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Australian Research in Power System Transformation

Characterisation of Load for Essential Services

Topic 6 - Essential System Services

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Advitech acknowledges all First Peoples as the Traditional Owners of the lands where we conduct our business. We pay our respects to Elders past, present and emerging. As engineers and scientists, we also acknowledge the contributions of First Peoples to engineering and sustainability, both traditional and contemporary.

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Executive Summary

Australia's electricity system is transitioning to a distributed, renewable-dominated network, increasing the need for essential system services such as frequency, inertia and voltage support to be sourced from demand-side assets. Mid-sized industrial loads represent a significant but underused opportunity to meet this need. They account for a substantial share of National Electricity Market (NEM) demand, are expected to grow faster than residential electrification, and yet remain under-characterised, underserved and largely absent from demand response (DR) markets. This project, undertaken under the Australian Research in Power System Transformation (AR-PST) Stage 5 program, Topic 6: Essential System Services, addresses that gap. Drawing on qualitative engagement with 22 mid-sized industrial companies in the Hunter Valley region of New South Wales, the study develops a taxonomy of industrial load types, a dual-axis classification framework for assessing barriers and capability factors, and a scored assessment of DR participation potential across a cohort spanning 11 industry sectors and annual energy consumption between 280 MWh and 100,000 MWh, and a peak demand ranging between 100 kVA and 2,400 kVA.

Data was collected through semi-structured interviews, follow-up communications and document analysis, including electricity billing records and energy audit reports. The study-specific classification framework assesses six (6) barriers to DR participation and five (5) capability factors that support it, together with a graduated notice-period component. This produces both a composite raw score and a normalised index for each participant. The framework was applied consistently across the full cohort, with scoring decisions documented to support transparency and reproducibility.

The results show a cohort shaped more by barriers than by readiness for participation. The most common barriers were technology availability and data deficiency, each affecting 73% of companies, followed by continuous process constraints at 68%. Other barriers, including limited dynamic operating capability and restricted participation availability, were also present across approximately 50% of the cohort. On the capability side, energy use data was nearly universal, present in 95% of companies, while on-site generation limitations were identified in 64%. Despite widespread interest in demand response, only two companies in the cohort had prior or current enrolment in a formal DR program.

A central finding is that DR suitability among mid-sized industrial companies is not determined by industry sector alone. Instead, it depends on the specific combination of operational flexibility, energy awareness, data availability, and technical constraints at each site. In practice, this means no single industrial sector offers a uniformly accessible demand-response opportunity.

The study also identifies a critical commercial constraint: for labour-intensive facilities, participation incentives must cover not only the difference between peak and off-peak energy prices, but the full operational cost of a curtailment event, particularly displaced labour. For most mid-sized industrial participants, current NEM DR mechanisms do not meet this threshold. This helps explain why stated willingness to participate has not translated into active enrolment across the cohort.

The project also produced a taxonomy of 53 industrial load types across nine (9) functional categories: Mechanical, Thermal, Compressed Air, Environmental Control, Pumping and Water Systems, Testing and Specialised Loads, Fabrication, Surface Treatment, and Background Loads. Each was characterised by operating profile, control dependency and flexibility potential. Compressed air systems and pumping loads emerged as the most flexible and broadly distributed load types, making them the strongest near-term candidates for automated DR control signal mechanism, similar to the Demand Response Mode flags used under the AS 4755. Such interfaces would allow these loads to adjust their operation in response to an external demand signal, which could be issued by either a retailer or a Distributed Network Service Provider (DNSP), depending on the urgency of the service required. Retailer-led signals could be more suited to price-based or scheduled demand response, while DNSP-led. It is worth noting that this study did not investigate which entity, such as a retailer, aggregator, or DNSP, would issue such a signal; defining that governance and technical architecture is one of the key objectives of the proposed future standardisation work.

Taken together, these findings point at two constraints operating at two levels: organisational barriers within individual companies, such as inertia, labour cost, and limited internal awareness, and a separate,

market-wide constraint arising from the absence of a consistent, standardised framework for industrial DR participation. It is this second, system-level gap that prevents industrial loads to participate in ways that are accessible, measurable and reliable at scale. At present, each industrial DR integration remains a bespoke exercise, with no standardised telemetry requirements, measurement and verification protocols, or control interface specifications tailored to the Australian industrial context. Australia's existing DR standard, AS 4755, is aimed at residential appliances and does not address this gap. As a result, the lack of standardisation compounds many of the barriers identified across the cohort.

It is acknowledged that standardisation cannot resolve every barrier identified in this study. The continuous process constraint, present in 68% of the cohort, reflects a genuine operational and safety limitation that no technical or governance framework can remove. However, even within continuous-process facilities, separable and non-production loads, such as compressed air, lighting, and pumping, were consistently identified. A standardised framework would not eliminate the continuous process constraint itself, but would provide the metering, verification, and control specifications needed to identify and activate this separable fraction, an opportunity that is currently inaccessible due to the absence of any common mechanism for doing so.

Three future research priorities follow directly from these findings. First, a structured program is needed to identify and estimate demand-side sources of inertia across the NEM. Second, a small number of deep, customer-centred site engagements should move from characterisation to implementation through Level 2 Energy Audits and tailored demand-side management case studies. Third, the technical and governance foundations for a formal industrial DR standard should be developed. The taxonomy, scored assessments, barrier and capability data, and stakeholder relationships established through this study provide a strong empirical and practical foundation for that next phase of work.

Purpose

The purpose of this project is to investigate the potential for existing mid-sized industrial companies in the Hunter Valley region of NSW to provide system services into the National Electricity Market (NEM), to identify the barriers that constrain this potential, and to define the implementation pathways through which it could be realised.

The provision of services that help maintain critical operating parameters, including voltage stability, frequency regulation, and overall power quality, is fundamental to the reliable operation of any electricity network. Historically, these services have been delivered by centralised thermal generators such as coal-fired power plants. As Australia's power system shifts toward a distributed architecture, with large-scale renewable generation displacing synchronous plant, the question of how system services will be maintained is one of the central engineering challenges. Industrial loads, given their scale and geographic distribution, represent a significant and largely untapped resource for meeting this challenge.

Due to this missing understanding, industrial demand-side participation has remained a minor fraction of the assets and services under active management in the NEM. A persistent gap exists between the benefits that have been anticipated from demand-side management and what has been commercially realised. Closing this gap requires a clearer understanding of both the technical capabilities of industrial loads and the commercial, organisational, and operational barriers that prevent access to that capability.

This project addresses that need directly by delivering:

- A first-of-kind characterisation of industrial load flexibility among mid-sized companies in a representative Australian regional economy;
- A structured taxonomy of industrial load types and their inherent demand response suitability;
- A systematic assessment of the barriers and capability factors that determine a site's practical capacity to participate in Demand Response (DR) programs;
- A set of findings and recommendations intended to inform power system planners, market operators, regulators, and future researchers; and
- Publicly available outputs that can directly support ongoing industry and regulatory discussions about the future structure and operation of the NEM.

Significance

Australia's electricity system is undergoing its most significant engineering transformation since the Industrial Revolution. The progressive retirement of coal-fired generation and the rapid expansion of renewable energy capacity are reshaping the supply side of the NEM at a pace and scale with few international precedents. By 2050, close to half of Australia's electricity supply is projected to come from millions of privately owned distributed generators; a trajectory that fundamentally alters how system services must be planned, procured, and delivered.

This transition has increased Australia's energy market volatility and requires a rethinking of traditional grid management strategies to maintain system stability, reliability and efficiency in an increasingly decentralised system. In the Australian electricity market, the Australian Energy Market Operator (AEMO) is responsible for coordinating dispatch to ensure real-time balance between supply and demand; this process is inherently demand-driven. However, increasing generation variability introduces the risk of frequency and voltage instability if not properly managed, reinforcing the emphasis on the need for flexible, dispatchable resources that can respond reliably to system signals. Industrial loads, given their scale and geographic distribution, represent a significant and largely untapped resource for meeting this need.

To date, Australia has no qualitative or quantitative understanding of industrial loads operating at the megawatt level. Given the magnitude and operational flexibility across sectors, industrial load will not only be critical to the future provision of system services but must also be considered in any planning activities involving distributed energy resources. In a decentralised yet highly interconnected energy system, electricity networks must be responsive to shifting demand patterns.

Against this backdrop, the role of industrial loads in the future grid has been consistently underestimated. Research and regulatory attention over the past fifteen years has focused predominantly on residential and small-commercial Distributed Energy Resources (DER), such as rooftop solar, residential batteries, electric vehicles, and domestic hot water systems. Industrial loads, despite constituting a far greater share of total electricity demand, have been treated as too operationally complex, too commercially reluctant, or too diverse to be practically engaged. This characterisation is increasingly difficult to sustain, as AEMO's 2024 Integrated System Plan projects that industrial electrification will drive new load that is six times that expected from residential electrification more broadly (AEMO, 2024).

The significance of this research lies in what it makes possible. Without a clear, empirically grounded understanding of which industrial loads can participate in demand response, under what conditions, and subject to which constraints, system planners and market operators are unable to reliably include industrial flexibility in NEM planning. This project provides evidence-based findings that are directly relevant to power system planners seeking to quantify and integrate industrial DR capacity into supply-demand forecasts, and to market operators and regulators developing incentive structures and market mechanisms to activate demand-side participation for industrial electricity users. In addition, the finding might be relevant to standards development bodies considering the development of a formal DR framework applicable within the NEM.

This issue is not just an economic problem for companies but one that could impact the electricity system as a whole. In this study, on-site generation used as a complement to grid connection was captured as a positive capability factor because on-site generation improves DR readiness by giving the company more options to respond to a curtailment event. However, large industrial consumers struggling with high electricity costs may choose to self-generate energy behind the meter to the point of partial or full disconnection from the grid. If this trend were to accelerate or become a reality, the NEM would lose some of its most flexible and substantial demand-side assets, reducing system inertia, limiting management flexibility, and concentrating grid infrastructure costs on a smaller remaining customer base. Establishing clear and accessible pathways for industrial participation in demand response addresses one of the key economic drivers of this trend and, in doing so, contributes to the broader goal of system stability.

Roadmap

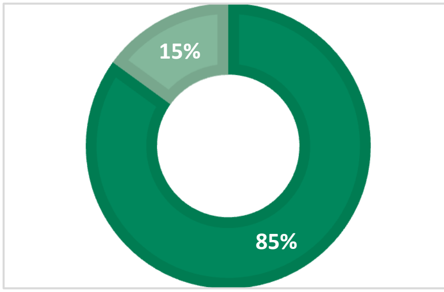
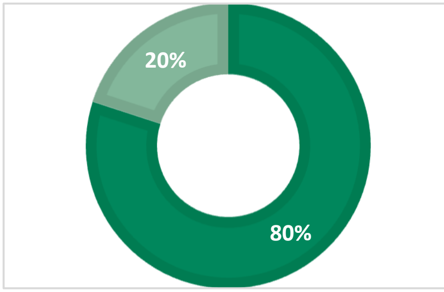
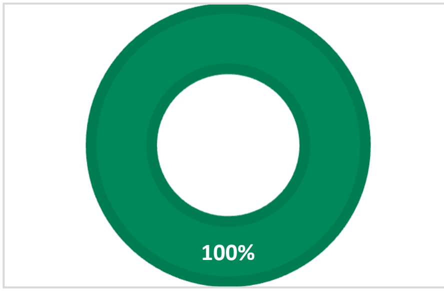
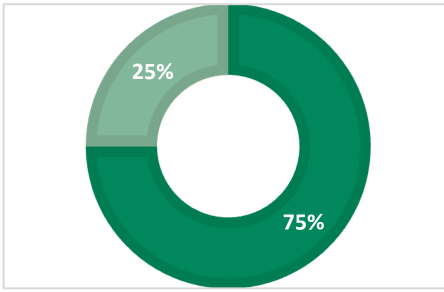
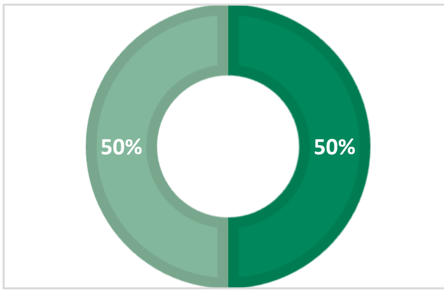
This project is conducted under the Australian Research in Power System Transformation (AR-PST) Stage 5 program, specifically Topic 6: Essential System Services. It builds directly on the body of work established under AR-PST Topics 4, 6, and 8 in preceding stages, and is positioned as the applied, industry-engaged complement to the more computational and theoretical research conducted across those topics.

The AR-PST roadmap includes significant focus on demand-side participation and the future provision of system services by distributed assets. To the knowledge of the authors, this primary research reflects the first recorded engagement with diverse industrial loads regarding their ability to unlock additional DR flexibility. It is expected that the data that is collated as the result of this project will form an important basis for any future work regarding incentive schemes for load shifting. Concretely, the research meaningfully progresses open question 1.3 from the Roadmap Topic 6 research plan, which concerns the characterisation and coordination of flexible loads as contributors to essential system services.

Earlier AR-PST stages tended to frame industrial demand-side participation as a long-horizon possibility, something achievable within ten to fifteen years, contingent on technological change and market reform. This project shifts that frame. By engaging directly with industrial companies operating today, characterising their loads as they currently exist, and assessing their DR capability against market mechanisms that are already in place, the research focuses on what is achievable over the next one to ten years, and what is required to unlock it.

Table 1 summarises progress against the key roadmap tasks and the open questions addressed by this stage of the research.

Table 1: Progress against ART-PST Topic 6 Roadmap - Stage 5

Roadmap Task	Progress in This Stage	Progress
Load Flexibility and Characterisation	Directly addressed through the engagement of industrial stakeholders and developed a taxonomy across the industrial participants.	
Industrial taxonomy of load and service classification	Taxonomy of 53 load types across 9 categories developed; operational characteristics and flexibility potential rated for each.	
Barriers to demand-side participation	Development of a scoring framework for barriers and capabilities and applied across the full participant cohort.	
Quantification of Industrial demand-response capacity	The level of DR potential from each participant was assessed via normalised scoring, and the aggregated capacity characterised by sector and load type.	
Incentives and implementation	Identified through stakeholders' engagement; forms the basis for the recommended future research work.	

Analytical Framework

Central to this research is the recognition that a business's capacity to participate in DR is not determined by a single factor, but by the interplay between conditions that constrain participation and conditions that enable it. The study therefore adopts a dual-axis analytical framework, distinguishing between barriers, factors that reduce the likelihood or feasibility of DR participation, and capabilities factors, which reflect characteristics that enhance a site's practical ability to respond. Critically, these two sets of factors are not independent: removing a barrier can unlock a latent capability, and building a capability can neutralise a barrier. A company lacking in-house energy expertise, for example, faces both an educational barrier and a data deficiency; addressing the former through targeted support can directly improve the latter, creating a compounding improvement in DR readiness.

Six (6) barriers and five (5) capability factors were identified through the stakeholder engagement process and structured into a weighted scoring framework applied consistently across all 22 participating companies. The barriers, ranging from continuous process constraints, which received the highest negative weighting, through to labour cost considerations, reflect conditions that are largely structural and may require targeted intervention to address. The capability factors, led by existing DR participation and dynamic operational flexibility, reflect conditions that are more immediately actionable and that signal a company's proximity to active participation. In addition to these binary assessments, the framework incorporates a graduated score for a company's minimum required notice period prior to a curtailment event, acknowledging that response speed is as operationally significant as response availability.

Figure 1 presents this conceptual framework schematically. The framework is described in full, with the weighting rationale of its application across the participant cohort in Section 4.2 Taxonomy of Loads.

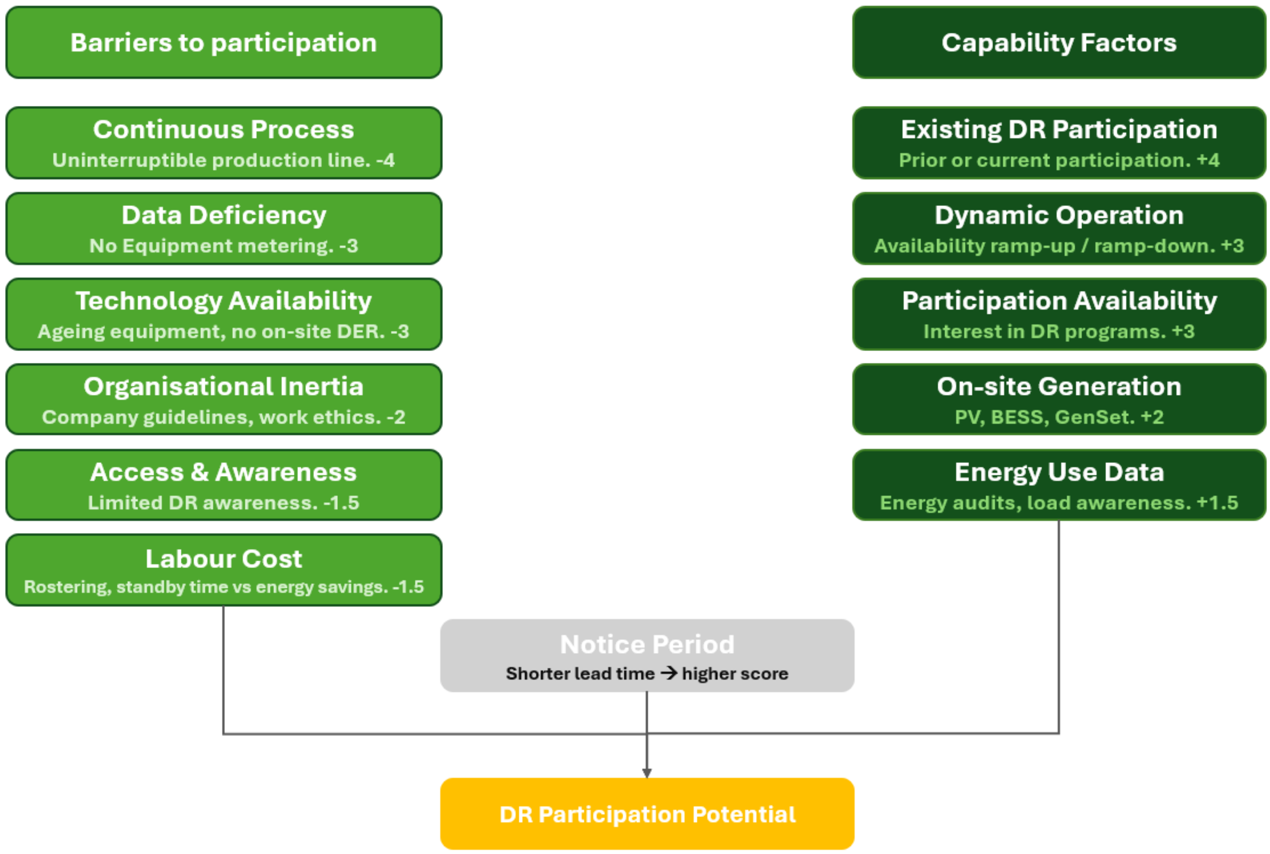


Figure 1: Barriers and Capability Factors for Industrial Demand Response Participation

In Figure 1, the left column identifies the six (6) barriers assessed for each participating company, each associated with a negative score weighting reflecting its materiality as a constraint. The right column identifies the five (5) capability factors; each associated with a positive weighting. The notice period assessment, in the centres, provides a graduated score based on the minimum lead time a company requires before a demand response event can be initiated. These three inputs are combined into a composite raw score, which is subsequently normalised to produce a relative DR participation potential index across the cohort. The scoring weights are not arbitrary: they reflect considered judgements about the relative significance of each factor to actual DR outcomes, informed by the engagement process and validated against participant responses.

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Nomenclature

Abbreviation	Definition
ABS	Australian Bureau of Statistics
AECOM	AECOM Australia Pty Ltd
AEMO	Australian Energy Market Operator
AEMC	Australian Energy Market Commission
AR-PST	Australian Research in Power System Transformation
ARENA	Australian Renewable Energy Agency
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCCEEW	Department of Climate Change, Energy, the Environment and Water
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organisation for Standardisation
RMIT	RMIT University
FCAS	Frequency Control Ancillary Services
ISP	Integrated System Plan
NEM	National Electricity Market
ANZSIC	Australian and New Zealand Standard Industrial Classification
AS	Australian Standard
AS/NZS	Australian and New Zealand Standard
BESS	Battery Energy Storage System
CER	Consumer Energy Resources
DER	Distributed Energy Resources
DNSP	Distributed Network Service Provider
DR	Demand Response
DRED	Demand Response Enabling Device
DRM	Demand Response Mode
DSM	Demand-Side Management
EV	Electric Vehicle
GW	Gigawatt
GWh	Gigawatt-hour
kW	Kilowatt
kWh	Kilowatt-hour
LM	Load Management
M&V	Measurement and Verification
MW	Megawatt
MWh	Megawatt-hour
PV	Photovoltaic
p.a.	Per annum
RO	Reverse Osmosis

Abbreviation	Definition
RTP	Real-Time Pricing
ToU	Time of Use
TWh	Terawatt-hour
CNC	Computer Numerical Control
DOL	Direct-On-Line (motor starting method)
HEPA	High-Efficiency Particulate Air
HV	High Voltage
LV	Low Voltage
HVAC	Heating, Ventilation, and Air Conditioning
UPS	Uninterruptible Power Supply
VSD	Variable Speed Drive
NSW	New South Wales
%	Percent
+	Positive
-	Negative
°C	Degree Celsius

1. Introduction

Increased electricity generation from renewable sources, such as wind and solar, is considered a key part of the clean energy transition. However, unlike fossil fuel power plants, these renewable sources are intermittent and cannot generate electricity on request. Without effective management, the amount of intermittent renewable generation in a power system must be limited to ensure reliable fulfilment of electricity demand (Kamana-Williams & Bishop, 2024).

The Australian power network is currently undergoing one of its most significant engineering transformations since the Industrial Revolution. Historically, electricity was generated at a small number of large power stations and delivered to consumers via long-distance transmission systems. Now, the current trajectory is towards a decentralised power system that generates energy from numerous Distributed Energy Resources (DER), such as community batteries, utility-scale solar, home rooftop solar, batteries, and electric vehicles, located throughout the network. This transformation is being driven by the national transition to net zero emissions and the ongoing need for secure, reliable energy. By 2050, almost half of Australia's electricity supply is expected to come from millions of privately owned distributed generators. A coordinated and well-planned approach is therefore essential to ensure energy security as these new sources are integrated into the system (Hargroves, et al., 2023; Race for 2030, 2023).

The past fifteen years have seen annual electricity demand in the NEM decline by approximately 18%, driven primarily by the uptake of behind-the-meter rooftop solar and improved energy efficiency across industries and households. This trend is now reversing. The electrification of transport, industrial processes, and residential heating is projected to drive a significant net increase in electricity demand over the coming decades. The pace and scale of this increase will depend on the speed of electrification across sectors, but industrial and commercial loads are expected to account for the majority of NEM-supplied electricity well into the future (AEMO, 2024; Williams, et al., 2023; Energy consumption - NSW State of the Environment Report, 2025).

As the electricity system transitions from centralised to decentralised and as renewable generation introduces inherent variability in supply, the grid will experience periods of stress in which the balance between demand and supply approaches or exceeds the boundaries of system stability. Traditional grid management strategies, designed for a system dominated by dispatchable synchronous generation, are not adequate for this environment. DSM now plays a critical role in forecasting and balancing short-term energy needs, helping to maintain system stability by aligning demand with available supply, relieving local network congestion, and supporting frequency and voltage stability and overall power quality. Beyond system security, DSM, in particular demand response, enables market-responsive behaviour: reducing load during high-price periods and increasing consumption to absorb surplus renewable generation that would otherwise be curtailed (AEMO, 2025; ARENA, 2025; CSIRO and Energy Network Australia, 2017; Race for 2030, 2023).

