RACE for 2030
RELIABLE AFFORDABLE CLEAN ENERGY

B4: Opportunity Assessment Literature Review

Flexible demand barriers and behavioural factors

Discussion Paper

RACE for Business

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Flexible Demand Barriers and Behavioural Factors Literature Review

Discussion Paper: RACE CRC, B4 Flexible Demand Opportunity Assessment

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SUMMARY: BARRIERS ON A PAGE

The summary findings of this discussion paper outlining key barriers to flexible demand derived from literature references are presented in tabular format as Table 1 immediately following. A slightly more detailed elaboration appears in Section 7: Summary and Conclusion. These summary findings are based on Sections 3-5, and also appear as subsection headings in blue font. The main content of this report describes barriers to flexible demand that are common across stakeholders and customer end-use sectors in Section 3, classified for the sake of imposing some conceptual structure on a set of barrier categories that are commonly recognised in the literature. Barriers that are especially associated with particular stakeholders are presented in Section 4, with barriers that are associated with particular customer end-use market segments (industrial, commercial and residential) presented in Section 5. Further details can be found in the references cited within each section.

The organisation of this discussion paper is presented in Section 1, including a brief description of the literature review method can be found as Section 1.2, with further details in the Appendix. There is some discussion of barrier and stakeholder categorisation in Section 2. After the exploration of the literature contents in Sections 3-5, the following Section 6 briefly discusses issues associated with prioritising barriers for further investigation as part of a process of identifying the most promising opportunities to address them, a process described in Section 2.2.

Table 1: Flexible Demand Barriers on a Page

	Regulators & planners	Networks	Retailers	Aggregators	Large (industrial) users	Medium (commercial) users	Small (residential) users
Technology							
• More (and improved) metering is required for network visibility and for financial settlement	Yellow	Red	Red	Red	Yellow	Red	Yellow
• Communications connectivity and automation is required to integrate end-users with markets for firm capacity • Changing consumer consumption patterns is difficult without automation • Lack of standards and interoperability issues impact on scalability in the commercial sector	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red
• High load density is required to fulfill the needs of many electricity industry applications	Yellow	Red	Yellow	Yellow	Red	Yellow	Green
Economic							
• More certainty is required to justify investment	Yellow	Yellow	Red	Red	Red	Red	Red
• Many markets are either absent or lack transparency	Red	Yellow	Yellow	Red	Red	Red	Yellow
• Retailers face high transaction costs and end-user apathy	Green	Yellow	Red	Red	Yellow	Yellow	Yellow
• Customer savings may not be material to overall financial consideration • Smaller energy savings from smaller site loads makes the business case more difficult	Green	Green	Yellow	Yellow	Red	Red	Yellow
Regulatory & policy							
• Clarity is required on the role and priorities of regulators • Targets could support improved prioritization of FD	Yellow	Yellow	Yellow	Yellow	Red	Yellow	Yellow
• Technical standards favour incumbent solutions	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow
• Network services need a supportive regulatory framework	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow
• Aggregators require a level playing field with other actors in the market	Yellow	Green	Yellow	Red	Red	Red	Yellow
Markets							
• Buyers of FD lack strong incentives	Yellow	Yellow	Yellow	Yellow	Red	Red	Yellow
• More clarity is required on how to register capacity in markets and determine demand response baselines	Yellow	Yellow	Yellow	Red	Red	Red	Yellow
• Access to capital may be an issue for high capital cost interventions	Green	Green	Green	Yellow	Red	Red	Yellow
• Cost reflective options often not offered and fair proportion of value created from FD may not be passed through to industry	Yellow	Yellow	Red	Red	Yellow	Yellow	Red
Behavioural and Cultural							
• Cultural biases exist in the electricity industry	Red	Red	Red	Red	Yellow	Yellow	Yellow
• A range of behavioural factors impact on customer perceptions • Behavioural factors, misaligned incentives and perceived risks of disruption are a significant barrier in the commercial sector • Financial benefits, risk management, ease-of-use and trust are important factors for consumers • Demographics and lifestyle typologies may be required to segment and attract customers in the Residential Sector	Green	Yellow	Yellow	Red	Red	Red	Red
• Load flexing in the industry sector can impact on production	Green	Yellow	Yellow	Red	Red	Red	Yellow
• Government building portfolios could influence the market but must overcome internal purchasing/ decision making barriers	Green	Green	Yellow	Yellow	Green	Red	Yellow

Barriers to Implementing Flexible Demand

1. Introduction

1.1 *Barriers and Why They Matter*

There are numerous publications on the topic of drivers and barriers to flexible electricity demand and customer-side participation. These publications include reports written by industry, government, the community sector and academic researchers, covering a wide range of countries and regulatory environments. They touch on various stakeholder roles, demand management programs, mechanisms, and goals. They provide evidence from practically derived expert knowledge, theoretical analysis, software simulation, empirical data collection and case studies.

