. The study leveraged international best practices while adapting methodologies to suit the unique characteristics of New Zealand's electricity system.

By providing a comprehensive analysis of DSF potential in New Zealand, this suite of reports aims to inform policymakers, industry stakeholders, and researchers, ultimately contributing to the development of a more flexible, efficient, and sustainable electricity system for the country.

2. Acknowledgements

EECA would like to acknowledge the invaluable contributions of data providers and survey respondents in this work.

Respondents			
McAlpines Ltd	Pukepine Sawmills (1998) Ltd	Graymont	Meridian Energy
Winstone Wallboards Limited	Oji Fibre Solutions	ANZCO Foods	Simply Energy
Methanex New Zealand	Astro pine ltd	Pan Pac Forest Products Limited	Genesis Energy
Whakatane Growers Ltd	Sequal Lumber Limited	Dominion Salt Ltd	Mercury Energy
Comfortech Building Performance Solutions	Kiwi Lumber	Fonterra	Network Tasman
DB Breweries Limited	WML	Cottonsoft	Waipa Networks
Timberlands	Pure Bottling	Fulton Hogan Ltd	Scanpower
Inghams	Alsco	Oceania healthcare	Alpine Energy
Tegal	The Tasman Tanning Co	Timberlands	Horizon Energy Distribution Limited
			PowerNet

Table of contents

Figures

Tables

3. Acronyms and abbreviations

ACRONYM	Full Name
ANZSIC	Australian and New Zealand Standard Industrial Classification
Berkeley Lab	Lawrence Berkeley National Laboratory
CC	Customer Count
CR	Co-benefit Ratio
DER	Distributed Energy Resources
DERMS	Distributed Energy Resources Management System
DR-PATH	Demand Response Model developed by Lawrence Berkeley National Lab
DSF	Demand Side Flexibility
DSO	Distribution System Operator
DWP	Dispatch Weighted Price
EA	Electricity Authority
EDB	Electricity distribution business
EECA	Energy Efficiency and Conservation Authority
EEUD	Energy End-Use Database
EMI	Electricity Market Information
EMS	Energy Management Systems
ENA	Electricity Networks Aotearoa
ESS	Energy Storage System
EV	Electric Vehicle
f	Capital Recovery Factor
FC	Fixed Initial Capital Cost
FO	Fixed Operating Cost
GHG	Greenhouse gas
GXP	Grid Exit Point
HVAC	Heating, Ventilation, and Air Conditioning
IC	Incentive to consumers
ICP	Installation Control Point
ICT	Information and communication technology

ACRONYM	Full Name
IEA	International Energy Agency
kWp	kilowatt-peak
LBNL	Lawrence Berkeley National Laboratory
LF	End use constraint factor
LT	Loss
MBIE	Ministry of Business, Innovation and Employment
MDAG	Market Development Advisory Group
Mt	million tonnes
MW	Megawatt
MWh	Megawatt-hour
NPV	Net present value
NZAS	New Zealand Aluminium Smelters
NZEM	New Zealand Electricity Market
PPA	Power Purchase Agreement
RE	Renewable Energy
RETA	Regional Energy Transition Accelerator
TJ	Terajoule
TL	Technical Limit
TOU	Time of Use
TSO	Transmission and System Operator
UC	Uptake Cap
VC	Variable Initial Capital Cost
VO	Variable Operating Cost
VRE	Variable Renewable Energy

4. Purpose of this report

This report presents a literature review of work undertaken on DSF in New Zealand and globally; and the current state of demand-side flexibility in the New Zealand Electricity Market (NZEM).

The report is structured as follows:

- Literature review: This section summarises previous research on DSF, barriers to entry, and classifications of different types and sources of DSF.
- Current state of demand response in New Zealand: Here, we provide an overview of global trends and best practices in demand response, offering insights relevant to the New Zealand market.

5. Literature review

This section is a summary of Jacobs's review of existing literature on flexibility services globally. We reviewed publicly available reports and studies on DSF conducted in New Zealand and other jurisdictions. The sources are a mix of academic papers, and industry papers commissioned by IEA, European Commission and other international organizations. The purpose of this review was to lay out the current understanding of flexibility services – definitions, benefits, challenges faced by other jurisdictions, DSF potential, and recommendations to improve participation in DSF programs.

The learnings from this review served as a point of comparison for insights that came out of this engagement with EECA – understand similarities and differences in potential and challenges in other jurisdictions. The insights from this review was also used as a guide in interviews with stakeholders.

5.1. Overview of flexibility services

Flexibility classification

Flexibility can be classified based on whether the energy load is[1]:

- storable
- shiftable or
- inflexible.

Storable loads: Loads that can be stored and used at a different time than when it was produced. Examples of this type of load are batteries and thermal storage, including water heaters.

Shiftable loads: Loads that can be shifted to run at a different time, either earlier or later than originally planned. These loads need to be scheduled in advance, as they usually operate on a set cycle that cannot be paused once started. Examples include appliances like washing machines, dryers, and dishwashers.

[1] Plaum et al., 2022, EDNA report

Inflexible loads: Loads that cannot be shifted, either due to consumer comfort requirements or because shifting is not possible, such as room lighting. However, inflexible loads could potentially be temporarily interrupted if consumers are provided with sufficient incentives – although in many instances the utility of the load is such the required incentive makes the load effectively inflexible.

Storable loads are the most versatile category of flexible loads while inflexible loads are the most restrictive of the three categories. Inflexible loads would require increasingly larger incentives to participate the higher the DSF requirement is.

