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The full potential of flexible electricity use in New Zealand

Summary and insights report

ENERGY EFFICIENCY & CONSERVATION AUTHORITY
TE TARI TIAKI PŪNGAO

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1 Foreword

Demand-side refers to the consumers of electricity, e.g., residential homes, commercial businesses, industrial facilities. Demand side flexibility involves a consumer changing when they use electricity in response to signals from the electricity market. It typically involves shifting load to:

- shave peaks or avoid consumption during high-price periods, and
- fill valleys in the use of the electric grid or shift more consumption to low price periods.

Load shifting may be done manually or aided by technology such as batteries or energy management systems.

EECA's role is to promote energy efficiency, conservation and renewable energy use for the benefit of all New Zealanders. A key pillar of its strategy is 'Empowering energy users', and flexibility is a way to help put more power back into users' control, while also contributing to a secure and affordable energy system.

As New Zealand's energy system evolves, understanding and harnessing the power of DSF becomes increasingly important. DSF can help deliver a more secure, affordable and sustainable energy system to support our economy and society. This study aimed to provide a detailed assessment of the current landscape, full 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 DSF in New Zealand through a thorough literature review and stakeholder engagement.
- Quantify the potential for DSF across different sectors and regions of the country through forecasting under various demand growth scenarios.
- Identify barriers and enablers for DSF implementation.
- Develop recommendations for unlocking the full potential of DSF in New Zealand.

To achieve these objectives, the 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 summary and supporting 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.

2 Executive summary

Key findings

This project has quantified the potential impact of demand side flexibility (DSF) on the New Zealand electricity system now and in the future. The key findings are:

Peak MW impact

Our analysis calculates the potential impact of DSF on national peak demand is between 1,700 and 1,900 MW, or around 25% of current peak electricity demand across New Zealand. This corresponds to a total value of almost $3 billion of avoided investment in generation and network infrastructure if applied to Transpower's estimate of $1.5 billion[1] in system cost reduction for each GW of peak demand reduction.

Energy impact

In energy terms, the model estimates that approximately 1,350 GWh of energy per year (roughly 3% of annual energy demand) could be shifted away from peaks at a procurement price (e.g. incentive payment) of less than $500/MWh. By 2040, this figure increases to almost 2,000 GWh. While a small proportion of total demand, this amount is significant in terms of peaking generation. This makes a case for DSF to be considered alongside other potential options to meet peak loads, such as diesel fired peakers which could cost in excess of $500 per MWh.

1 Transpower_Electrification Roadmap_SCREEN3_LR.pdf page 29

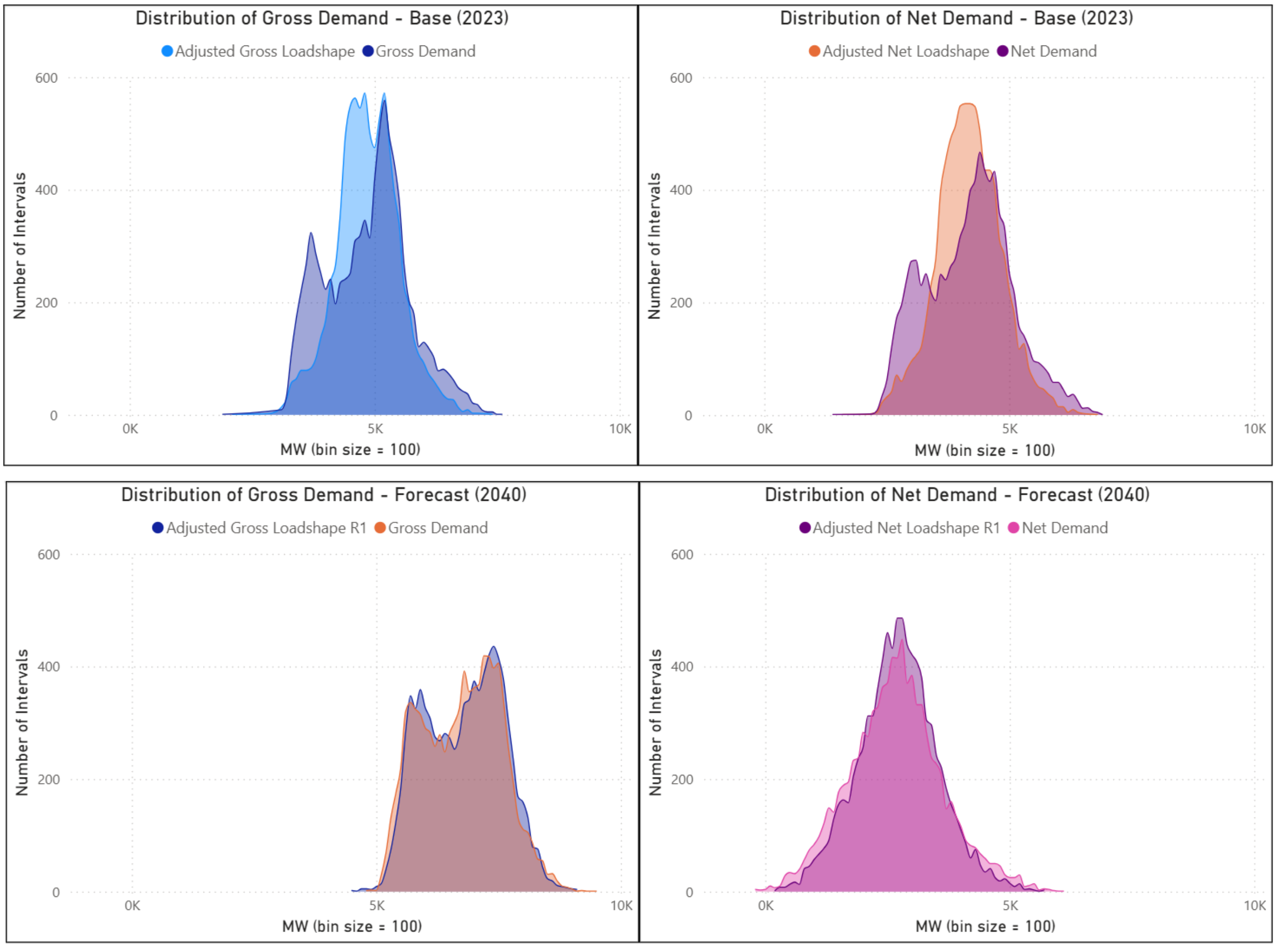
Detailed findings – Flattening the curve

Implementing DSF (moving load from peaks to troughs) at scale could significantly flatten the curve of the country's electricity load, reducing demand at peak times by up to 1,900 MW and increasing it at off-peak times.

The graphs below show what happens to the distribution of load when the full potential of DSF is applied to 2023 and 2040 for both gross and net demand (gross demand minus non-dispatchable generation). These graphs show national demand on the horizontal axes and a count of the number of periods with the associated demand on the vertical axis; a high value on the vertical axis indicates that the associated load level is common and a low value indicates that it is a less common load level.

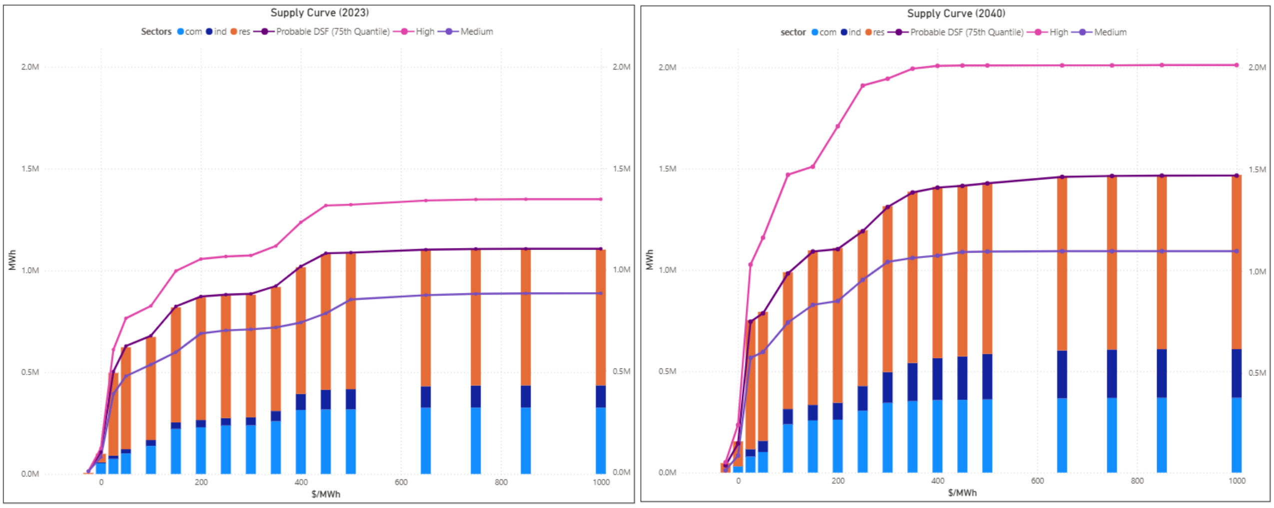
In all four graphs below, the distribution of load is compressed towards the middle of the chart by the application of DSF, i.e. very high and very low load is made less common and moderate load is made more common, representing a more stable power system load profile over time, which is generally easier to supply and manage.

Figure 1 Demand distribution before and after DSF



Generally, when load is shifted, there is a reduction in wholesale costs, however this may not be sufficient to cover the full cost of DSF. The model used in the study represents this gap as a 'procurement price' which represents the additional payments (e.g. incentives) needed to make an investment in flexibility capacity economic. The study's supply curves (below) illustrate the range of energy available from DSF at varying procurement price/incentive levels, providing valuable insights to compare with other options for meeting peak load. The model estimates that based on 2023 data, approximately 1,350 GWh of energy (roughly 3% of annual energy demand) could be accessed at a procurement price of less than $500/MWh, with the residential sector contributing the largest share, followed by the commercial and industrial sectors. By 2040, with the increased electrification of industrial processes and decreasing costs of technologies such as batteries, the maximum available shiftable energy for under $500/MWh increases to almost 2,000 GWh.