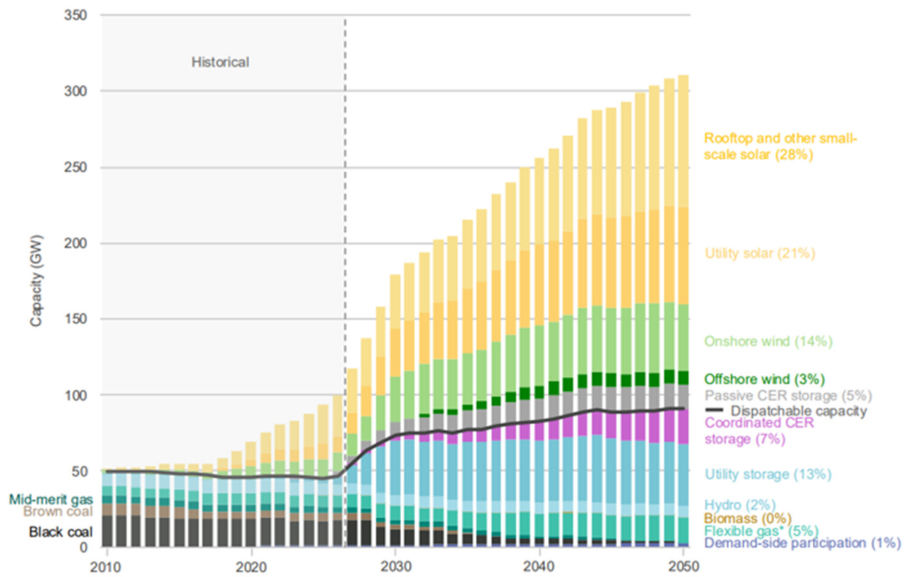

Figure 2: Annual NEM electricity generation 2008-2026 and forecast to 2050 (AEMO, 2026)

Figure 2 from AEMO's 2026 Integrated System Plan projects that the total capacity will grow dramatically to nearly 300 GW by 2050. This growth is almost entirely driven by rooftop and small-scale solar, utility-scale solar, and onshore and offshore wind. It is important to note that this figure represents projected investment in each technology under the least-cost optimal development path, not the power actually delivered at any given time, as no technology produces power continuously due to weather conditions, outages, fuel availability, and other operational constraints. Figure 2 also shows demand-side participation appearing as a distinct category in the projected years. While it accounts for only 1% of the total capacity by 2050, small in absolute GW terms relative to the total, its presence as a formal capacity category in AEMO's planning framework is significant, confirming that demand-side assets are expected to contribute as a recognised system resource rather than as passive consumers. Furthermore, coordinated and passive CER storage also appear as growing categories from the 2030s onward, reflecting the expectation that residential and small commercial assets will be progressively integrated into grid management. However, the comparative scale of industrial loads, which are absent from this chart as a distinct named category, is much greater to the commercial and residential assets, representing an underutilised and under-characterised resource that deserves equivalent recognition in system planning (ARENA, 2025; AEMO, 2024; AEMO, 2020; Consumer Energy Resources sub-Working Group, 2025; Williams, et al., 2023; AEMO, 2026).

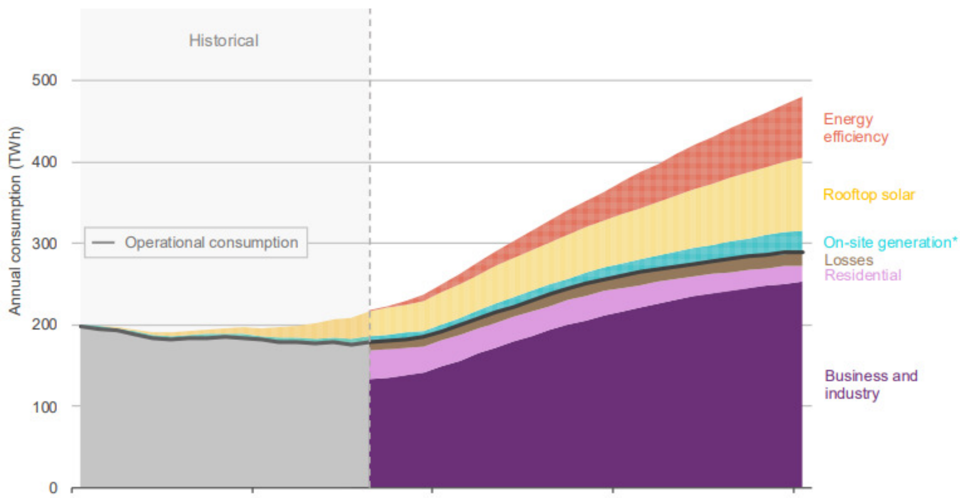

Figure 3: Projected NEM load growth by sector: industrial electrification vs. residential EV and electrification (AEMO, 2026)

Where Figure 2 illustrates the transformation of Australia's generation capacity, Figure 3 presents the demand-side counterpart, showing projected annual electricity consumption in the NEM through to 2050, and split across business and industry, residential and offset categories. The figure makes clear that business and industrial consumption is projected to grow substantially and to dominate total NEM demand throughout the forecast period, far exceeding the residential sector in absolute terms. While improved energy efficiency and rooftop solar generation will partially offset this growth, industrial and commercial loads are still projected to account for the majority of NEM-supplied electricity for the foreseeable future. Understanding the nature and controllability of these loads is therefore a vital step in delivering a least-cost energy transition and ensuring that the system services required for grid stability remain available as synchronous generation retires (AEMO, 2024).

Despite their scale and significance, industrial loads have received comparatively little structured attention as candidates for demand response. Most load management and DR programs have been designed and implemented for residential and small commercial consumers, and industrial energy users are often regarded as too operationally complex, too commercially reluctant, or too diverse to engage practically. Real-world evidence has begun to challenge these assumptions. An ARENA-AEMO trial conducted over three years demonstrated that more than 200 MW of controllable load could be sourced from small- to medium-sized industrial facilities, exceeding the equivalent results from residential programs (ARENA, 2025). For the purposes of this study, mid-sized industrial loads were defined as those with an annual energy demand not exceeding 100,000 MWh, thereby distinguishing them from the large energy-user tier typically engaged through existing bespoke DR arrangements. This potential remains largely untapped, not because industrial loads are technically incapable of responding, but because the organisational, informational and structural barriers that prevent participation are compounded by the absence of a consistent, standardised framework that would make industrial DR accessible, measurable and reliable at scale (Scharnhorst, et al., 2024; Ranaboldo, et al., 2024).

This project is designed to address that gap directly. Conducted under the Australian Research in Power System Transformation (AR-PST) Stage 5 program, Topic 6: Essential System Services, this study investigates the potential for existing mid-sized industrial companies in the Hunter Valley region of New South Wales to participate in demand response and provide system services to the NEM. Through direct engagement with 22 industrial participants spanning multiple sectors, the research develops a taxonomy of industrial load types and their inherent flexibility, a classification framework assessing barriers and capability factors, and a set of findings intended to inform power system planners, market operators, regulators, and future researchers (RMIT University, 2021; Hargroves, et al., 2023).

The engineering challenge ahead is not solely one of supply-side planning. Effectively integrating renewable generation into a reliable and stable grid requires a parallel investment in the digital and regulatory infrastructure that enables real-time coordination between supply and demand. This includes the metering, telemetry and data management capability needed to identify, commit and verify demand-side response at the equipment level (Zhang, et al., 2025; Race for 2030, 2023; Williams, et al., 2023).

In this context, one of the most significant findings of this study is that 88% of participating companies had no submetering or equipment-level energy data. This is not a peripheral limitation of the research. It reflects a structural gap between the infrastructure that currently exists across mid-sized Australian industry and the infrastructure that meaningful industrial DR participation requires.

2. Research

Industrial loads can provide system services, such as voltage and frequency stability, to the power grid through various load management strategies. These strategies also benefit the company by flattening its energy profile through shifting consumption and thereby avoiding peak demand penalties. By avoiding, delaying or advancing planned consumption, such as shifting load utilisation time, the end-consumer can provide the supply side a valuable and cost-effective alternative to increasing or decreasing electricity production. The below sections discuss state-of-the-art in such methodologies.

2.1 Literature Review

2.1.1 System Services

System services, also referred to as ancillary services, are the range of technical capabilities that electricity networks require to maintain safe and reliable operation beyond the simple balance of supply and demand. In the National Electricity Market, these include frequency control ancillary services (FCAS), inertia (rate of change of frequency), system strength, voltage support, and system restart capability. Historically, these services were provided as a by-product of large synchronous generators: coal, gas, and hydro power plants, which inherently contributed inertia, voltage regulation, system strength, and frequency response simply by being connected to the grid and operating.

The progressive retirement of coal-fired generation and the rapid expansion of non-synchronous renewable sources are fundamentally altering the system services landscape. AEMO's Integrated System Plan projects that by 2050, close to half of Australia's electricity supply will come from distributed renewable generators, creating an urgent need to identify and develop new sources of system services from the demand side of the market (AEMO, 2024).

Despite this, demand-side assets have historically provided a negligible fraction of the system services capacity in the NEM. This gap between the theoretical potential of demand-side resources and their actual commercial participation has been consistently noted in the literature. Golmohamadi’s international review of heavy industries identifies industrial loads as carrying adjustable potential exceeding 25% of their total energy consumption, drawing primarily on case studies from cement, aluminium smelting, and oil refining. While this figure is from an international case study, it indicates a substantial reserve that remains largely untapped due to structural, commercial, and technical barriers. The challenge of realising this potential, rather than its existence, is the central problem this study addresses (Golmohamadi, 2022).

2.1.2 Load Management

Load Management (LM) refers to the practice of deliberately adjusting, increasing or decreasing the electrical energy consumption by end users, typically in response to price signals, system operator instructions, or automated control mechanisms. Load management requires actions to manage the load at all times. Industrial loads with highly stable and predictable patterns pose a low risk to the electrical distribution network. On the other hand, companies with highly unpredictable load profiles and large peaks in demand require both a higher and more costly level of flexibility in the distribution network (Capiau & Van Daele, 2016).

2.1.2.1 Types of Load Management & Flexibility Production

Understanding the characteristics of an industrial production process is essential when assessing LM or DSM potential. The operational boundaries of each process largely determine how much flexibility can realistically be provided. Several key parameters should be evaluated:

- Marginal cost of activation – particularly where flexibility actions affect production output;
- Storage or buffer capacity – which allows operations to be shifted in time with minimal production impact;
- Reaction time – the speed at which a process can ramp up or down following a control signal;
- Maximum activation duration: – Depending on the process, this may range from several minutes to multiple hours.

- **Activation frequency:** Number of times flexibility can be deployed within a given timeframe.
- **Flexibility volume:** – quantity of load that can be shifted or curtailed.
- **Technical impact on the production process:** – In some cases, modifying one sub-process may create bottlenecks or operational constraints elsewhere within the production system.

These parameters formed the conceptual basis for the questions developed for the stakeholder engagement conducted in this study, ensuring that each interview systematically captured the information necessary to assess flexibility potential at the individual site level, as described in Section 4.1.

The majority of historical LM programs have targeted large energy users, where load magnitude justifies bespoke technical and contractual arrangements with utilities. Mid-sized industrial consumers have received comparatively little structured attention, despite representing a significant aggregate share of NEM demand. Björk and Karlsson noted as early as 1985 that industrial loads were largely overlooked for load management applications due to the perceived complexity of their energy demand and equipment; this characterisation has persisted in the literature for four decades and remains a key motivation for this study (Bjork & Karlsson, 1985).

2.1.3 Demand-Side Management (DSM)

2.1.3.1 DSM Strategies and Scope

Demand-side management isn't new terminology; it was invented in the late 1970s, along with many of the frameworks used to plan and implement it in the years that followed (Gellings, 2017). DSM refers to the planning and execution of measures that influence electricity consumption behaviour on the demand side, with the objective of modifying the equipment load profile. This is typically achieved by reducing consumption during peak periods or shifting energy use to off-peak hours through changes in the timing and magnitude of demand. Depending on the nature and timing of the measures applied on the consumer side, DSM can be categorised into Energy Efficiency, Time-of-Use (ToU), Demand Response, and Spinning Reserve (Gelazanskas & Gamage, 2014) (Gellings, 2017).

Once the operational boundaries of each process and the characteristics of the industrial facility have been determined, demand-side management DSM can be implemented through several distinct strategies, each with a different operational purpose and impact on production. Table 2 summarises these approaches.

Table 2: DSM Strategies: Purpose, Trigger, and Enabling Conditions

DSM Strategy	Purpose	Signal / Trigger	Key Enabling Condition
Peak Shaving	Reduce demand peaks to avoid network tariff penalties.	Internal; no market signal required.	Primarily economic; lowers demand charges.
Load Shifting	Move consumption from high-price to low-price periods.	Price signal or operator instruction.	Batch or variable-load processes; inventory buffer.
Load Reduction	Curtail production when prices make it uneconomical.	Sustained high market price.	Flexible production schedule; low order demand.
Load Increase / Valley Filling	Increase consumption during periods of surplus or low prices.	Low wholesale price or renewable surplus signal.	Storage or inventory capacity; flexible scheduling.
Demand Response	Temporarily modify electricity consumption in response to a direct system operator instruction, price incentive, or market signal	Signal from a system operator / aggregator	On-site storage or buffer; process flexibility.

Demand curtailment, valley filling, and load shifting, presented as DSM strategies in Table 2, also function as the three operational modes through which demand response specifically is delivered.

Demand response is a specific subset of DSM that focuses on actively adjusting electricity consumption in response to price signals, system conditions, or incentive mechanisms. DR programs encourage end-use consumers to modify demand through enabling technologies such as advanced metering, dynamic pricing, DER, and direct incentive payments during periods of system stress. Within a DR context, these three DSM strategies, demand curtailment, valley filling, and load shifting, function as the principal modes of delivery. By managing demand rather than constructing additional generation or storage capacity, DR addresses intermittency at minimal incremental cost (Zhang, et al., 2025; Gelazanskas & Gamage, 2014; Gellings, 2017; Kamana-Williams & Bishop, 2024).

2.1.3.2 DSM in Residential

AS/NZS 4755 is Australia's principal demand response standard, establishing a standardised framework for communication and control of demand response capability in electrical appliances. The standard was developed to enable a wide range of appliances and manufacturers to connect and respond to remote signals in a consistent way, and Australia was among the first countries to develop such a national-level capability (AEMO, 2020).

However, the standard's scope is explicitly residential and small commercial. Its Demand Response Modes, Demand Response Enabling Device (DRED) interface architecture, and communication protocols are designed for single-phase and three-phase appliances, such as air conditioners, hot water heaters, pool pumps, and EV chargers, which operate at the scale of individual households or small businesses. Industrial equipment, with its vastly different control interfaces, process interdependencies, safety obligations, and load magnitudes, lies entirely outside the standard's intended scope (Pearson, 2021) (AEMO, 2024) (AECOM, 2014).

Australia has a substantial number of loads that could, in principle, be controlled as DER; however, a range of technical, economic, regulatory, social, and operational barriers must be overcome before this can be realised. Addressing these challenges will be essential to the development of a robust and practical demand response standard applicable to industrial loads.

2.1.3.3 DSM in Industrial Settings

While substantial literature exists on the theoretical potential of industrial DSM (Bjork & Karlsson, 1985; Capiau & Van Daele, 2016; Golmohamadi, 2022; Ranaboldo, et al., 2024; Scharnhorst, et al., 2024; Shoreh, et al., 2016; Williams, et al., 2023), comparatively few studies engage directly with the equipment and load types through which this potential would be realised. Where industrial sectors have been examined in depth, DR potential is found to be highest in industries with large inventory buffers and inherent thermal or mechanical storage (Golmohamadi, 2022). Golmohamadi's review of heavy industries identifies cement and metal manufacturing as the most promising sectors, given the flexibility of mills, crushers, and electrolysis smelting pots and the buffering capacity of large raw material inventories (Golmohamadi, 2022). Williams et al. extend this to a cross-sector comparison, finding that industrial DSM is primarily constrained by technical and economic factors rather than behavioural ones and that the flexibility of individual facilities depends heavily on process-specific conditions rather than sector-level generalisations (Williams, et al., 2023).

Shoreh et al. provide a foundational survey of industrial DR applications, confirming that industrial consumers have traditionally participated in DR through bespoke, incentive-based arrangements with utilities, with participation rates well below the sector's real potential. The survey identifies ancillary service provision, including frequency control and voltage support, as among the most valuable contributions industrial loads can make, and identifies the heterogeneity of industrial equipment as a persistent obstacle to standardised program design (Shoreh, et al., 2016).

Scharnhorst et al. provide more recent empirical evidence from 20 semi-structured interviews with experts from German industrial and commercial companies, finding that the most frequently cited barriers to DR participation are concerns about diminished product quality, disruptions to production processes, human resource management challenges, and revenue uncertainty (Scharnhorst, et al., 2024). Beyond identifying these barriers, the authors conclude that overcoming them requires both internal and external intervention, specifically, greater resourcing and information within companies to build the internal capability needed to participate, and stronger external incentives and adapted regulatory frameworks to make participation commercially viable. These findings are consistent with the barriers identified through the stakeholder engagement conducted in this study, particularly the Continuous Process, Labour Cost, and Organisational Inertia barriers, and confirm that the challenges observed in the Hunter Valley cohort are not idiosyncratic to the Australian context but reflect internationally consistent structural constraints.

2.1.4 Demand Response

2.1.4.1 Definition and Importance

Demand response is the intentional and temporary modification of electricity consumption by end users in response to time-varying price signals, system operator instructions, or direct incentive mechanisms. It is a specific and active subset of DSM, which encompasses the full range of measures that influence the level and pattern of demand, including energy-efficiency upgrades, behind-the-meter generation, and passive scheduling. DR refers specifically to the deliberate, signal-driven adjustment of consumption in response to external grid conditions. The three principal DR modes are: (i) demand curtailment, where demand is decreased, either to meet demand constraints or to match supply, such as by turning off an appliance; (ii) valley filling, where electricity consumption is increased, such as to balance supply from intermittent renewables, such as by turning on an appliance; and (iii) load shifting, where demand is shifted to meet constraints, such as by scheduling an appliance to run at preferred times. By managing demand rather than constructing additional generation or storage capacity, DR addresses intermittency at minimal incremental cost (Williams, et al., 2023).

The importance of DR to modern power systems is not limited to individual consumer cost savings. At the system level, DR reduces the need for expensive peaking generation plants that operate only during high-demand periods, extends the operational life of network infrastructure by smoothing demand peaks, and provides a cost-effective means of absorbing intermittent generation without curtailment. By managing demand rather than constructing additional supply or storage capacity, DR addresses intermittency with minimal incremental capital expenditure.

DR also contributes directly to system security. Loads capable of providing a rapid, quantifiable, and repeatable response to a dispatch signal are functionally equivalent to a generating asset from a system operator's perspective; they can be used to provide frequency regulation, spinning reserve, and voltage support in the same way that a controllable generator would. This equivalence is central to the long-term vision for industrial DR in the NEM: not merely as a commercial arrangement between a consumer and a retailer, but as a formal contributor to essential system services (AEMO, 2024) (RMIT University, 2021).

2.1.4.2 Price and Incentive-Based DR Programs

DR programs are broadly classified into two categories based on the mechanism through which they engage consumers: price-based and incentive-based programs (Williams, et al., 2023).

Price-based programs use time-varying electricity prices to encourage voluntary shifts in consumption. The two principal variants are ToU pricing, where retail prices increase by a pre-defined amount during specified peak periods, and Real-Time Pricing (RTP), where prices vary continuously in response to wholesale market conditions. Evidence from DR trials suggests that price-based programs are generally more appealing to consumers than incentive-based programs, as they preserve consumer autonomy and do not require advance commitment to curtailment (Williams, et al., 2023). However, their effectiveness depends on the consumer's ability and willingness to respond; a condition that is more readily met in residential and small commercial settings than in industrial ones, where process constraints limit the scope for price-responsive adjustment.

Incentive-based programs offer direct payments or bill credits in exchange for committing to curtail or modify load on request. These programs are more common among large industrial consumers, whose high consumption gives them the bargaining power to negotiate bespoke arrangements with utilities or aggregators, and whose process constraints mean that financial incentives, rather than price signals, are typically required to justify the operational disruption of participation (Williams, et al., 2023). Williams et al. confirm that electricity costs typically represent a small fraction of total costs for industrial consumers, meaning that price signals alone rarely provide sufficient motivation; incentive payments must be structured to exceed the cost of displaced labour or foregone production (Williams, et al., 2023).

In the NEM, industrial and commercial consumers can access both types of programs through several mechanisms

2.1.4.3 Demand Response and Industrial Loads

In the Australian context, Lashmar et al. find that C&I consumers are motivated primarily by financial benefit but frequently lack awareness of the system and community dimensions of DR participation, and that a clear, structured implementation pathway from awareness to activation is absent from current energy management guidance. (Lashmar, et al., 2023)

The barriers that suppress industrial DR participation are well-documented in the international literature and consistent with the findings of this study. Scharnhorst et al., drawing on empirical interviews with industrial and commercial companies in Germany, find that concerns about product quality, production process disruption, human resource management, and revenue uncertainty are the most frequently cited impediments (Scharnhorst, et al., 2024). These correspond directly to the Continuous Process, Labour Cost, and Organisational Inertia barriers identified in this study's classification framework. Critically, Scharnhorst et al. observe that overcoming these barriers requires not only bridging internal knowledge gaps but also adapting external incentive structures, a finding that points toward the inadequacy of current program designs for mid-sized industrial consumers.

The literature consistently identifies structural challenges that suppress industrial DR uptake beyond individual site barriers: small consumers are overlooked by utilities and aggregators; the dual knowledge of process operations and DR participation pathways is rarely present within the same organisation; and load types with high cross-industry DR potential, such as compressed air systems, are consistently underexploited because programs are designed for individual customers rather than load categories. Digitalisation, including submetering and real-time data analytics, is identified as a precondition for reliable participation, as it addresses the data deficiency that prevents sites from credibly committing to and verifying curtailment events (Williams, et al., 2023; Scharnhorst, et al., 2024; Ranaboldo, et al., 2024). All three structural challenges and the data deficiency that underpins them are directly evidenced in this study's cohort. Shoreh et al. confirm that industrial consumers have traditionally participated below their real potential, and that realising this potential would reduce reliance on more expensive alternatives such as peaking plant or large-scale battery storage; a case that is not only economically compelling in the Australian context, but operationally urgent given the accelerating retirement of synchronous generation (Shoreh, et al., 2016).

2.2 Literature Gap

Within the industrial sector, load management has traditionally been applied at the large energy user end, smelters, and large chemical plants, where the load magnitude justifies the cost of bespoke technical and contractual arrangements. The literature contains comparatively little on load management in mid-sized industrial settings, and none that specifically addresses the Hunter Valley or comparable Australian regional industrial economies.

The literature review above establishes a clear picture: industrial demand response potential is large, structurally underutilised, and constrained by a combination of technical, organisational, and regulatory barriers that have proven persistent across markets and jurisdictions. The following gaps are directly relevant to this study.

- There is no published, empirically grounded characterisation of industrial DR potential among mid-sized industrial companies in Australia. The existing literature addresses large energy users (smelters, data centres, chemical plants) or residential and small commercial loads. The mid-sized industrial tier has received almost no systematic attention (Golmohamadi, 2022; Williams, et al., 2023; Shoreh, et al., 2016).
- There is no taxonomy of industrial loads developed from direct stakeholder engagement in an Australian regional industrial context. The load characterisations available in the international literature are largely derived from engineering models or single-sector case studies, and do not reflect the operational realities of diverse mid-sized Australian industrial facilities (Shoreh, et al., 2016; Ranaboldo, et al., 2024).
- The interplay between barriers and capability factors at the site level has not been systematically modelled. The literature identifies barriers and capabilities as separate categories but does not

examine their reciprocal relationship; specifically, how removing a barrier can unlock a latent capability, and how building a capability can neutralise a barrier (Scharnhorst, et al., 2024; Ranaboldo, et al., 2024).

- No Australian equivalent of a standardised industrial DR framework exists. AS 4755 covers only residential and small commercial loads. The absence of standardised telemetry, measurement and verification, and participation protocols is a structural gap that the literature identifies as a root cause of low industrial DR uptake, but which no existing Australian research program has been specifically designed to address (AEMO, 2020).

This study addresses the first three gaps directly through its stakeholder engagement methodology, load taxonomy, and barrier-capability classification framework. The fourth gap is identified as the primary recommendation for future research, building on the characterisation work completed here.

3. Background

The objective of this research project is to investigate the potential for existing mid-sized industrial companies and their loads to provide system services into the NEM. The research focuses on the barriers to such potential and the implementation path to realise this potential. A qualitative, interview-led methodology was adopted, which was designed to generate contextual and operational insights that quantitative surveys alone would be unlikely to uncover.

3.1 Research Design

A qualitative research approach was adopted for this project to reflect its exploratory nature. The research domain for industrial demand response participation in mid-sized industrial settings remains relatively under-characterised in both the Australian context and internationally. While there is substantial literature on the demand-side management and demand response domains, little is available for the industrial sector. Qualitative methods were considered most appropriate for identifying the operational, organisational, and commercial factors that shape an industrial company's potential capacity to provide system services in the NEM.