The essence of the concept of a 'barrier' is a condition that, if removed or diminished, will permit or encourage some desirable goal, in this case – the realisation of valuable flexible demand. The Intergovernmental Panel on Climate Change [1], discussing distributed renewable energy technologies, defined a barrier as "any obstacle to reaching a goal, adaptation or mitigation potential that can be overcome or attenuated by a policy program or measure". The identification of barriers is important in that if measures can be taken to diminish their impact, the potential value of flexible demand can be realised.

This literature review represents an attempt to identify a broad scope of barriers that need to be removed in order realise additional flexible demand potential in the current context in Australia.

1.2 *Methodology and Organisation*

This discussion paper is not a systematic review, however it aims for comprehensiveness by following some steps of the rapid review process described by [2]. The process involves defining research questions and compiling a list of literature resources by conducting keyword searches on selected databases. The compiled literature is further screened to filter references particularly relevant to the research questions. The resulting reference base forms the foundation of the review. The search and screening of literature included both searching academic publication databases and identifying relevant grey literature.

Academic publications relevant to the review were identified by querying Science Direct and Scopus databases using strings of keywords determined from the research questions (see Appendix for details), with combinations of Boolean operators included to refine the search. Relevant grey literature in both the Australian and international contexts were found using Google Scholar database, as well as suggestions from the B4 project Industry Reference Group members. The initial compilation of grey literature references was based on the relevance of their title and executive summaries/introductions to any the research questions. Academic references were selected in a similar way to grey literature references, using the title and abstract to determine relevance to the research sub-questions. Further relevant references were identified using the 'snowballing' technique, where the ScienceDirect "recommended articles" feature and citations within the searched documents, are used to grow the literature base. The search resulted in an initial library of 302 literature references.

After the initial literature search, the resultant library was further screened. This involved reading the abstract/summary, introduction and conclusions of each reference, and excerpts from the content where relevant. Key topics corresponding to each of the research sub-questions that each reference covered were identified, and each reference tagged with a list of subquestion relevant keywords. Each research subquestion could then be addressed by closer reading of the references tagged with relevant keywords. Where references covered similar material, priority was given to review papers, more recent publications, and Australian content.

As discussed in Section 2, there are many dimensions for categorising flexible demand barriers. This creates numerous possible ways of structuring the results of the literature review. The approach taken in this review, structures the discussion of barriers in sections according to the following.

- Common Barriers: These are broad classes of barriers, which could impede flexible demand 'potential' but have not been specified in the source material as associated with particular stakeholders or end-use sectors. The nature of these barriers is described in Section 2.1 and the literature regarding these barriers is detailed in Section 3.
- Role Specific Barriers: These are specific classes of barriers that address the specific circumstances of particular actors in the supply and demand sides of the flexible demand industry. The nature of these barriers is described in Section 2.3 and the literature regarding these barriers is detailed in Section 4. Barriers are discussed in this section if the source material confirms that it is consistently associated with a particular role, whereas a barrier that is identified only in Section 3 may not be associated with all actors.
- Barriers for Specific End-Use Sectors: These are barriers that the source material specifically associates with particular end-use sectors. Again, a barrier that is identified only in Section 3 may not apply especially strongly to any given sector, but is merely claimed by the source material to apply generally. Barriers for specific end use sectors are separately treated also because the scope of the B4 Flexible Demand Opportunity Assessment has particular focus on end-user needs (which differentiates the project from many other studies on the topic). These barriers are detailed in Section 5.

It is understood that there will be significant overlap between specific barriers and common barriers, creating some level of duplication for the reader. However, the intention is to enable the reader to quickly turn to the section most relevant to their need and obtain some level of insight without having to read the entire report.

Other lenses and subtopic structures that could have been used to segment this report (see Section 2.3 below for more detail) include (i) flexible demand capabilities, (ii) flexible demand programs and case studies, and (iii) electricity market segments (retail, network, frequency control ancillary services: FCAS etc). These were not adopted (i) in order to avoid excessive duplication and (ii) because they significantly overlap with the other literature reviews in the project (Technoeconomic literature review, Research State of the Art literature review).

It is further noted that this Barriers Literature Review will significantly inform the subsequent Policies, Pricing and Markets literature review.

2. Categorising Barriers

2.1 *Categorising Flexible Demand Potential and Barriers*

Noting the extremely large number of contextual dimensions (geographical, social, technological, economic, legal, historical, cultural and so on), a huge number of barriers have been identified in the literature and many of the conclusions drawn are specific rather than general. Conversely, some conclusions are drawn in the literature that are expressed generally, which hides the detail of the evidence that shows them to be true in specific contexts.

In order to simplify analysis, the wide variety of barriers can be classified into similar groups, or categories. A particularly useful categorisation is one for which barriers within the same category can be successfully addressed using similar methods.