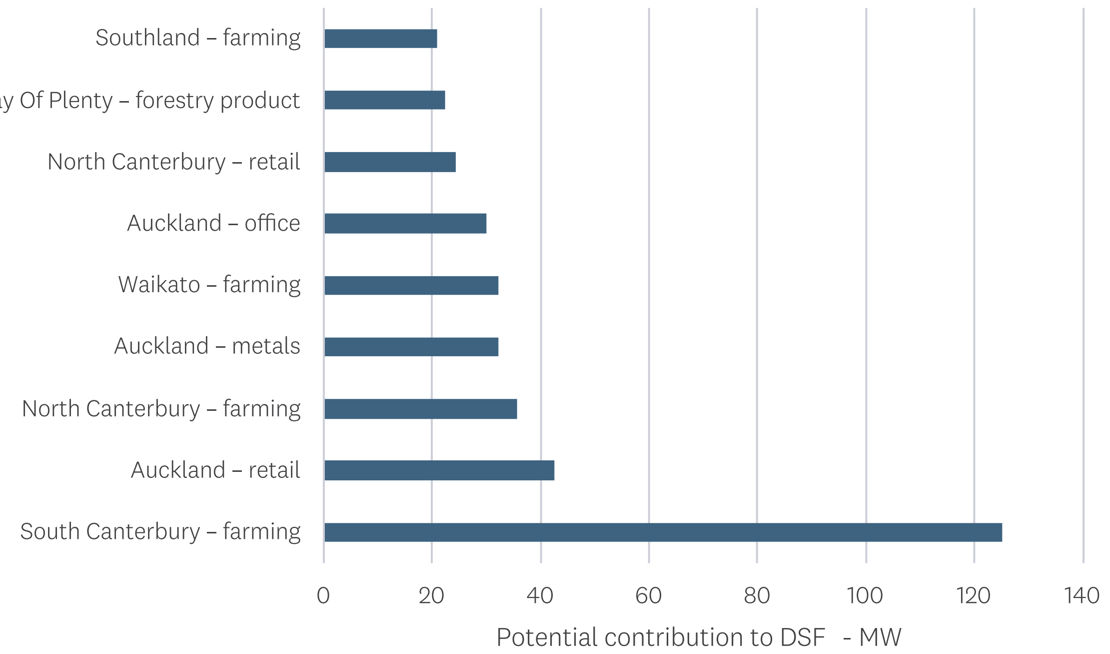
Figure 2 Shift supply curve - 2023 & 2040



Regionally, the residential sector offers the largest shift potential across the main centers due to its load shape having a strong correlation with national load. Some industrial sectors also stand out in specific regions. For instance, farming shows significant potential in Canterbury, forestry in the Bay of Plenty, Gisborne, Hawkes Bay, and Manawatū, and metals in Auckland and Southland. These regional variations highlight the importance of tailored approaches to DSF implementation that consider local industry characteristics and load profiles.

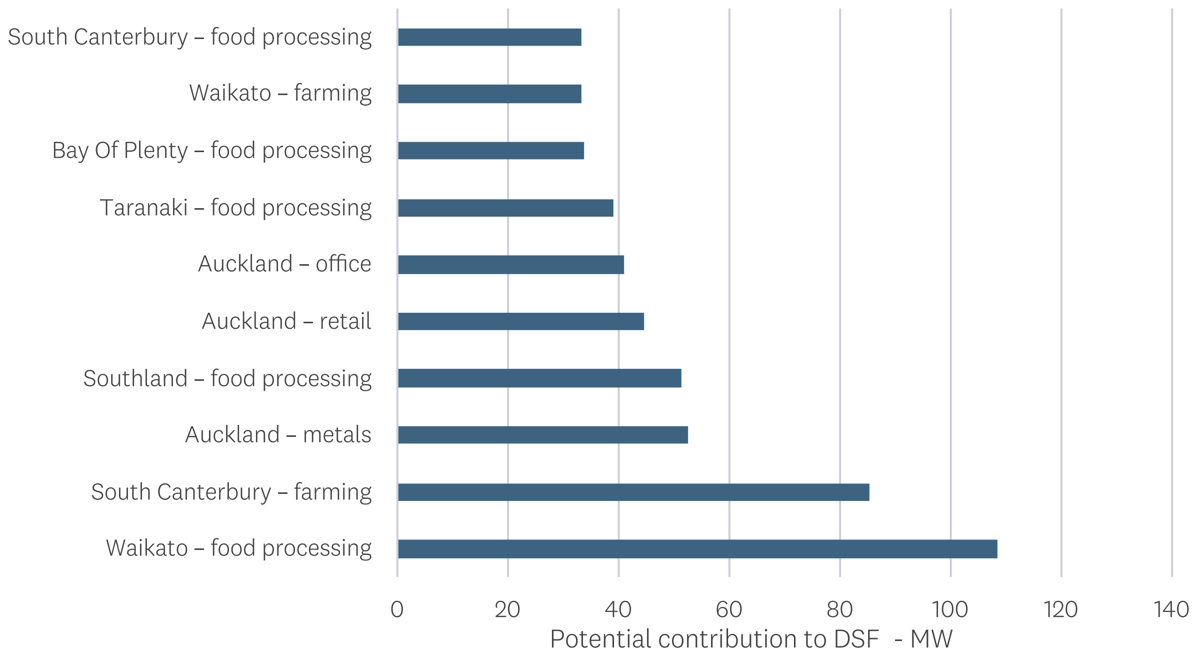
The graphs below show that - outside the residential sector in the main centres - the top ten potential contributors to DSF from the 2023 analysis were farming - particularly in South Canterbury - retail and offices in the large main centres, metals in Auckland, and forestry products in the Bay of Plenty. The primary drivers of this potential are the magnitude of the demand and how well it coincides with the national peak the national load profile.

Figure 3 Potential contribution to DSF by region and sector in 2023 - top 10



By 2040, the electrification of process heat - particularly in food processing - pushes farming and commercial loads out of the top ten contributors in some regions and provides good DSF opportunities across Waikato, Southland, Taranaki, the Bay of Plenty, and Canterbury.

Figure 4 Potential contribution to DSF by region and sector in 2040 - top 10



The study highlights the importance of better understanding both technical potential and real-world constraints, such as consumer willingness to participate, the costs of implementing DSF technologies, and the need for additional payments to trigger investment in them.

Stakeholder surveys of large industrial users of electricity and electricity distribution businesses revealed a broad range of views on the potential of DSF generally, and for individual businesses. Surveys revealed potential bias arising from differences in knowledge and experience on DSF, as well as concerns about the practicalities of integrating DSF with inflexible production processes and contractual expectations. These responses highlighted that maintaining production is the key priority for most industrial load customers and that DSF that reduces productivity faces some challenges being broadly accepted in the sector.

To encourage large-scale demand-side flexibility across the industrial sector, it will be important that the education piece is a "two-way street" with the policy, regulatory, and programme management agencies learning from the industrial sector participants as much as the other way around. Clarifying that DSF includes options that would not impact production, such as batteries (albeit at a relatively high cost), could reduce some of the bias against DSF in the industrial sector. Similarly, the development of DSF incentive programmes would benefit from greater understanding and appreciation of the technical and commercial constraints on shifting or reducing production and the associated costs to the industrial consumer. The survey responses go some way to addressing this by providing responses about which end uses industrial users currently consider flexible, but more work could be done in this area.

Background and methodology

DSF can offer numerous benefits to the electricity system and its stakeholders - electricity consumers, network operators, distribution utilities.

It enhances grid stability by helping balance supply and demand, reduces costs by deferring or avoiding investments in generation and network infrastructure, and facilitates the integration of variable renewable energy sources. DSF empowers consumers to actively participate in the electricity market, allowing them to optimise when and how they use electricity thereby reducing their energy costs. By smoothing demand peaks and filling valleys, it improves overall system efficiency and can contribute to reduced greenhouse gas emissions by optimising the use of renewable energy and reducing the need for peaking plants.

DSF can be classified into three main categories: storable, shiftable, and curtailable loads:

Storable loads include technologies like batteries and thermal storage systems that can store energy for later use.

Shiftable loads are appliances or processes that can be rescheduled, such as washing machines, dishwashers, or certain industrial processes.

Curtailable loads can be temporarily reduced or interrupted, like some industrial operations.

Each category offers different levels of flexibility and response characteristics, making them suitable for various grid management applications. This study compiled a comprehensive electricity load dataset covering all consumer electricity demand connected to the New Zealand electricity market. The dataset is disaggregated based on ANZSIC (Australian and New Zealand Standard Industrial Classification) codes, aggregated to regional level, and collected at 30-minute intervals for at least one year. Data sources included electricity retailers and the Electricity Market Information (EMI) system, with scaling methods used to estimate missing data, particularly for residential loads. This unique dataset provides a solid foundation for analysing and forecasting DSF potential across different sectors and regions of New Zealand.

The DSF model developed for this study (and made available for future applications and development) uses pre-determined load profiles to estimate DSF potential. The model identifies signals to shift load and incorporates economic assessment to determine which DSF resources are economically viable. The model considers three scenarios to capture uncertainty, providing a nuanced view of potential outcomes.