The study combined six (6) complementary methods:

- Literature Review of Demand Side Management and Demand Response frameworks, as well as relevant Standards (including AS 4755);
- Literature review of Demand Response in industrial settings in Australia and internationally;
- Semi-structured Stakeholder interviews were conducted for the majority in person, with only a small number via Teams meetings;
- Follow-up engagements were conducted through telephone calls and email correspondence to verify and expand upon initial responses;
- Document analysis, including electricity bills, energy audit reports; and
- Integration of existing energy audit data from previous Advitech-led site assessments. These provided a baseline of independently verified equipment-level consumption and operational data for a subset of participants, supplementing and cross-validating information gathered through the primary interview process.

This structured research approach allowed the researchers to assess the extent to which demand-side management, demand response, and the provision of system services, as a whole, have been addressed so far in both the literature and real-world industrial applications. This sequencing of the research methods laid the foundation for the stakeholders' interviews, enabling comparisons between theoretical findings in the literature and practical conditions observed in industrial settings. It is often the case that research papers and their findings do not align with real-world scenarios. This approach was intended to identify potential gaps between academic research and the loads available and the operational realities influencing industrial participation in the provision of system services.

3.2 Focus Area

Stakeholder engagement was geographically focused on a single region: the Hunter Valley, NSW. This region was selected for its diverse and established industrial base spanning sectors such as manufacturing, mining, food processing, environmental services, and data infrastructure, providing sufficient sectoral variety to enable cross-industry comparisons. Due to the abundance of renewable resources, the region is undergoing a significant energy transition, moving away from historical dependence on coal-fired generation and the closure of thermal power plants, thus making the question of industrial load flexibility particularly pertinent to local grid stability. Furthermore, Advitech's established professional presence in the region facilitated access to companies that may otherwise have been reluctant to engage with an externally initiated research program. This access facilitated a more meaningful stakeholder engagement that would typically be achieved through cold outreach methods.

3.3 Stakeholder Engagement Sampling Strategy

Participating companies were recruited through three complementary channels: Advitech's existing professional networks within the Hunter Valley industrial community; referrals from industry bodies and professional organisations; and engagement with companies that had previously participated in Advitech-led energy studies.

Mid-sized industrial companies were selected to ensure representation across a range of industry sectors, energy consumption scales, and operational profiles. In total, the study engaged 22 industrial participants, with annual energy consumption ranging from approximately 280 to 100,000 MWh, a spectrum that effectively captures both ends of mid-sized industrial loads.

Due to the commercial and confidential nature of the information provided during the stakeholder engagement, all participating companies were anonymised for the purpose of this Project and report, identified only by alphabetical designation. The participant group comprises two distinct cohorts. The Primary participants, consisting of companies engaged directly through the stakeholder engagement process, are identified as Companies A through N. The supplementary cohort, consisting of companies drawn from previous energy audits, is designated AA through LL, preserving the distinction between the two cohorts throughout the report.

Figure 4 and Figure 5, provide a graphical representation of the annual energy consumption across the full participant group. Figure 4 presents the complete list of industrial sites; Figure 5 excludes the two highest-energy consumers to provide greater resolution among the remaining participants. Figure 6 illustrates the annual energy consumption by sector.

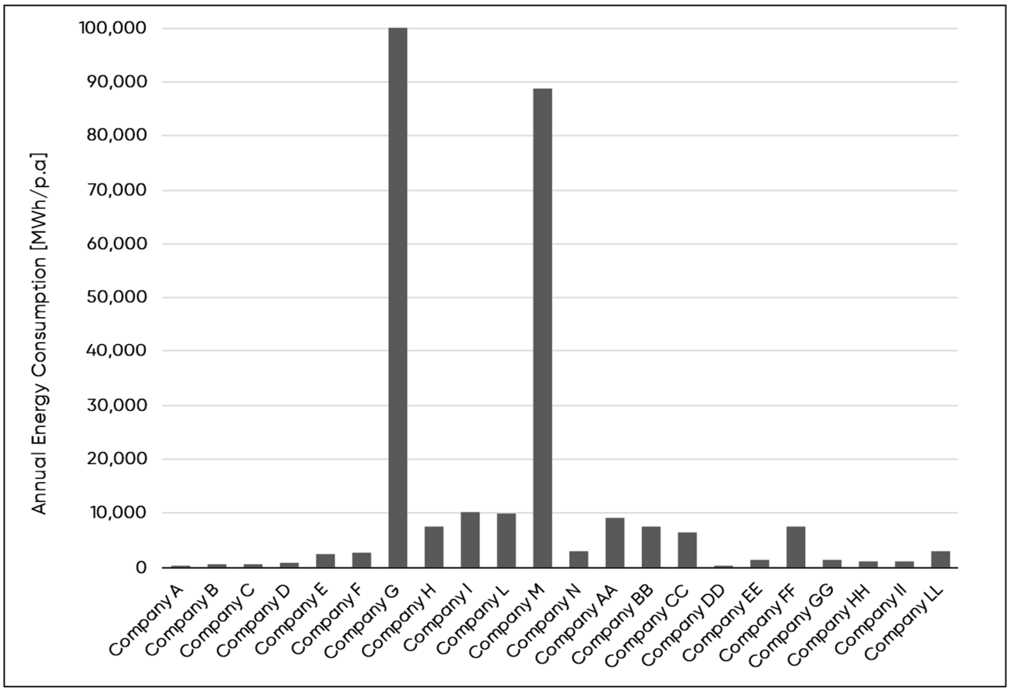

Figure 4: Energy Consumption by Industrial Participants

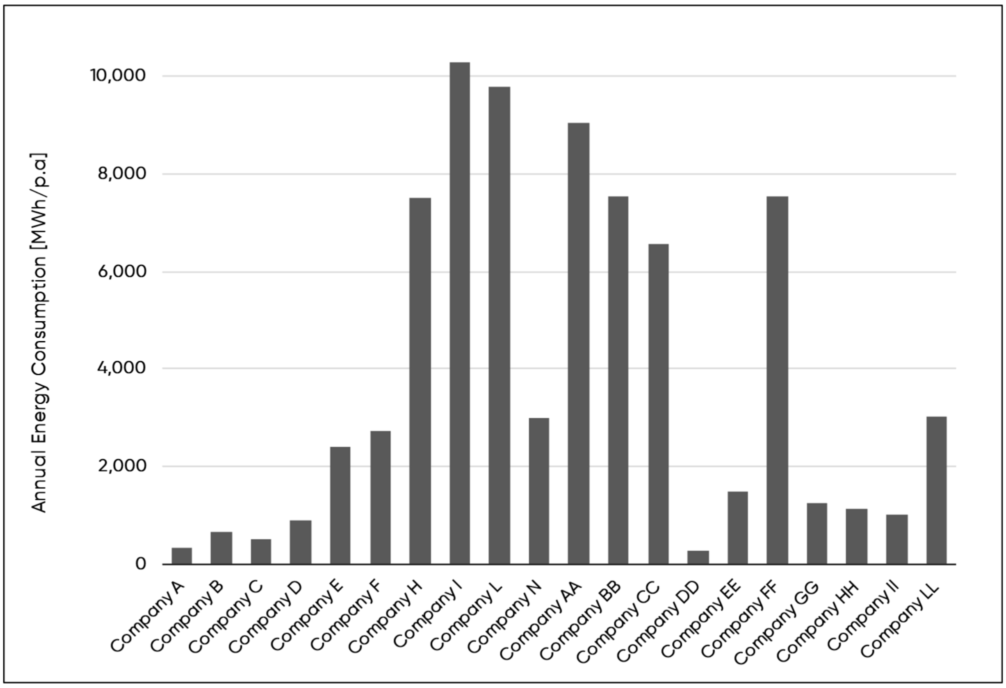

Figure 5: Energy Consumption by Industrial participants Without Major Users: Company G and M.

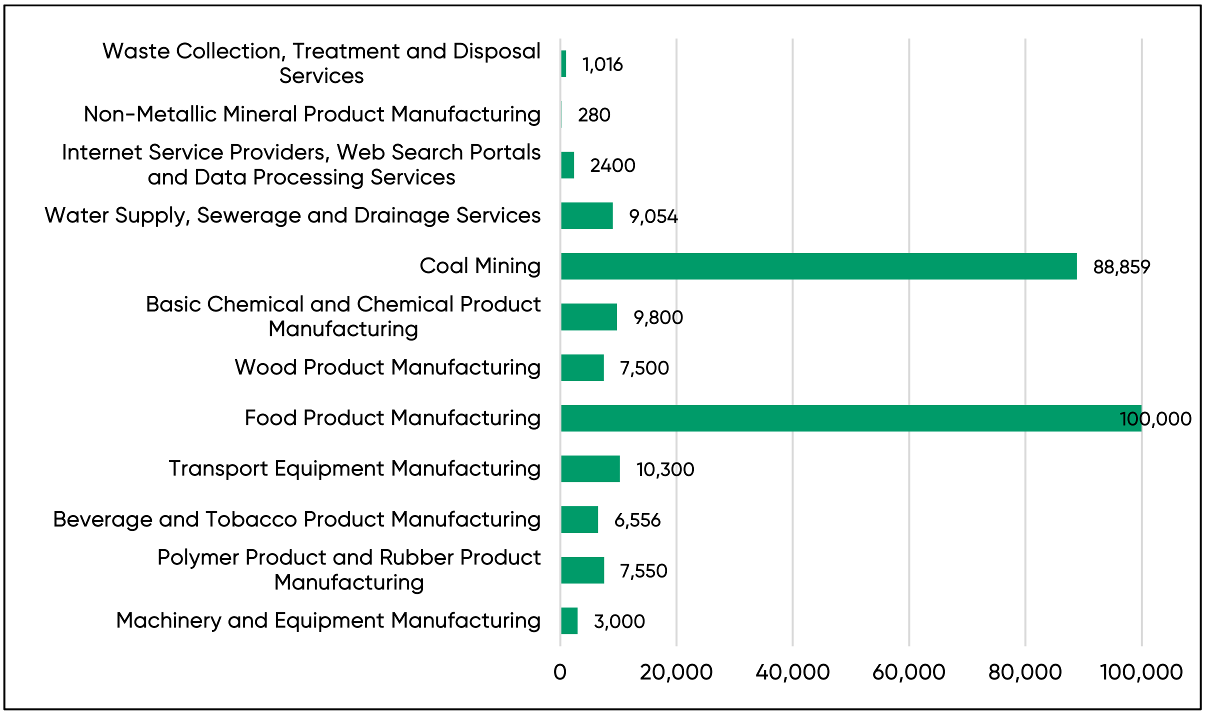

Figure 6: Annual Energy Consumption by Sector in MWh

4. Methodology

4.1 Stakeholder Engagement

The Hunter Region was selected due to its status as Australia's largest regional economy, its diverse industrial base, and its growing renewable energy sector. While several other Australian regions, including the Pilbara, Gladstone, the Illawarra, Kwinana, and the Latrobe Valley, are similarly significant industrial centres and together account for a substantial share of national industrial emissions, most are characterised by a narrower, sector-dominant industrial profile, such as Gladstone's concentration in alumina and coal export or the Pilbara's in iron ore and resources (Climateworks Centre, 2022). The Hunter is distinguished not by being an outlier in industrial opportunity, but by the breadth of its industrial base, spanning mining, manufacturing, food processing, defence, and an emerging renewable energy sector, which made it particularly well suited to a study seeking cross-sectoral comparison rather than depth within a single dominant industry. Advitech's 30-year presence in the Hunter also provided an established network to support this research.

Advitech's engagement strategy centred on major industrial energy users, renewable energy developers, and market participants. Utilising its industry connections, Advitech identified stakeholders specifically on the basis of their potential to provide demand response and system services, prioritising companies with flexible operational processes, significant energy consumption or generation profiles, or characteristics likely to indicate latent DR capacity. This selection focus reflects the core research objective of the study, to characterise and assess industrial demand response potential, rather than a broader survey of industrial energy users generally. Initial outreach to approximately 50 industry representatives yielded a 40% response rate, with a subsequent 60% conversion to active participation. Initial meetings followed a structured questionnaire developed from Advitech's experience in industrial energy auditing, centred on a core set of thematic areas including working conditions, energy consumption profile, existing on-site generation and storage, DR awareness and participation history, operational constraints, and barriers to flexibility. Insights from these initial discussions informed more detailed, tailored assessments for individual participants where warranted. The questionnaire's thematic structure was informed by the load management and flexibility parameters identified in Section 2.1.2.1, specifically marginal cost of activation, storage or buffer capacity, reaction time, maximum activation duration, activation frequency, flexibility volume, and technical impact on the production process. Framing the interview questions around these parameters ensured that the data collected from each participant was directly applicable to the barrier and capability classification framework described in Section 4.2. A full list of questions and their data analysis is provided in Appendix A and Appendix B, respectively.

The participant cohort was further supplemented by companies from previous energy audits conducted by the Advitech team. These additional participants were not engaged through the primary outreach process but were included on the basis of existing operational data that were sufficiently deep and relevant to support the study's analytical framework. To ensure consistency and eliminate potential for differential treatment, all supplementary participants were assessed using the same criteria and questionnaire as those applied to the primary cohort.

Primary participants engaged through the stakeholder outreach process are identified as Companies A through N throughout this report. Companies identified through previous Advitech energy audits and incorporated as a supplementary cohort are designated AA through LL. This distinction is maintained to preserve transparency regarding the source and depth of data available for each participant.

The full participant group spans 5 industry sectors: Food and Beverage, Construction, Manufacturing, Mining, and Technology. Breaking the sectors down further, there are representatives from the following business types:

- Data Centres;
- Coal Mining;
- Meat Processing;
- Wine Making;
- Rail and Transit Systems;
- Providers of heavy machinery equipment and support solutions (parts, servicing, technology);
- Manufacturers of cladding, steel, human therapeutics, fluid asset intelligence solutions, wheels, drilling equipment, and tool systems;
- Machining, repairs and fabrication services for mining, defence, transport and food industries; and

- High-voltage electrical systems, safety solutions, and communication infrastructure for mining, tunnelling, and heavy industry.

4.1.1 Preliminary Data Acquisition

Primary data was collected through qualitative research techniques, specifically semi-structured interviews and document analysis. These methods were selected because they provide contextual and operational insights that quantitative surveys are unlikely to surface, particularly in an exploratory research domain where the dimensions of the problem are not yet fully characterised.

A series of semi-structured interviews was conducted on-site or by telephone. The interviews follow a conversational format and were structured around a core set of thematic areas, including working conditions, energy consumption profile, existing on-site generation and storage, DR awareness and participation history, operational constraints, and barriers to flexibility. The interview structure also allowed participants to raise issues that fell outside the predetermined framework. This approach was intentional, as rigid question schedules would have constrained the richness of the operational context that participants could offer, particularly regarding process interdependencies, safety constraints, and commercial sensitivities that are rarely disclosed in response to a structured questionnaire.

4.1.2 Industry Sectors Participation

Table 3 summarises the full participant industry sectors classified by ANZSIC, along with the energy consumption range and the primary load categories observed across the participant cohort. The sector classifications are based on the Australian and New Zealand Standard Industrial Classification (ANZSIC) subdivision codes. (ABS, 2006; DCCEEW, 2006)

Table 3: Summary of Participating Companies by Industry Sector

Industrial Sector	No. of Companies	Energy Consumption [MWh/p.a.]	Primary Load Categories Observed
Machinery and Equipment Manufacturing	5	315 – 3,000	Mechanical, Compressed Air, Thermal, Background, Specialised Loads, Surface Treatment.
Polymer Product and Rubber Product Manufacturing	3	650 – 7,500	Thermal, Compressed Air, Background, Environmental Control.
Beverage and Tobacco Product Manufacturing	3	1,260 – 6,556	Environmental Control, Pumping, Compressed Air, Background.
Transport Equipment Manufacturing	2	2,726 – 10,300	Mechanical, Thermal, Compressed Air, Surface Treatment,

Industrial Sector	No. of Companies	Energy Consumption [MWh/p.a.]	Primary Load Categories Observed
			Specialised Loads, Fabrication.
Food Product Manufacturing	2	3,026 – 100,000	Compressed Air, Pumping, Background, Environmental control.
Wood Product Manufacturing	1	7,500	Thermal, Mechanical, Surface Treatment.
Basic Chemical and Chemical Product Manufacturing	1	9,800	Environmental Control, Thermal, Background.
Coal Mining	1	88,859	Mechanical, Compressed Air, Pumping, Environmental Control.
Water Supply, Sewerage and Drainage Services	1	9,054	Compressed Air, Background, Thermal, Pumping.
Internet Service Providers, Web Search Portals and Data Processing Services	1	2,400	Background Environmental Control
Non-Metallic Mineral Product Manufacturing	1	280	Mechanical, Compressed Air, Surface Treatment, Thermal, Pumping, Background.
Waste Collection, Treatment and Disposal Services	1	1,016	Compressed Air, Background, Pumping.

4.1.3 Stakeholder Data Collection Methods

To assess the potential demand response capacity of an industrial site, the most important part was understanding the stakeholders' knowledge of their process(es) and operation(s). The interviews were structured to progress through three stages, moving from general site-level understanding toward increasingly specific operational and technical detail.

The first stage covered general questions assessing participants' knowledge of site energy consumption, electricity tariffs, working conditions, and in-situ energy generation. The second stage shifted to more targeted questions regarding their industrial processes, primary energy-intensive equipment, and operational or physical limitations within their working environment. A full list of questions asked can be found in Appendix A. Where participant and site conditions permitted, a third stage was conducted, including a brief walk-through of the facility, allowing direct observation of daily operations and major equipment in use. This physical engagement provided contextual detail that interview responses alone could not consistently convey.

Initial interviews were followed up through telephone calls and email correspondence to clarify responses, obtain supporting documentation, and confirm data where ambiguity existed. Where participants were willing to share electricity billing records, energy audit reports, or emissions disclosure documents, these were reviewed to corroborate self-reported consumption figures and tariff arrangements.

It is acknowledged that the conversational interview format introduces the possibility of self-reporting bias, a limitation discussed further in Section 4.1.6. Nevertheless, the iterative follow-up process, combined with secondary data triangulation where available, provided reasonable confidence in the integrity of the dataset.

4.1.4 Validity and Reliability

Research quality was maintained through several measures. Data triangulation, comparing interview responses against available documentary evidence, published emissions disclosures, and secondary benchmarks, was employed wherever possible to reduce reliance on self-reported information. The iterative follow-up process provided an opportunity to resolve inconsistencies and confirm data prior to analysis. The classification framework was applied uniformly across all 22 participants, with scoring decisions documented to ensure transparency and reproducibility.

The following limitations, which are discussed in more detail in Section 4.1.6, do not invalidate the findings, but should be considered when assessing the generalisability and precision of the conclusions drawn.

- Self-reporting bias: participants may have overstated their DR readiness or understated operational constraints, particularly where there was a desire to present the company favourably.
- Sample characteristics: the cohort was drawn primarily from Advitech's professional network, which may introduce selection effects; companies with an existing relationship with an energy consultancy may have higher baseline energy literacy than the broader industrial population.
- Industry-specific variability: the scoring framework applies uniform weightings across diverse sectors; it is acknowledged that the relative importance of individual factors may differ by industry type.
- Depth of collected information: the level of detail provided by participants varied considerably, with some companies unable or unwilling to share electricity billing records or consumption breakdowns, limiting the precision of certain data points.

The participant cohort was drawn primarily from Advitech's existing professional network within the Hunter Valley industrial community, supplemented by referrals from industry bodies and companies from previous Advitech energy audits. This recruitment approach may introduce selection effects: companies with an established relationship with an energy consultancy are likely to have higher baseline energy literacy and greater familiarity with energy management concepts than the broader industrial population. The cohort may therefore represent a more engaged subset of mid-sized industrial companies than would be obtained through a random or cold-outreach sampling strategy, a consideration when extrapolating the findings to the wider industrial sector.

4.1.5 Ethical Considerations

Given the nature of the stakeholder engagement in this study, which involved direct access to commercially sensitive operational data, energy consumption records, and internal business practices, ethical considerations were an integral component of the research methodology rather than a procedural formality. The intended public availability of the final report further reinforced the importance of establishing clear and consistent protocols governing the treatment of participant data from the outset of the engagement process.

All participating companies provided informed consent prior to engagement. Participants were advised of the purpose of the research, the manner in which their data would be used, and the conditions under which it would be stored and published. Participation was voluntary, and companies were free to withdraw from the study or decline to provide specific information at any stage of the engagement process.

The handling of all data collected during the study was governed by four principles:

1. All participating companies and individual contacts were anonymised prior to analysis and publication. Companies are identified throughout this report by alphabetical designation only, as described in Section 3.3.
2. All data was stored and managed in accordance with Advitech's certified integrated management system, which operates under ISO 9001 quality management standards, ensuring that data handling, access controls, and document retention practices met a verified and independently audited standard throughout the project.
3. Data obtained through the stakeholder engagement process was used solely for academic analysis and the strategic research objectives of the AR-PST Stage 5 program. It was not used for commercial purposes, shared with third parties, or applied to any purpose outside the scope of this project without explicit authorisation.
4. Confidential or commercially sensitive information disclosed by participants during the engagement process was excluded from publication.

It is believed that participants were more willing to share operational details, internal constraints, and commercially sensitive information when they had confidence that the data would be handled responsibly and that their organisation would not be identifiable in the published findings.

4.1.6 Limitations

The following limitations are acknowledged in the interpretation of the results presented in this report.

These limitations do not invalidate the findings but rather should be considered when assessing the transferability and extent of the conclusions. Potential limitations of the study include:

4.1.6.1 Self-reporting bias

Primary data was collected through conversational interviews and follow-up correspondence, with participants self-reporting their operational characteristics, energy consumption patterns, and attitudes toward demand response participation. As with any qualitative, interview-based methodology, there is an inherent risk that responses reflect how participants wish to present their organisation rather than its precise operational reality. In particular, participants may have overstated their openness to DR participation, their existing energy management practices, or their technical capabilities, particularly where there was a desire to appear progressive or engaged on energy matters. Such degree was observed as approximately 50% of the cohort expressed willingness to participate in DR program, yet only 1 company had and available notice period of 2-8 hours, while the remainder had opted for 24 hours' notice period. It is remarkably challenging to eliminate self-reporting bias entirely within a qualitative, interview-based methodology of this kind; it can only be meaningfully mitigated through an independent, professional assessment of a site's actual engineering capability, which is precisely the approach proposed in the customer-centric demand-side management study of future work outlined in Section 8.2. This risk was partially mitigated by cross-referencing self-reported data with available documentary evidence, such as electricity bills, energy audit reports, and emissions disclosures, and by an iterative follow-up process that provided an opportunity to probe and verify initial responses. Nevertheless, some degree of self-reporting bias cannot be entirely ruled out in the dataset.

4.1.6.2 Limited sample size

From the early stages of stakeholder engagement, it became apparent that obtaining comprehensive industrial load data was considerably more difficult than anticipated. While the majority of participating companies demonstrated a clear awareness of their overall energy consumption, including monthly usage figures and daily fluctuation patterns, 88% of the cohort had no breakdown of energy consumption at the equipment or process level. The absence of end-use submetering data created gaps in the load identification analysis and constrained the depth of characterisation that could be achieved for a number of participants.

4.1.6.3 Industry-specific variability

The scoring and classification framework developed for this study applies uniform weightings to barriers and capability factors across all participating companies, regardless of industry sector. This approach was necessary to enable consistent comparison across a diverse cohort, but it carries an inherent limitation; the relative significance of individual barriers and capability factors is likely to differ by sector. A continuous process constraint, for example, carries different practical implications in a food processing facility than in a heavy engineering workshop, even where both attract the same negative weighting under the framework. Similarly, the value of on-site generation as a capability factor may be considerably higher for a site with a significant daytime load than for one operating predominantly on night shifts. These sector-specific nuances were acknowledged and considered in the findings; however, they are not fully captured by the normalised scoring index. Future research involving larger, sector-stratified samples would allow the framework weightings to be refined and validated at the industry level.

4.1.6.4 Depth of collected information

A related limitation concerns the transferability of the findings. While the industrial load types and taxonomy developed in Section 4.2 Taxonomy of Loads can be extrapolated across broader industry sectors, given that similar equipment categories appear consistently across comparable industrial settings; there is no single sector that presents a straightforwardly accessible DR opportunity. DR suitability is not determined by industry type alone; it depends on the specific combination of operational flexibility, energy awareness, available data, and technical constraints present at each individual site. Accordingly, while load characterisation can be meaningfully applied at the sector level, the potential for DR participation must be assessed at the company level. This distinction is central to the findings discussed in Section 5.5 Findings and Discussion.