Flexibility characteristics

Energy loads can be further characterized based on six characteristics[2]:

- whether they are capacity or energy focus,
- by their response direction (unidirectionally upwards or downwards, or bidirectional)
- response speed,
- response duration,
- availability, and
- predictability.

Focus (capacity or energy): Indicates the energy-to-power ratio of the flexible load. Loads with a low ratio can deliver high power but only for short durations, making them suitable for short-term flexibility services such as frequency regulation. These are considered capacity-type loads. Conversely, loads with a high ratio can sustain power for extended periods, and can therefore be considered as energy-type loads that are better suited for longer applications, such as peak shaving.

Response direction: Specifies the direction of the load's power flow. Some loads are unidirectional, meaning they either function solely as a load or solely as a producer, but not both. Bidirectional flexibility sources, on the other hand, can provide upwards flexibility (decreasing consumption or increasing generation) at times and providing downwards flexibility (increasing consumption or decreasing generation) at other times.

Response speed: The time between when a signal is sent to the flexible resource and when the resource adjusts its consumption or production.

Response duration: The amount of time the flexible resource can sustain the service it provides.

Availability: Determines when and how often the flexible resource can be called upon. Examples of this are electric vehicles that are only available when plugged in. Or dishwashers and washing machines, which might be activated at varying hours during the day.

Predictability: This characteristic has to do with how accurately the availability of the resource can be estimated. A battery system is an example of a predictable resource.

[2] Plaum et al., 2022, EDNA report

Actors in flexibility services

There are 3 key actors in flexibility services[3]. These are:

- Buyers of flexibility services: This includes Transmission System Operator (TSO) and Distribution System Operator and in some jurisdictions, retailers
- Providers of flexibility services: This is primarily the consumers – residential, commercial and industrial consumers with flexible loads
- Aggregators: Serve as an intermediary between providers and buyers of flexibility services, who bundle multiple customers' load or generation to be traded on the flexibility market.

Value of flexibility services

Benefits overview

There are many benefits to enabling flexibility services in the power system[4] that accumulate to different participants in the system. One of the challenges of enabling market DSF is ensuring that different elements of the revenue stack can be recognised and commercialised by the market and regulatory framework.

The table below lists some of these benefits and the associated parties:

Table 1. Benefits of demand-side flexibility

Party	Benefits
TSO/DSO	Avoided investments
TSO/DSO	Avoided grid losses
TSO/DSO	Provision of peak capacity
TSO	Balancing services and Ancillary Services
TSO/DSO	Congestion management
DSO	Voltage support
Generators/Producers	Avoided investments in central capacity
Generators/Producers	More efficient use of central capacity
Consumers	Additional energy savings, resilience

Users of flexibility services such as TSOs and DSOs benefit by avoiding or postponing investment in investment of physical infrastructure (grid, generation capacity) when utilizing flexibility services to manage congestion and provision of ancillary services.

[3] EDNA report

[4] EC Europe, IEA, EDNA report

Consumers on the other hand who provide flexibility services gain financial benefits through direct payments from DSOs/TSOs when they provide flexibility services and savings on electricity bills.

Case Studies

A few studies have attempted to quantify benefits of utilizing DSF. Smart Energy Europe commissioned one such study[5] wherein they conducted an analysis of the economic benefits of utilizing flexibility for European consumers in 2030, based on a comparison between two modelled future scenarios with and without flexibility services.

The study estimated the following benefits:

Wholesale benefits

- €4.6 billion (5%) saved due to lower costs to generate electricity compared to a scenario without DSF.
- €9 billion saved on avoidance of 'lost load' not served by the available generation. Note that "lost load" in this context possibly includes economic load curtailment and self-supply rather than solely energy scarcity.
- 15.5 TWh (61%) reduction on renewable energy curtailment
- 37.5 million tonnes (Mt) reduction in annual GHG emission – nearly 84 kilos per capita

Benefits for security of supply

- €2.7 billion saved annually by enabling 60 GW of DSF compared to installing 60 GW of peak generation capacity.
- €262–690 million saved across the EU27 in European balancing markets in 2030, a balancing energy cost saving of 43% to 66%.

Benefits for the distribution grid

- €11.1–29.1 billion saved in investment needs at EU 27 annually between 2023 and 2030. This represents between 27% to 80% of today's forecast investment needs.

Benefits for consumers

- Direct benefits of more than €71 billion (about 355 EUR/household/year) saved annually for the providers of flexibility services
- €300 billion (about 1500 EUR/household/year) in indirect benefits from demand-side flexibility as a whole, stemming from reductions in energy prices, generation capacity costs, investment needs for grid infrastructure, system balancing costs, and avoided carbon emissions.

In the New Zealand context, BCG's "The Future is Electric" study[6] estimated that a smarter, more flexible electricity system will save around $10 billion on an NPV basis to 2050, incorporating demand response, smart electric vehicle (EV) charging, and distributed energy resources.

[5] Smart Energy Europe

[6] BCG, The Future is Electric

5.2. Challenges and barriers to flexibility services and potential solutions

Broadly, there are three dimensions to the challenges and barriers for widespread adoption of flexibility services. These are technological, behavioural, and markets and regulation.

Technological

Technological barriers can be further classified as communication barriers and appliance barriers to the extent that effective coordination of DSF services requires communication protocols and energy-consuming devices capable of responding.