In conclusion, this analysis and accompanying DSF model reveal very significant potential for demand-side flexibility in New Zealand's electricity market. Realising this potential will require addressing behavioural, technological, regulatory, and market challenges. The insights provided can inform policy decisions, market design, and investment strategies to enhance the flexibility and efficiency of New Zealand's electricity system. As the country continues its transition towards a more secure, affordable and sustainable energy system to support our economy and society, demand-side flexibility is poised to play an essential role in optimising the efficiency and value of the existing grid infrastructure. By doing this, DSF helps the NZ electricity system maintain grid stability and improve grid security while putting downward pressure on electricity prices and facilitating the integration of renewable energy sources.

3 Acknowledgements

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

Respondents

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

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4 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 Berkeley 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
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

5 Purpose of this report

This report summarises the more detailed accompanying reports and draws insights and recommended future work.

The report is structured as follows:

- Introduction to demand-side flexibility in New Zealand
- Load data collection and processing: This section covers the load data collection approach and processing that formed the basis for the demand-side flexibility modelling.
- Modelling methodology: This section documents the modelling methodology and development process.
- Modelling outcomes: This section presents modelling outcomes.
- Implications for DSF programme development

6 What is demand-side flexibility?

Demand-side flexibility (DSF) refers to the ability of electricity consumers to adjust their consumption patterns in response to external signals, such as price changes or grid conditions. It is an integral component of modern electricity systems, enabling better integration of renewable energy sources, improving grid stability, and potentially reducing the need for additional generation and network capacity. DSF can be achieved through various means, including load shifting, peak shaving, and valley filling, all of which contribute to a more balanced and efficient electricity system. DSF is already being deployed in many electricity systems globally and has demonstrated significant benefits. Additional information is available in the accompanying Literature Review report.

DSF can be classified into three main categories based on the nature of the load: storable, shiftable, and curtailable.

> ***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.
>
> ***Curtailable loads:*** Loads that cannot be shifted, either due to consumer comfort requirements or because shifting is not possible, such as room lighting. However, curtailable 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.

Demand-side flexibility (DSF) offers a range of significant benefits to the electricity system and its various stakeholders. At its core, DSF enhances grid stability by providing a mechanism to balance supply and demand more effectively. This enables more efficient use of existing infrastructure which means the electricity system can defer or even avoid costly investments in additional generation capacity and network upgrades. This is the biggest benefit from DSF, and this cost-saving potential extends to consumers, who may see lower electricity prices because of reduced system costs and the opportunity to participate in DSF programs. Furthermore, improved supply-demand balance can lead to a reduction in the frequency and severity of power fluctuations, potentially decreasing the risk of blackouts and improving overall power quality.

Table 1 Benefits and beneficiaries of demand-side flexibility

PARTY	BENEFITS
TSO/DSO	Avoided investments
TSO/DSO	Avoided grid losses
TSO	Provision of peak capacity
TSO	Balancing services
TSO	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

Another important benefit of DSF is its role in facilitating the integration of variable renewable energy sources into the grid by ensuring the introduction of more renewables can be achieved at an attractive price point for energy users. As variable renewable sources such as wind and solar become the default technologies for generation, intermittency of these sources presents challenges for grid management. DSF provides a valuable tool to address these challenges by allowing demand to be shifted to periods of high renewable generation, thereby maximising the utilisation of these clean energy sources, and reducing reliance on fossil fuel-based peaking plants. This not only avoids environmental harm by reducing greenhouse gas emissions but also contributes to energy security by decreasing dependence on imported fuels and reduces costs for consumers.

Beyond these system-wide benefits, DSF empowers consumers by giving them an active role in the electricity market. Through participation in DSF programs, consumers can potentially reduce their energy costs by shifting their consumption to periods of lower prices or by providing flexibility services to the grid. This increased engagement can lead to greater energy awareness and potentially drive further efficiency improvements. Additionally, for industrial and commercial consumers, DSF can offer new revenue streams and enhance competitiveness by optimising energy costs. On a broader scale, the implementation of DSF can stimulate innovation in energy technologies and services, fostering the development of a more dynamic and responsive energy ecosystem that is better equipped to meet the challenges of a rapidly evolving electricity landscape.

7 Current state of demand-side flexibility in the New Zealand electricity market

New Zealand's electricity market has been making strides in implementing demand-side flexibility (DSF), although significant untapped potential remains. Our electricity system's unique characteristics, including its high proportion of renewable energy (predominantly hydropower) and nodal pricing system, create both opportunities and challenges for DSF implementation.

One of the most notable developments in New Zealand's DSF landscape is the agreement between New Zealand Aluminium Smelters (NZAS) and Meridian Energy. This arrangement, established in 2024, allows NZAS to reduce its power consumption during periods of high demand or low supply, potentially providing up to 185 MW of flexible capacity to the grid. This agreement represents a significant step forward in large-scale industrial demand response and demonstrates the potential for similar arrangements with other large industrial consumers.

Transpower ran a demand response program from 2015 to 2020. This program allowed large consumers to offer load reductions, primarily in response to Transpower's outage requirements. Additionally, Transpower has developed FlexPoint, a Distributed Energy Resources Management System (DERMS) that aims to provide a platform for DER providers and flexibility traders to register their services and respond to grid needs.

For smaller commercial and industrial consumers, platforms like SimplyFlex, launched by Simply Energy in 2023, are making it easier to participate in demand response by aggregating load from multiple participants enabling the flex service to be monetised via energy and ancillary markets such as the 13 MW of interruptible load that Open Country Dairy offers through the programme. SimplyFlex is helping to unlock DSF potential among consumers who might otherwise find it challenging to engage in the demand response market individually.

The FlexTalk programme has been refining and demonstrating the necessary communication and data exchange protocols to enable widespread integration of smart devices with the electricity system.

The residential sector in New Zealand has long been engaged in a basic form of DSF through ripple control hot water, which allows distribution companies to manage hot water heating loads, which provides 150-200 MW of DSF. Ripple control has provided reliable hot water load management options for several decades and, while the equipment is aging and the proportion of national hot water load connected to ripple control is decreasing, it could continue to do so for the near-to-medium term. In the longer term, however, we would expect that hot water load control will be integrated with modern smart grid technologies, presenting an opportunity for modernisation and enhanced flexibility.

However, several challenges remain. The regulatory environment for DSF is still evolving, with the Electricity Industry Participation Code not yet providing specific mechanisms to facilitate DSF growth. The recent introduction of the first standardised flexibility product (the super-peak contract) in January 2025 represents a step towards improving price signals for flexibility services, but further regulatory development is needed, including standardisation of communications and services, and clarification of the potential revenue streams available to DSF providers. Awareness and adoption of DSF among consumers and businesses remains limited.

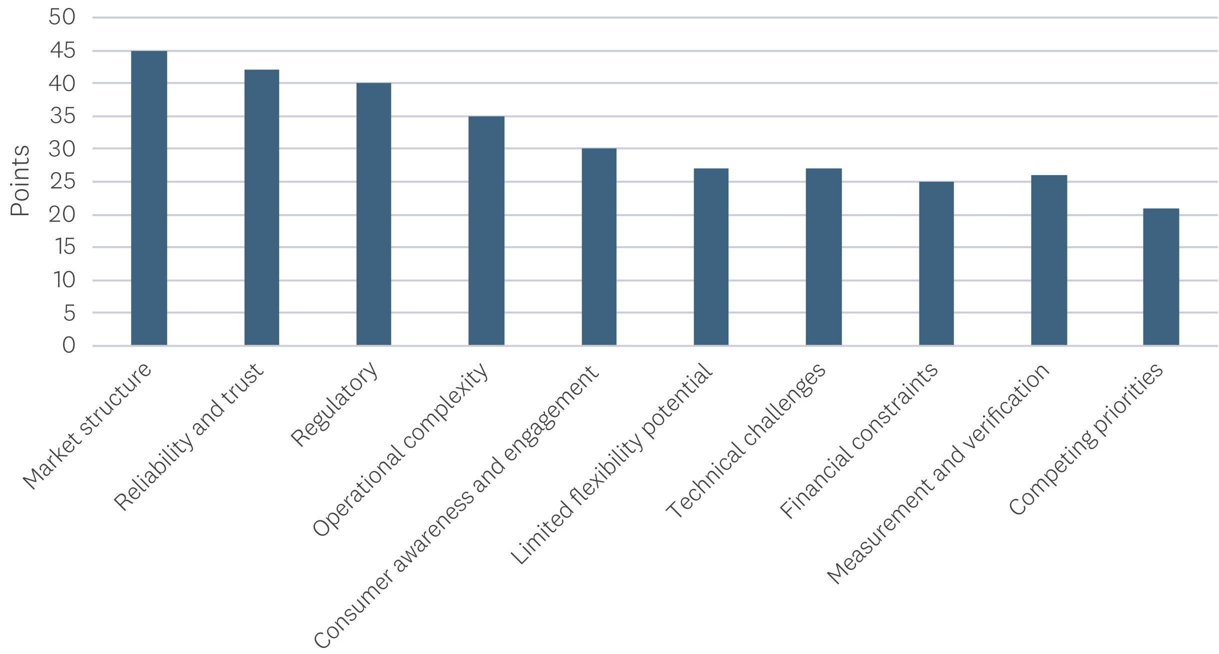
Looking ahead, several factors present opportunities for growth in DSF. The increasing penetration of variable renewable energy sources in New Zealand's electricity system will drive greater need for flexibility. The ongoing growing demand for electrification of transport and heat sectors will create new opportunities for flexible loads. Technological advancements in communication, control, and energy storage are making DSF more accessible and cost-effective.

In conclusion, while New Zealand has made good use of ripple control hot water historically and has made significant progress in implementing DSF, particularly in large-scale industrial applications and through innovative platforms for smaller consumers, there remains considerable untapped potential. Addressing regulatory, technological, and awareness barriers will be essential for unlocking the full benefits of DSF in New Zealand's evolving electricity landscape.

8 Barriers to greater uptake of demand-side flexibility

The stakeholder surveys and literature review conducted as part of this study have revealed several significant barriers to the widespread adoption of demand-side flexibility (DSF) in New Zealand's electricity market. These barriers can be broadly categorised into technological, behavioral, and regulatory/market-related challenges.