One categorisation approach in the literature is the idea of 'potentials'. For example:

- Technical potential: Given some total aggregate capacity of electrical loads, the idea of 'technical potential' for flexible demand is the quantity of that capacity that could be foregone, given the current state of technology and provided some conditions of technical feasibility are met. 'Technical barriers' then, are in principle understood to be those technical conditions that prevent the 'technical potential' from being greater than it is.
- Economic potential: Similarly, if the 'economic potential' for flexible demand is the quantity of load demand that could be foregone at a net economic gain (benefits exceed costs), then 'economic barriers' are understood to be those conditions that prevent the economic potential from being greater than it would be otherwise.

Defining broad categories of potential permits the quantification of the significance of any particular barrier, based on the amount of flexible demand that could be achieved with and without the barriers in that category being removed.

Figure 1 (after [3]) gives one defined ordering of the barrier categories from which we can broadly define a hierarchy (or a metaphorical pyramid or funnel) of distinct flexible demand "potentials", starting with a total physical potential (e.g. actual installed capacity or theoretical maximum economic installed capacity). Each successive potential is defined as the previous potential in the hierarchy after being reduced due to the influence of the corresponding barrier category.

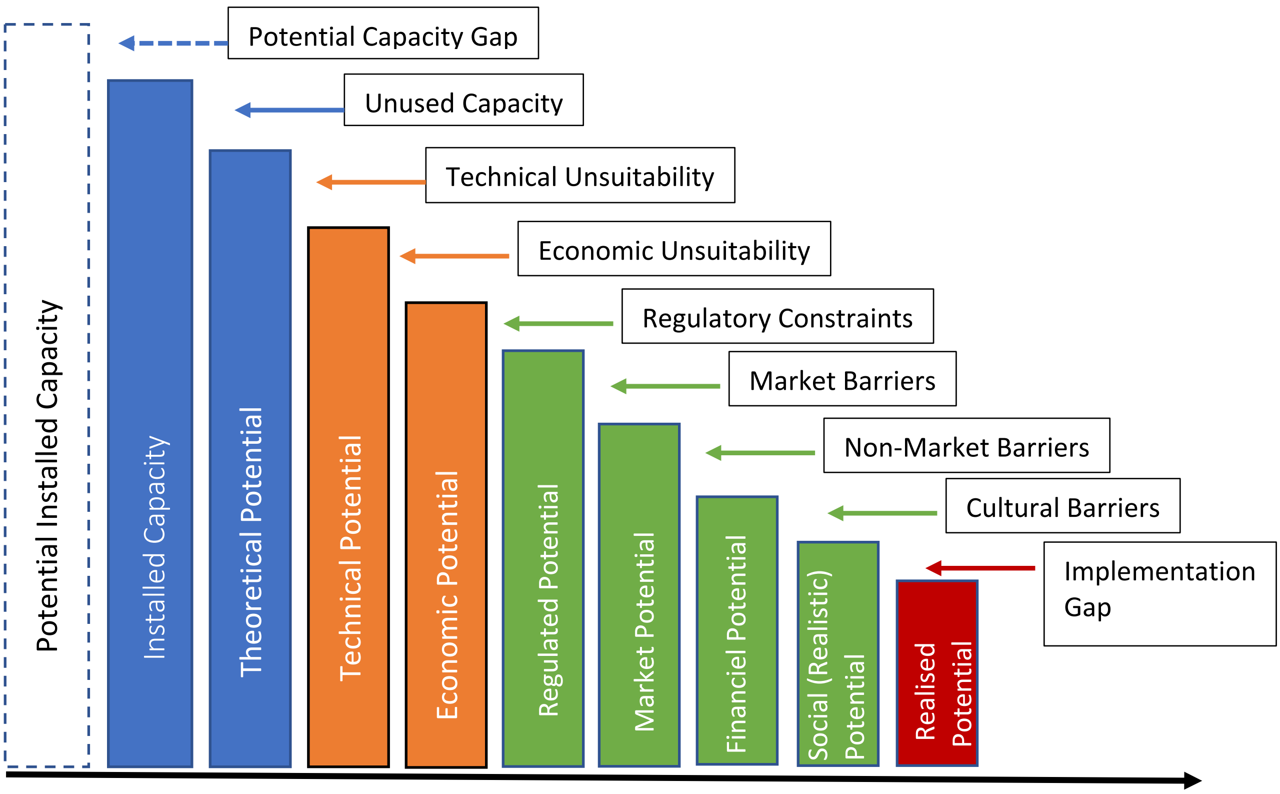

Figure 1: Barriers and the Potential Pyramid

The broad barrier categories used in the literature are typically minor variants of each other. For example, alternative terminology to "practical potential" include terminology such as "achievable potential" [3] or "actual potential", or "realisable potential" and so on. [4] discusses "theoretical", "technical", "economic", and "practical" potentials, which would be defined relative to 'total' potential or "installed capacity", (defined) theoretical barriers, technical barriers, economic barriers and practical barriers.