Several of the limitations identified above are not incidental to this stage of the research; they are, in part, a product of the gaps in industrial DR infrastructure, data availability, and standardisation that this study set out to characterise. The proposed follow-on research program directly addresses each of these limitations: through site-based audit methodology that replaces self-reported data with verified measurements; through in-depth case studies that provide the operational depth a broad survey cannot achieve; and through the development of a standardised industrial DR framework that would establish the technical and measurement foundations currently absent from the sector. In this sense, the limitations of Stage 5 are also its most important outputs, as they define the work that needs to be done next and are discussed in Section 8, Future Work.

4.2 Taxonomy of Loads

The main objective of this project was to investigate and assess the potential of industrial electrical loads to provide system services in the NEM, including participation in demand-side management and load flexibility programs such as demand response, as well as the barriers to this potential. The project was based on a series of interviews, follow-up phone calls, and emails with the industrial participants.

A central output of this study was the development of a taxonomy of industrial loads observed across the participating companies. The taxonomy of loads serves two purposes: first, to characterise the types of operational behaviour of loads present within mid-sized industrial facilities in the Hunter Valley; and second, to assess the inherent flexibility of these loads as a basis for evaluating their suitability for demand response participation. Understanding load characteristics at this level of granularity was a necessary precondition for translating industrial DR potential from a theoretical concept into an operationally credible proposition. The taxonomy of load of nine functional load categories and their associated operation type and control dependency classifications, presented in section 5.4.2 and summarised in Table 10, is defined by equipment behaviour rather than regional characteristics and is therefore expected to be broadly transferable to industrial facilities in other NEM regions, including comparable industrial centres such as Gladstone, the Pilbara, and the Latrobe Valley. However, the specific distribution of load types and the barrier and capability scores derived from this study's cohort reflect the particular industrial mix of the Hunter Valley and should not be assumed to apply directly elsewhere. Scaling the scored assessment to other NEM regions would require an equivalent stakeholder engagement process applied to the relevant local industrial base, following the same methodology described in Section 4.1.

The following section presents a structured methodology assessment for industrial electrical loads and their potential to provide system services, including participation in demand-side management and load flexibility programs, such as demand response. The approach combines qualitative and quantitative data to create a consistent, scalable framework for comparing companies across sectors.

The methodology used during this case study is built on four core pillars, which integrate:

- Data Analysis: Layout of collected data for each individual company;
- Constraints and Capability Assessment: Identification of organisational and operational constraints, and technical behaviour capabilities;
- Scoring: evaluation matrices to uniformly assess the constraints and capabilities; and
- Load Characterisation: Equipment-level load characteristics.

The outcome is a Load Flexibility Index supported by a taxonomy of industrial loads, enabling identification and prioritisation of high-potential sites for system services such as demand-side response, as well as the barriers to such potential.

4.2.1 Survey Data Analysis

Qualitative research methods were utilised to collect and analyse data to understand demand management in an industrial setting.

This stage of the project was considered one of the key components for the successful translation of data collected during stakeholder engagement, as it laid the foundation for subsequent stages of data analysis and consequently the successful development of the taxonomy of load.

Following the stakeholders' engagement interview, interview transcripts and reviewed documents were coded, and patterns were compared across companies to identify common practices and differentiators (taxonomy). Following, the data was extrapolated into an Excel spreadsheet and analysed.

The data was laid out in order to identify commonalities among industrial companies, from general site knowledge to more complex operational energy consumption. Furthermore, the data gathering was used to identify common barriers each company would face for unlocking the potential participation in DR programs. This stage was also used to identify positive characteristics or capability factors that would allow a company to participate in DR programs. The full questionnaire data analysis is available in Appendix B.

The data was categorised in the following sections:

- Industrial classification, based on the ANZSIC Classification code;
- Operational working conditions, including working days, shift patterns, and daily operating hours;
- Previous energy auditing activity and the availability of existing audit findings;
- Annual energy consumption, drawn from electricity billing records and participant-reported figures;
- Primary energy-intensive equipment, comprising the loads identified by participants as the most significant consumers of electricity within their operations;
- Energy breakdown at the equipment level, where submetering data or equivalent load disaggregation was available;
- Electricity tariff structure, including time-of-use arrangements, demand charges, and contractual peak thresholds;
- Additional energy sources, including the use of coal, natural gas, biomass, or other supplementary fuels;

- In-situ energy generation and storage, including photovoltaic solar systems, battery energy storage systems, diesel generators, and uninterruptible power supplies;
- Dynamic operation potential, assessing whether the company had identified opportunities for load shifting, load ramp-up or ramp-down, or the ability to turn specific equipment on or off in response to an external signal; and
- Participation availability, covering whether the company had an existing interest in DR programs, was currently enrolled in any program, or had participated in one previously.

Although no results were drawn from it, the research also compiled additional information on the presence of frequency and voltage, regulating assets, specifically direct online motors and Power Factor correction, respectively.

4.2.2 Constraints Assessment

The objective was to quantify the extent to which operational, technical, and organisational barriers limit load flexibility and participation in DR programs.

Upon laying out the data, a pattern emerged, and common constraints and capability factors were identified. As anticipated, the cohort shared commonalities and differentiating factors that were already evident during the stakeholders' engagement but became more evident during the data analysis. One common trait was the dynamic operation and continuous processes. While continuous processes were considered non-negotiable in terms of load flexibility, industrial stakeholders remained interested in participating in DR programs; however, they often opted for a 24-hour notice period.

Common constraint categories are discussed in the following subsection.

4.2.2.1 Constraints Categories

During the information-gathering stage of stakeholder engagement, an analysis of the data indicated familiarity with the companies' constraints in modifying electrical load, thus hindering their ability to provide system services. The identified constraints are presented below.

Organisational Inertia

The participant has expressed interest in demand response participation or has identified opportunities to curtail load, but progress has been constrained by deeply embedded workplace culture, operational conventions, or company-level policies that resist change. This barrier is characterised by an unwillingness or inability to alter established routines, even where the energy or commercial case for doing so is recognised. Examples include shift patterns that have remained unchanged for decades, such as production equipment being started at the beginning of a conventional day shift regardless of grid conditions, or an organisational culture in which proposals to modify operational practices could face internal resistance from staff or management.

Labour Cost

The participant would not consider altering shift patterns or equipment usage in response to a demand-response signal because the associated labour costs would materially outweigh any potential energy savings. This barrier operates at two levels. At the strategic level, energy expenditure represents a sufficiently small proportion of overall operating costs that it does not attract meaningful management attention or drive operational decisions. At the operational level, curtailing or rescheduling a production process for the duration of a DR event would directly result in idle labour time, translating an energy saving into an equivalent or greater wage cost. For DR to be viable for labour-intensive industrial facilities, the financial incentive offered through DR program participation must exceed the cost of displaced labour.

Access and Awareness

The participant has expressed interest in demand response participation but has not identified opportunities to curtail load and faces a gap between that intent and its practical realisation. This barrier has both internal and external dimensions. Internally, it encompasses an absence of in-house electrical engineering knowledge and a limited understanding of end-use energy consumption or load breakdown within the facility. Externally, it reflects the reality that many mid-sized industrial companies are not considered sufficiently large by aggregators, retailers, or program administrators to be viable DR participants.

Technology Availability

The participant has expressed interest in demand response participation or has identified opportunities to curtail load, but the equipment and infrastructure currently installed at the facility do not support an effective response. This includes ageing process equipment, such as older industrial air conditioning systems, that requires continuous standby operation rather than being cycled on and off as needed; equipment that lacks the control interfaces necessary for automated or remotely triggered response; and facilities operating from leased premises where the landlord is unwilling to support the installation of on-site generation, such as storage or solar infrastructure.

Data Deficiency

The participant has expressed interest in demand response participation but does not have sufficient visibility of their electricity consumption to understand how their operational patterns connect to their energy use, or to identify which loads could feasibly be curtailed or rescheduled. This includes an understanding of potential low-energy modes of operation for 1-2 hour periods. This barrier goes beyond basic billing data and reflects the absence of submetering, load disaggregation, or interval data analysis at the equipment or process level. Without this information, a site cannot reliably identify which equipment draws the most power, which processes are candidates for ramp-up or ramp-down, or what a low-energy operating mode would look like for a defined curtailment window of one to two hours. In practice, this means that even operationally willing participants are unable to make credible commitments to a DR program without first undertaking a structured energy audit at Level 2 or Level 3 under AS 3598.

Continuous Process Dependency

The participant operates one or more continuous processes in which equipment must remain running throughout the production cycle to ensure efficient resource use and product integrity. This barrier represents a fundamental constraint on DR participation, as it limits the fraction of total facility load that can be made available for curtailment regardless of the participant's willingness or technical capability. For the purposes of this framework, a process is classified as continuous where an unplanned interruption is defined as a curtailment event with less than one hour's notice and would result in product wastage or material losses exceeding $1,000; require extensive recalibration or restart procedures before normal operations could resume; or create an unacceptable health and safety risk due to the process requiring continuous human supervision. It is noted that the presence of a continuous process does not entirely preclude DR participation. Facilities operating continuous processes may still have discrete, separable loads available for curtailment, but this significantly reduces the available DR capacity relative to the total facility demand.

4.2.2.2 Capabilities Categories

Similar to the constraint categories, there was a pattern in the potential of an industrial site to provide system services and therefore participate in demand-side management, specifically demand response programs. The identified capabilities are:

Energy Use Data

The participant demonstrated awareness of their site's energy usage patterns and daily consumption fluctuations, including knowledge of electricity tariffs and a general understanding of which equipment or processes are the most energy-intensive. This capability reflects the foundational layer of energy literacy required to identify loads with flexible operability and to begin assessing DR participation potential. Energy Use Data was strongly correlated with prior energy auditing activity across the cohort; companies that had previously undertaken a formal energy audit consistently demonstrated a more detailed and reliable understanding of their consumption profile than those that had not. It is noted that this capability, while broadly present, does not in itself indicate submetering or equipment-level load disaggregation; its presence confirms awareness, not operational readiness.

On-site Generation

The participating company had one or more distributed energy resources installed on the premises, including photovoltaic solar panels, battery energy storage systems, diesel or gas generators, uninterruptible power supplies, or alternative fuel sources such as bioenergy or biogas. The presence of on-site generation indicates a capacity for partial grid independence, which supports DR participation by allowing the company to substitute self-generated energy for grid supply during a curtailment event, reducing the operational impact of load reduction. Where on-site generation is paired with storage, this capability is considerably more valuable as a DR enabler, as it decouples the timing of generation from the timing of consumption and allows the company to respond to dispatch signals regardless of prevailing generation conditions.

Dynamic Operation

The participating company had identified one or more pieces of equipment or production processes with confirmed or potential flexible operability; that is, the ability to ramp consumption up or down, or to switch loads on and off, in response to an external signal or operational instruction. Dynamic operation capability does not require that all facility loads be flexible; it requires that at least some loads can be adjusted without immediately compromising production output, product quality, or workplace safety. The presence of this capability is the most direct technical indicator of accessible DR capacity at a site and received the joint second-highest positive weighting in the scoring framework alongside Participation Availability.

Participation Availability

The participating company expressed a willingness to participate in demand response programs, either by seeking more information about available programs or by indicating readiness to enrol subject to sufficient financial incentive or compensation for any operational downtime, inconvenience, or production adjustment required. This capability reflects the company's commercial disposition toward DR engagement rather than a confirmed technical capacity. Its presence is a necessary but not sufficient condition for participation: a company may be willing to participate but remain unable to do so without first addressing data deficiency, technology availability, or continuous process constraints.

Existing Participation

The participating company was currently enrolled in, had previously participated in, or had a confirmed future commitment to a formal demand response program or curtailment agreement. This capability received the highest positive weighting in the scoring framework, reflecting the well-established finding in the literature that demonstrated prior engagement is the strongest single predictor of continued and future participation.

4.2.2.3 *Curtailment*

Each participating company was asked to identify the minimum notice period they would require before being able to respond to a demand response event; that is, the shortest lead time between receiving a curtailment signal and being able to reduce or modify their load in a meaningful and safe way. This question was designed to assess not only whether a company could participate in DR, but also the operational conditions and timeframes under which such participation would be practically feasible. The responses provide a direct measure of each site's operational responsiveness and inform the notice period scoring component of the classification framework described in Section 4.2.3.

It is worth noting that where a participant was unable to provide a definitive response to the notice period question, either due to uncertainty about their operational constraints or insufficient information to make a reliable assessment, a default value of 24 hours was assigned for scoring consistency and normalisation across the cohort. This conservative default reflects the least favourable notice-period weighting in the framework and ensures that unconfirmed flexibility is not inadvertently credited to the composite score.

4.2.3 Scoring Approach

A purpose-built classification framework was developed to enable systematic comparison of DR participation potential across the participant cohort. The framework assesses each company against two sets of factors: barriers that reduce the likelihood of participation were assigned negative weightings, and capability factors that enhance the likelihood of participation were assigned positive weightings. A composite raw score is calculated for each participant and subsequently normalised to a 0–1 index to facilitate relative ranking.

The barrier factors and their weightings are presented in Table 4 and reflect the relative degree to which each constraint is likely to prevent or delay participation in a demand response event. Continuous process constraints received the highest negative weighting, reflecting the fundamental incompatibility between uninterruptible production processes and the load reduction requirements of a DR event. Technology and data deficiencies were assigned the next highest negative weighting, recognising that without adequate metering infrastructure or flexible equipment, participation is effectively precluded regardless of willingness. Organisational and educational barriers, while significant, were considered more amenable to intervention and were weighted accordingly.

Table 4: Barriers to Demand Response Classification Scoring Framework

Constraint Category	Score Weighting
Continuous Process	-4
Technology Availability	-3
Data Deficiency	-3
Organisational Inertia	-2
Labour Cost	-1.5
Access & Awareness	-1.5

On the positive side, existing DR participation was assigned the highest capability weighting, as demonstrated, prior engagement is the strongest predictor of future participation. Dynamic operational capacity, the ability to ramp loads up or down in response to an external signal, received the next highest weighting, followed by participation availability, on-site generation, and energy use data. Scoring Framework are presented in Table 5.

Table 5: Capability Factor Enabling Demand Response Participation Scoring Framework

Constraint Category	Score Weighting
Existing Participation	+4
Participation Availability	+3
Dynamic Operation	+3
On-site generation	+2
Energy Use Data	+1.5

In addition to the binary barrier and capability scores, the framework incorporates a graduated score for the minimum notice period a company requires prior to a curtailment event. Shorter notice periods are assigned higher positive scores, reflecting greater practical utility to system operators. Table 6 presents the scoring framework for curtailment.

Table 6: Notice period Scoring Criteria

Notice period	Hours	Score Weighting
0 – 1 hour	0 – 1	+4
1 – 2 hours	1 – 2	+3
2 – 8 hours	2 – 8	+2
8 – 24 hours	8 – 24	+1
24 hours or more	24+	0

4.2.4 Load Categories & Characterisation

Industrial equipment identified during the stakeholder interviews and data analysis was compiled and categorised by load characteristics, enabling classification of electrical equipment by control dependency and inherent flexibility potential.

Control dependency represents the ability of the equipment to be automated, requires manual intervention or involves a combination of both. Flexibility ratings were assessed using the following classifications:

- Low: Load shifting would materially impact the production process and is generally not feasible without significant operational consequences and adjustments;
- Medium: load shifting requires advance planning and may have minor process impacts, but is achievable under appropriate conditions; and
- High: load shifting can be accomplished without materially impacting the production process

A total of 53 distinct load types were identified across the industrial participation cohort and grouped into nine functional categories. Each load type was subsequently characterised according to its operational behaviour, control dependency, and flexibility potential. Together, these categories encompass the full spectrum of energy-intensive activities observed at the participating industrial sites, from background infrastructure to heavy machinery production processes. The identified categories and their identified quantities are presented in Figure 7 below. The identified characteristics of each respective category are discussed in Section 5.4, with the full taxonomy of load in Section 5.4.2.

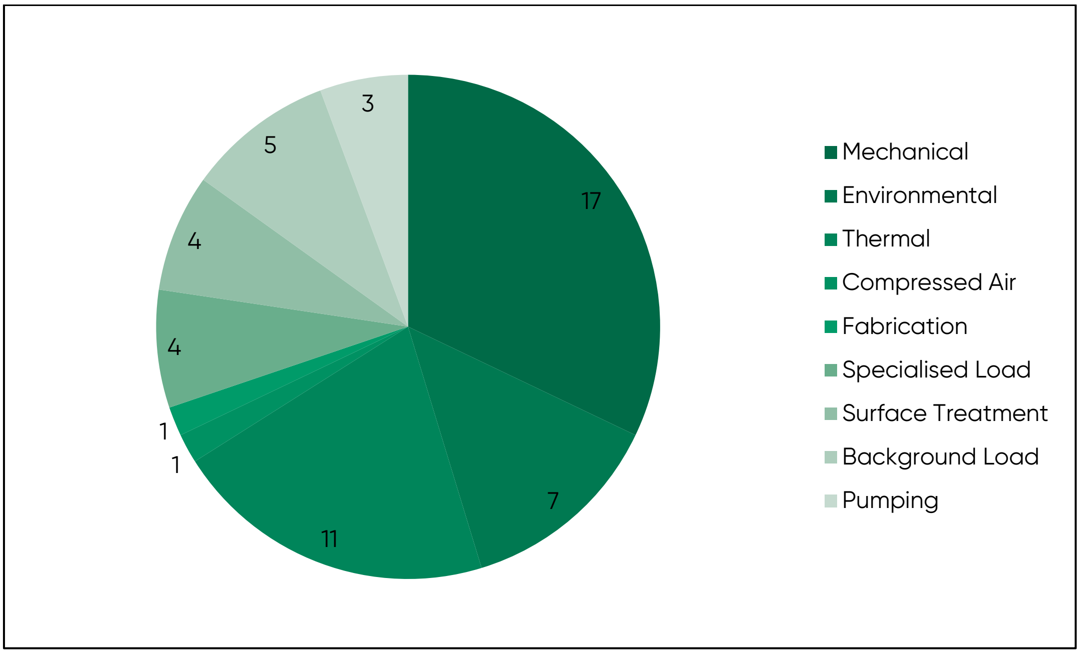

Figure 7: Distribution and Characterisation of Industrial Loads

5. Results

This section presents the results of the barrier and capability classification, scoring, and load characterisation analysis conducted across the 22 assessed companies. The results are organised across four (4) subsections: barrier classification, capability factor assessment, DR participation potential scoring, and load identification and characterisation. The findings drawn from these results are discussed in Section 5.5.

5.1 Barriers & Classification

The barriers refer to the technical, operational, and organisational constraints that limit a company's ability to participate in demand response programs. Six (6) barrier categories were assessed for each participant, as defined in Section 4.2.3. Each barrier was scored as binary (1 = present, 0 = absent), with a negative weighting applied when the barrier was identified. Table 7 summarises the prevalence of each barrier across the full cohort of 22 companies.

Table 7: Barrier prevalence and weighting across the 22-company cohort.

Barrier	Prevalence	Key Constraint
Technology Availability	73%	Ageing equipment, rental premises, and absence of on-site DER. Limits response capability regardless of operational willingness.
Data Deficiency	73%	No submetering at the equipment or process level. Prevents credible DR commitment, baselining, or verification.
Continuous Process	68%	Uninterruptible production cycles. The highest weighting fundamentally limits accessible DR capacity.

Barrier	Prevalence	Key Constraint
Organisational Inertia	55%	Entrenched shift patterns, workplace culture resistant to operational change.
Labour Cost	55%	Cost of displaced labour exceeds energy savings under current incentive structures.
Access and Awareness	32%	Absence of in-house electrical engineering knowledge and market access pathways.

Technology Availability and Data Deficiency were the two most prevalent barriers; each identified in 73% of participating companies. Their co-occurrence across the cohort reflects a structural relationship: a facility without adequate metering infrastructure typically lacks the equipment-level load data required to identify flexible loads, commit to a curtailment quantum, or verify its DR program after an event. Together, these two barriers represent the most pervasive and practically significant constraints on industrial DR readiness in the cohort.

The Continuous Process barrier was present in 68% of companies and carries the highest negative weighting in the framework. Its prevalence means that for the majority of participating companies, a significant fraction of the total facility load is structurally inaccessible for curtailment, regardless of expressed interest or technical capability, because the process cannot be interrupted within the 1-hour notice threshold without incurring product loss, equipment damage, or health and safety risks. It is important to note, however, that the presence of a continuous process does not preclude DR participation entirely; facilities operating continuous processes may still have separable, non-production loads available for curtailment, as discussed in Section 5.5.

The barriers classification results presented in Table 7 are illustrated graphically in Figure 8, which provides an aggregated view of barrier prevalence across the full participant group, split between the primary and supplementary cohorts. This comparison allows the relative barrier profiles of the two cohorts to be assessed side by side, highlighting both the commonalities that reflect sector-wide structural constraints and the differences arising from the distinct recruitment channels and operational contexts of each group. Figure 9 and Figure 10, disaggregate the results further, presenting the barrier classification for each individual company within the primary and supplementary cohorts, respectively. These figures reveal the degree of variation within each cohort, pointing to a central finding: barrier profiles are site-specific. No two companies share an identical combination of constraints, and the presence or absence of a single high-weighted barrier can substantially alter a company's composite score and DR participation profile.