Figure 5 EDB's ranking of obstacles to greater uptake of DSF



Technological Barriers

One of the primary technological barriers identified is the lack of standardised communication protocols for appliances and energy management systems. This issue was highlighted in both the literature review and the surveys of Electricity Distribution Businesses (EDBs). The absence of common standards makes it difficult and costly for energy service providers to integrate various devices and systems, hindering the scalability of DSF solutions. EEA and EECA's FlexTalk project in New Zealand, which focuses on active managed charging of electric vehicles, emphasised the importance of open communication standards for enhancing interoperability and real-time data exchange. Furthermore, in 2025 the Flex Talk project completed a small-scale test of the installation and functionality of devices in homes. The project's next step is a large-scale trial of in-home smart devices and consumer energy resources to manage flexibility on the electricity network.

Another significant technological challenge is the limited adoption of smart appliances and enabling technologies. While smart meters have been widely deployed in New Zealand, the uptake of other technologies such as home energy management systems, smart thermostats, and controllable loads remains low. This gap was evident in the industrial survey, where only 40% of respondents reported using energy management systems, and even fewer (21%) had onsite renewables or energy storage systems. The literature review suggests that widespread adoption of smart appliances is essential for seamless integration and automated handling of DSF delivery.

Behavioral Barriers

The stakeholder surveys revealed significant behavioral barriers among industrial consumers and some EDBs. The most prominent issue is the prioritisation of production continuity over energy flexibility. Most industrial respondents indicated that their operations are not sensitive to electricity prices and must continue regardless of energy costs. This “production first” mentality limits the willingness to participate in DSF programs, especially if there is any perceived risk of disruption to core operations.

Lack of awareness and understanding of DSF benefits is another key behavioral barrier. While about half of the industrial respondents were familiar with demand response, there was a general reluctance to shift energy usage. This reluctance stems from a combination of factors, including perceived complexity of DSF programs, concerns about data privacy, and uncertainty about the potential benefits. The literature review corroborates these findings, suggesting that many consumers find DSF programs difficult to understand and sign up for, and may hold misconceptions about data collection.

The surveys also highlighted a divide in the perception of DSF benefits between those actively engaging in DSF programs and those who don’t. Active participants generally perceived greater benefits from DSF, suggesting that experience with DSF programs can positively influence attitudes. However, convincing non-participants to take the first step remains a challenge and it is likely that the active participants had positive views of DSF before they were active participants which led them to becoming more involved.

It is important to recognise that behavioral barriers to greater uptake of demand-side flexibility (DSF) among industrial consumers are not solely a matter of education or awareness. While informational campaigns and training programs can play a role in improving understanding of DSF concepts and benefits, they may not address the fundamental economic and operational realities faced by many industrial consumers. The stakeholder surveys in this study revealed a clear “production first” mentality among industrial respondents, with most indicating that their operations must continue regardless of electricity prices. This prioritisation of production continuity over energy flexibility is not simply a result of lack of knowledge, but rather a rational response to the specific market conditions and production processes these businesses operate within.

For some industrial consumers, the potential disruption to their core operations posed by DSF participation may outweigh the benefits unless it did not interrupt production at all, e.g. a battery. The nature of certain industrial processes, particularly those that are continuous or highly sensitive to interruptions, may make it technically infeasible or economically unviable to adjust operations in response to grid signals. Furthermore, in industries where profit margins are thin or where there is intense competition or rigid production contracts, the financial incentives offered by current DSF programs may not be sufficient to offset the risks and costs associated with altering production schedules or investing in flexible technologies. It is therefore essential to acknowledge that, for some industrial consumers, limited participation in DSF may be considered a business decision rather than a result of information deficiency. This understanding should inform the development of DSF policies and programs, encouraging a more nuanced approach that considers the diverse operational constraints and economic realities of different industrial sectors.

Regulatory and Market Barriers

The literature review and stakeholder surveys identified several regulatory and market-related barriers to DSF uptake. One of the primary issues reported was the current market structure, which was ranked as a top obstacle by EDB respondents.

The lack of clear legislation and standardised contracts for DSF participation was another barrier highlighted in the literature review. This uncertainty around market structure can make it difficult for potential DSF providers, especially smaller consumers and aggregators, to assess the risks and benefits of participation. The EDB survey responses echoed this concern, with respondents calling for industry collaboration and government incentives to better implement DSF.

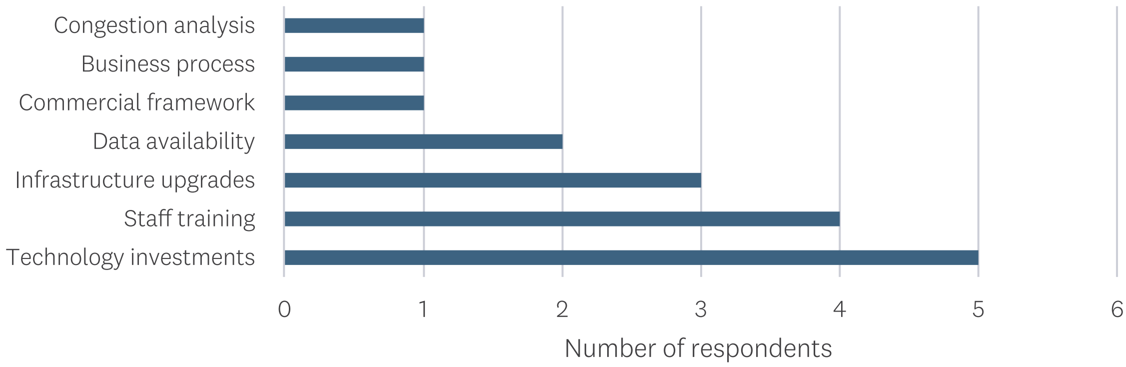
Pricing mechanisms and incentive structures were also identified as potential barriers. While many industrial respondents indicated a willingness to explore alternative pricing mechanisms, the current structures often don't provide sufficient economic incentives for DSF participation. This is particularly true for industrial consumers, who require significant financial motivation to consider adjusting their operations for DSF purposes.

The literature review pointed out that in some jurisdictions, system operators' lack of trust in DSF services is a barrier to growth. While this wasn't explicitly mentioned in the New Zealand context, it could be a factor influencing the slow integration of DSF into system operations.

Infrastructure and Capacity Limitations

One third of the EDBs that responded were of the view that none of their load was currently DSF enabled and five out of six cited technology investments as key upgrades needed to increase uptake of DSF in their network, closely followed by staff training and infrastructure upgrades.

Figure 6 Developments needed to increase DSF uptake - EDB responses



Overcoming these barriers will require a multi-faceted approach. Technological barriers could be addressed through the promotion of open standards and incentives for smart appliance adoption. Behavioral barriers might be mitigated through education campaigns, simplified DSF programs, and demonstration projects that showcase the benefits of DSF. Regulatory and market barriers could be tackled through policy reforms that provide clear frameworks for DSF participation and compensation, improve market access for aggregators, and create more attractive incentive structures.

The industrial sector may require tailored solutions that can unlock flexibility potential without compromising critical operations. This could involve focusing on non-critical processes, developing more sophisticated energy management systems, or creating innovative financial products that better balance the risk-reward profile of DSF participation.

Addressing these barriers will be essential for realising the full potential of DSF in New Zealand's electricity market. As the country continues its transition towards a more renewable and flexible energy system, overcoming these challenges will be essential for creating a more efficient, stable, and sustainable electricity network.

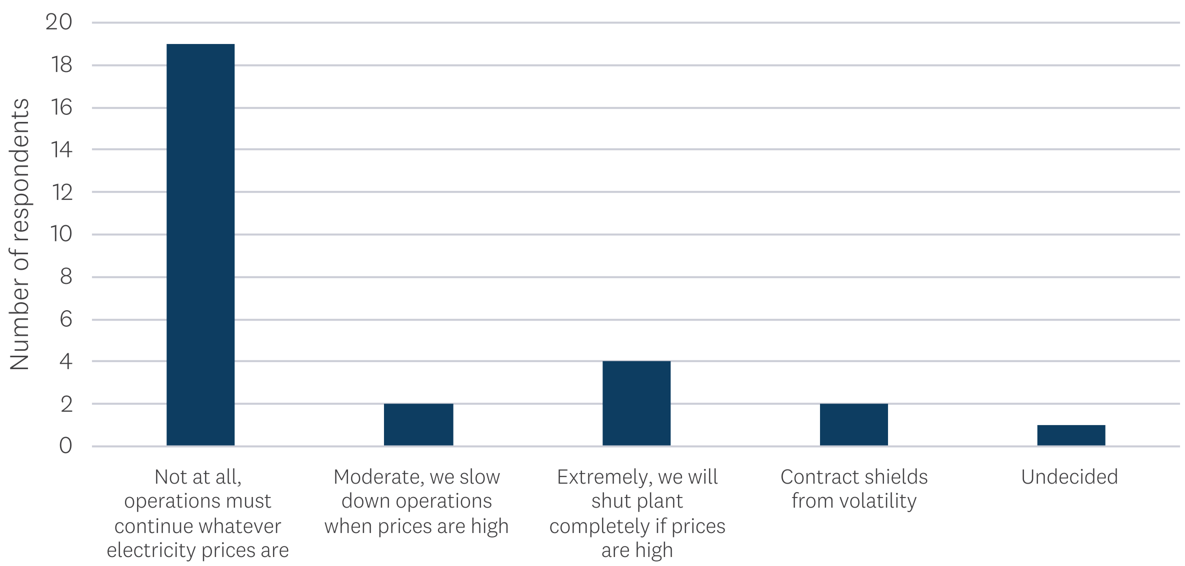
9 Stakeholder views

The purpose of the stakeholder surveys was to gather insights from a diverse range of industrial sector stakeholders and Electricity Distribution Businesses (EDBs) to complement the data analysis and modeling in the broader study of demand-side flexibility (DSF) in New Zealand's electricity market. These surveys aimed to capture the perspectives, experiences, and challenges of both end-users who would implement DSF and the EDBs who might launch programs to incentivise DSF participation.