Communications protocols

Open and standardised communication protocols in appliances eases the integration with flexibility platforms. To make integration with household DER as cost-efficient as possible, it is recommended to adopt a limited number of open communication protocols to be used in consumer devices such as heat pumps, batteries, electric cars and HVAC systems.[7]

A study by FAN and LCP Delta identified interoperability as a major challenge for harnessing grid flexibility of heat pumps in Netherlands. Energy service providers that want to use heat pumps for energy management are forced to invest heavily in different technologies that basically fulfil the same role, due to the broad range of protocols that are being used today. ("Connected heat pumps in the Netherlands – update 2023 - Flexible Energy")[8]

Recognizing the importance of interoperability, EEA and EECA in New Zealand launched the flexibility project FlexTalk. This was focused on active managed charging of electric vehicles; however similar lessons can be applied for other appliances. Some of the conclusions of the project include[9]:

Open communication standards/protocols are a key enabler of flexibility

- Agreed industry standardization of protocols will provide enhanced interoperability, real-time data exchange, improved flexibility and scalability
- The two most mature open communication protocols are OpenADR and IEEE 2030.5, each have advantages specific to their intended use case

Smart appliances

Smooth integration of smart appliances with aggregator software and automated handling of DSF delivery makes it easier for consumers to participate and for aggregators to manage provision of flexibility services. Hence, widespread adoption of smart appliances will be a key enabler of DSF.[10]

---

[7] EDNA report

[8] FAN, LCP Delta

[9] FlexTalk project

[10] EDNA report

This is supported by several studies including a study[11] by EcoGrid which found that 87% of residential peak load reduction is accounted for by households having equipment that controlled their heating system to respond automatically to price signals. The study further reiterated the necessity of standardized smart grid equipment.

However, consumers are unlikely to pay a premium for specific technology that will enable smart appliances to be controlled for DSF purposes (e.g. HEMS, EV chargers) unless there is a clear mechanism for monetizing the associated DSF. To accelerate the adoption of enabling technology for smart appliances for end users, these enabling technologies could potentially receive incentives in the early stages of their development[12]. Such incentives would aim to reduce the initial acquisition cost to end users to speed up the uptake of DSF-enabled smart appliances and encourage consumer participation.

Behavioural

Behavioural barriers encompass the human element - on the consumer and sector sides - that inhibit greater uptake of DSF. This includes a lack of knowledge but also and low willingness to participate - even with relatively high levels of knowledge - on the part of consumers and system operators.

Lack of knowledge

Several studies[13] have identified lack of knowledge about providing demand-side flexibility on the consumer side as a barrier to widespread adoption of flexibility services. To address this, education initiatives may be rolled out to increase awareness about the possibility of delivering flexibility services.

Low willingness to participate by consumers

There are several reasons why consumers are unwilling to participate in flexibility programs. A few studies have identified the following[14]:

- People find it hard to understand, difficult to sign up, do not see it as user-friendly,
- Might hold the misconception that their personal data is being collected.
- Insufficient savings/benefits

Potential solutions[15] include:

- Make participation as seamless and simple as possible
- Simpler DSF programs

---

[11] EcoGrid

[12] EC Europe

[13] EDNA report, ACER, UsersTCP

[14] ibid

[15] EDNA report, UsersTCP, Enefirst, EC Europe, EEA Europe, EcoGrid

  - Simplify the enrolment process: When designing the demand-response program, focus on creating as automated and frictionless a process as possible.
  - Simplify the program and tariff structures: Invest resources in developing programs and tariffs that require minimal customer knowledge, offer pre-programmed default settings, and provide straightforward steps for setting preferences.
  - Simplify billing
  - Contractual arrangements should be simple, transparent and fair and allow consumers to access any service provider of their choice, without previous permission of the supplier. Standard contracts should be put in place to ensure smooth contractual process, fair financial adjustment mechanism and standard communications procedures.
- Use of smart appliances and other enabling technologies
- Use of regulations to make it easier to engage in demand side flexibility (DSF) activities
  - Embed demand flexibility functions in appliances. Mandate manufacturers of household appliances to embed demand flexibility functions into their appliances, e.g., smart appliances.
  - Set demand flexibility defaults: Mandate electrical appliance manufacturers to preset devices to energy-saving or demand flexibility modes by default. For instance, default settings on smart thermostats can be configured to reduce heating during peak hours. Ensure, however, that users have the flexibility to override and customize these settings to avoid any potential backlash related to social license to automate (or perceived loss of control or independence)
- Implement consumer protection standards especially regarding data collection and data management
- Increase economic incentives
  - Economic benefit on system level (e.g. reduced investment, avoided curtailment) from using consumers' flexibility is reflected in the economic compensation or other benefit to the customer
  - Develop other business models that can result in greater attractiveness to the customers
  - Promote tariff structures that better reflect price signals (whilst ensuring tariff simplicity, e.g., TOU tariffs instead of fixed-price tariffs). Policies to this effect may be implemented such as:
    - Progressively phasing out regulated prices for all customers and enabling innovative grid tariff structures that incentivise network customers for delivering the flexibility needed to the system, (e.g. through time of use tariff schemes, more capacity-based tariffs or different contractual options).
    - Guarantee the same or lower bills than customers' old tariffs: Consider adding (as a minimum) a risk-free period in the initial months that will guarantee that consumers do not pay more than they would have on their old tariff. This can increase consumers' confidence to sign up.
    - Offer incentives, such as tax breaks or subsidies, for consumers who actively replace or upgrade equipment to enable flexibility.