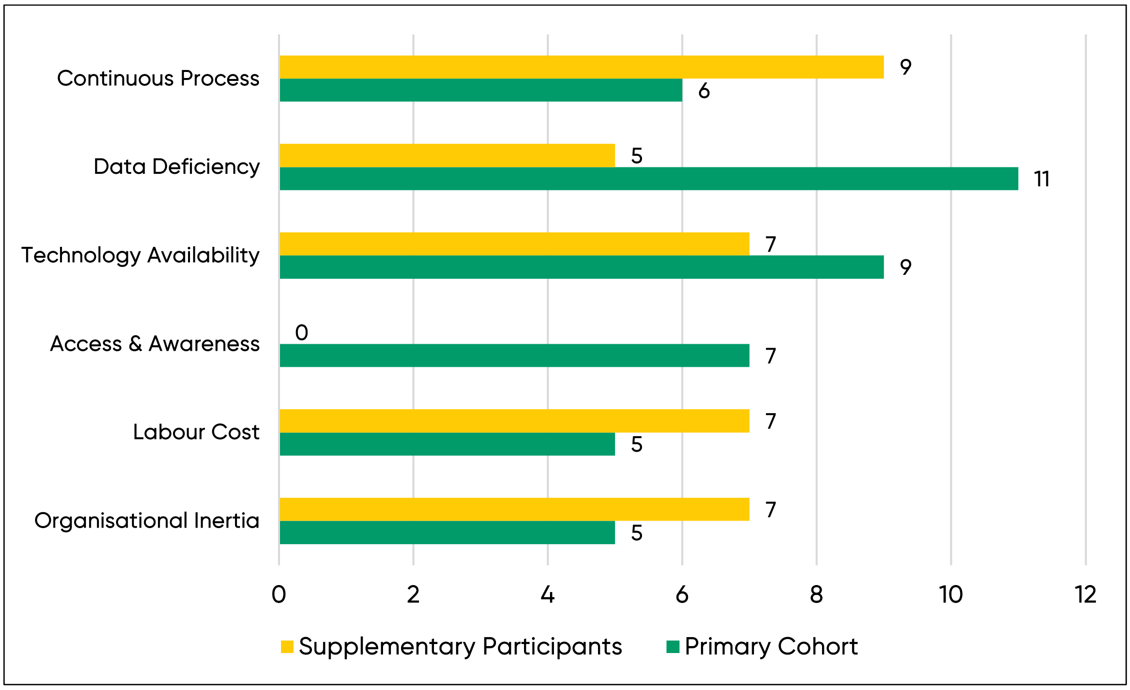

Figure 8: Barriers of each Participant Group Cohort

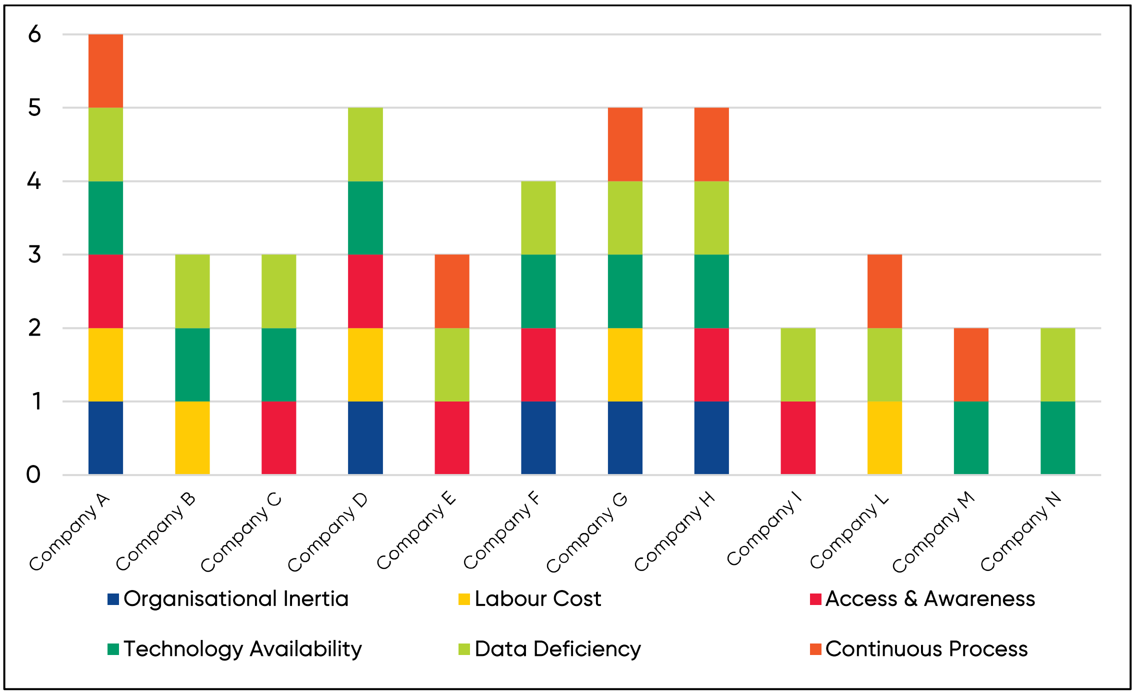

Figure 9: Barriers for Individual Primary Cohort

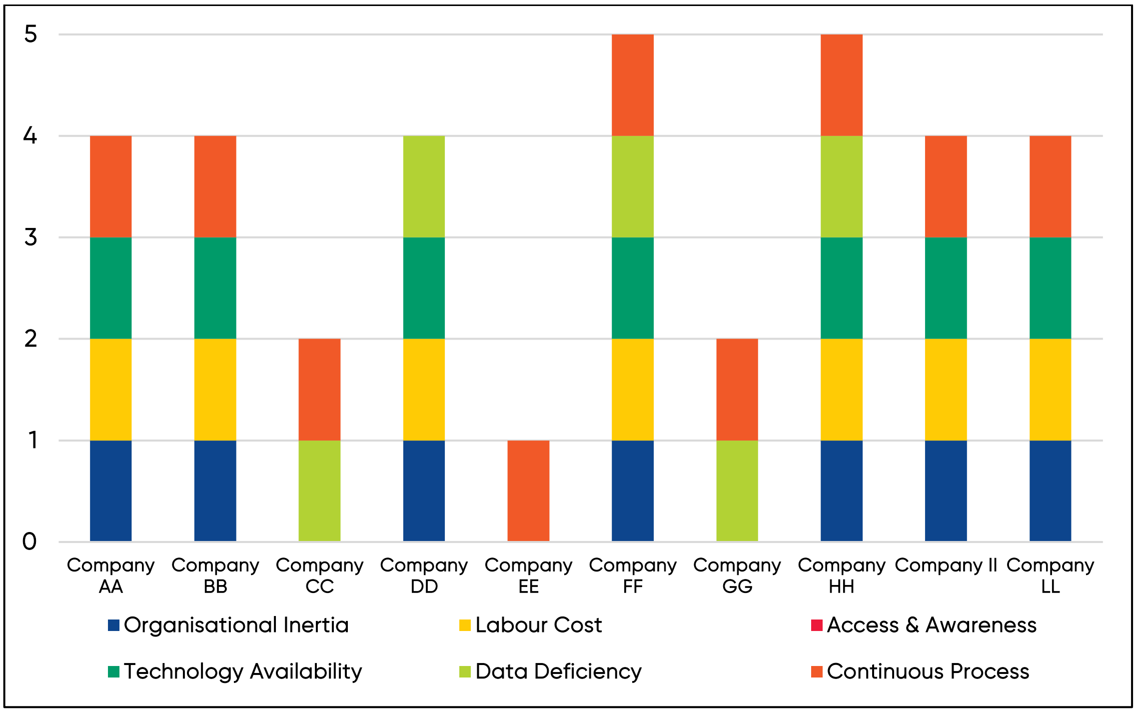

Figure 10: Barriers for Individual Supplementary Cohort

5.2 Capability Factors

Capability factors are the attributes, resources, and operational characteristics that enable a company to participate in DR programs. Five (5) capability categories were assessed for each participant. As with the barriers, each factor was scored as binary (1 = present, 0 = absent), with a positive weighting applied where the capability was identified. Table 10 summarises the prevalence and weighting of each capability factor across the full cohort.

Table 8: Capability factor prevalence and weighting across the 22-company cohort

Capability Factor	Prevalence	Key Observations
Energy Use Data	95%	Broad awareness of overall consumption – present in nearly all companies but rarely extends to equipment-level detail.
On-Site Generation	64%	PV, genset, or BESS present at the site. Improves DR viability and reduces grid exposure during curtailment.
Dynamic Operation	55%	The company has identified equipment with flexible operability or confirmed the potential to ramp up/down or turn on/off.
Participation Availability	50%	Expressed interest in DR program participation, subject to sufficient incentive or compensation.
Existing DR Participation	9%	2 companies in the cohort had prior or current enrolment in a formal DR program.

Energy Use Data was the most prevalent capability factor, present in 95% of companies. However, this high prevalence should be interpreted with care. As discussed in Section 4.1.6, the Energy Use Data capability reflects an awareness of overall site energy consumption, such as monthly billing totals, approximate annual figures, and a general understanding of energy-intensive equipment, rather than submetering or equipment-level load disaggregation.

On-Site Generation was present in 64% of companies, most commonly rooftop photovoltaic systems, with several participants also reporting diesel gensets or gas-fired backup generation. The presence of on-site generation is a positive DR indicator because it provides partial independence from grid supply during curtailment events and, in facilities with battery storage, enables load shifting in response to tariff signals. In facilities with PV only and no storage, the contribution to DR is more limited, as the generation profile does not necessarily align with curtailment windows.

The capability factor results are presented in Table 8 are illustrated graphically in Figure 11, which provides an aggregated view of capability factor prevalence across the full participant group, split between the primary and supplementary cohorts. This aggregated view allows the enabling characteristics of the two cohorts to be compared directly, revealing the extent to which positive DR indicators are distributed across the participant group and identifying which capability factors are broadly present versus those that remain the exception. Of particular note in the aggregated view is the prevalence of Energy Use Data alongside the complete absence of Existing DR Participation, a combination that captures, in a single visual, a broad baseline of energy awareness that has yet to translate into any active program engagement. Figure 12 and Figure 13 disaggregate the results to the individual company level for the primary and supplementary cohorts, respectively. These figures illustrate that while capability factors such as On-Site Generation and Dynamic Operation are present in a meaningful proportion of both cohorts, their distribution is uneven, and, crucially, their effectiveness as DR enablers depends on addressing the barriers that exist alongside them. A company with confirmed dynamic operation capability but a severe data deficiency, for example, cannot reliably act on that flexibility without first establishing the metering foundation that makes curtailment commitments credible.

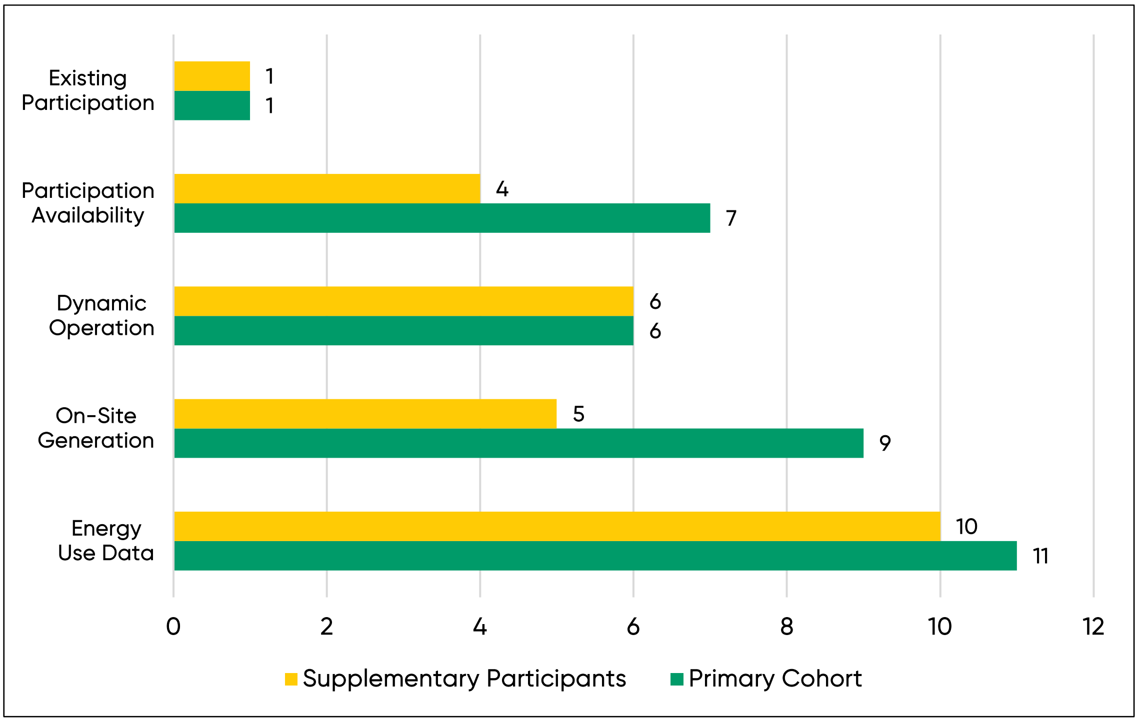

Figure 11: Aggregated Capability Factors for Participant Group Cohort

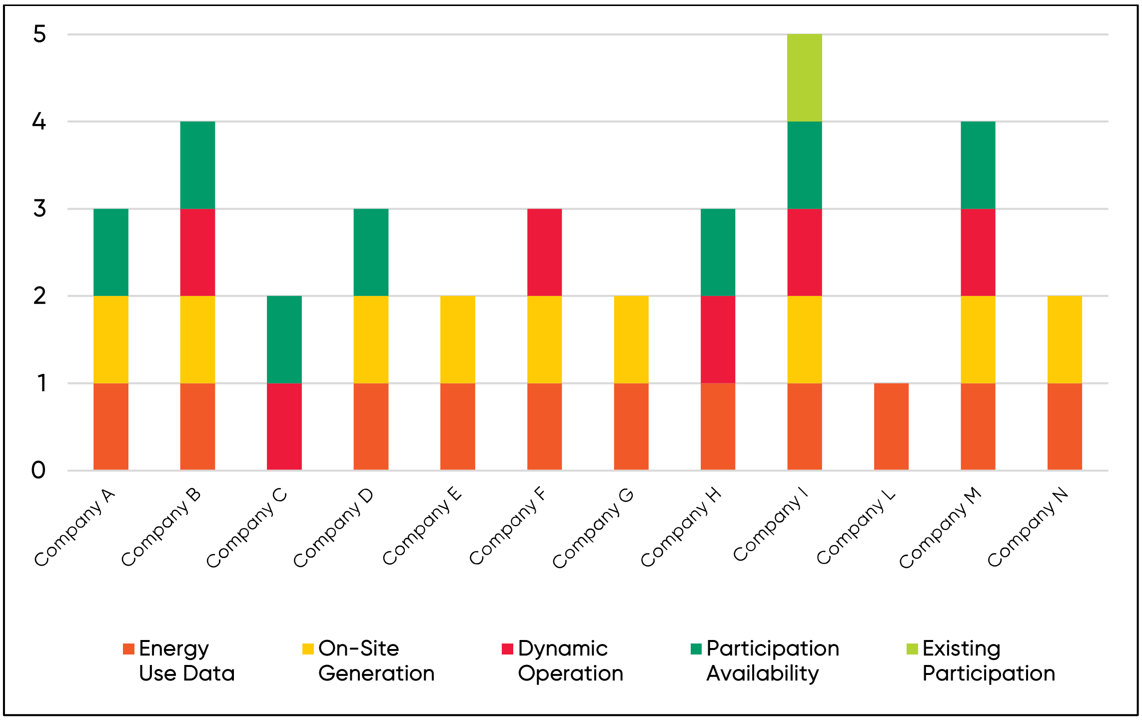

Figure 12: Capability Factor for Individual Primary Cohort

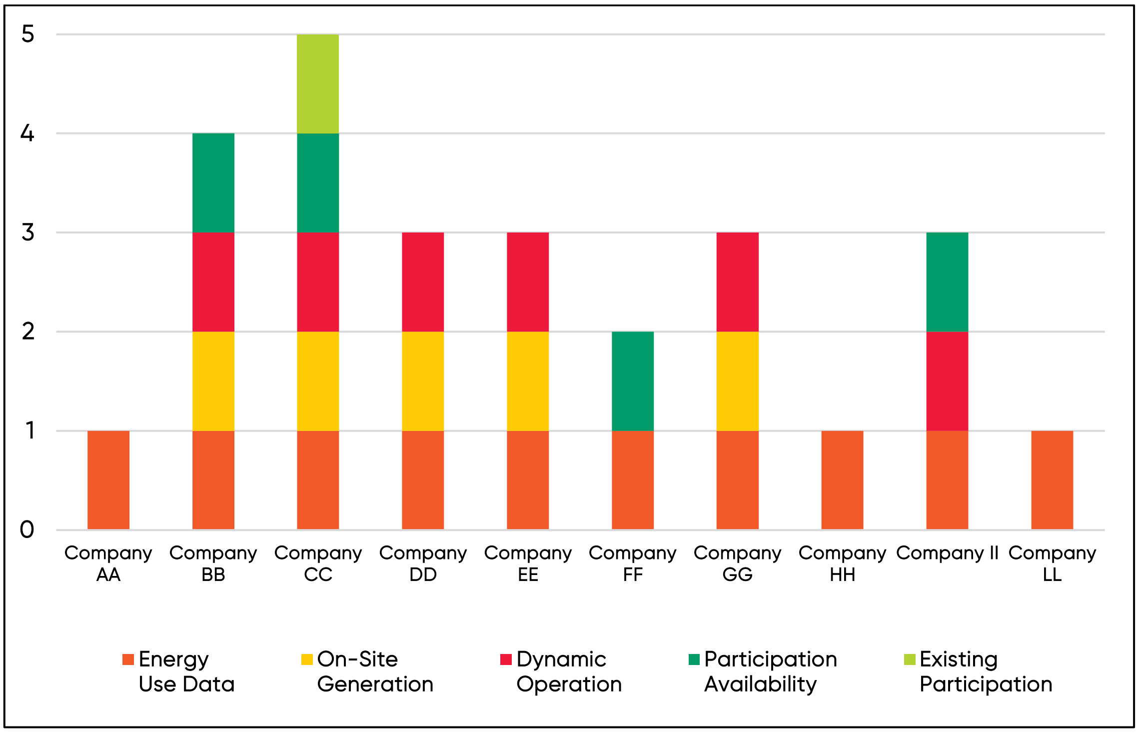

Figure 13: Capability Factor for Individual Supplementary Cohort

5.3 Scoring

The composite raw score for each participant was calculated by summing the weighted barrier penalties, capability factor contributions, and the graduated notice period score.

Raw scores in this study range from a theoretical minimum of -15 to a theoretical maximum of +21.5. Because this range is not symmetrical around zero, the raw score was normalised to a 0 to 100% scale to express each company's position on a consistent percentage basis, indicating its relative potential for DR participation. A company with a low normalised score indicates a barrier-dominated profile and a correspondingly low likelihood of participation without first addressing the underlying barriers. A company with a high normalised score indicates a capability-dominated profile, where capability factors outweigh barriers, and a strong likelihood of viable DR participation under appropriate program conditions. It is noted that a normalised score of 41.1% corresponds to a raw score of zero, the point at which barriers and capabilities exactly offset in the underlying raw score; scores below this threshold indicate a net barrier-dominated profile, while scores above it indicate a net capability-dominated profile.

Against this backdrop, a high normalised score indicates a capability-dominated profile and a correspondingly stronger potential for DR participation, while a low normalised score indicates a barrier-dominated profile and a correspondingly weaker potential for participation under current conditions. The normalised score is best understood as a relative ranking measure, indicating each company's position within the cohort and against the theoretical best and worst possible outcomes under this framework, rather than a measured probability of participation under any specific level of incentive, since the relationship between incentive size and actual participation behaviour was not modelled or measured in this study.

Table 9 presents the participating cohort, based on their ANZSIC characterisation, energy consumption and scoring results.

Table 9: Industrial Participants, Annual Energy Consumption and Score

Industrial Participant	Categorisation ANZSIC	Energy Consumption (MWh/p.a.)	Raw Score	Normalised Score
Company A	Machinery and Equipment Manufacturing	315	-8.5	18%
Company B	Polymer Product and Rubber Product Manufacturing	650	2	47%
Company C	Machinery and Equipment Manufacturing	500	-0.5	40%
Company D	Machinery and Equipment Manufacturing	895	-1.5	37%
Company E	Internet Service Providers, Web Search Portals and Data Processing Services	2,400	-5	27%
Company F	Transport Equipment Manufacturing	2,726	-3	33%
Company G	Food Product Manufacturing	100,000	-10	14%
Company H	Wood Product Manufacturing	7,500	-6	25%
Company I	Transport Equipment Manufacturing	10,300	9	66%
Company L	Basic Chemical and Chemical Product Manufacturing	9,800	-7	22%

Industrial Participant	Categorisation ANZSIC	Energy Consumption (MWh/p.a.)	Raw Score	Normalised Score
Company M	Coal Mining	88,859	2.5	48%
Company N	Machinery and Equipment Manufacturing	3,000	-2.5	34%
Company AA	Water Supply, Sewerage and Drainage Services	9,054	-9	16%
Company BB	Polymer Product and Rubber Product Manufacturing	7,550	-1	38%
Company CC	Beverage and Tobacco Product Manufacturing	6,556	6.5	59%
Company DD	Non-Metallic Mineral Product Manufacturing	280	-3	33%
Company EE	Beverage and Tobacco Product Manufacturing	1,477	2.5	48%
Company FF	Polymer Product and Rubber Product Manufacturing	7,528	-9	16%
Company GG	Beverage and Tobacco Product Manufacturing	1,260	-0.5	40%
Company HH	Machinery and Equipment Manufacturing	1,136	-12	8%
Company II	Waste Collection, Treatment and Disposal Services	1,016	-3	33%
Company LL	Food Product Manufacturing	3,026	-9	16%

5.3.1 Score Distribution

Across the 22 assessed companies, raw scores ranged from −12.0 to +9.0, with a mean of −3.1 and a median of −3.0. Normalised scores ranged from 8% to 66%. Only five (5) companies, representing 23% of the cohort, recorded a positive raw score, indicating that barriers outweigh capability factors for the vast majority of participants under current conditions. Seventeen (17) companies (77%) recorded negative raw scores, confirming a cohort that is, on paper, barrier dominated.

The score distribution can be characterised across four (4) bands. Two (2) companies recorded scores at or above +3.0, indicating a profile with high readiness potential for DR participation, where capability factors substantially outweigh barriers: Company I (Transport Equipment Manufacturing, +9.0, 66%) and Company CC (Beverage and Tobacco Product Manufacturing, +6.5, 59%). Three (3) companies recorded moderate positive scores between 0 and +3.0: Company M (Coal Mining, +2.5, 48%), Company EE (Beverage and Tobacco Product Manufacturing, +2.5, 48%), and Company B (Polymer Product and Rubber Product Manufacturing, +2.0, 47%). Eight (8) companies recorded scores between −5 and 0, indicating that barriers are present but potentially addressable through targeted intervention. Nine (9) companies recorded scores at or below −5.0, indicating profiles deeply dominated by barriers, with severe structural constraints on DR participation.

Company I is the highest-scoring participant in the cohort, with a score of +9.0 (66%). This result reflects a profile combining confirmed dynamic operational capability, on-site generation, DR participation availability, the absence of a dominant continuous process constraint, and a comparatively short-notice period tolerance of approximately 8 hours. Company HH is the lowest-scoring participant at −12.0 (8%), reflecting the simultaneous presence of organisational inertia, labour cost, technology availability, data deficiency, and continuous process barriers, with limited offsetting capability factors.

The specific intervention required depends on which barrier is present: a Data Deficiency barrier is addressable through a structured Level 2 Energy Audit under AS 3598.2, of the kind proposed in the follow-on customer-centric DSM study in Section 8.2, which would establish the equipment-level sub-metering needed to credibly identify and commit to flexible loads.

An Access and Awareness barrier is addressable through targeted energy literacy and DR program education, requiring no capital investment, only improved information and engagement with existing market mechanisms.

A Technology Availability barrier, where the underlying process itself is not a continuous one, is addressable through modest capital investment in sub-metering, automated control interfaces, or on-site generation.

Even where a Continuous Process barrier is present, separable, non-production loads, such as air compressors and pumping systems, typically remain available for curtailment independently of the constrained process itself, as discussed further in Section 5.5.4. This was directly demonstrated by a supplementary cohort participant with a continuous process and a below-threshold classification score of -1 (38%), who independently shifted its operational window to create a curtailment interval and ramped flexible loads down to between 50 and 75% of normal consumption, confirming that load shifting remains operationally achievable even within a constrained facility when the company is motivated to investigate it; this case is discussed in further detail in Section 5.5.5.

Notably, Company I and Company CC, the two highest-scoring participants in the cohort, both had prior or current enrolment in a formal DR program, consistent with the framework's weighting of Existing DR Participation as the strongest single predictor of continued and future participation. It is noted that a Labour Cost barrier, where present in this band, is not resolved through these interventions, as it reflects a structural economic constraint requiring the incentive redesign discussed in Section 5.5.5, rather than a site-level fix.

5.3.2 Sector-Level Patterns

At the sector level, the Transport Equipment Manufacturing sector recorded the highest average raw score (+3.0), driven primarily by Company I's high score of +9.0, compared with Company F's −3.0. The Beverage and Tobacco Product Manufacturing sector recorded the second-highest sector average (+2.8), with participants scoring positively or near-neutral: company CC +6.5 (59%), Company EE +2.5 (48%), and Company GG −0.5 (40%). The Coal Mining sector (Company M only) recorded +2.5 (48%).

The Machinery and Equipment Manufacturing sector, the largest in the cohort at five (5) companies, recorded the lowest average score of any multi-company sector at −5.0, with every individual company scoring negatively. Scores within this sector ranged from −0.5 (Company C) to −12.0 (Company HH), illustrating that within-sector variation is as analytically significant as between-sector differences. The Data Processing Services sector (Company E only) recorded −5.0 independently, consistent with the technology and data deficiency profile typical of a data centre operating environment. The Food Product Manufacturing sector recorded an average of −9.5, driven by a combination of large-scale continuous processes, strict regulatory and food safety constraints, and limited dynamic operational capability across both participants.

As with the earlier analysis, sector averages should not be used as the basis for program targeting. The within-sector variation observed, particularly in Machinery and Equipment Manufacturing and Polymer Product Manufacturing, which ranged from +2.0 to −9.0 across three companies, confirms that site-specific assessment remains the more reliable and equitable basis for determining DR readiness.

5.3.3 Notice Period Results

Within the primary cohort, the minimum notice period responses ranged from one (1) hour to an absolute unwillingness to participate regardless of lead time. One company indicated a willingness to respond with as little as one hour's notice, reflecting a high degree of operational scheduling flexibility and an absence of continuous process dependency. One company indicated a minimum of eight hours, reflecting a facility where production adjustments require advance coordination but remain feasible within a working day.

Two companies, Company L and Company G, expressed an absolute unwillingness to interrupt operations under any notice period, citing irreversible production losses, health and safety obligations, or contractual commitments that make DR operationally impractical regardless of lead time.