By engaging with these key stakeholders, we sought to evaluate the current state of demand response, identify barriers and enablers for DSF implementation, and gain a more nuanced understanding of the potential for DSF across different sectors and regions. The surveys were designed to provide valuable context and real-world insights that would inform the development of recommendations for unlocking the full potential of DSF in New Zealand, ultimately contributing to the creation of a more flexible, efficient, and sustainable electricity system for the country.

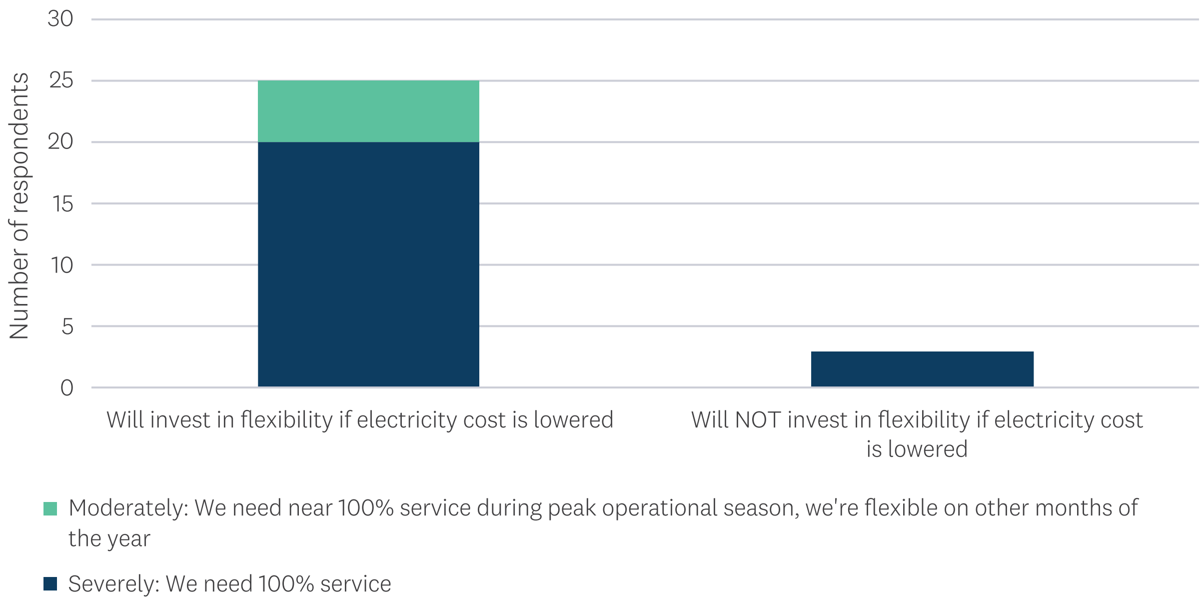
For industrial users, the survey revealed that production continuity is the top priority, with most operations running 24/7 and being insensitive to electricity prices.

Figure 7 Self-reported electricity price sensitivity



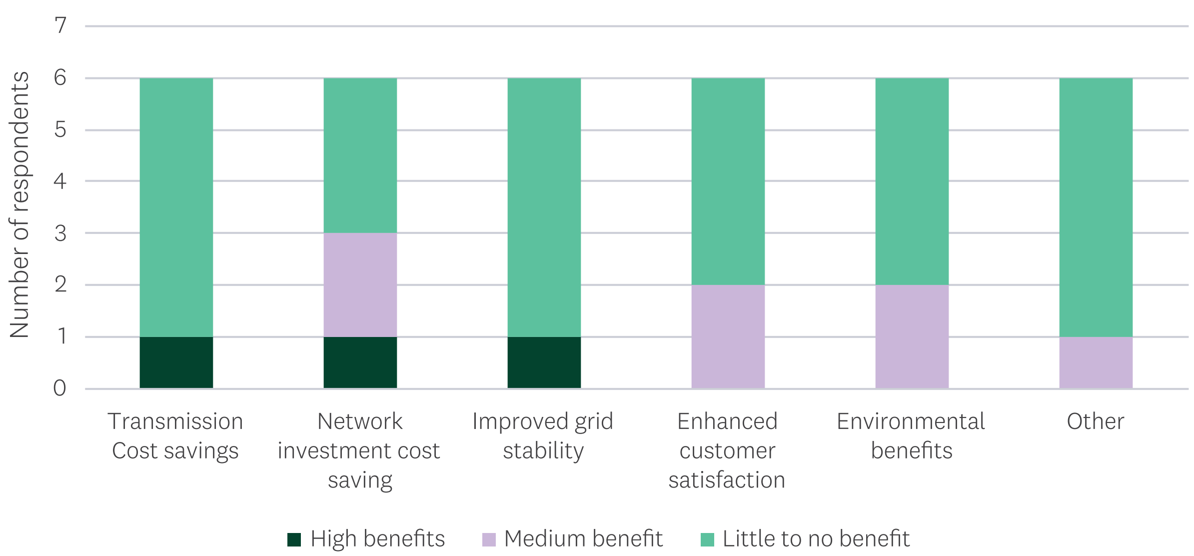
While there is a perception of limited flexibility in shifting loads, many respondents expressed openness to exploring DSF if it does not disrupt production and if the financial incentives are attractive. Once industrial participants start exploring DSF, it is possible to discover greater flexibility in shifting some loads that may currently be perceived as inflexible. The survey identified potential areas for DSF implementation, such as water heating and pumping, and highlighted the need for tailored solutions that address each industry's specific operational requirements

Figure 8 Willingness to invest in DSF combined with impact of disruption on production



EDB responses indicated a mixed level of experience with DSF programs, with half of the respondents having implemented such initiatives. While current DSF potential is perceived as low, EDBs demonstrated familiarity with various DSF technologies and incentive mechanisms, such as ripple control and time-of-use pricing. The survey revealed that most EDBs have limited capacity to support DSF, with only one respondent able to support DSF for 100% of their load. To enhance DSF capabilities, EDBs identified technology improvements and staff training as key investment areas.

Figure 9 EDB views of benefits gained from EDB programmes



Both industrial users and EDBs identified several barriers to DSF implementation. For industrial users, the main challenges were operational inflexibility and potential production disruptions. EDBs cited market structure and reliability/trust issues as significant obstacles. However, both groups showed willingness to engage in DSF programs if system-wide adoption issues are resolved and appropriate incentives are in place. EDBs particularly emphasised the need for industry collaboration and government incentives to better implement DSF.

The survey highlighted some divergent perspectives between current DSF participants and non-participants, with active participants perceiving greater benefits from DSF programs. Looking ahead, EDBs anticipate changes in the DSF landscape, expecting distributed storage and electric vehicles to play larger roles by 2040.

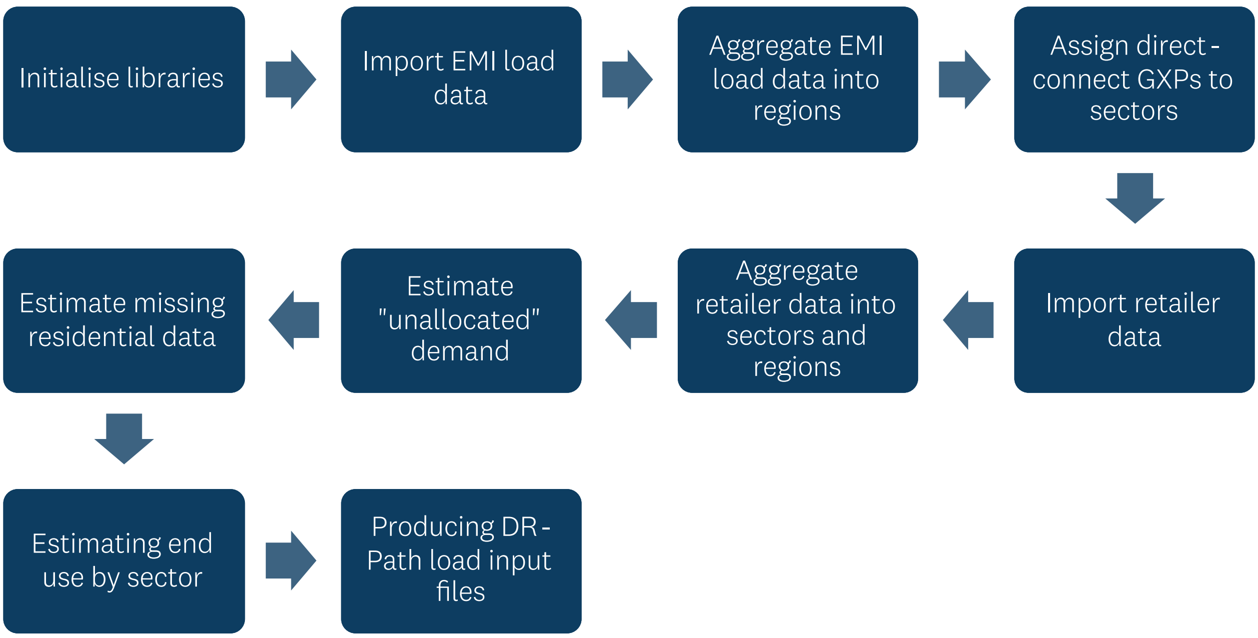
10 Load data collection

The data collection process for this study aimed to create a comprehensive and detailed dataset of electricity consumption across New Zealand. The primary objective was to build a load dataset that was collectively exhaustive, mutually exclusive, and disaggregated by sector, region, and time at 30-minute intervals. To achieve this, data collection primarily relied on electricity retailers, who were best positioned to provide consistent information meeting the required criteria due to their geographical spread and billing roles.