- Foster a sense of social recognition and belonging by acknowledging and highlighting the efforts of DSF providers who have successfully adopted DSF habits. Publicly acknowledging their achievements, via, for example, a business newsletter or in consumers energy bills, can create a positive social norm and encourage others to follow suit.
  - A behavioural study[16] provides a different perspective that recommends focusing more on consumers' environmental motivations to participate. This study found that:
  - The likelihood of participation in flexibility programmes increased as more people perceived personal and environmental benefits and felt able to use energy flexibly. Conversely, perceived costs and risks were negatively related to these outcomes.
  - Environmental self-identity showed the strongest relationship with all three indicators of participation (acceptance, interest, and intention to participate), while price consciousness was only related to the intention to participate.
  - The study inferred from this that a conceptualization of demand response participation as an economically rational decision is too narrow. Rather, people seem to recognize the collective environmental consequences of participation and can thus be intrinsically motivated via a moral route of decision making.

Low willingness to participate by system operators/ network companies

Lack of trust from the system operators in demand side flexibility services is another barrier to growth.[17] SOs are wary whether they can rely on DSF services to deliver SO requirements when called which leads to SOs preferring to procure balancing and ancillary services from generators instead of DSF providers.

Regulation and Markets

There are several markets where DSF might participate. These include i) ancillary services, ii) system balancing, iii) wholesale market/energy trading, iv) network and generation capacity markets.[18]

Market access

Consumers/DSF providers and their aggregators must be given equal access to flexibility markets to increase competition and wider adoption of flexibility services. In this regard, several potential solutions have been proposed[19]:

- Clear legislation which allows for non-discriminatory access of aggregated flexibility to the flexibility market. To encourage participation, regulation should also be put in place to make it easier for aggregated sources to participate, such as, allowing independent aggregators to participate, lowering minimum bid size, among others.
- Promotion of the use of flexibility services from aggregated flexible resources

---

[16] Sloot et al

[17] EDNA report

[18] 2024 Market Monitor, Eid et al.

[19] EC Europe, EEA Europe, EDNA report, IEA, ACER

- Dismantling of barriers to entry and creation of supportive investment frameworks to enable small flexibility resources to participate in all DSF markets on an equal footing with traditional centralized sources of flexibility

Efficient market design

Regulation pertaining to DSF markets is often identified as a barrier to flexibility adoption. In Europe, variation between markets in different countries, unclear definitions of roles, and regulation that limits the possibility of trading flexibility from DER are identified as barriers to flexibility services. Therefore, aligning market arrangements and product specifications is critical to facilitate smoother integration.[20]

Market design considerations

One study summarizes some reflections and conclusions on market designs for flexibility[21]:

- Time: The time dimension and market time window are key to market design. Some assets will have advantages in some time windows based on activation time, ramping speed and duration. For optimal resource allocation this needs to be reflected in market design.
- Aggregators: Aggregators may be able to provide services or products where individual assets may not.
- DSO/TSO integration: Some of the flexibility assets will have geographical relevance both in the distribution grid and in the transmission grid. That means that market design would need to support simultaneous participation of both multiple DSOs and TSOs in the same marketplace in order to ensure optimal resource allocation.
- Multi-market, multi-period: The market design should recognize that some of the assets have relevance in multiple markets and in multiple time periods and incentivize the optimal allocation of resources over these.
- Investments: In addition to support short-term optimal resource allocation of flexible assets, the market design needs to incentivize the right amount of investment. That is, in addition to covering the short run marginal cost of flexible operation, capital cost of the flexibility needs to be covered over the lifetime of operation, either by the market clearing price or by side payments.

Furthermore, IEA recommends fair market compensation[22] for the multiple flexibility benefits of agile technologies situated near sites of electricity use. This can be achieved by:

- Improving the temporal granularity of market prices by shortening settlement (or trading) periods for intraday and real-time markets.

[20] EDNA report, ACER

[21] Del Granado et al.

[22] IEA

- Improving the locational granularity of price signals, for instance through nodal pricing, flexibility marketplaces or network tariffs.
- Establishing market rules and co-ordination platforms, including between transmission and distribution system operators, that help DSF providers stack multiple revenue streams while maintaining grid reliability.

DR potential

Quantification of DSF potential often varies depending on methodology adopted by authors. Establishing a framework for identifying DSF potential is essential in any DSF potential study.

Attributes that contribute to DSF potential

Williams and Bishop offer a framework and identifies attributes that contribute to DSF potential. These are i) Energy storage, ii) inventories, and iii) outcome flexibility.[23]

- Energy storage decouples the energy inputs of a process from the outputs, meaning the outcome can be maintained without continuous power supply.
- Inventories allow a process outcome to be maintained despite interrupted electricity inputs, as sufficient stock is present to maintain auxiliary workflows while deferring the operation of power-intensive technologies. In general, larger inventories increase DSF potential, by allowing for longer deferral of electricity demand from power-intensive processes.
- Outcome flexibility allows a process to be interrupted without immediately compromising the desired outcome. It can include tolerance in the magnitude or timing of an output from a process, and/or in the desired outcomes they support. For example, flexibility in outcome magnitude is demonstrated for space heating and cooling, due to comfort ranges of temperature and relative humidity which can be increased with appropriate clothing. Thus, space heating or cooling may be interrupted, and power demand deferred, without compromising user requirements for comfort. Timing outcome flexibility is demonstrated with domestic EV delayed-charging algorithms, which allow EVs to be charged overnight, while ensuring their batteries are sufficiently charged for use in the morning.

DR potential in New Zealand

William and Bishop also estimated the potential of demand response in New Zealand[24] and concluded the following.