In addition to other common barrier categories, [5] identifies a category called "institutional" barriers, relating to (i) market structure, (ii) non-market design and decision-making structure, (iii) financing and incentives, (iv) regulatory, and (v) cultural barriers. An additional barrier of (vi) "complexity" is also included, referring to the numerous interactions among actors, barriers, and technologies that make the full impact(s) of any given action or intervention extremely difficult to achieve. The taxonomy in [5] is taken in this review as foundational because it has been successfully applied numerous times to electrical power technology in the recent Australian context, and the reviewed barrier frameworks in the international literature are broadly consistent with it.

The "Cultural" institutional barrier of [5] explicitly includes cultural, social and behavioural barriers. Various interventions for addressing social barriers, and various frameworks for describing human behaviour are described by [6], [7], [8] suggesting possible subcategories of cultural barriers that include (i) knowledge, (ii) values and (iii) habits barriers.

Other categories mentioned in the literature include "technological", "organisational" [9]; "social" [10]; "political", "legal", and "environmental" [11] barriers. [12] offers a variation on the above in that it distinguishes "market failures/ imperfections" from "market distortions", combines "economic and financial" as well as "social, cultural and behavioural", includes "institutional" as a separate category rather than an overarching larger category, and combines within “other barriers”: government policy uncertainty; environmental barriers; risk perception barriers; and infrastructure barriers.

[11] categorises barriers in accordance with the acronym PESTLE for Political, Economic, Social, Technical, Legal and Environmental, barriers. Reference [13], which analyses opportunities for improving the greenhouse emissions performance of buildings, groups barriers within one of: economic barriers; hidden costs/benefits; market failures; cultural/ behavioural barriers; information barriers; and structural/ political barriers. The category “informational” has the disadvantage that it can apply across a wide range of other categories.

A notably unique categorisation of barriers to “local flexibility markets” from [1] was derived as a bottom up aggregation from individual barriers independently identified by various interviews and surveys. Although recognising barrier characteristics such as “socio-economic”, “technical” and “legal” as distinct dimensions, the taxonomy presented there comprises, at the coarsest decomposition and in order of relevance: current lifestyles, administration, trust, technical, standardisation and cost barriers (See Figure 2.). These six broad categories are further decomposed into 29 subcategories, although again, each of which map reasonably well into the taxonomy given above.

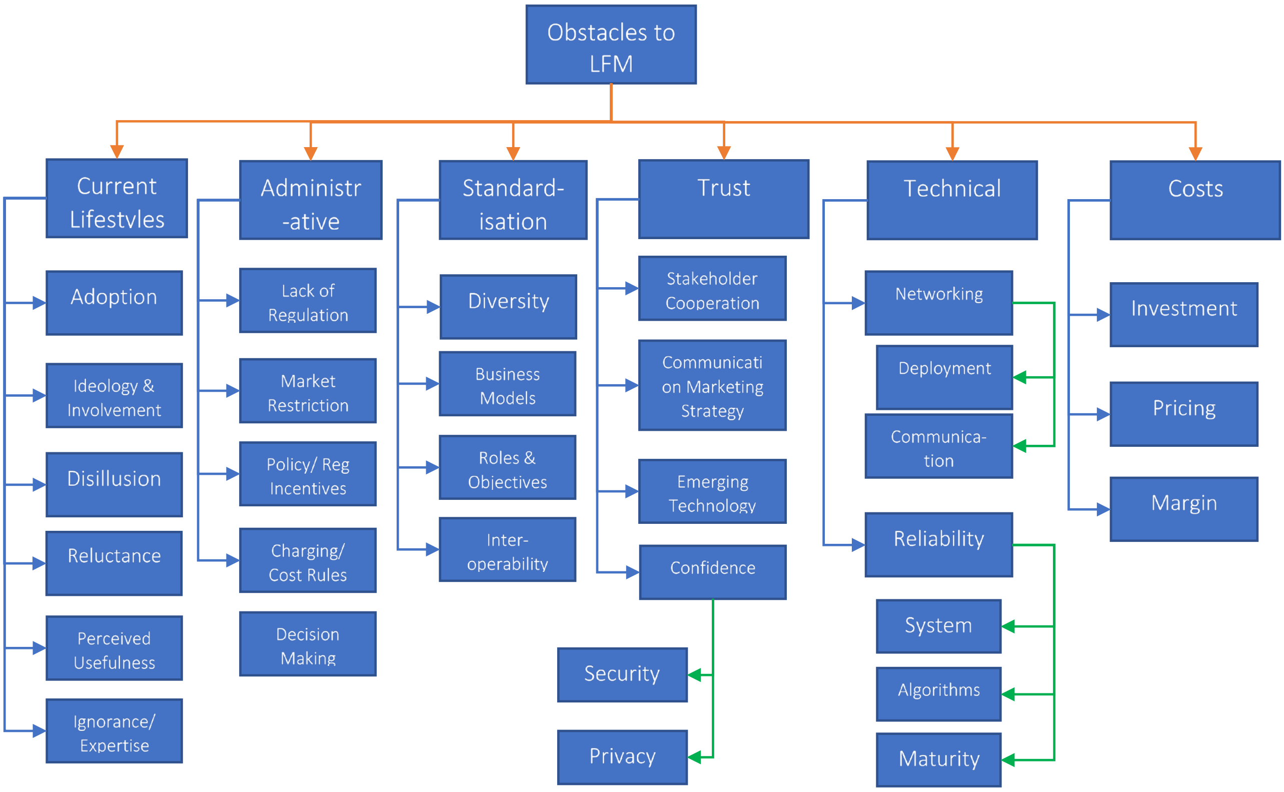

Figure 2: Barrier Taxonomy after Figure 1 of Zabaleta et al. (2020)