We requested half-hourly demand data from several retailers, classified according to region (based on the Regional Energy Transition Accelerator definition) and sectors (largely based on the 2006 Australian and New Zealand Industry Classification, with the addition of a residential category). To ensure completeness, we also collected data from the Electricity Market Information (EMI) system, which provided a comprehensive reference point for all demand and included direct-connect industrial loads not captured in the retail data. This EMI data was used to identify and fill gaps in the retailer-provided information.

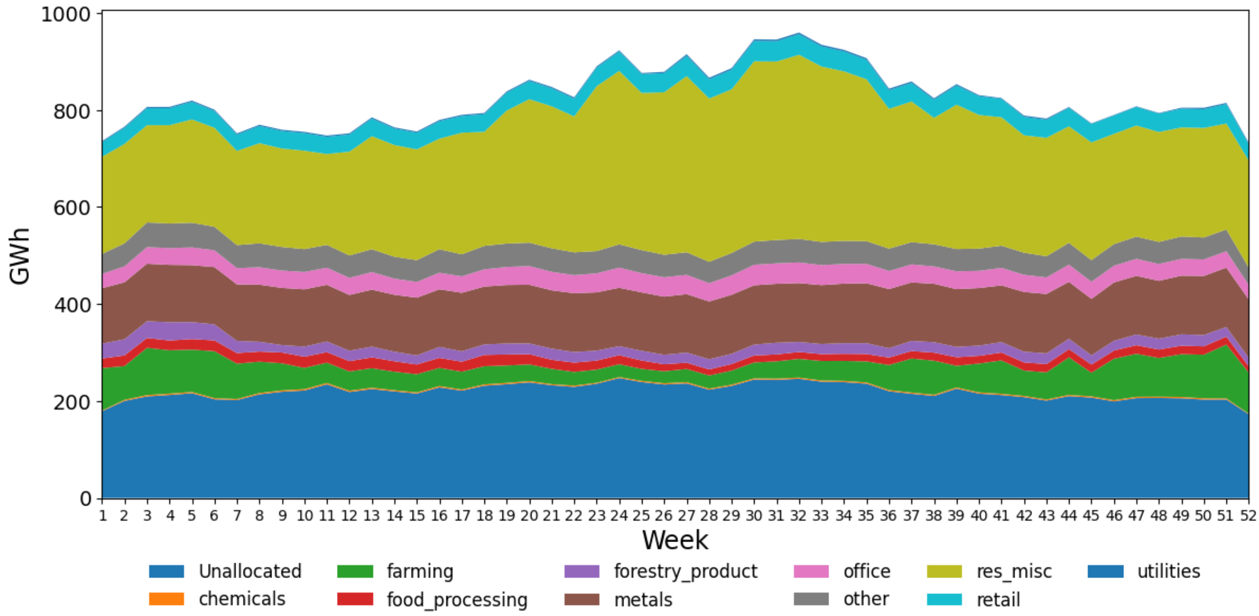
The data collected underwent extensive processing to ensure consistency and accuracy. This included aggregating load by datetime, region, and sector, and addressing issues of double-counting between EMI and retailer data. Where data was missing, particularly for residential loads, the team employed scaling methods based on known residential ICP (Installation Control Point) counts to estimate the full residential demand.

Figure 10 Load data processing schematic



The result was a unique dataset that, to our knowledge, is the only electricity load dataset in New Zealand meeting all their specified criteria, covering a full year at 30-minute resolution with comprehensive regional and sectoral breakdowns.

Figure 11 Weekly load by sector



11 Modelling demand-side flexibility potential

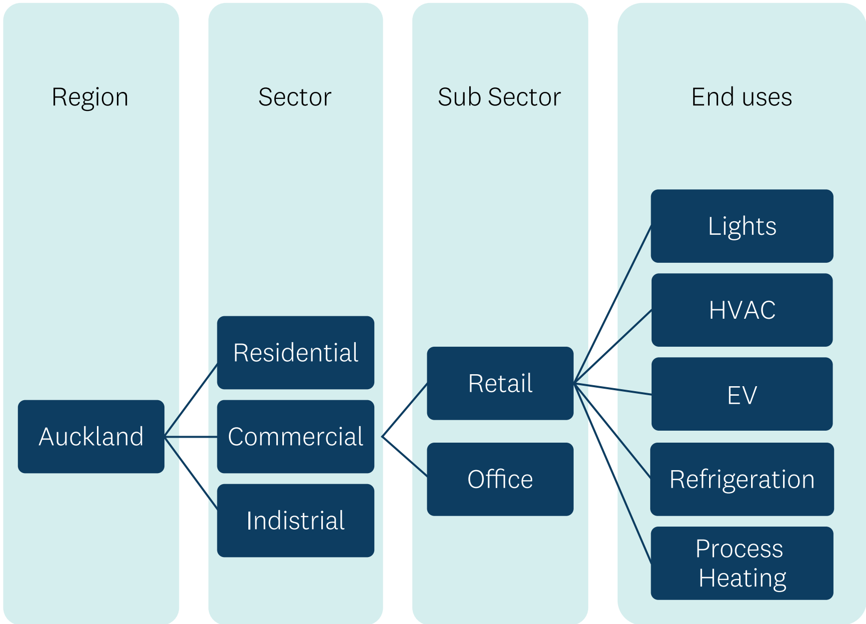
The purpose of the demand-side flexibility (DSF) model is to quantify and evaluate the potential for demand response in the New Zealand Electricity Market. It aims to estimate how much electricity demand can be shifted or reduced during peak periods, and at what cost, across various sectors and regions of the country. By simulating different scenarios and incorporating economic factors, the model provides insights into the viability and impact of implementing DSF strategies. This information aims to enable policymakers, regulators, and industry stakeholders to make informed decisions about investments in DSF technologies, design of incentive structures, and integration of DSF into broader energy market operations. The model serves as a tool to enhance the efficiency, stability, and sustainability of New Zealand's electricity system by identifying opportunities to better match electricity demand with supply, particularly in the context of increasing renewable energy integration and evolving grid management challenges.

The demand-side flexibility (DSF) modelling approach developed for this study is designed to estimate the potential for demand response based on clusters of pre-determined load profiles, using total national level demand to construct a governing DR signal. The model aggregates end-use level load profiles to create a gross national demand, from which renewable generation is subtracted to derive the net national demand used for calculating DR potential.

The model employs two main types of demand response: shed and shift. For shed potential, the model focuses on the top 250 hours of peak load in the net national-level load shape, assigning higher weights to intervals with higher net demand (adjusted for RE generation). This approach targets periods where cheaper and cleaner forms of energy have the lowest contribution, potentially offering higher value for DR resources. The shift potential, on the other hand, is calculated based on the difference between the rolling average of the net load and the actual net load, aiming to smooth out the overall demand profile. The shift potential is further refined by generating an estimated dispatch based on static price signal and constraints on shift operations.

A key feature of the model is its use of load clusters, defined as unique combinations of various subsectors within broader categories of industrial, commercial, and residential consumers, further classified by region and end use. The model currently utilises 165 such load clusters. For each cluster, the model applies the national-level DR signal to estimate the available DR potential for different end-uses, considering factors such as price signals, technical limitations, and operational constraints.

Figure 12 Load cluster hierarchy



The economic assessment of shift potential is an important component of the model. It incorporates various cost inputs, including fixed and variable capital costs, operating costs, and factors such as uptake caps and co-benefits. The model calculates a net procurement price, which represents the "missing money" or net cost required to facilitate specific levels of demand response over and above the arbitrage revenue during demand-response events and co-benefits. This information is used to generate supply curves that illustrate the energy available from shifting at different price points.

Finally, the model considers three scenarios for shift demand response: top, median, and probable outcome. The scenarios are derived based on the energy captured with in shift demand response windows across a specified number of hours. The probable outcome includes the demand response windows distributed around the 75th percentile of the captured energy. This approach helps to account for the uncertainty associated with shift dispatch and provides a range of potential outcomes. The model's outputs, including the estimated shift potential, economic viability, and supply curves, offer valuable insights for policymakers and stakeholders in understanding and leveraging the potential of demand-side flexibility in the New Zealand electricity market.

12 Key outcomes from demand-side flexibility modelling

The DSF modelling conducted in this study provides valuable insights into the potential for demand response in New Zealand's electricity market. The model estimates demand response based on clusters of pre-determined load profiles, using total national level demand to construct a governing DR signal. This approach allows for a comprehensive assessment of DSF potential across different sectors and regions, considering various end-uses and their specific characteristics. The regional DSF potential that is aligned with national DR signal will be captured by the model - however there are specific instances where DSF potential are more aligned to provide demand response for regional peaks (e.g. due to impact of inter-regional transmission constraints or due to misalignment of load shapes with the national demand profile).

One of the key findings from the modelling is the substantial potential for shift DSF to reduce the magnitude and frequency of very high and very low load periods. The model demonstrates that implementing shift DSF could significantly compress the distribution of the national gross loadshape, effectively reducing peak loads and increasing off-peak loads. This smoothing effect has important implications for grid stability and efficiency, potentially reducing the need for additional generation capacity and improving overall system reliability.

The key difference seen in 2040 DSF forecast compared to 2023 DSF is that the shift demand response predominantly moves peak demand to dispatch intervals with cheaper renewable energy. As a result, the model creates new peaks of gross load during the day, resulting in a similar distribution of gross load after DR. The remaining shift DR (outside of the ones coinciding with RE generation) can be seen in net load distributions and they compress the resulting distribution, reducing the frequency of very high and low load periods. It is important to note that models do not consider inter-regional transmission constraints which can be a major limiting factor in achieving the modeled DSF potential in 2040.