- Up to 69% of New Zealand's electricity demand is suitable for demand response, which can be harnessed through retrofitting and incentivization
- Demand response potential is abundant across all sectors. "The residential, commercial, industrial, and agricultural sectors each offer considerable DR potential, with water heating, refrigeration systems, and electric motors key candidates."

---

[23] Williams and Bishop

[24] Williams and Bishop

- Electrification of transport will offer additional DSF potential.
- Adoption of future technologies should consider controllability.

In their study, for each energy end use, DSF potential is assigned one of three levels of confidence. High confidence is assigned to applications with energy storage. Medium confidence is assigned to applications with inventories but without energy storage. Low confidence is assigned to applications with only outcome flexibility. These confidence boundaries reflect the ease of DSF implementation and the likelihood of DSF potential. In all cases, DSF potential requires a controllable technology, which is either interruptible or schedulable.

Jacobs believe these figures should be treated as a theoretical maximum. Their study assumes end-uses are willing to be controlled, have the necessary equipment and adjust operations to enable DSF. It is important to note that this literature estimates theoretical potential without considering end-users' willingness to participate and other decision factors to participation. Hence, figures here should be taken as upper range of DSF potential.

DR potential per sector

According to the same study, total national DSF potential for each sector, and the non-flexible electrical loads, are shown in figure below. 20% of national electricity demand is flexible with high confidence, 30% with medium confidence, and 19% with low confidence providing the total of 69% of national electricity demand that the study estimated to have some level of demand response potential.

"The industrial sector contributes the highest total DSF potential, with 43,988 TJ of flexible load (35% of total electricity demand)." However, the largest share of high-confidence DSF potential is from the residential sector, with 12,737 TJ (9% of total demand).

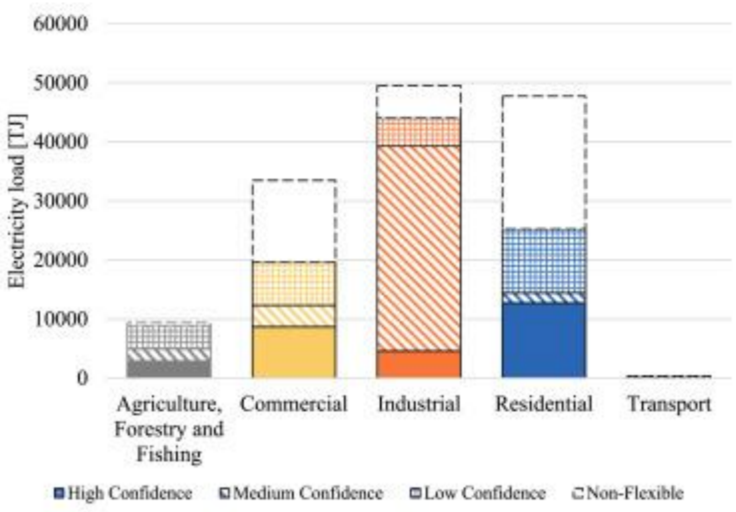

Figure 1. Sources of demand response by sector (Willams and Bishop)

Additional DSF potential can be harnessed from future electrification of light vehicles. 40% electrification of these sources can increase high-confidence DSF potential as shown in figure below.

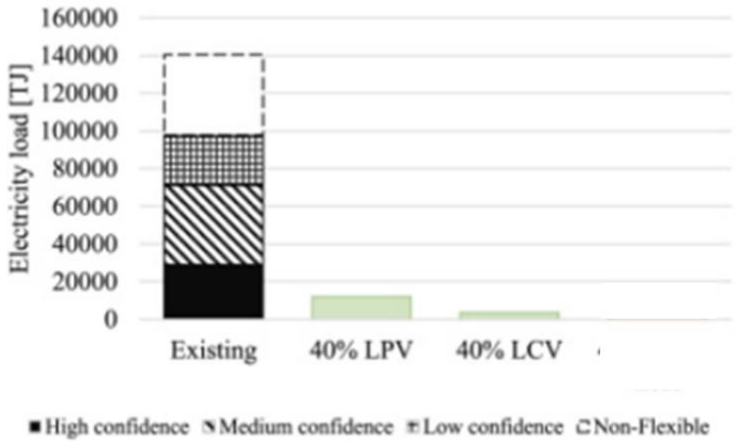

Figure 2. Potential demand response by confidence levels, including future transport electrification (Williams and Bishop)

The six technologies with the highest DSF potential across all sectors are shown in figure below. Industrial heating has the highest DSF potential, with ~20,000 TJ (14% of total existing demand)[25]. The next-largest contribution is from hot water cylinders, with 17,245 TJ (12% of total demand), which have a high confidence of DSF potential and are present across three sectors.

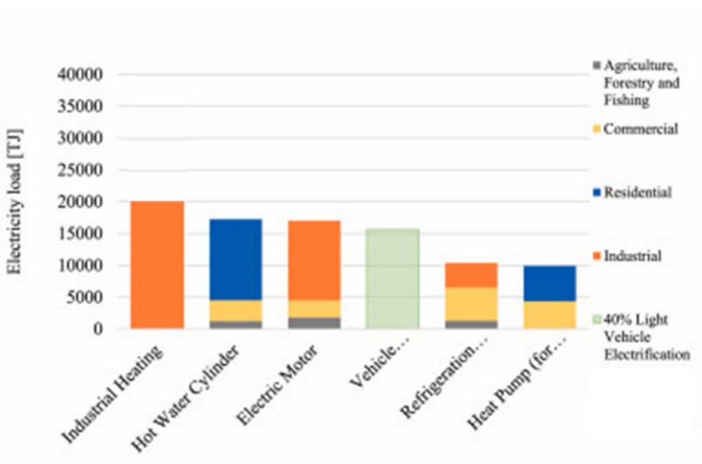

Figure 3. Sources of demand response by technology (Willams and Bishop)

Large demand response potential already exists in the New Zealand power system (equivalent to 69% of total electricity demand)26, which can be accessed by retrofitting controllers and providing price incentives. The most promising of these technologies include:

- Hot water heating in the residential and commercial sectors.
- Refrigeration systems in the commercial and industrial sectors.
- Heat pumps for space heating/cooling in the residential and commercial sectors; and

---

[25] Not included from this figure is existing DR being provided by Tiwai Point aluminium smelter

[26] Excluding Tiwai smelter

- Electric motors in industrial processes with sufficient inventories.