The taxonomy implied by the structural organisation of the report [14] on Smart Grids is also unusually distinctive.

2.2 How the Barriers and Potentials Concept is Used

A principal purpose for barrier identification is as part of a strategic, problem solving process, to identify the more promising solutions to a perceived problem. A generic process (that can be applied to specific situations) is given by the following steps.

1. Identify apparent potential and actual sources of flexible demand.
2. Identify potential barriers that could account for the difference between potential and realisable performance. This could be achieved by considering analogous examples and case studies. Or this could be done through individual consideration of relevant stakeholder perspectives.
3. Identify potential enablers and promising opportunities for intervention[1] to remove, overcome or reduce the impact of identified barriers.
4. For each promising opportunity for intervention, confirm which barriers are addressed and which barriers remain for each category of potential. Use this analysis to determine whether all required barriers are removed sufficient to unlock the unrealised potentials.
5. Assess the most promising intervention opportunities (from the available candidates) based on
    a. the magnitude of unrealised potential,
    b. the cost and difficulty of implementing them, and
    c. the difficulty of addressing the other barriers required to realise unrealised potential and/or the likelihood of them being satisfactorily addressed in the future.

The methodology described in steps 2 and 3 above was followed in [15] and applied to flexible demand potentials in the residential sector in the Netherlands. A literature review identified a broad initial set of hypothetical barriers. These were then refined by a combination of expert advice and further reviews of more specific literature results, including quantitative results, to prioritise these hypotheses. Finally, further testing was undertaken to obtain further evidence for or against the priority ones. In [16], a systematic method for evaluating and prioritising "market handicaps" to demand response is presented. It provides detailed suggestions for synthesising expert knowledge of the criticality and difficulty of identified barriers into a consensus summary. After applying the prioritisation method to Germany, Spain and the Netherlands across thirty-four hypothesised barriers, regulatory barriers were identified as both the most difficult and the most important to ameliorate.

In Step 2 it is inadvisable to cast the net too broadly and end up considering an excessive number of "hypothetical" barriers. Hence literature that disproves the relevance of barriers can be just as important as confirming ones that are relevant. Conversely, examining too few barriers risks being ignorant of important hidden barriers. Similar hypothetical barriers can be aggregated into groups to find a balance that simplifies analysis but maintains a level of rigour.

2.3 Other Approaches to Categorising Barriers

Barriers can be specified along several other dimensions, distinct from the barrier categories listed in Section 2.1 above. For example, sources of potential flexible demand may be associated with one (or perhaps more than one) of each of the following:

[1] Most uses of the word 'opportunity' in this review will be to refer to an 'opportunity for intervention' rather than to an achieveable intrinsically desirable condition, that is, it should be understood as a means rather than an end.

- flexible demand ‘capabilities’ (shed, shift or shimmy, [17], [18]). These will be associated with specific notice, response, and duration periods (Figure 3) [19], and may be further characterised by various activation prices and possible guarantees of reliability.
- Economic or industrial sector or subsector, load customer type and customer scale.
- End-use (service or technology).
- Flexible demand product market, mechanism or program, and system benefit value stream.

Any given barrier will typically inhibit a subset of specific potential sources, and a given potential source may be inhibited by several barriers. In practice, barriers may be required to be described highly specifically to identify suitable remedial intervention opportunities. For example, [15] specified one of its barriers to be “P9: The negative consequences of an increase in the price per kilowatt-hour for large electricity users form a barrier to dynamic network tariffs for households”.