Figure 13 Gross/Net demand distribution before and after load-shifting

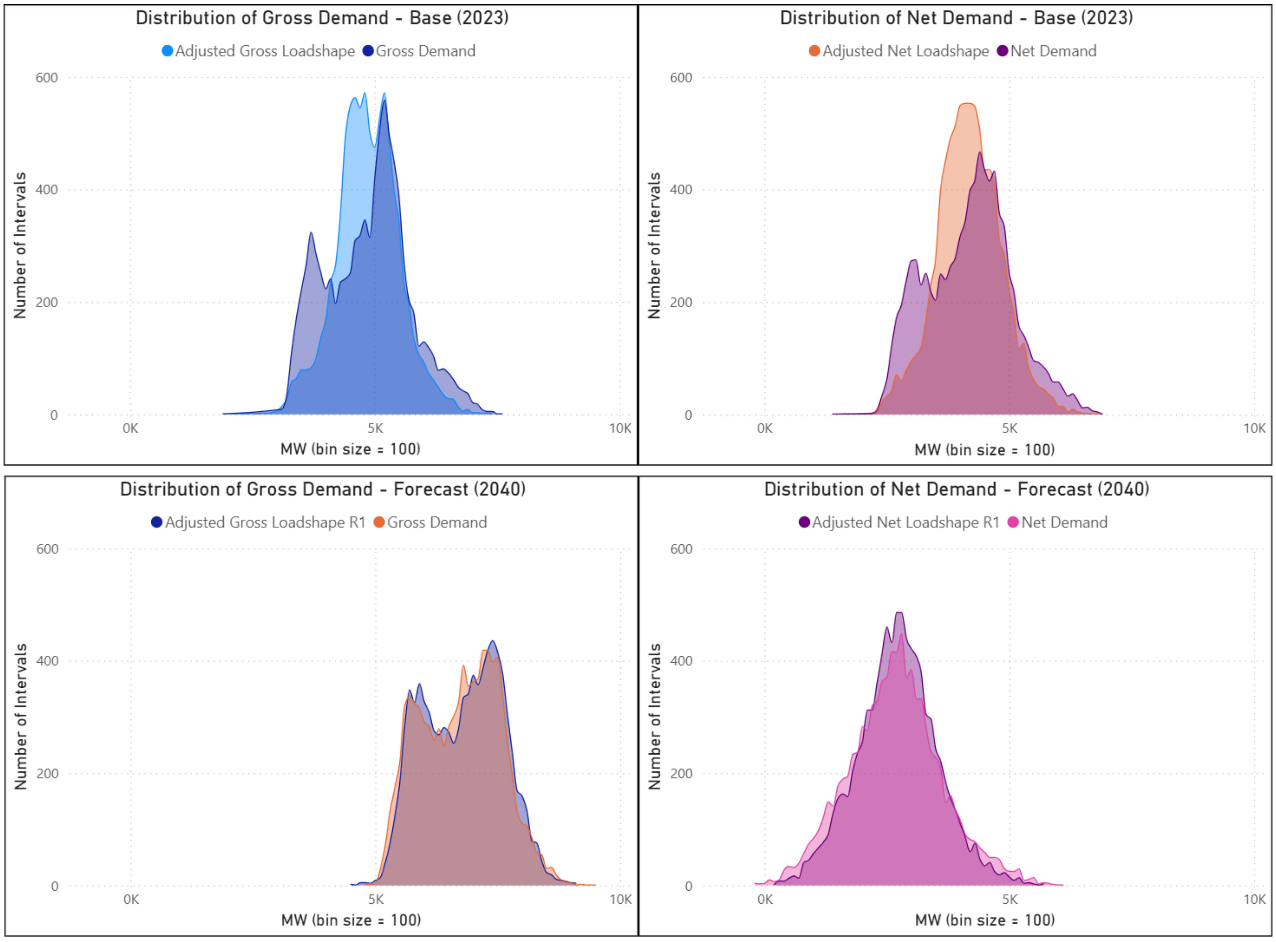
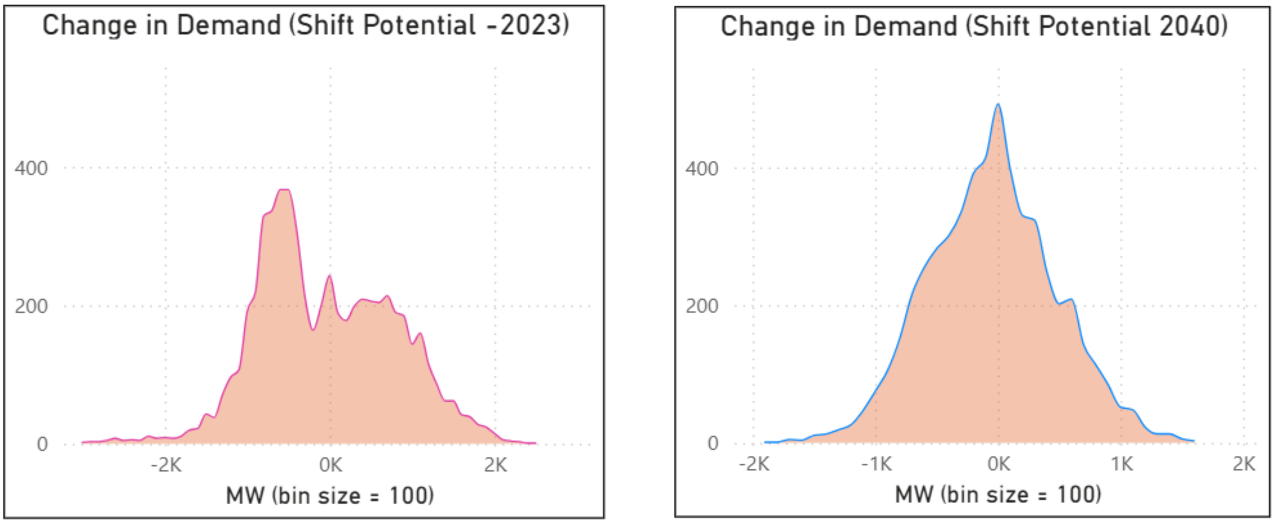


Figure 14 Shed and take distributions



The model reveals interesting patterns in shift potential across different sectors and regions. While the residential sector tends to dominate shift potential across the main centers due to its strong correlation with national load, some industrial sectors stand out in specific regions. For instance, in terms of maximum available potential, farming shows significant potential in Canterbury, forestry and food processing in the Bay of Plenty, Gisborne, Hawkes Bay, and Manawatū, and metals in Auckland and Southland.

Table 2 Max shift response

Max shift response for 75th Quantile(2023)

region	chemicals	farming	food_processing	forestry_product	metals	office	res_misc	retail	utilities
Auckland	3.88	2.71	4.19	3.66	32.34	30.13	433.40	42.63	2.61
Bay Of Plenty	0.12	5.05	18.88	22.39	0.27	3.95	5.39	2.84	0.04
Gisborne	0.02	0.29	0.35	0.28	0.04	1.31	10.90	0.90	0.05
Hawkes Bay	0.09	3.64	3.77	0.70	1.09	4.25	84.86	2.96	0.17
Manawatu_Wanganui	0.30	8.71	2.35	10.56	0.38	6.51	52.65	5.93	0.08
Nelson_Marlborough_Tasman	0.08	3.04	0.94	4.64	0.19	3.39	47.16	3.53	0.06
North Canterbury	1.38	35.63	5.17	2.30	4.48	18.84	123.34	24.41	0.25
Northland	0.05	4.44	0.29	0.38	0.29	3.73	41.38	3.01	0.05
Otago	0.23	12.91	1.37	1.23	3.68	7.49	72.53	8.81	0.47
South Canterbury	0.15	125.12	3.12	0.46	0.49	3.12	19.51	3.94	0.15
Southland	0.83	20.93	8.26	0.79	19.09	2.74	28.24	3.01	0.11
Taranaki	0.62	9.84	0.34	0.65	4.40	2.67	26.11	2.03	2.15
Waikato	0.58	32.19	5.38	2.83	5.06	12.35	146.43	9.96	0.49
Wellington	0.56	2.89	1.77	0.95	1.03	16.48	172.29	16.83	0.20
West Coast	0.01	1.37	0.03	0.01	0.14	0.75	5.93	0.87	0.04

Max shift response for 75th Quantile(2040)

region	chemicals	farming	food_processing	forestry_product	metals	office	res_misc	retail	utilities
Auckland	2.16	15.63	24.11	4.51	52.44	40.95	559.50	44.68	2.36
Bay Of Plenty	0.13	4.92	33.84	20.59	0.27	7.31	27.15	6.35	0.04
Gisborne	0.02	0.30	0.48	0.30	0.04	2.48	15.24	1.25	0.06
Hawkes Bay	0.09	4.02	3.37	0.72	0.87	5.83	101.75	3.30	0.17
Manawatu_Wanganui	0.29	9.83	31.22	12.69	0.44	13.76	71.10	6.32	0.09
Nelson_Marlborough_Tasman	0.08	3.54	1.01	5.79	0.25	5.07	60.36	4.64	0.09
North Canterbury	1.38	27.48	6.35	1.93	3.96	27.14	207.81	28.68	0.29
Northland	0.05	4.51	25.15	0.43	0.34	6.27	55.03	3.59	0.05
Otago	0.22	14.81	2.59	1.07	9.74	12.35	88.72	10.56	0.49
South Canterbury	0.16	85.20	33.22	0.38	0.48	12.46	25.47	4.82	0.18
Southland	0.54	22.23	51.29	0.51	26.20	5.50	34.85	3.66	0.15
Taranaki	0.88	11.83	39.15	0.63	3.31	4.10	36.85	2.75	2.17
Waikato	0.61	33.29	108.34	5.56	4.79	17.69	189.08	11.53	0.41
Wellington	0.63	3.71	1.55	1.16	0.94	21.49	212.99	16.71	0.24
West Coast	0.01	2.83	15.59	0.68	0.16	1.56	7.92	1.32	0.05