Emerging demand response potential

Two pathways are being prioritized for decarbonisation in New Zealand: electrification of industrial process heat and electrification of transport. Both pathways present considerable potential for demand response. [27]

Meanwhile, New Zealand Electricity Authority's paper[28] estimates a more modest DSF potential of only up to 300MW. On the other hand, Flex Forum estimates nearly 2.5GW of DR potential.[29]

5.3. Improving Industrial Demand Response

A paper by ACEEE identifies ways to enable industrial demand response.[30] This largely mirrors the challenges, barriers and potential solutions identified earlier.

Some of the key recommendations are:

- Technological: ICT enables effective demand flexibility programs by supporting monitoring, management, and coordination of energy both in and between the grid's demand and supply sides.
- Financial/Business case: For industrial customers to commit to capital investments and change their operations to increase load flexibility, a strong business case must be made. Two key items to consider are:
  - Electricity cost savings: reduction in peak demand lowers demand charges; reduction in overall energy consumption; payments from shifting/changing load in response to a DR request
  - Risk:
    - Customers are averse to unexpected disruption to production processes
    - Programs can financially de-risk early adopters

New Zealand's Electricity Authority[31] in its paper published May 2025 proposed a roadmap with recommendations on how to enable industrial demand flexibility focusing on "explicit" DR, i.e., DR that responds to instruction from system operator or receives payment explicitly for DR purposes. Short-term recommendations include standardizing a flexibility product and in the long term, removing barriers to participation.

---

[27] Williams and Bishop

[28] EA Issues and Options Paper Rewarding Industrial Flexibility

[29] FlexForum

[30] ACEEE

[31] EA Issues and Options Paper Rewarding Industrial Flexibility

5.4. Observations and recommendations

DSF has long been discussed as a fundamental and material component of future electricity systems that will massively reduce the need for investment in network and peaking supply capacity.

However, it has proved difficult to bring together the various social, technical, and economic constraints that affect participation of DSF providers. Therefore, studies have tended to make assumptions and set some parameters that are outside the scope of work resulting, for example, in assuming that the current self-reported intention to participate is largely fixed or that willingness to participate will effectively reach 100% of all applications that appear technically feasible.

Therefore, to address this material gap in the research base, particularly in the New Zealand context, Jacobs and EECA completed this study that brings together the qualitative views of industry and produce a quantitative model that incorporates them - and model sensitivities around them – alongside technical and economic constraints. In this way, this paper avoids a pessimistic view that self-reported willingness-to-participate today is unchangeable while also avoiding the assumption all such reservations will be moot once the appropriate DSF incentives and platforms are in place.

6. Current state of demand-side flexibility in New Zealand

New Zealand's electricity market has unique characteristics that shape the landscape for demand side flexibility (DSF). The prevalence of hydro generation – as a low-carbon and dispatchable source of electricity – plus geothermal resource and sustained low demand growth has meant that the penetration of variable renewable energy (VRE) is low in New Zealand relative to similar economies. However, given that the new generation pipeline is dominated by wind and solar plant, and that key decarbonisation pathways involve greatly increased electrification, establishing a framework to enable DSF will become increasingly critical. This section provides an overview of the current state of DSF in New Zealand, examining the market structure, existing programs, regulatory framework, and key stakeholders.

6.1. Market Structure and Renewable Energy Integration

New Zealand's electricity market is characterized by its high proportion of renewable energy, with hydropower, geothermal, and wind contributing significantly to the generation mix. In 2024, approximately 85% of New Zealand's electricity was generated from renewable sources, down from 88% in 2023 due to dry hydrological conditions. This high renewable penetration creates both opportunities and challenges for DSF:

1. *Opportunities:*
    - The variability of wind resource throughout the year increases the value of flexible demand that can respond to supply fluctuations.
    - Nodal pricing provides strong spot market signal for DSF where it provides the most value.
    - Learning from overseas jurisdictions
2. *Challenges:*
    - Periods of high lake levels can lead to extending periods of low spot price and little volatility, affecting the commercial incentive for investing in shorter-term load-shifting DSF.

The wholesale electricity market in New Zealand operates on a nodal pricing system, with prices calculated every half-hour at each of the approximately 250 nodes across the transmission network. This granular pricing structure provides a solid foundation for locational DSF programs, although the complexity may be perceived as a barrier for smaller participants.

6.2. Existing DSF Programs and Initiatives

New Zealand has seen several significant developments in demand side flexibility in recent years:

1. New Zealand Aluminium Smelters (NZAS) and Meridian Energy Agreement: In 2024, NZAS and Meridian Energy struck a groundbreaking demand response agreement. This arrangement allows NZAS, which consumes approximately 13% of New Zealand's electricity, to reduce its power consumption during periods of high demand or low supply. This agreement represents a significant step forward in large-scale industrial demand response, potentially providing up to 185 MW of flexible capacity to the grid,

all of which (and an additional 20 MW) was called on during winter 2024. The arrangement operates over multiple weeks with long phase in and phaseout periods and limited availability, and is very much a 'dry year' product.