Where a participant was unable to provide a definitive response to the notice period question, either due to uncertainty about their operational constraints or insufficient information to make a reliable assessment, a default value of 24 hours was assigned to ensure scoring consistency and normalisation across the cohort. This conservative default reflects the least favourable notice period weighting in the framework and ensures that unconfirmed flexibility is not inadvertently credited in the composite score.

Figure 14 illustrates the number of hours of notice period reported by the participating companies.

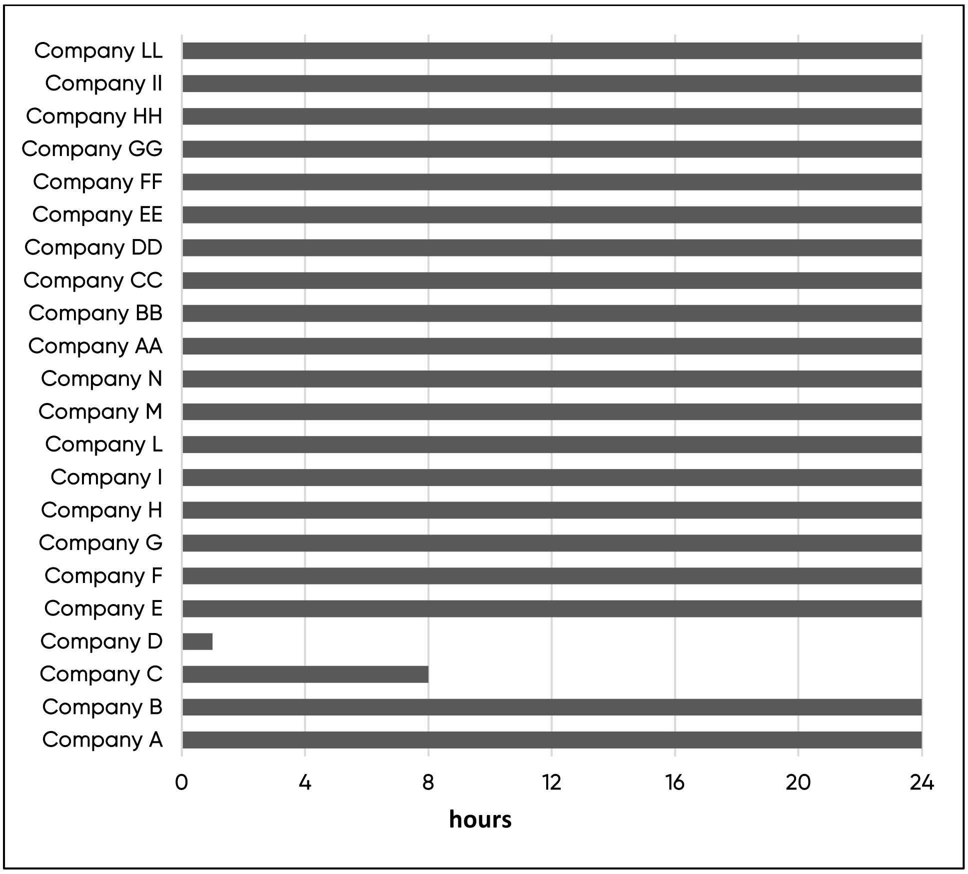

Figure 14: Hourly Notice Period per Participating Company

5.4 Load Identification & Characterisation

As discussed in section 4.2.4 Load Categories & Characterisation, nine (9) load categories were identified across 11 industrial sectors in this assessment; these categories span the full spectrum of energy-intensive activities among industrial participants, from background infrastructure to heavy machinery production. The categories and their defining characteristics are presented below.

5.4.1 Characterisation

5.4.1.1 Mechanical Loads

Mechanical loads constitute the largest single category, with 17 distinct equipment types identified. This category encompasses production-critical machinery, including CNC machines, machine presses, cutting machines, overhead cranes, chippers, refiner guns, board forming machines, roll presses, trimming machines, moulders, planers, and conveyors. The majority of mechanical loads operate on a continuous or on-demand basis and are either manned or hybrid in their control dependency, meaning their operation is directly tied to production schedules and labour availability. As a consequence, the flexibility potential for most mechanical loads was rated low, as the interruption or curtailment of these loads would directly impact production output, process continuity, or workplace safety.

The prevalence of continuous mechanical loads across the cohort is a significant constraint on aggregate DR potential. Many participants reported that their core production equipment could not be interrupted mid-cycle without incurring material quality losses, equipment damage, or safety incidents; this finding underscores the importance of distinguishing between theoretical and operationally realisable load flexibility.

5.4.1.2 Thermal loads

Eleven (11) thermal load types were identified, including furnaces, coal and gas boilers, plastic injection machines, vulcanisers, curing ovens, infra-red ovens, hot presses, and industrial stirrers. Thermal loads exhibit a bimodal flexibility profile. Continuous thermal loads, such as furnaces, boilers, and stirrers, are rated as low flexibility, as they form the backbone of uninterruptible process-heat requirements. Batch thermal loads, including plastic injection machines, vulcanisers, curing ovens, and infra-red ovens, are rated as having medium flexibility, as their cycle-based operation allows for scheduling adjustments, provided sufficient advance notice and operational planning are in place.

5.4.1.3 Compressed Air

Air compressors were the only equipment type identified within the compressed air category, appearing across multiple participants in various industrial settings. Despite their ubiquity, air compressors are notable as the only load type in the study rated highly flexible. Their cyclical operation pattern and automated control make them well-suited to demand response: compressor cycling can typically be adjusted within short timeframes, and stored air pressure provides a degree of operational buffer that allows brief interruptions without immediately impacting downstream processes. This characteristic makes compressed air systems a logical entry point for industrial DR participation, and one that warrants further investigation as a candidate for standardised control interfaces.

5.4.1.4 Environmental Control

Six (6) environmental control load types were identified: refrigeration chillers, process ventilation fans, humidifiers, HEPA filtration systems, Odour Control Furnace, and condenser systems. Flexibility ratings across this category are mixed. Refrigeration systems and HEPA filtration are rated low flexibility, particularly in food processing and pharmaceutical manufacturing contexts, where strict temperature and air quality standards impose regulatory constraints on any interruption. Process ventilation fans exhibit medium flexibility in some applications, depending on whether their primary function is comfort ventilation or safety-critical fume extraction.

The regulatory and quality-assurance constraints observed in this category illustrate a broader challenge for industrial DR programs: the potential for flexibility cannot be assessed in isolation from the compliance obligations governing a facility's operating environment. This is an area where greater collaboration between energy market operators, industry regulators, and standards bodies would be beneficial; a gap that future research could productively address.

5.4.1.5 Pumping and Water Systems

Three pumping and water system load types were identified: water pumps, wastewater treatment systems, and reverse osmosis (RO) water systems. All three are rated high flexibility, making this the most consistently flexible category in the taxonomy. Pumping loads are inherently schedulable; coupled with water storage capacity, they can provide a natural buffer that decouples pumping activity from instantaneous demand, allowing operations to be shifted to off-peak periods without disrupting production. Wastewater treatment processes similarly offer batch scheduling flexibility, provided that buffer tank capacity is sufficient to absorb the deferral period.

The high flexibility of pumping loads, combined with their large energy consumption in mining and large-scale processing applications, suggests that this category may contribute a substantial proportion of accessible DR capacity relative to the number of load types. Further quantification of this capacity, particularly within the mining sector, where pumping loads are often substantial, would benefit from more detailed load studies.

5.4.1.6 Testing and Specialised Loads

Four (4) specialised load types were identified: high-voltage and low-voltage (HV/LV) electrical testing equipment, transmission testing rigs, transformer winding and testing equipment, and process ventilation fan testing. These loads are characterised by batch operation, hybrid control dependency, and medium flexibility. Their DR suitability is primarily determined by scheduling flexibility rather than the ability to interrupt testing proceedings. Testing activities can, in principle, be deferred or rescheduled, but the lead time required to do so may be significant, and in some cases, testing schedules are driven by external customer commitments or regulatory requirements.

5.4.1.7 *Fabrication*

Similar to compressed air, welding machines were the sole fabrication load type identified across the cohort. These loads are on-demand and manned, rated low flexibility, as their operation is directly tied to skilled labour availability and project scheduling. While individual welding events may be short in duration, the aggregate demand from welding operations in heavy engineering facilities can be material. The manned and project-driven nature of this load type limits the applicability of automated or preprogrammed DR response strategies.

5.4.1.8 *Surface Treatment*

Four (4) surface-treatment load types were identified: shot and sand blasting equipment, painting machines, and wash bays. Shot and sand blasters, and painting machines are rated medium flexibility given their batch operating mode, while wash bays are rated low flexibility due to their on-demand, manned operation. Surface treatment loads are generally post-production activities; as such, they may offer more scheduling than upstream production loads, provided that buffer stock or work-in-progress inventory can absorb the deferral.

5.4.1.9 *Background Loads*

Five (5) background load types were identified: lighting, air-conditioning systems, servers and cooling infrastructure, hot water systems, and electric forklifts. HVAC systems are rated as having medium flexibility, as their cyclical operation and thermal inertia allow for short-duration curtailment or setpoint adjustment without immediate impacts on comfort or process quality. Lighting, servers, and hot water systems, by contrast, are continuous automated loads rated low flexibility; they represent essential building services that cannot be meaningfully curtailed without impacting occupant safety, data integrity, or hygiene standards. Electric forklifts represent a partial exception, in which charging schedules can be managed and there is some flexibility to shift the charging load to off-peak periods.

5.4.2 Taxonomy of Load Categories and Industrial Loads

The taxonomy of load developed from the industrial load identified across the industrial stakeholders that have medium and high flexibility potential, including operational type, control dependency, and flexibility potential assigned to each load type, is presented below in Table 10. The Full taxonomy of load is presented in Appendix C.

It is acknowledged that this taxonomy characterises load types by their general operating profile, control dependency, and indicative flexibility potential, rather than by their specific suitability for individual DSM strategies, such as those presented in Table 2 in Section 2.1.3.1 or market mechanisms such as FCAS, wholesale energy markets, or local network flexibility services. Establishing which load categories could realistically participate in a given mechanism, and under what ramping, scheduling, or response-time constraints, requires a level of equipment-specific technical detail that was not available from the majority of participants in this study, consistent with the data deficiency barrier identified in Section 5.1. This level of detail can only be reliably established through a structured, site-based energy assessment of the kind proposed in the customer-centric demand-side management study outlined in Section 8, which would generate the equipment-level data needed to map specific load types to specific DSM strategies and market participation pathways with confidence.

The operation types referenced in Table 10 are defined as follows:

- Continuous: equipment or processes that operate without interruption for the duration of the production cycle, where stopping mid-cycle results in product loss, equipment damage, or process restart penalties.
- Batch: equipment or processes with a defined start and end to each production cycle, where the load is technically schedulable in time, subject to operational and economic constraints such as labour cost and production planning requirements.

- Cyclical: equipment that operates in a repeating on-off or high-low pattern as part of its normal function, independent of any single production event, such as compressors or pumps responding to pressure or level setpoints.
- On-demand: equipment that is activated as required by an operator or a specific task, with no fixed operating schedule, typically tied to labour availability and immediate production needs.

The control dependency categories are defined as follows:

- Automated: equipment that operates under programmed or automatic control with minimal or no direct operator intervention during normal operation.
- Manned: equipment that requires direct operator control or supervision to function, such that its operation is inherently tied to labour presence and availability.
- Hybrid: equipment that combines automated control with a degree of operator oversight or intervention, such that full automation is not achieved, but some operational flexibility exists independent of direct manual control.

Flexibility potential, as assigned in Table 10, reflects the practical capacity of each load type to be curtailed, shifted, or modulated without unacceptable operational safety or product consequence and is informed by both the operation type and control dependency classification above.

Table 10: Taxonomy of Industrial Loads Identified Across Participating Industries with Medium and High Flexibility Potential

Equipment / Load Type	Operation Type	Dependency	Flexibility Potential
Mechanical Loads			
Winery equipment (presses, crushers, RVD, et cetera)	On-demand	Hybrid	Medium
Chippers	Batch	Hybrid	Medium
Thermal Loads			
Dryer	Batch	Automated	Medium
Oil heating	Cyclical	Automated	Medium
Plastic injection machines	Batch	Automated	Medium
Vulcanisers	Batch	Automated	Medium
Infra-red / curing ovens	Batch	Hybrid	Medium
Compressed Air			
Air compressors	Cyclical	Automated	High
Environmental Control – System maintaining safety-critical, regulatory, or process safety			
Refrigeration (chillers)	Continuous	Automated	Medium
Pumping and Water Systems			
General pumping systems	Cyclical	Automated	High
Wastewater treatments	Batch	Automated	High
RO water system	Batch	Automated	High
Testing / Specialised Loads			

Equipment / Load Type	Operation Type	Dependency	Flexibility Potential
High & Low Voltage testing	Batch	Hybrid	Medium
Transformer winding & testing	Batch	Hybrid	Medium
Transmission testing	Batch	Hybrid	Medium
Ventilation fan testing	Batch	Hybrid	Medium
Fabrication			
Welding machines	On-demand	Manned	Medium
Surface Treatment			
Shot / Sand blasters	Batch	Hybrid	Medium
Painting machines	Batch	Hybrid	Medium
Wash bay	On-demand	Manned	Medium
Background Loads – building services and ancillary infrastructure with no safety consequence			
Comfort air conditioning	Cyclical	Automated	Medium
Electric forklifts	On-demand	Manned	Medium

Table 10 above, outlines the load categories based on the types of equipment reported by the industrial participants during the stakeholders' engagement interview. Mechanical loads were the most widely distributed category across the participating facilities, with 15 companies acknowledging the use of equipment falling under this category, reflecting the dominance of capital equipment in mid-sized manufacturing and engineering operations. The thermal category was the second most popular category with equipment used across different types of sectors such as food processing, manufacturing, and mining. Compressed air systems, while representing only a single equipment type, appeared across a broad range of participants and consistently in combination with other high-demand mechanical and thermal loads.

Pumping and water system loads, while present in fewer facilities, were concentrated among the highest-energy-consuming participants, notably in mining and large-scale food processing, where their contribution to total facility demand is proportionally significant. Specialised testing loads were confined to participants whose primary business involves electrical testing and equipment commissioning, making them sector-specific rather than broadly distributed.

Figure 15 and Figure 16, present the load characterisation results as stacked bar charts, illustrating the distribution of load categories across individual companies within the primary and supplementary cohorts, respectively. Each bar represents a load category, with the stacked segments indicating which companies in the cohort reported equipment in that category. This format allows the concentration and spreads of each load type to be assessed simultaneously, revealing not only how many companies operate within a given category but also which specific participants contribute to it.

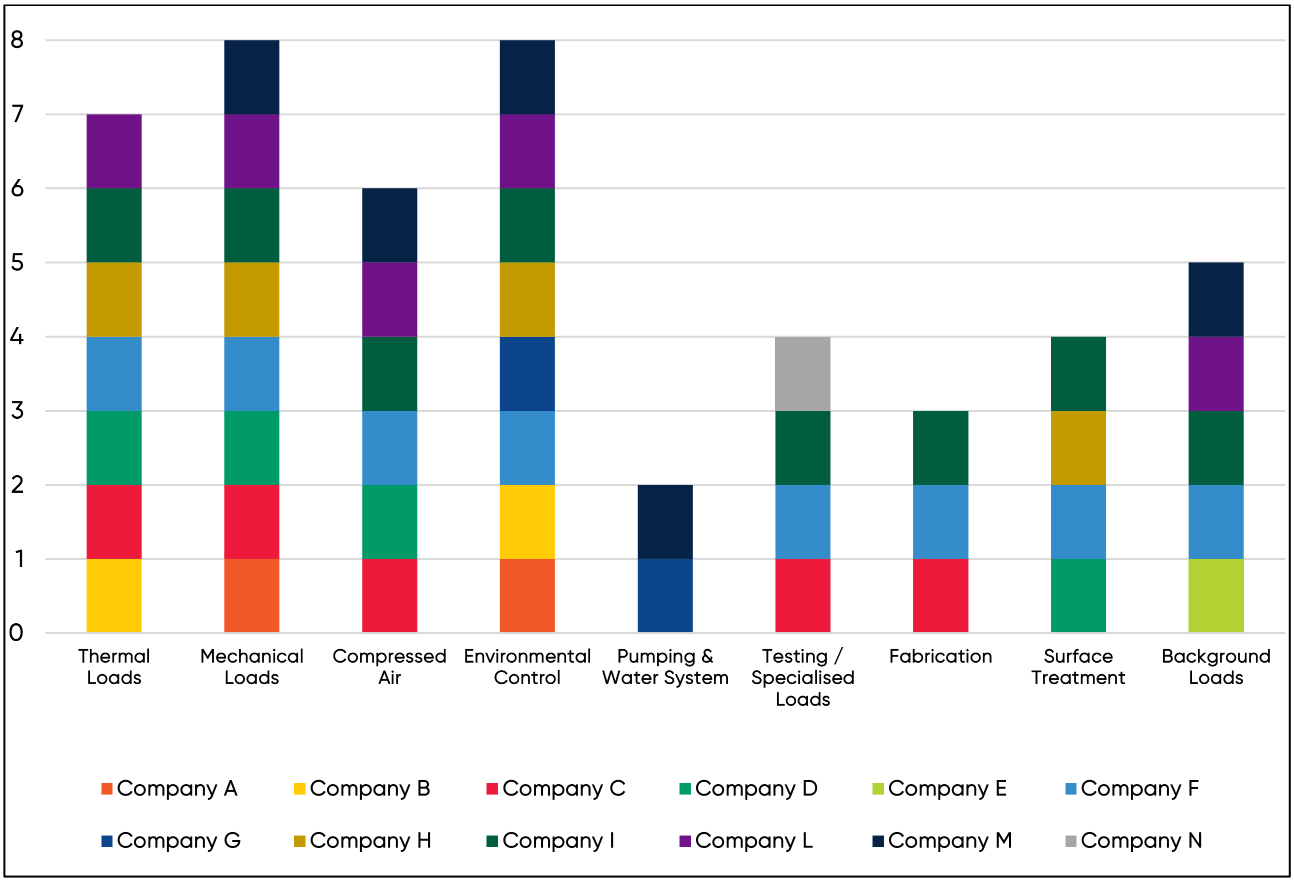

Figure 15: Load Characterisation in Primary Industrial Sectors

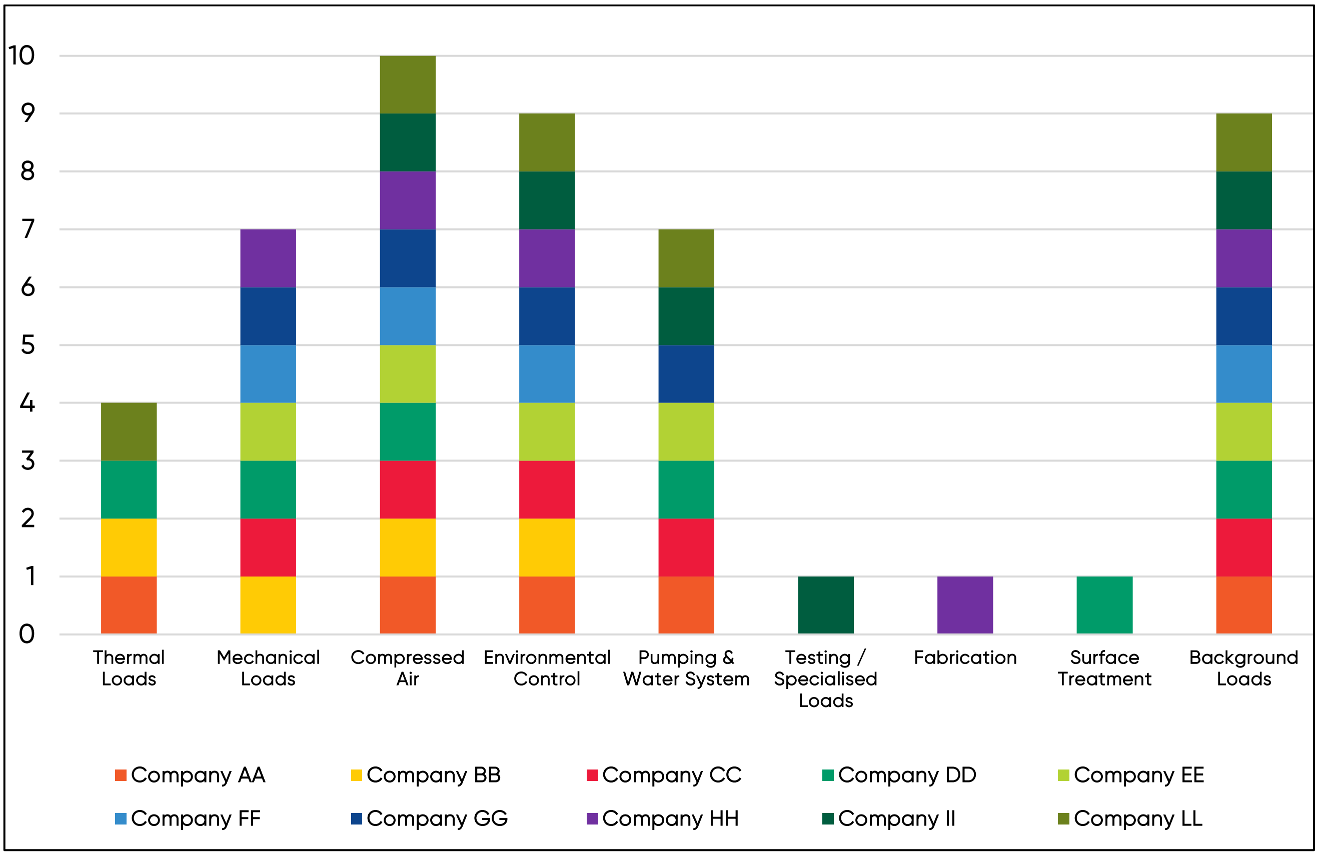

Figure 16: Load Characterisation in the Supplementary Industrial Sectors

Figure 15 shows that within the primary cohort, Compressed Air and Mechanical Loads are the two most broadly distributed categories, appearing across the largest number of individual companies. Company F and Company I account for the widest load category coverage within the primary cohort, each reporting equipment across the greatest number of categories, a result consistent with their roles as manufacturers and maintainers of complex industrial equipment requiring diverse energy-consuming processes. Thermal loads are distributed across a moderate number of participants, with notable contributions from Companies H, G, L, and F. Environmental Control loads are concentrated among a smaller number of participants, reflecting the sector-specific nature of process-critical cooling, ventilation, and filtration requirements. Testing and Specialised loads appear only in Companies C, F, I, and N, confirming their sector-specific distribution.

Figure 16 shows that within the supplementary cohort, Compressed Air, Environmental control and Background Loads are the most broadly distributed categories, each appearing across the majority of supplementary participants. This is consistent with the finding noted in Section 5.4.2 that compressed air is among the most widespread load types in industrial settings, and that background loads such as lighting and HVAC are present in virtually all facilities, regardless of sector. The supplementary cohort also shows a more prominent presence of Pumping and Water System than the primary cohort, driven by participants in waste management, water treatment, and beverage processing.

It is worth noting that the supplementary cohort exhibits a more complete and evenly distributed load profile across all nine categories than the primary cohort. This is almost certainly a methodological effect rather than a real operational difference: the supplementary cohort data comes from energy audits, which systematically capture all load types present at a facility, whereas primary cohort data comes from self-reported interviews, where participants naturally focus on what they consider their most significant or energy-intensive loads. This reinforces the limitation discussed in Section 4.1.6, where self-reported data underrepresents loads that participants do not perceive as primary energy consumers, even when those loads (such as compressed air or background systems) are operationally significant and potentially highly flexible from a DR perspective.

5.5 Findings and Discussion

The analysis conducted across the 22-company participant cohort produced a set of findings that are both empirically grounded and analytically significant. This section presents those findings thematically, moving from the classification results and sector-level patterns through to the operational, economic, and systemic observations that together define the industrial DR landscape in the Hunter Valley. Throughout, the findings are contextualised against the relevant literature and connected to the broader implications for industrial DR program design, incentive structures, and future research priorities in the NEM.