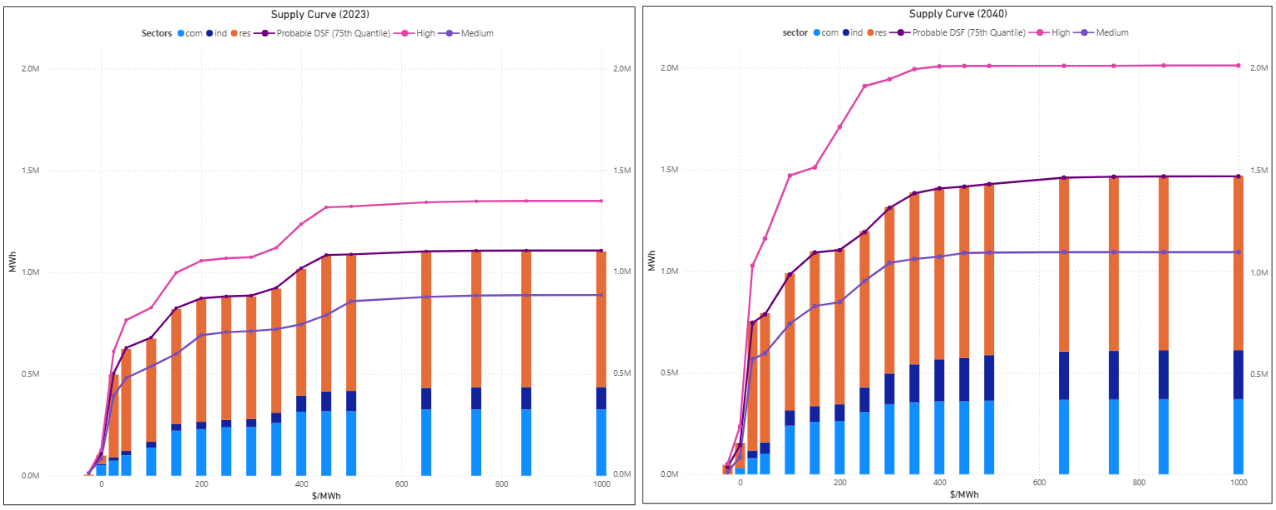
The economic assessment of DSF potential provides valuable insights for policymakers and market participants. For the base year of 2023, model estimates that a maximum of 1350 GWh of energy could be accessed at a procurement price of $500/MWh with the probable (75th quantile) DSF outcome being 1100 GWh. These prices are comparable to the operating cost of a diesel generator. The probable DSF for 2040 forecast shows an increase in the energy captured at similar procurement prices - a total of 1450 GWh can be access at $500/MWh.

The supply curves below illustrate the range of energy available from shift DR across different procurement price levels, capturing uncertainty within the limits of high - and median-energy DR windows. These findings can inform the development of pricing strategies and incentive structures to encourage DSF participation.

Note the amount available at negative or very low prices, indicating that the capability already exists or the cost is low enough that energy arbitrage during shift windows is sufficient. The assumption for existing DR in forecast year and the base year are the same. Higher procurement prices indicate more expensive DSF technologies, such as batteries, where energy arbitrage falls further short of covering the capital and operating cost of the DSF technology.

Some of the shift in procurement prices between 2023 and 2040 is driven by falling technology costs, in particular battery storage costs. For example, as battery costs fall, the revenue required in excess of spot price arbitrage during the DSF window drops, resulting in more DSF available at lower procurement prices.

Figure 15 Shift supply curves



Finally, the modelling outcomes underscore the importance of considering both technical potential and economic viability in DSF implementation. While the model identifies significant theoretical potential for demand response, realising this potential will depend on various factors, including the costs of implementing DSF technologies, the willingness of consumers to participate, and the design of market mechanisms to incentivise DSF. The model's incorporation of different scenarios (top, median, and 75th quantile of captured energy) provides a nuanced view of potential outcomes, helping stakeholders to plan for a range of possibilities in the development of DSF programs and policies.

13 Implications for development of DSF programmes

The outcomes of this study provide several actionable insights with respect to the development of programmes to encourage greater - and more efficient - use of DSF, which we classify as:

- Confirming the lowest-hanging fruit
- Improving the national dataset
- Addressing behavioural barriers
- Addressing market and commercial barriers

While addressing technical barriers is an important issue to overcome, we consider that a lot of high-value work is already being done in this area, so we will not discuss it further in this report.

Confirming the lowest-hanging fruit

DSF programmes should focus - in the first instance - on opportunities that provide a large volume of low-cost flexibility. Our modelling shows that residential DSF in the main centres provide the bulk of the opportunity, primarily due to the strong correlation with the national load. The residential DSF potential is further compounded by the fact that large residential loads (space and water heating and, increasingly, vehicle charging) are relatively simple to make flexible with smart controllers with minimal impact on service quality.

However, some regions and industries stand out as also offering significant potential. In particular:

- Food processing in the Bay of Plenty, Waikato, and North Canterbury
- Farming in Canterbury and Waikato, likely irrigation loads
- Metals in Southland and Auckland, i.e. NZAS and NZ Steel - noting that both have flexibility agreements in place
- Forestry products in Bay of Plenty and Manawatū/Whanganui
- Offices in the main centres

These load clusters should be investigated in more detail with a view to confirming the cost of accessing the DSF opportunity at a site level. This would further refine how much load is shiftable with a low-cost solution such as a smart load controller, how much would need be stored with a potentially high-cost solution such as a battery, and how much would need to be curtailed resulting in a high opportunity cost of lost production.

Improving the national dataset

This project has developed a load dataset previously unavailable in New Zealand, but the one-off nature of the collection led to some compromises where data was not available or does not exist. For example, there is not enough high-resolution end-use data to generalise to the whole economy. As flexibility characteristics are driven more by end-use than sector, this can have a material impact on the outcomes of demand-side flex modelling. Establishing a programme that meters industrial loads at the end-use level within the site would provide a great deal of value for future iterations of DSF modelling.

In addition, the model outcomes are sensitive to technical and commercial assumptions about DSF technologies, such as capital and operating cost, maximum utilisation, and co-benefits. Establishing a framework of establishing and updating this parameter set would lead to increasingly robust outcomes in subsequent iterations of this work.

Addressing behavioural barriers

It is important that addressing behavioural barriers does not focus only on educating consumers about the benefits DSF but, also, acknowledges that consumers are best placed to understand their own context the impact that has on willingness to participate.

Industrial consumers are hesitant to participate in demand-side flexibility programs due to concerns about production disruption. To address this, we can consider developing the following suite of programs:

- Gradual Implementation Program: This would allow industrial consumers to start with small, manageable adjustments to their energy consumption patterns, gradually increasing participation as they become more comfortable with the process.
- Process Optimisation Support: Offering technical assistance to help industries identify and implement energy flexibility measures without compromising production quality or output.
- Financial Incentive Scheme: Developing a robust reward system that compensates industries for their participation, potentially including both direct payments and long-term energy cost reductions.
- Risk Mitigation Fund: Establishing a fund to compensate industries for any production losses directly attributable to participation in flexibility programs.
- Education and Training Initiative: Providing comprehensive training on the benefits of demand-side flexibility and how to integrate it into existing industrial processes.
- Technology Upgrade Grants: Offering financial support for implementing smart energy management systems that facilitate easier participation in flexibility programs.
- Collaborative Research Program: Partnering with industries to conduct research on process-specific flexibility measures, addressing unique challenges in different sectors.
- Regulatory Sandbox: Creating a low-risk environment where industries can experiment with flexibility measures without fear of regulatory penalties.
- Recognition and Certification Scheme: Developing a certification program that recognises and promotes industries actively participating in demand-side flexibility.

- Data-Driven Decision Support: Providing tools and platforms for real-time data analysis to help industries make informed decisions about when and how to adjust their energy consumption.

These programs would aim to address the main concerns of industrial consumers and provide further insights for programme developers, demonstrating that participation in demand-side flexibility can be achieved without significant risk to core operations.

Addressing market and commercial barriers

Tiered incentive structure

Our modelling showed that most DSF cannot cover its costs based on energy arbitrage during DSF events alone, so would need additional revenue streams to be economically viable. The procurement price curves show the gap between the levelised cost of the technology and income from energy arbitrage increasing as the lower cost options are exhausted, providing a useful starting point for additional revenue required.

This incentive structure could take several different forms:

- Technology-Specific Rebates: Implement rebate programs for DSF-enabling technologies, with rebate amounts aligned to their potential impact and cost-effectiveness as identified in our study.
- Guaranteed shifting/shedding revenue: as with the technology-specific rebate but provide the rebate in return for shifting during DSF events.
- Performance-Based Incentives: Introduce performance-based incentives that reward consistent and reliable DSF participation, potentially through a points-based system that can be redeemed for bill credits or other benefits.
- Support to maximise co-benefits: To be considered as a first step before rebates agreed, provide support to DSF provider to ensure that co-benefits are maximised, reducing the “missing money” made up by any rebate.

Pilot programmes

Implement regional pilot programs to test various incentive structures and gather real-world data on their effectiveness in increasing DSF uptake.

Industrial DSF contracts

Create a standardised contract framework for industrial consumers to participate in DSF programs, with incentives tailored to their specific operational constraints and potential.

Regular review mechanism

Establish a mechanism for annual review and adjustment of incentive structures based on market response and technological advancements.

In combination, further work on the improvements and intervention outlines above could activate latent DSF capability and maximise the DSF capability that is already activated, contributing to a more balanced and efficient electricity system.

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