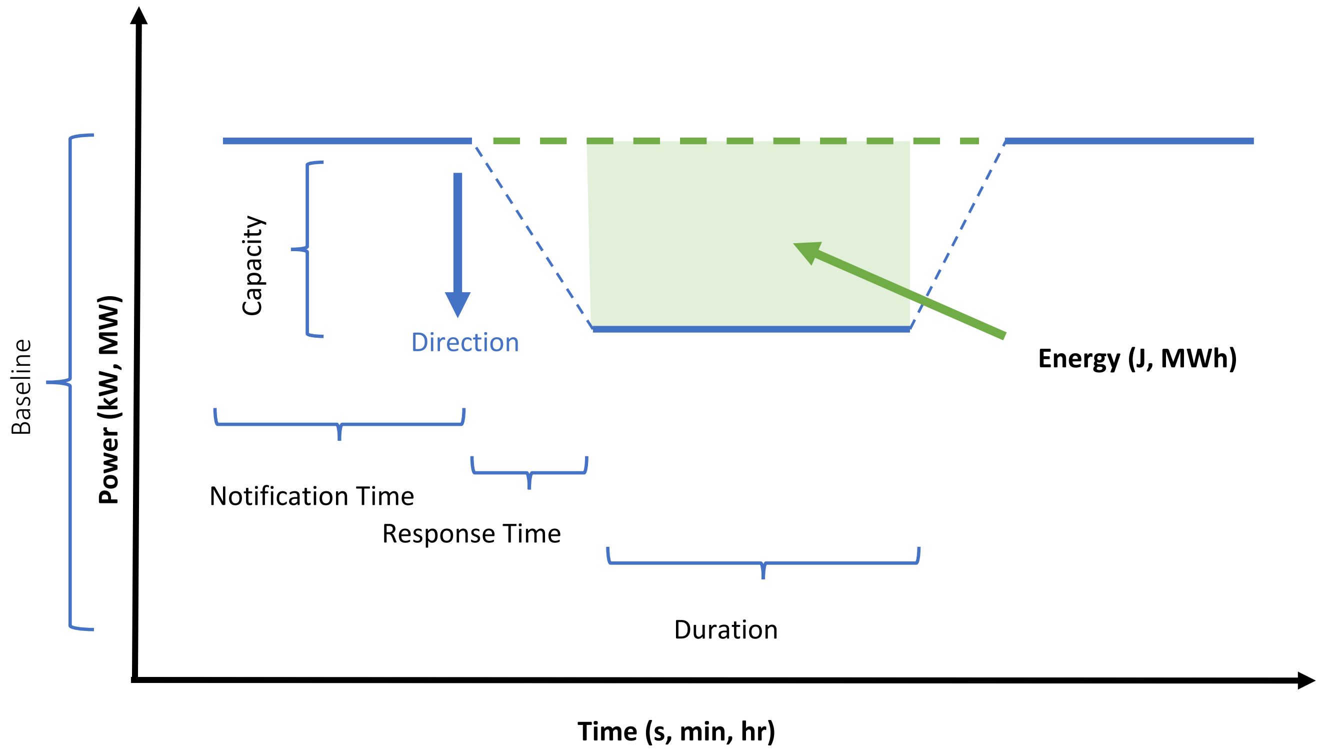

Figure 3: Characterisation of flexibility products

Because barriers are particular to potential sources of flexible demand, the relevance of any given barrier found in the literature may be specific to

- a stakeholder role,
- specific sectors or customer scales,
- energy consumption technologies, control mechanisms or end-uses, or
- product markets, coordination mechanisms, demand management programs and benefit value categories.

Different stakeholder roles will be more or less affected by different barriers [20]. Section 3 will provide an indication of which stakeholder roles are more directly affected by which barriers. Also relevant are the particular roles that are best placed to address any given barrier. Some relevant stakeholder roles include:

- electricity account customers, electricity supply end-users,
- electricity retailers, intermediaries (aggregators) and wholesalers,
- generators,
- Distribution Network Service Providers, Transmission Network Service Providers,
- market operators and system operators (this is the same organisation, AEMO, in the two main Australian electricity markets, the NEM and WEM),
- regulators, policy makers,
- citizens.

3. Barriers that appear commonly across sectors

This section describes common barriers relating to the broad categories of flexible demand potential discussed in Section 2.1. It is noted that, many issues could fit under multiple barrier categories.

3.1 Common technical and technology barriers

References [21] and [10] discuss (i) technological barriers in the capabilities of sensing the operational condition of the network and loads, (ii) computing sensor data to enable operational control, communicating sensor and operational control data, and (iii) standardisation of technical communication protocols among devices.

3.1.1 More (and improved) metering is required for network visibility and for financial settlement

Related to sensing, but also computing, [14] discusses low observability in LV grids in a chapter on technical solutions and platforms. It finds that distribution network investment savings were difficult to determine due to "*inadequate load and generation forecasting at the distribution level*". In the Netherlands electricity market, [10] was more specific about sensing technology, citing the measurement resolution of smart meters, and timely access to smart meter data (technical aspects) as a low priority, but finding the regulatory aspects of these barriers to be higher priority. The technical metering and data exchange requirements for supporting frequency response was also regarded as a lower priority barrier. [40] identifies a need for enabling infrastructure investment to support time of use tariffs.

3.1.2 Communications connectivity and automation is required to integrate end-users with markets for firm capacity

Both [21] and [10] note numerous technical barriers to efficient demand response capability that are related to the sensing and control of the network and connected devices. [21] regards these as fundamental barriers to flexible demand.

Reference [22] mentions "lack of interval meters, lack of digital communications systems, as well as limited energy end-use management and control systems" as barriers to demand response. [23] found that the high cost of [end use control] infrastructure was a barrier.