5.5.1 Classification Results and DR Participation Potential

Across the 22 assessed companies, the combined barrier and capability assessment produced raw scores ranging from −12 to +9. The mean raw score of −3.1 and a median of -3. re. These results confirm a cohort that is, on balance, barrier-dominated: 77% of companies recorded a negative raw score, reflecting a combination of conditions that would make DR participation difficult to initiate or sustain under current market and program arrangements. The remaining 23% recorded positive raw scores, indicating that their operational and capability profiles are more conducive to participation, subject to the specific barriers present at each site. It is important to note that a negative composite score does not necessarily indicate that a company is unsuitable for any form of DR participation as discussed in section 5.3.1. Even companies with a dominant Continuous Process barrier typically retain separable, non-production loads, such as compressed air and pumping systems, that remain available for curtailment independently of the constrained process itself. A negative score therefore reflects constrained or partial DR potential at the whole-site level, rather than the complete absence of accessible flexibility .

Table 11 groups the cohort into four score bands, summarising the profile characteristics and primary constraints associated with each band. The groupings are illustrative rather than prescriptive; they reflect the composite barrier and capability assessment rather than a single determinative factor.

Table 11: DR Participation Potential Score Bands Across Participating Cohort

Score Band	Companies	Raw Score Range	Profile Summary
High readiness (≥ +2.5)	CC, EE, I, M	+2.5 to +9	Dynamic operation confirmed; on-site generation present; expressed DR interest. Primary constraint: notice period and incentive structure.
Moderate readiness (0 to +2)	B,	0 - +2.0	Mixed barrier and capability profile. Specific barriers are addressable through targeted interventions (e.g., auditing, submetering). Good entry-point candidates.
Below threshold (−3 to 0)	II, GG, DD, C, D, N, F, BB	−0.5 to −3.0	Structural barriers present but not dominant. Technology and data deficiency are primary constraints. DR is possible with investment in metering and capability building.
Barrier-dominated (< −3)	A, E, H, L, AA, FF, HH, LL, G	−5 to −12	Continuous process, technology gaps, and organisational constraints combine to significantly limit accessible DR capacity. Partial participation is possible only through separable loads.

The most significant finding from the classification analysis is that only two companies in the cohort had prior or current enrolment in a formal DR program, representing 9% of the cohort. While this is a small fraction, it is analytically significant: both companies scored among the highest in the cohort, even without the positive weighting of (+4) existing participation. The positive scoring is driven primarily by strong performance across multiple capability factors, including dynamic operational capability and on-site generation, rather than by the Existing DR Participation weighting itself. The presence of the Existing DR participation capability factor in both companies is nonetheless a meaningful observation: it indicates that these two companies, already operating at a high level of DR potential on other measures, had also gone on to translate that readiness into actual program enrolment, whereas the rest of the cohort had not. The remaining 91% of the cohort, despite the broad interest expressed, had not translated willingness into active program enrolment. This is the clearest possible illustration of the activation gap identified by Lashmar et al. in the Australian commercial and industrial context, where the gap between a company's expressed interest in DR participation and its actual enrolment in a program is not primarily a question of willingness, but of accessibility, infrastructure, and program design (Lashmar, et al., 2023).

5.5.2 DR Suitability is Site-Specific, Not Sector-Specific

The classification results confirm a finding that emerged clearly during the stakeholder engagement: no single industry sector presents a uniformly accessible demand-response opportunity. DR suitability depends on the interoperability between barriers and capability factors, and the specific combination of operational flexibility, energy awareness, available data, and technical constraints at each site, not on the sector to which a company belongs.

The transport and equipment manufacturing sector recorded the highest average raw scores across the cohort, followed by the beverage and tobacco product manufacturing and coal mining sectors, with average raw scores of 9, 6.5, 2.5, and 2.5, respectively. Food and tobacco product manufacturing was featured by three wineries; these results reflect the wineries' combination of seasonal batch production, which provides significant scheduling flexibility outside the harvest window, on-site photovoltaic generation, and the absence of continuous process constraints at their operational scale, confirming dynamic operational capability. However, this profile is not inherent to the beverage sector: it reflects a specific set of operational conditions present at these four (4) facilities.

The most instructive finding at the sector level is the within-sector variance. Within the polymer products sector, scores ranged from +2 (Company B) to −9 (Company FF) across three (3) companies in the same ANZSIC classification; a spread of eleven (11) points driven entirely by site-specific differences in continuous process dependency, data availability, and technology infrastructure. Similarly, within machinery and equipment manufacturing, the largest sector in the cohort with five companies, every company recorded a negative score, but for reasons that differed substantially across participants: some were constrained by CNC machinery cycles, others by data deficiency, others by organisational inertia. This within-sector spread exceeds the between-sector variation in several cases, confirming that sector label explains very little of this variation in DR readiness across this cohort.

This finding has a direct implication for how industrial DR programs are designed and targeted. Sector-based eligibility criteria, which have historically simplified program administration, will systematically exclude viable participants from low-scoring sectors and include non-viable participants from high-scoring sectors. The barrier and capability framework developed in this study provides a more accurate and equitable basis for site-level assessment, and underscores the importance of the customer-centric, site-based assessment approach and the standardised technical and governance framework proposed as future research priorities in Section 8. It is consistent with Williams et al.'s finding that industrial DSM flexibility depends on process-specific conditions rather than sector-level generalisations and reinforces the case for site-specific assessment methodologies of the kind proposed in the follow-on research program (Williams, et al., 2023).

5.5.3 Data Deficiency, Energy Auditing, and the Path to DR Readiness

Technology Availability and Data Deficiency were the two most prevalent barriers in the cohort, each present in 73% of participating companies. Their co-occurrence reflects a structural link: a facility without adequate submetering cannot understand its load profile at the equipment level; without that understanding, it cannot identify which loads are flexible, commit to a curtailment quantum, or verify its DR response. The data deficiency is, in part, a direct consequence of the technology gap.

An important distinction emerged from the engagement between two levels of energy awareness. Most companies had a reasonable understanding of their overall energy consumption, monthly billing totals, ToU charge periods, and approximate annual figures were generally known. What was almost universally absent was the next level of granularity: the distribution of that consumption across individual processes and equipment, and how it varied in real time. This distinction maps directly onto the difference between a Level 1 and a Level 2 Energy Audit under AS 3598: the former captures aggregate billing data, while the latter provides the equipment-level load disaggregation that DR participation requires. Very few companies had undertaken a Level 2 audit, and fewer still maintained ongoing submetering after completing one.

A clear pattern emerged between companies that had undertaken prior energy audits and the potential for DR participation. Companies that had previously conducted a formal energy audit consistently scored higher in the capability assessment. Energy use data, the capability factor most closely associated with prior auditing, was present in 95% of the cohort at the basic level, but this high prevalence reflects an awareness of overall consumption rather than equipment-level understanding. The companies that genuinely stood apart in terms of DR readiness were those that had gone beyond basic billing awareness to obtain a structured map of their energy consumption at the process and equipment level.

Several high-energy companies, particularly in mining and food processing, engaged external energy consultants as a routine practice. For these companies, energy literacy in the formal sense was not a barrier: they had the data. What constrained them was not awareness but operational inflexibility, including continuous processes, strict food safety and quality assurance obligations, or staffing requirements that made curtailment practically impermissible regardless of how complete their energy picture was. This confirms that energy literacy and data availability, while necessary conditions for DR participation, are not sufficient conditions.

5.5.4 Continuous Processes, Separable Loads, and Accessible DR Capacity

The continuous process barrier was present in 68% of the cohort and carries the highest negative weighting in the classification framework. Its prevalence means that for the majority of participating companies, a significant fraction of total facility load is structurally inaccessible for curtailment, not because the company is unwilling, but because the process cannot be interrupted without incurring product loss, equipment damage, or health and safety risk within the one-hour notice threshold defined in the framework.

However, continuous process constraints do not render a facility entirely unsuitable for DR. In every case where such a constraint was identified, the facility also operated discrete, separable loads, compressed-air systems, comfort HVAC, lighting, pumping, forklift charging, and surface-treatment equipment, which were not subject to the same restriction. The continuous process barrier reduces the accessible DR capacity relative to total facility demand; it does not eliminate it. For continuous process facilities, the most readily accessible DR pathway is curtailment or shifting of these non-production loads, which, in some facilities, represented a meaningful fraction of total consumption.

This observation was reinforced by one supplementary cohort participant, Company BB operating an 18- to 24-hour, two-to three-shift working pattern with a continuous production process, that independently undertook a load management assessment. The company shifted its operational window by one hour in each direction to create a two-hour interval during which flexible loads were ramped down to between 50% and 75% of normal consumption. Despite having a continuous process and scoring below the positive threshold in the classification framework, this company demonstrated that load shifting is operationally achievable when the company itself is motivated to investigate it. The finding from their assessment is discussed in further detail in Section 5.5.5 below.

Accurately quantifying the separable load fraction of a continuous process facility was not possible for most participants without submetering data. This is one of the most concrete and actionable gaps identified in this study: the accessible DR capacity of continuous-process facilities cannot be credibly estimated without equipment-level consumption data. This reinforces, from a different angle, the same conclusion reached through the data deficiency analysis: the metering infrastructure gap is not merely an organisational inconvenience; it is the primary obstacle between theoretical and operationally accessible industrial DR capacity.

5.5.5 Labour Cost, Incentive Thresholds, and the Economics of Industrial DR

The Labour Cost barrier was present in 55% of the cohort and emerged from the engagement as one of the most analytically important findings in the study, not because it was the most prevalent barrier, but because it defines the minimum incentive threshold that DR programs must meet to be commercially viable for labour-intensive mid-sized industrial companies.

The fundamental economic logic is straightforward. Electricity costs typically represent a small fraction of total operating costs for industrial consumers. The dominant cost item is labour (Williams, et al., 2023). When a DR event requires curtailing or rescheduling a production process, the energy cost savings achieved are rarely sufficient to offset the labour costs incurred due to idle time, shift penalty rates, or standby supervision.

This dynamic was directly evidenced by the supplementary cohort participant who undertook the shift-timing assessment described in Section 5.5.4, when the energy savings from the two-hour ramp-down window were quantified against the associated labour cost, driven by the shift premium required for an earlier start and later finish, the net financial benefit was negative. The company did not proceed with a DR program. This outcome is not a failure of motivation; it is a rational commercial response to an incentive structure not designed around the cost structures of labour-intensive industry.

The minimum incentive required for industrial DR participation is therefore not the energy cost differential between peak and off-peak periods. It is the full operational cost of the curtailment event, which, for labour-intensive facilities, means the cost of displaced labour plus any product loss, restart costs, or compliance overhead.

A related economic barrier is the capital investment in demand management infrastructure. The payback period for submetering, control systems, or on-site generation is typically 3 to 4 years. Electricity contracts, however, are commonly negotiated on 12-to-24-month terms. This creates a rational reluctance to commit capital, as the financial case depends on tariff conditions that the company cannot guarantee to maintain. This is a market-design issue rather than a company-level problem, and it will not be resolved without greater tariff stability, explicit DR investment incentives, or multi-year DR program contracts that provide the revenue certainty necessary to justify upfront capital expenditures.

5.5.6 Seasonal Consumption Patterns

A supplementary analysis of seasonal consumption patterns was conducted for twelve facilities within the cohort for which sufficiently detailed tariff-period billing data was available, examining the proportion of annual electricity consumption occurring in off-peak, shoulder, and peak tariff windows.

Across this subset, consumption was split, on average, 40.4% off-peak, 36.3% shoulder, and 23.3% peak, though substantial variation exists among individual companies. Six companies, including Company A, Company D, and Company AA, were off-peak dominant, with off-peak consumption ranging as high as 56.0% of total annual use. Five companies, including Company DD, Company EE, and Company HH, were shoulder dominant, with shoulder-period consumption reaching as high as 51.6%. Only one company, Company BB, was peak dominant, with 74.3% of its annual consumption occurring during peak tariff periods, a result a tariff structure in which no shoulder period was defined for that site. This analysis warranted seasonal variation, with energy consumption spiking during colder months, namely June-September.

This finding is relevant to the demand response potential for two reasons:

- First, the predominance of off-peak and shoulder consumption across most of the cohort indicates that many participating companies have already, whether deliberately or incidentally, structured their operations to avoid peak tariff periods, which is itself a passive form of demand-side management consistent with the Peak Shaving strategy described in Table 2. This suggests that the foundational behaviour required for more active DR participation, namely the capacity to shift or avoid high-cost consumption periods, is already present in much of the cohort, even where the company itself does not characterise its operations in these terms.
- Second, the wide variation in seasonal consumption profile across the cohort reinforces the central finding of this study that DR suitability is highly site-specific: a company already concentrated in off-peak and shoulder periods has comparatively little additional flexibility to offer through further load shifting, whereas a company such as Company BB, with a high proportion of peak-period consumption, may represent a more significant, if currently unexploited, opportunity for peak demand reduction.

A further finding from the bill analysis conducted as part of this study was the materiality of demand (kVA) charges within participants' electricity bills. Across the companies for which detailed billing data were available, kVA charges, levied on a customer's maximum demand during the billing period regardless of total energy consumed, accounted for between 11% and 22% of the total electricity bill. This is a substantial proportion and represents an existing internal financial incentive for peak demand management. The financial benefit of reducing maximum demand accrues directly and immediately to the company through a reduced kVA charge in its next billing cycle. This finding reinforces the DSM strategy identified in Table 2. For companies with a high proportion of kVA charges relative to total billing cost, peak shaving represents a more immediately actionable and self-funding entry point into demand-side management than formal DR program participation and may serve as a practical first step toward the broader DR readiness this study assesses. Identifying which specific loads drive a facility's peak demand event, however, requires the equipment-level data that most participants in this cohort currently lack, reinforcing the case for the structured, site-based energy assessments proposed in the customer-centric demand-side management study outlined in Section 8.2, which would allow individual companies to translate this self-funding incentive into a concrete, actionable peak-shaving program.

5.5.7 DR Program Engagement and Notice Requirements

Despite the prevalence of barriers across the cohort, engagement yielded strong, consistent positive feedback on interest in DR participation. 50% of companies expressed either active interest in DR programs or willingness to participate, subject to a clearer understanding of what would be required. This level of expressed interest, in a cohort with only two existing or prior participation, confirms that the gap between awareness and activation is not a motivational problem, but a structural and informational one.

The engagement also revealed a clear preference for financial motivation over system-service motivation. Most participants framed their interest in DR primarily in terms of reducing electricity costs rather than contributing to system services or renewable integration. This is consistent with Lashmar et al.'s finding that Australian C&I consumers are motivated primarily by financial benefit and are frequently unaware of the system and community dimensions of DR participation. The Author points toward an important communication and education gap: companies that are operationally capable of DR participation may not engage with programs framed around system stability or grid services unless a clear and concrete financial return is also articulated (Lashmar, et al., 2023).

5.5.8 Distributed Energy Resources and On-Site Generation

On-site generation was present in 64% of the cohort, most commonly in the form of rooftop photovoltaic systems, with several participants also reporting diesel gensets or gas-fired backup equipment. The presence of on-site generation is the second most common positive capability factor in the framework and contributed meaningfully to higher classification scores where other capability factors were also present.

Several participants with PV systems noted that the absence of battery storage significantly limited the practical DR value of their generation capacity. Without storage, solar generation peaks in the middle of the day and does not align with the periods of highest network stress in the NEM's current dispatch pattern. The combination of on-site PV without storage provides limited flexibility for DR purposes beyond passive reduction of grid imports during generation hours. In a future grid with higher solar penetration and more frequent midday oversupply events, this alignment will improve. In the current market, the highest DR value from on-site generation comes from facilities where PV is sized to a significant fraction of facility demand and where battery storage or flexible load scheduling allows the generation profile to be matched to curtailment windows.

The presence of on-site generation is prejudiced by whether the site is owner occupied or leased.

5.5.9 Thermal Buffer Loads and Regulatory Constraints

Cold storage and refrigeration loads are consistently identified in the literature as among the most promising candidates for industrial DR, given the thermal inertia of the stored medium (Capiau & Van Daele, 2016). A cold storage facility can allow refrigeration compressors to cycle down for a defined period, drawing on the thermal buffer of the stored product, before temperature approaches the quality threshold that requires the compressors to restart. In theory, this provides a natural, cost-free DR window proportional to the facility's thermal mass.

In practice, this theoretical flexibility was not accessible to the most energy-intensive food and beverage participant in the cohort. Facilities operating under strict quality assurance obligations and food safety regulatory requirements identified legal liability, insurance conditions, and customer contract obligations as binding constraints on any temperature excursion. The concern was not the physics of the buffer; it was the regulatory and contractual consequences of any exceedance, which in some cases would trigger batch rejection, customer claims, or certification revocation.

This finding illustrates a broader principle relevant to the Environmental Control load category in the taxonomy: Low flexibility ratings for refrigeration, ventilation, and process cooling systems reflect not a technical inability to cycle the equipment, but the regulatory, safety, and product quality obligations that make doing so operationally impermissible in practice. Accurately assessing the accessible DR capacity of a facility, therefore, requires an understanding of both its technical load characteristics and the regulatory environment in which it operates. This dimension is not captured in current DR assessment frameworks and represents an important gap for future standardisation work.

5.5.10 Load Categories with the Highest Near-Term DR Potential

Drawing together the taxonomy, classification, and engagement findings, several load categories emerge as the most practically accessible near-term DR opportunities across the cohort.

Compressed air systems represent the single most consistently accessible DR load type in the taxonomy. Rated High flexibility and present across multiple sectors, their cyclical operation and automated control make them well-suited to short-notice curtailment without process impact. Stored air pressure provides an operational buffer that allows brief interruptions without immediately affecting downstream processes. Their cross-industry ubiquity makes compressed air a strong candidate for a standardised automated DR control interface.

Pumping and water systems similarly carry high flexibility ratings across all three identified sub-types: general pumping, wastewater treatment, and RO water systems. Water storage capacity provides a natural buffer that decouples pumping activity from instantaneous demand, allowing operations to be shifted to off-peak periods without production impact. In mining and large-scale food processing, where pumping loads are substantial, this category may represent a disproportionately large share of accessible DR capacity relative to its number of load types.

Comfort HVAC and air conditioning, classified under Background Loads, offers medium flexibility across the cohort through thermal inertia, short duration setpoint adjustments, or cycling, all of which are achievable without immediate occupant impact. While individual HVAC systems are relatively modest in capacity, their prevalence across all 22 participating facilities makes their aggregate contribution non-trivial.

Batch-process thermal and mechanical loads, offer medium flexibility where scheduling adjustments can be made with sufficient advance notice. The practical accessibility of this flexibility depends on shift structure and labour cost implications, as discussed in Section 5.5.5: the load is technically moveable, but the economics of moving it are sometimes unfavourable under current incentive arrangements.

5.5.11 The Standardisation Gap and Implications for Future Research

The findings presented across this section converge on a structural conclusion: the barriers preventing industrial DR participation in the NEM are not primarily technical. They are accumulated by the absence of a consistent, standardised framework that would make industrial load participation accessible, measurable, and reliable at scale. As Scharnhorst et al. observe, overcoming these barriers requires not only bridging internal knowledge gaps but also adapting the external frameworks that govern participation (Scharnhorst, et al., 2024).

The specific gaps identified through this study fall into four (4) areas. First, metering and data infrastructure: the near-universal absence of submetering reflects the absence of any requirement for industrial participants to maintain or report equipment-level consumption data. Second, measurement and verification: without agreed baselines and M&V protocols, DR contributions cannot be reliably attributed, limiting the confidence of system operators and aggregators in industrial load as a dependable resource. Third, control interface standardisation: the diversity of industrial control systems and automation platforms makes automated DR signal response technically complex and costly on a case-by-case basis. Fourth, incentive design: current incentive structures do not consistently cover the full operational cost of DR for labour-intensive mid-sized companies, particularly those requiring shift-pattern adjustments.

The characterisation work completed in this study, the taxonomy of load, the barrier and capability framework, and the scored assessment of 22 companies across 11 ANZSIC sectors, is the empirical foundation from which the technical and governance requirements of an industrial DR standard can be derived. Before a standard can be written, the problems it needs to solve must be clearly and credibly defined. This study provides that definition. The follow-on research priorities identified in Section 8 build directly on these findings, with the objective of developing the standardised foundations that the NEM requires to treat industrial demand-side flexibility as a reliable, attributable, and scalable system service (Scharnhorst, et al., 2024; Ranaboldo, et al., 2024).

6. Conclusion

This project set out to investigate the potential for existing mid-sized industrial companies in the Hunter Valley region of New South Wales to participate in demand response and provide system services into the NEM. It builds directly on the foundational work established under AR-PST Stage 5 Topic 6, which identified the characterisation and coordination of flexible industrial loads as an open research question of material significance to system security. To the knowledge of the authors, this study represents one of the first systematic, empirically grounded engagements with diverse mid-sized industrial loads in Australia conducted specifically for this purpose, filling a gap that has persisted in both the domestic and international literature for the mid-sized industrial tier.

The central finding of the study is clear: significant industrial demand-side capacity exists within the Hunter Valley industrial base, but the conditions required to activate it are not yet in place for the majority of companies. Across the 22 assessed participants, raw scores ranged from −12.0 to +9.0 with a mean of −3.1, indicating a cohort that is, on balance, barrier-dominated. Technology availability and data deficiency were the most prevalent barriers, each present in 73% of companies, followed by continuous process constraints at 68%. Critically, only two (2) companies in either the primary or supplementary cohort had prior or current enrolment in a formal DR program, despite 50% expressing interest in participating and 55% confirming some degree of dynamic operational flexibility. This finding is the single most significant result of the assessment: it demonstrates that willingness and partial capability are present across the cohort, but that neither has been translated into active participation. The gap is organisational, not motivational.

The depth and completeness of the data collected varied considerably across participants. While the majority of companies provided sufficient information to support a reliable classification, several participants were limited in what they could share due to commercial sensitivity, contractual obligations, or the absence of internal data at the equipment level. One company was excluded from the scored assessment entirely due to insufficient available data. In cases where information was partial, conservative assumptions were applied and noted accordingly. The findings presented in this report are grounded in the data that was available and should be interpreted in the context of these limitations. The near-universal absence of submetering, present in only 12% of the cohort, was the most pervasive data constraint and the primary factor limiting the precision of the load identification and DR capacity assessment.

The study produced three (3) practical outcomes with immediate utility. First, a taxonomy of 53 industrial load types across nine functional categories, characterised by operation type, control dependency, and flexibility potential, a reference framework that did not previously exist for the mid-sized Australian industrial sector and that can be applied directly by program designers, aggregators, and system planners assessing industrial DR capacity. Second, a scored classification of 22 companies that identifies both the most and least accessible DR candidates within the cohort and provides a repeatable methodology for similar assessments. Third, a clear characterisation of the minimum incentive threshold required for industrial DR participation: the incentive must exceed not the energy cost differential between peak and off-peak periods, but the full operational cost of the curtailment event, most critically, the cost of displaced labour, a design requirement that current NEM DR mechanisms do not consistently meet for mid-sized industrial participants.

The findings are consistent with and extend the body of work developed across prior AR-PST stages. Earlier stages in Topics 4, 6, and 8 established the theoretical and computational framework for understanding the provision of distributed system services; this study grounds that framework in the operational realities of industrial facilities operating today. Where prior work framed industrial demand-side participation as a long-horizon possibility, the evidence gathered here confirms that the prerequisite capability now exists in a meaningful proportion of the cohort, and that the primary obstacles are infrastructural and institutional rather than technological. This shift in framing, from what might be possible in 10-15 years to what is accessible within 1-10 years, given targeted intervention, is the most practically significant contribution this stage makes to the broader AR-PST research program (RMIT University, 2021; Hargroves, et al., 2023).

The study also captured, outside its primary scope, the presence of frequency and voltage-regulating assets across several participating facilities, specifically, direct-online motors contributing rotational inertia and power-factor correction equipment providing reactive power support. These assets are currently invisible to system operators and unquantified in NEM planning frameworks. While no results are drawn from this component of the engagement in the current stage, the finding identifies an additional dimension of industrial contribution to essential system services that warrants dedicated investigation and is reflected in the proposed future work.

The characterisation work completed in this stage defines precisely the work that must follow. Three (3) research priorities emerge from the findings: a structured discovery and estimation of demand-side inertia sources across the NEM; a small number of deep, customer-centric site engagements that move from characterisation into implementation through Level 2 Energy Audits and tailored DSM case studies; and the development of the technical and governance foundations required for a formal industrial demand response standard applicable within the NEM. The taxonomy, barrier and capability data, scored company assessments, and stakeholder relationships developed in this stage provide the empirical and relational foundation from which the program can proceed without delay (Lashmar, et al., 2023; Ranaboldo, et al., 2024).