2. Transpower's Demand Response Programme: Transpower, the national grid operator, ran a demand response program from 2015 to 2020. The program allowed large consumers to offer load reductions primarily in response to Transpower outage requirements.

3. FlexPoint: Transpower Distributed Energy Resources Management System (DERMS) that aims to provide a platform where DER providers, including flexibility traders, can register their services and allow FlexPoint operator to call on that when required, and subsequently tracks DER performance and manages settlement.

4. SimplyFlex: Launched by Simply Energy in 2023, SimplyFlex is an innovative platform that enables smaller commercial and industrial consumers to participate in demand response. The platform aggregates load from multiple participants, making it easier for smaller entities to engage in the demand response market.

5. Flex Forum: Established in 2022, the Flex Forum is an industry-led initiative that brings together stakeholders from across the electricity sector to promote the development and integration of flexible demand resources. The forum has been instrumental in identifying barriers to DSF adoption and proposing solutions.

6. Demand-Side Bidding in the Spot Market: While demand-side bidding has been technically possible in the New Zealand electricity market for some time, participation has historically been historically limited.

7. Interruptible Load: Several large industrial consumers, particularly in the pulp and paper industry, have agreements with their retailers or Transpower to reduce load during peak periods or system emergencies.

8. Ripple Control: A long-standing form of DSF in New Zealand, ripple control allows distribution companies to manage residential hot water heating loads. While effective, this system is aging and not integrated with modern smart grid technologies.

9. Spot Price Pass-through: Some retailers offer plans that expose customers to spot market prices, incentivizing them to shift consumption to lower-priced periods. These plans proved popular for several years but, as spot prices increased from 2017 onwards, the risk of spot market exposure become clear and popular interest in directly spot-linked tariffs reduced.

6.3. Regulatory Framework

The regulatory environment for DSF in New Zealand is still evolving. Key aspects of the current framework include:

1. Electricity Industry Participation Code: This code, administered by the Electricity Authority, provides the rules for the electricity market. While it does not explicitly prohibit DSF, it also does not provide specific mechanisms to facilitate its growth.

2. Transmission Pricing Methodology: Recent changes to this methodology aim to provide more efficient price signals with respect to the beneficiaries of transmission investment. However, the removal of the Regional Coincident Peak Demand (RCPD) removed a clear revenue/cost saving available to DSF..
3. Default Distribution Agreement: This standardized agreement between distributors and retailers is currently under review, with potential implications for how DSF can be implemented at the distribution level.
4. Electricity Price Review: A 2019 government-led review of the electricity sector recommended several measures to enhance competition and consumer participation, including recommendations related to DSF.
5. Review of Electricity Market Performance: MBIE undertook a review of electricity market performance in the wake of winter 2024, with the objective of advising on the impact current market design and rules and potential improvements. The review discussed the potential of “demand management” to offset some of the need for supply and network investment at a high level but tended to focus on longer time-scale solutions, such as that provided by NZAS, which mitigate dry-sequence risk rather than short time-scale solutions. The review expressed a view that the large number of EDBs in the New Zealand system was a barrier to greater uptake of highly distributed DSF.

6.4. Key Stakeholders and Their Roles

Several stakeholders play crucial roles in the development and implementation of DSF in New Zealand:

1. Electricity Authority: As the market regulator, it has a considerable influence on the rules and structures that can enable or hinder DSF.
2. Commerce Commission: Competition regulator ensuring that regulates the Transpower and the distribution companies with respect to their regulated revenue and price paths.
3. Ministry of Business, Innovation and Employment: Ministry responsible for energy policy.
4. Transpower: The transmission system operator has been actively exploring DSF as a tool for managing system security and deferring network investments.
5. Distribution Companies: These entities are increasingly interested in DSF as a means of managing local network constraints, although their involvement is currently limited. They are also a key customer and potential revenue stream for third-party DSF providers.
6. Retailers: Some innovative retailers are offering DSF-enabling products, but many remain focused on traditional retail models. Retailers could also use third-party DSF to manage the energy costs, so are a key potential DSF customer.

7. Large Industrial Consumers: These entities are the primary participants in existing DSF programs, with significant untapped potential remaining.

8. Technology Providers: A growing ecosystem of companies is offering DSF-enabling technologies, although market uptake remains limited.

9. Industry groups and civil society:

   - FlexForum is a cross-sector group that focuses on the role of flexibility in the NZEM.

   - ENA: Electricity Networks Association represents EDBs.

   - Rewiring Aotearoa is a self-funded advocacy organisation supporting accelerate electrification and uptake of consumer energy resources.

6.5. Challenges and Opportunities

Despite its potential benefits, DSF faces several challenges in the New Zealand context:

1. Limited Awareness: Many consumers and businesses are not fully aware of the potential benefits of DSF.

2. Regulatory Barriers: The current market rules and structures do not always facilitate easy participation in DSF, particularly for smaller consumers.

3. Lack of commercial incentive: For many customers, tariff structures provide little commercial incentive to invest in DSF.

4. Technology Adoption: The rollout of smart meters has been extensive, but the adoption of other enabling technologies (e.g., home energy management systems) remains low.

5. Market Complexity: The nodal pricing system and half-hourly settlement periods can be challenging for smaller participants to navigate.