Reference [14] identified a need for market platform technology, but observed that regulators were "*Lacking the digitalisation perspective*" and that there are issues with *"emerging platforms fragmentation"*. A Netherlands study [15] found that (from a regulatory perspective) the lack of standards among platforms was a high priority for assessing the confirmed delivery (transfer of energy) of frequency response services, “metering, allocation, billing, reconciliation and data exchange” and smart meter data access.

3.1.3 HIGH PROPORTION OF DEMAND IS REQUIRED TO BE RESPONSIVE TO FULFILL THE NEEDS OF MANY ELECTRICITY INDUSTRY APPLICATIONS

In order to achieve a sufficient quantity of demand response (that is also spatially and temporally etc. suitable), [22] notes that a large share of load would be required for demand response to make a material impact (specifically referring to the wholesale spot market), and the ability to curtail demand must be suitably guaranteed at the required time [24]. Similarly, [9] described “limited supply of energy [curtailable load]” as a (technical) barrier.

3.2 COMMON ECONOMIC (COST-BENEFIT) BARRIERS

Inherently low system value is recognised as a possibility in [21]. Evidence from a recent Australian survey [19] indicates that this is a top ranked barrier for each of the industrial sector (*business case, technology costs*), the commercial sector (*business case*, ranked highly significant by survey respondents) and the residential sector (insufficient financial incentive, customer engagement and interest). [25] (on the topic of renewable energy technology barriers) mentions *high costs* in general and *costs of batteries* as a technology specific economic barrier.

3.2.1 MORE CERTAINTY IS REQUIRED TO JUSTIFY INVESTMENT

Reference [26] found that “*expected revenues are uncertain and may not exceed required investments costs*”. [9] bundled a range of criteria under the concept of *financial cost* (*investment, service, maintenance*) and described it as a barrier to innovation in the energy sector. [23] identified insufficient attention paid to *investment recovery* as a cause of demand response ambitions failing, and the undesirability of stranding high cost investment in peaking generation plant is mentioned by [24]. [27] concludes that ‘*Importantly, uncertainty surrounding the* (*economic and commercial*) *value of demand response’* is the single most significant barrier to widespread rollout of demand response.

Reference [21] identified potential problems associated with the eventually diminishing marginal productivity of system value relative to the quantity of flexible demand available (i.e. marginal benefits (and corresponding efficient market prices, realised by feedback from ‘market forces’ in a market based industry) decrease with the deployed quantity.

3.3 COMMON MARKET STRUCTURE, MARKET FAILURE AND MARKET DESIGN BARRIERS

Market failures are distinguished from other market barriers in [21], [9], [28] and [12]. However, the terminology in the literature is inconsistent, as many such distinctions are important only relative to the discussion in which they originally appear. For example the economic barriers of [9] and the “economic and financial” barriers of [12] appear to include barriers in all the categories that [5] lists as “institutional” (see above). Market structure barriers [21] are sometimes distinguished from market failure and market design barriers, and the institutional barriers of [12] and organisational barriers of [9] are similar to the "non-market design and decision making structures" above.

3.3.1 MANY MARKETS ARE EITHER ABSENT OR LACK TRANSPARENCY

Barriers due to market failures include the general issues of *public goods* (positive externalities) and (negative) *externalities* [28]. An example of a public good market failure is where the economic value to the full (electricity) system (*system value*) is insufficiently recognised by the market [21]. It can alternatively be described as inefficient prices [29], which could then be categorised as an incentives barrier. It can manifest as *low market demand* for engagement in flexible demand markets [29] and is described by [24] as *difficulties establishing demand response as a valuable resource*. Various market-based enablers to overcoming *barriers associated with demand response as a system resource* are mentioned in [30], particularly for frequency control ancillary services (FCAS) and similar services.

Market failures may also be due to *imperfect information*, *incomplete markets*, or *imperfect competition* ([21], [9], [28], [12]). Other contributors to market failure and market imperfection in the energy sector include the *highly regulated nature of the energy market*, *lack of competition*, *high transaction costs and investment requirements*, *restricted access to technology*, and *limited information and awareness* [12].

Reference [14] identified market (structure) barriers including *market fragmentation and inefficiency*, and concluded that well defined *product definitions* for demand response are required in the European Union. Similarly in the United States, [26] found that - specifically regarding ancillary services - the current rules and definitions in the electricity market for electricity market service providers may not be suitable. These concerns may be ameliorated to some extent in the NEM by the relatively mature FCAS market and the more recent 2020 Wholesale Demand Response Mechanism rule change [31].