7. Knowledge Sharing

This section distils the critical learnings, insights, and conclusions from this study that are directly relevant to the current state and future direction of the Australian electricity sector. The findings are presented not as academic observations but as actionable knowledge: information that power system planners, market operators, regulators, policy makers, standards bodies, and industrial companies can draw on to make better decisions about how industrial demand-side management strategies, in particular demand response, are identified, valued, and activated within the NEM.

The study engaged twenty-two (22) mid-sized industrial companies across 11 ANZSIC industry sectors in the Hunter Valley region of New South Wales, collectively representing 356,028 MWh of annual electricity consumption. It produced a taxonomy of 53 industrial load types, a scored barrier and capability assessment for each participant, and a set of empirically grounded findings about the conditions under which industrial DR participation is feasible, the constraints that prevent it, and the minimum requirements for activating it at scale. The insights below are drawn directly from that body of evidence.

7.1 The Overarching Message

The collective weight of these insights points to a single overarching conclusion: the industrial DR potential to the NEM is larger, more willing, and more technically capable of contributing to system services than current program participation rates suggest. The gap between potential and participation is not primarily a function of what industrial companies cannot do. It is a function of what the system does not yet provide: accessible participation pathways, standardised technical frameworks, adequate incentive structures, and metering infrastructure that enables credible DR commitments.

This is an important reframing for the sector. If the barriers to industrial DR are understood as company-level problems, the policy response should focus on education and outreach. If they are understood as systemic and structural, as this study's evidence indicates, the policy response requires changes to market design, regulatory frameworks, and technical standards. Both are needed, but the latter is the more consequential and the more urgent.

Australia has the industrial base, the renewable energy growth trajectory, and the policy motivation to develop a world-leading capability in industrial demand response. The Hunter Valley cohort engaged in this study represents a cross-section of that industrial base; diverse in sector, scale, and operational profile, but consistent in one finding: the willingness to participate is present, and the infrastructure to support it is not. Closing that gap is within reach, and the research program proposed in Section 8 defines the most direct path to doing so.

7.2 Dissemination and Engagement

The findings of this study will be shared across multiple channels and audiences to maximise their influence on the sector. The final report is published openly under the AR-PST program and is available to all stakeholders without restriction.

The participating companies in this study will be provided with a summary of the cohort-level findings, enabling them to contextualise their own barrier and capability profile against the broader participant group.

Findings will also be communicated through Advitech's established industry networks, including professional associations, industry bodies, and direct client relationships, to reach the broader population of mid-sized industrial energy users beyond the study cohort. Industry-facing communication will focus on practical, immediately actionable insights: the role of energy auditing as the entry point to DR readiness, the high near-term flexibility of compressed air and pumping loads, and the economic case for proactively engaging with DR programs rather than waiting for regulatory mandates.

8. Future Work

The findings of this study identify a set of research priorities that extend directly from its results and limitations. Three areas of future work are proposed, each addressing a specific gap identified through the stakeholder engagement and analysis conducted at this stage. Together, they form a coherent and sequenced program: characterising what exists in the system, understanding how individual sites can be activated, and establishing the standardised foundations that make activation scalable and reliable across the NEM.

8.1 Discovery and Estimation of Demand-Side Inertia Sources in the NEM

The stakeholder engagement conducted in this study identified, in addition to the primary demand response analysis, the presence of rotating industrial assets that contribute to system inertia across the participating facilities. These included direct-on-line (DOL) motors, synchronous machines, and power factor correction equipment operating in ways that are not currently visible to system operators or captured in AEMO planning frameworks. While supply-side inertia sources, such as large synchronous generators, are well characterised, demand-side inertia contributions from industrial loads remain poorly understood, particularly as an increasing proportion of industrial machinery is operated via variable speed drives (VSDs) that decouple rotating mass from the grid. The NEM currently lacks a verified, spatially and temporally resolved understanding of where demand-side inertia exists, how much is available, and how it behaves under real system disturbance conditions.

This knowledge gap carries direct consequences for system security: as synchronous generation retires, conservative operational interventions by system operators become more frequent and more costly, and the risk of cascading instability during frequency disturbances increases. A structured discovery and estimation program, combining desktop analysis of industrial asset registers, targeted stakeholder engagement to confirm equipment configurations and operating modes, and conservative engineering estimation validated against available system data, would produce the operationally relevant inertia map that NEM planners currently lack.

The taxonomy and stakeholder network developed in this study provide a practical foundation for that work, reducing the time and cost of asset discovery and enabling immediate engagement with a cohort of industrial participants already familiar with the research objectives.

8.2 Unlocking Industrial Demand-Side Management: A Customer-Centric Study

This study identified significant industrial demand-side capacity across the Hunter Valley cohort but also found that the barriers preventing its activation are deeply site-specific and cannot be resolved through broad-brush program design alone. Eighty-eight per cent of participating companies had no submetering or equipment-level energy data, making credible DR commitments effectively impossible regardless of operational willingness. At the same time, the barrier and capability analysis demonstrated that DR suitability depends on the specific combination of operational flexibility, energy awareness, available data, and technical constraints present at each individual site; a finding consistent with Lashmar et al., who identify the absence of a structured implementation pathway from awareness to activation as a critical gap in Australian commercial and industrial DR engagement (Lashmar, et al., 2023).

These findings point to a clear need for a small number of deep, customer-specific engagements that move beyond characterisation into implementation: conducting Level 2 Energy Audits under AS 3598.2 to replace self-reported consumption data with independently verified load profiles; quantifying the technical and economic potential for demand flexibility at the site level; developing tailored education and capability-building frameworks to address the awareness and access barriers identified in this study; and producing replicable case studies and toolsets that can be applied across the broader industrial population.

Working in direct partnership with a retailer or distribution network service provider, this approach would bridge the gap between the theoretical potential for demand flexibility identified in Stage 5 and the practical, deployable solutions that industrial customers, aggregators, and system operators require. The cohort and operational insights developed in this stage provide an immediate foundation for site selection and engagement, eliminating the lead time that a cold-outreach recruitment process would require.

8.3 Foundation for an Industrial Demand Response Standard In the NEM

The most structurally significant finding of this study is that the barriers hindering industrial DR participation are not primarily technical; rather, they are compounded by the absence of a consistent, standardised framework that would make industrial load participation accessible, measurable, and reliable at scale.

Every industrial DR integration in the NEM is currently a bespoke engineering and commercial undertaking, with no standardised telemetry requirements, no consistent measurement and verification methodology, no defined interoperability protocols, and no common baseline for assessing and attributing demand-side contributions as essential system services. This adds cost, extends timelines, and prevents system operators from treating industrial load as a dependable, dispatchable resource. AS 4755, Australia's only domestic demand response standard, is explicitly scoped to residential and small commercial appliances and provides no applicable framework for industrial equipment. The international literature identifies this standardisation gap as a root cause of low industrial DR uptake across multiple jurisdictions, and Lashmar et al. confirm that Australian commercial and industrial consumers lack a clear, structured activation pathway that connects interest in DR participation to actual program enrolment (Ranaboldo, et al., 2024; Scharnhorst, et al., 2024; Lashmar, et al., 2023).

Addressing this gap requires dedicated preparatory research, not the drafting of the standard itself, which is the role of Standards Australia committees through broad consultation, but the rigorous technical and governance groundwork that makes formal standardisation achievable. This includes a gap analysis of existing international standards applicable to the Australian industrial context, a technical requirements specification covering interoperability, telemetry, control interfaces, and response time parameters; a measurement and verification and baseline methodology adapted to the operational realities of mid-sized industrial facilities; cybersecurity and data governance requirements for remote industrial access; and a structured stakeholder consultation process engaging industrial customers, OEMs, aggregators, distribution networks, AEMO, and bodies of Standards.

The stakeholder relationships, barrier and capability data, and load characterisation outputs developed in this stage are direct inputs to this work, providing the empirical evidence base from which functional requirements can be derived and against which proposed standard provisions can be tested. The result would be a clear, evidence-grounded path toward a formal industrial demand response standard, one that reduces the cost and complexity of participation, enables system operators to treat industrial flexibility as a reliable grid asset, and closes the regulatory gap that currently prevents the NEM from accessing the full potential of its industrial demand side.

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Appendix A

Source Data – Interview Questionnaire

Background information:

1. Have you done any previous work in managing your energy/electricity costs? If yes, can you please describe it? e.g. CAPEX projects – equipment, building envelope, onsite energy/electricity generation/storage, etc. this could include no cost solutions – processes, staff, etc.
2. Do you know the nature of your energy contract? – Who is your provider, what is your tariff structure?
3. Can you describe the overall strategy of your operations? In particular as it relates to energy/electricity use?
4. Do you have a baseline for energy/electricity use?
5. Do you have on-site generation / storage capacity? What type/for what purpose?
6. Do you use other sources of energy on site (gas, goal, alternative)? Why do you use those over electricity?

Status Quo

7. Energy demand profile: Do you know how and where your energy/electricity demand is used/distributed? i.e. Aircon, computer, hot water system, main processes, etc.
8. Do you know what are the primary devices/processes that dominate you your electricity bill in terms of output (capacity, temperature) and item (refrigeration, moving parts, pumps)

What are your three key considerations when controlling your energy/electricity use?

9. Choose from:
    a. Staffing (shift requirements)
    b. Cost of energy/electricity (time-based)
    c. GHG intensity
    d. Customer responsiveness
    e. Optimising "behind the meter" electricity supply/demand
    f. Just-in-time delivery/ supply chain considerations

Capacity for demand management

10. Can you ramp key electrical devices up / down? If yes, have you already experimented with ramping them? For what purpose?
11. Can you turn certain equipment ON/OFF – what minimum increments are possible? If yes, have you already experimented with ramping them? For what purpose?
12. How much notice would you need to turn ramp/off that equipment?
13. Time of day use shifting: Would using more electricity at one part of the day, allow you to use less electricity at another part of the day? Have you experimented with that?
14. Do you have access to time series data on your energy/electricity usage? Do you complete regular energy/electricity audits? For what purpose?
15. What costs do you accrue when you lose access to the electricity you need for your day-to-day operations (say, due to an unplanned outage)? How much notice would you need to be able to limit these impacts?
16. Do you already respond to requests to disconnect loads? For what purpose/s?
17. How frequently could you respond to a prompt to disconnect loads?

System services:

18. Number and size of DOL motors

19. Power factor correction measures
20. Number and size of Active and Passive front-end VSDs
21. Do you have any devices that automatically disconnect from the grid due to grid voltage or frequency?

What's required to get you to change?

22. Technical e.g. Local energy/electricity storage
23. Commercial e.g. $, staff flexibility

Appendix B

Questionnaire Data Analysis

Company	Industrial Classification	Working Conditions			Previous EA	Energy Consumption (MWh p.a. approx)	Primary Energy Consumption	Breakdown Energy	Energy Tariffs	Additional Sources of Energy	On-site Generation/ Storage	Size Solar System (MW)	Storage	PF Correction			Dynamic Operation	Participation Availability	Existing participation	Amount of Notice (hours)
		Days	Hours	Shifts										Available	Number	Working Condition				
Company A	Machinery and Equipment Manufacturing	5	17	2	NA	314.5	• CNC machines • HVAC	No	PPA	No	PV	100-110	No	Yes	1	Yes	Partial	Yes	No	24
Company B	Polymer Product and Rubber Product Manufacturing	5	24	3	Yes	650.0	• Air conditioners • Plastic injection machines	No	Time-of-use	No	PV	200	No	Yes	2	No	Yes	Yes	No	24
Company C	Machinery and Equipment Manufacturing	5	8 - 9	1	No	Company: 300 Across all sites: 500	• Vulcanisers for cable repairs • Machine presses • Air compressors • Welding machines (MIG) • Ventilation fan testing • Overhead cranes	No	NA	Gas [B]	No	NA	No	No	NA	NA	Partial	Yes	No	8
Company D	Machinery and Equipment Manufacturing	7	24	Various	No [A]	Three sites: 895	• Furnaces • Shot Blasters • Air compressors • Cutting Machines • Compressed air for all machines	Yes	Time-of-use	No	PV	0.1	No	Yes	2	Yes	Partial	Yes	No	1
Company E	Internet Service Providers, Web Search Portals and Data Processing Services	7	24	NA	NA	2,400.0	• Servers • Cooling	No	NA	Gen Set	UPS, PV	NA	Yes [C]	No	NA	NA	No	No	No	24
Company F	Transport Equipment Manufacturing	5	8	2	No	2,725.7	• CNC Machines • HVAC • Lighting • Compressed Air • Industrial Machinery • Welders • Overhead Cranes • Furnaces • Sand Blaster • HV & LV Testing • Hot Waters • Curing Ovens, • Wash Bay • Forklifts (electric and LPG) • Ventilation fans	No	Time-of-use	Natural Gas	PV	0.1	No	NA	NA	NA	Partial	NA	No	24
Company G	Food Product Manufacturing	7	24	Various	Yes	Nationally approx 100,000	• Refrigeration (chillers) • Waste water treatment (pumping)	No	Fixed Price Contract	Gen Set, Coal, Gas, Bio-methane (to boilers)	PV	2	No	Yes	NA	Yes	No	No	No	24
Company H	Wood Product Manufacturing	5	24	2	No	7,500	• 3 x Coal boiler • Chippers • Refiner guns • Board forming machines • Roll press • Trimming machines • Hot press • Humidifier • Planer • Crosscut saw • Painting machines • Moulders • Infra-red ovens • Curing oven	No	NA	Coal, Mixed Waste Wood	No	NA	No	Yes	4	Yes	Partial	Yes	No	24
Company I	Transport Equipment Manufacturing	7	24	2 - 3	No	NSW: 10,300 Hunter Valley: 6,830	• HVAC • Cranes • Compressors • Transmission testing • Welding machines • Gas boilers • Wash bays • Forklifts (electric and LPG)	Only by fuel type	PPA	Gen Set LPG	PV	1.66	No	NA	NA	NA	Yes	Yes	Past	24 hrs

		Working Conditions												PF Correction						
Company	Industrial Classification	Days	Hours	Shifts	Previous EA	Energy Consumption (MWh p.a. approx)	Primary Energy Consumption	Breakdown Energy	Energy Tariffs	Additional Sources of Energy	On-site Generation/ Storage	Size Solar System (MW)	Storage	Available	Number	Working Condition	Dynamic Operation	Participation Availability	Existing participation	Amount of Notice (hours)
Company L	Basic Chemical and Chemical Product Manufacturing	5	8	1 - 2	Yes	Approx. 9,800	• HEPA filter (Air Conditioning) • Manufacturing equipment (air compressors, stirrers, etc)	No	No PPA	Gen Set	PV	NA	No	NA	NA	NA	No	No	No	No
Company M	Coal Mining	Underground = 7 Control Room = 7 CHPP= 5	Underground = 24 Control Room = 24 CHPP= 24	Underground = 3 Control Room = 2 CHPP= 2	Yes	88,859	• Air compressors • Ventilation systems • Longwall • HVAC • Conveyors • Surface Pumps • UG Pumps • RO Water System • Lighting	Yes	Flat Rate [D]	PV [E]	No	NA	No	Yes	1	Yes	Yes	Yes	No	2 - 3
Company N	Machinery and Equipment Manufacturing	5	8	1	NA	Hunter Valley: 1,000 NSW: 3,000 National: 4,500	• Transformer winding and testing	No	Renewables PPA	PV	PV	Hunter Valley: 100kW National: 340kw	No	NA	NA	NA	No	NA	NA	NA
Company AA	Water Supply, Sewerage and Drainage Services	7	24	NA	Yes	9,054	• Lighting • Compressed Air • HVAC • Odour Control Furnace • Main Thermal Oil • Heaters • Auxillary Thermal Oil • Pumps • Blowers	Yes	Time-of-use	Natural Gas	No	NA	No	No	NA	NA	Limited	NA	No	NA
Company BB	Polymer Product and Rubber Product Manufacturing	5	18	2	Yes	7,550	• Gas Boiler • Bulk Oil Heating • CT Press Operation • Hot Feed Extruder • Banburry Mixer • Banburry Mill • Compressed Air • Chiller	Yes	Demand Tariff	Natural Gas	PV	0.1	No	Yes	NA	Yes	Partial	NA	No	NA
Company CC	Beverage and Tobacco Product Manufacturing	5	18	2 - 3	Yes	6,556	• Lighting • Bottling Systems (Compressed Air, Chiller, Nitrogen Generator unit, HVAC, Lighting etc) • Refrigeration Systems •Winery equipment (Pumps, Crushers, Pressers, Centro, RVD etc) • Electric Hot Water Heating • HVAC	No	Time-of-use	Natural Gas, LPG [F]	PV, Solar Thermal Hot Water System	Site A: 230 Site B: 200	No	Yes	NA	Yes	Yes	NA	Yes	NA
Company DD	Non-Metallic Mineral Product Manufacturing	5	14	2	No	280	• Compressed Air • Dryer • Water Recycling Plant • GM Rotox Saw • GM Lexa Saw • Synthesis Polishing Machine • Lighting • Sand Blast Exhaust Fan • CNC machinery • Air Conditioning	No	Time-of-use	NA	PV	NA	No	No	NA	NA	Yes	NA	No	NA
Company EE	Beverage and Tobacco Product Manufacturing	5	12	2	Yes	1,477	• Lighting • Bottling Systems (Compressed Air, Chiller, Nitrogen Generator unit, HVAC, Lighting etc) • Refrigeration Systems • Winery equipment (Pumps, Crushers, Pressers, Centro, RVD, etc) • Electric Hot Water Heating • Air Conditioning	No	Time-of-use	Natural Gas	PV	NA	No	Yes	NA	Yes	Yes	NA	No	NA

		Working Conditions												PF Correction						
Company	Industrial Classification	Days	Hours	Shifts	Previous EA	Energy Consumption (MWh p.a. approx)	Primary Energy Consumption	Breakdown Energy	Energy Tariffs	Additional Sources of Energy	On-site Generation/ Storage	Size Solar System (MW)	Storage	Available	Number	Working Condition	Dynamic Operation	Participation Availability	Existing participation	Amount of Notice (hours)
Company FF	Polymer Product and Rubber Product Manufacturing	5	24	3	No	7,528	• Extruders • Twisters and knitting heads • Chillers • Compressed Air • Lighting • HVAC	No	Time-of-use	LPG (forklifts)	No	NA	No	Yes	2	Yes	No	NA	No	NA
Company GG	Beverage and Tobacco Product Manufacturing	5	13	2	No	1,260	• Lighting • Compressed Air • Chiller • Nitrogen Generator unit • HVAC • Refrigeration Systems • Winery equipment (Pumps, Crushers, Pressers, Centro, RVD, etc) • Condensor	No	Time-of-use	Natural Gas	PV	170 [G]	No	Yes	1	Yes	Yes	NA	No	NA
Company HH	Machinery and Equipment Manufacturing	5	18	2 - 3	No	1,136	• Compressed Air • Lighting • HVAC • Fan Systems (paint & balsting booth • CNC Machines • Milling • Welding Machines • Assembly Machines	No	Time-of-use	LPG (forklifts and flame cutting equipment)	No	NA	No	Yes	1	Yes	NA	NA	No	NA
Company II	Waste Collection, Treatment and Disposal Services	6	10	1-2	Yes	1,016	• Continuous: - Compressed Air - Aerators - Gas Blowers - Transformers. • Intermittent: - Pumps - Evaporators - Lighting - Air Conditioning	Yes	Time-of-use	No	No	NA	No	No	NA	NA	Yes	Yes	No	NA
Company LL	Food Product Manufacturing	5.5	24	3	NA	3,026	• Compressed Air • Lighting • HVAC • Pumps • Refrigeration • Homogenisers	No	Time-of-use	Natural gas	No	NA	NA	Yes	1	Yes	No	NA	No	NA

A: Whilst Company D doesn't have an Energy Audit, they are interested in undertaking one
B: Company C does utilise gas for testing purposes only
C: Storage is achieved through UPS and Batteries
D: Flat rate with TOU distribution chargers
E: A 26 MW solar farm has been approved for the site, but is currently not present
F: Small amount of LPG used for process heating with the majority used for forklifts onsite
G: Consisting of a rooftop system and standalone PV array

Appendix C

Taxonomy of Load

Table 12: Full Taxonomy of Industrial Loads Identified Across Participating Industries

Equipment / Load type	Operation Type	Dependency	Flexibility Potential
Mechanical Loads			
CNC machines	Continuous	Hybrid	Low
Twister and Knitting Machine	Continuous	Automated	Low
Assembly Machines	On-Demand	Hybrid	Low
Machine press	On-Demand	Manned	Low
Winery equipment (presses, crushers, RVD, et cetera)	On-Demand	Hybrid	Medium
Cutting machines	On-Demand	Manned	Low
Mixer	Batch	Hybrid	Low
Overhead cranes	On-Demand	Manned	Low
Chippers	Batch	Hybrid	Medium
Refiner guns	Continuous	Automated	Low
Board forming machines	Continuous	Automated	Low
Roll press	Continuous	Automated	Low
Trimming machine	Continuous	Automated	Low
Planer	On-Demand	Manned	Low
Crosscut saw	On-Demand	Manned	Low
Moulders	On-Demand	Manned	Low
Conveyors	Continuous	Automated	Low
Thermal Loads			
Furnaces	Continuous	Automated	Low
Homogenisers	Continuous	Automated	Low
Dryer	Batch	Automated	Medium

Equipment / Load type	Operation Type	Dependency	Flexibility Potential
Hot Feeder Extruder	Continuous	Hybrid	Low
Oil heating	Cyclical	Automated	Medium
Coal / gas boilers	Continuous	Automated	Low
Stirrers	Continuous	Automated	Low
Plastic injection machines	Batch	Automated	Medium
Vulcanisers	Batch	Automated	Medium
Hot press	Batch	Hybrid	Low
Infra-red / curing ovens	Batch	Hybrid	Medium
Compressed Air			
Air compressors	Cyclical	Automated	High
Environmental Control – System maintaining safety-critical, regulatory, or process safety			
Refrigeration (chillers)	Continuous	Automated	Medium
Mine / Process ventilation fans	Continuous	Automated	Low
HEPA filtration systems	Continuous	Automated	Low
Humidifier (process)	Cyclical	Automated	Low
Odour control furnace	Continuous	Automated	Low
Condenser systems	Continuous	Automated	Low
Pumping and Water Systems			
General pumping systems	Cyclical	Automated	High
Wastewater treatments	Batch	Automated	High
RO water system	Batch	Automated	High
Testing / Specialised Loads			
High & Low Voltage testing	Batch	Hybrid	Medium
Transformer winding & testing	Batch	Hybrid	Medium
Transmission testing	Batch	Hybrid	Medium
Ventilation fan testing	Batch	Hybrid	Medium
Fabrication			

Equipment / Load type	Operation Type	Dependency	Flexibility Potential
Welding machines	On-Demand	Manned	Medium
Surface Treatment			
Shot / Sand blasters	Batch	Hybrid	Medium
Painting machines	Batch	Hybrid	Medium
Wash bay	On-Demand	Manned	Medium
Background Loads – building services and ancillary infrastructure with no safety consequence			
Comfort air conditioning	Cyclical	Automated	Medium
Lighting	Continuous	Automated	Low
Servers and cooling	Continuous	Automated	Low
Hot water system	Continuous	Automated	Low
Electric forklifts	On-Demand	Manned	Medium

Appendix D

Barrier and Capability Assessment Framework

Barrier	Organisational Inertia	Work Ethics
		Behavioral Patterns
		Company Guidelines / Framework
	Labour cost	Shift Patterns
		Machinery Usage Patterns
		Employees Downtime
	Access & Awareness	In-House Electrical Engineering Knowledge
		Understanding End-Use Energy Consumption / Breakdown Energy Consumption
		Understanding Participation to Provision of System Services
		Company Deemed not Big Enough by Power Industries to be a Relevant Participant
	Technology Availability	Rental Building Limitations
		Ageing Equipment / Machineries
		No Additional Energy Resources
	Data Deficiency	Understanding Conncection Between Usage Patterns and Energy Consumption
		Equipment Submetering
	Continuous Process	CNC Machinery
		Assembly Line(s)
		Processes that Depend on Other Processes
Capability Factor	Energy Use Data	Knowledge of Energy Usage & Patterns
		Awareness of Energy-Intensive Machinery / Equipment
		Undertaken Previous Energy Audit
	On-Site Generation	In-House Generation of Energy Source
		Usage of Additional Energy Source Beside Electricity
	Dynamic Operation	Potential for Ramp Up/Down / Turn On/Off
	Participation Availability	Interest in understanding more about DR Programs
		Interest in Participating in DR Programs
	Existing DR Participation	Present or Past Participation in Demand Response Programs