However, several factors present opportunities for growth in DSF:

1. Increasing Renewable Penetration: As New Zealand increases its penetration of VRE in the electricity system, the need for flexibility in the system will grow.

2. Electrification of Transport and Heat: The increasing electrification of these sectors will create new opportunities for flexible loads.

3. Technological Advancements: Improvements in communication, control, and energy storage technologies are making DSF more accessible and cost-effective.

Recent developments have also created new opportunities:

4. Large-Scale Industrial Participation: The NZAS-Meridian agreement has demonstrated the potential for significant demand response from large industrial consumers, potentially paving the way for similar arrangements with other industries.

5. Aggregation Platforms: The success of platforms like SimplyFlex shows the potential for technology to unlock DSF potential among smaller consumers.

6. Industry Collaboration: Initiatives like the Flex Forum are fostering greater cooperation and knowledge-sharing across the sector, which could accelerate DSF adoption.

7. Increasing Policy and Regulator Focus: DSF was identified as “secret sauce” of the energy transition in MDAG’s report to the Electricity Authority and has become a significant focus in the EA’s workstream to implement MDAG’s recommendation. The introduction of the first standardized flexibility product (the super-peak contract) in January 2025 is an example of concrete and rapid progress on improving price signals to flexibility services that is expected to continue.

In conclusion, while New Zealand has made significant, if early, strides in implementing DSF, with notable recent developments in large-scale industrial participation and innovative platforms for smaller consumers, significant untapped potential remains. The unique characteristics of the New Zealand electricity market, combined with recent initiatives and growing industry collaboration, present both challenges and opportunities for further DSF development. Moving forward, building on these recent successes, and addressing remaining barriers will be crucial to unlocking the full potential of DSF in New Zealand's electricity system.

7. References

ACEEE (https://www.aceee.org/sites/default/files/pdfs/enabling_industrial_demand_flexibility_-_aligning_industrial_consumer_and_grid_benefits.pdf)

ACER (https://www.acer.europa.eu/sites/default/files/documents/Publications/ACER_MMR_2023_Barriers_to_demand_response.pdf)

ACER (https://www.acer.europa.eu/sites/default/files/documents/Publications_annex/ACER_MMR_2023_Barriers_to_demand_response_Infographic.pdf)

BCG (https://web-assets.bcg.com/b3/79/19665b7f40c8ba52d5b372cf7e6c/the-future-is-electric-full-report-october-2022.pdf)

Del Granado et al. via ResearchGate (https://www.researchgate.net/publication/368166255_Flexibility_Characterization_Aggregation_and_Market_Design_Trends_with_a_High_Share_of_Renewables_a_Review)

EA (https://www.ea.govt.nz/documents/1095/03-Demand-Side-Flexibility-in-the-Wholesale-Electricity-Market-under-100-Renewables.pdf)

EA Issues Paper (https://www.ea.govt.nz/documents/7295/Rewarding_industrial_demand_flexibility_-_Issues_and_options_paper_v2.pdf)

EC Europa (https://energy.ec.europa.eu/publications/regulatory-recommendations-smart-grid-deployment_en)

EC Europa (https://energy.ec.europa.eu/system/files/2019-05/eg3_final_report_demand_side_flexiblity_2019.04.15_0.pdf)

EcoGrid (http://www.eu-ecogrid.net/images/Documents/150917_EcoGrid%20Findings_Recommendations.pdf

EDNA report

EEA Europa (https://www.eea.europa.eu/en/analysis/publications/flexibility-solutions-to-support)

EECA (https://www.eeca.govt.nz/insights/energy-in-new-zealand/demand-flexibility-a-smarter-grid/)

Eid et al. via Science Direct (https://www.sciencedirect.com/science/article/pii/S1364032116302222)

Enerfirst (https://enefirst.eu/wp-content/uploads/D2-2-Report-on-international-experiences-with-E1st.pdf)

FAN & LCP Delta. (https://flexible-energy.eu/wpcms/wp-content/uploads/2023/08/Final-report_Connected-HPs-in-NL-FAN-version-1.02.pdf)

FlexForum (https://flexforum.nz/how-much-flex-is-in-new-zealands-power-system-today-and-how-much-could-there-be-by-2030/)

FlexTalk (https://eea.co.nz/news-and-events/past-events/flextalk-webinars/flextalk-final-reports/)

http://www.eu-ecogrid.net/documents-and-downloads)

IEA (https://www.iea.org/reports/unlocking-the-potential-of-distributed-energy-resources)

Plaum et al. via Science Direct (https://www.sciencedirect.com/science/article/pii/S2352484722012999)

Simply Energy (https://simplyenergy.co.nz/change-matters/insights/demand-flexibility-demystified/)

Sloot et al. via ScienceDirect (https://www.sciencedirect.com/science/article/pii/S2214629621005181)

Smart Energy Europe LCP Delta. 2024 Market Monitor (https://insights.lcp.com/rs/032-PAO-331/images/LCP-Delta-Flexibility-Market-Monitor-2025.pdf)

Smart Energy Europe & DNV (https://smarten.eu/reports/report-l-demand-side-flexibility-quantification-of-the-benefits-in-the-eu/)

UsersTCP. The Behaviouralist (https://userstcp.org/wp-content/uploads/2024/02/applying-behavioural-insights-demandflexibility.pdf)

Valarezo, et al. MDPI

Williams & Bishop. Science Direct (https://www.sciencedirect.com/science/article/pii/S0301421524004075)

Williams, Bishop. Science Direct. (https://www.sciencedirect.com/science/article/pii/S0301421524004075)