3.4 COMMON REGULATORY AND POLICY BARRIERS

3.4.1 CLARITY IS REQUIRED ON THE ROLE AND PRIORITIES OF REGULATORS

In a 2011 Australian study [29], barriers ranked very highly by stakeholders include *lack of coordination at state / national level*, and absence of explicit demand management and environmental objectives in *National Electricity Law*. Similarly in the European Union, [14] calls for a *smart meter roadmap* beyond 2020 and a *common strategy on reliable IoT communications for the energy system*. In the United States, [22] describes a *lack of clarity regarding the boundaries between federal and state regulators* for jurisdictional responsibility for the energy industry as an important policy uncertainty barrier and calls for the *federal regulator to take a generally cooperative facilitation role* with respect to states and utility companies, rather than a strict regulatory role (see [32] for an Australian perspective on historical trends among regulatory institutions in this general direction).

Reference [33] specifically addresses the question "does the current regulatory system create financial disincentives to choosing [demand management] and thereby discourage network businesses from adopting [it]?". The estimated financial impact of economic regulations that favour network solutions over demand management solutions (or vice versa) are disaggregated into detailed components, showing how the network solution can be more profitable for particular case study examples. In contrast, the total economic impact of each solution is also calculated, disaggregated into capital and operational expenditure, demonstrating how the solution that is more profitable for the relevant decision maker (the network), can nevertheless be higher net economic cost.

Priority issues to be addressed by the regulators of European markets were examined thoroughly in [34]. These priority issues are ultimately determined to be: smart meters, the framework for remunerating distribution networks, the regulation of network tariffs, licensing and regulation of demand response providers/ intermediaries, and reform of consumer protection regulations.

3.4.2 TECHNICAL STANDARDS FAVOUR INCUMBENT SOLUTIONS

Overly inflexible technical standards regarding transmission network security are argued in [35] to be a barrier to renewable energy generation technologies, which inherently require more flexibility in their operation than more reliably dispatchable traditional generation.

3.4.3 TARGETS COULD SUPPORT PRIORITISATION

Absence of policies that might promote renewable energy is regarded as a barrier in [12] which cites an *absence of targets regarding (primary) energy savings, CO2 emission savings or renewable energy share* and [29] cites the *absence of carbon price* as a barrier to demand management, albeit one of fairly low priority.

3.5 COMMON MARKET BARRIERS

Following [5], barriers due to decision making structures outside the economic market are distinguished from broader economic structural features of the energy market, including market failures. These are in principle more susceptible to intervention. These can be described as "market barriers" in that they limit the scope and scale of the market for demand response. However, they are distinct from market failures (the departure of the actual market from the theoretical ideal of a "perfect" market), such as (i) market structure (the scale and relationship between organisations in the relevant industry) and (ii) the consequences of market design (in more highly regulated industries such as natural monopolies, the rules for market entry, products traded, and market actor relations are strongly constrained so that the resulting markets meet intended design objectives.) These are distinguished from "market failures" in [12] by being described as "market distortions".

3.5.1 BUYERS OF FLEXIBLE DEMAND LACK STRONG INCENTIVES

In [29] (2011, Australia), moderately highly ranked barriers included '*competing organisational priorities within utilities*' and '*split-incentives between property owners and tenants as energy users*', and *utility bias towards centralised supply*. [25] mentions '*incumbents with an interest in maintaining the status quo*' and '*conflicts with existing business models*'. However [29] ranks as one of the lower priorities the barrier '*demand management reduces profits (revenue) for electricity supplier*', and [15] finds that '*different interests between the electricity supplier and distribution service operator*' is not a barrier to the introduction of flexible demand in the residential sector in the Netherlands.

Particularly important (incentive) barriers [29] are that *local peak network constraints are not reflected in power prices*, and existing *time-based prices poorly reflect the temporally and locationally specific cost of supplying* *electricity*. Insufficient incentives for participation (of concern in the Australian market for reliability services, [36]) could be due to either a genuine economic barrier, or a market barrier due to inappropriate sharing of costs and benefits of demand response. The latter conclusion is strongly suggested by the cost-benefit analysis results in [33], which indicate significant net economic benefits if greater demand response potential was realised (primarily from network investment savings). [37] alludes to challenges in the design of a compensation mechanism for balancing services, when provided by demand response. Similarly, [30] discusses the challenges of developing business models within which a successful business case for demand response can be prosecuted by retailers.

Reference [29] *found that 'Disaggregated electricity market resulting in demand management benefits being hard to capture'* was ranked as a reasonably high priority barrier in 2011 in Australia. However, the following were not included among the higher priorities: a) *uncertainty who should be the recipient for avoided network costs resulting from demand response*, b) *uncertainty regarding which costs should be charged to embedded generators,* and c) *economic regulation doesn't allow for smart metering cost recovery*.

Reference [25] recommends that *incentives should match the local requirements of the distribution network,* which may vary across different locations (for renewable technologies). In the United States ancillary services market, [26] also discusses *revenue capture barriers* in depth. [11] also notes that barriers to revenue availability for the transmission network service provider or market operator exist for ancillary services. '*Unclear opportunities for value stacking'* are identified both by [36], for reliability reserve in the Australian market, and [14], for the general development of smart grid solutions in the European Union.

3.5.2 MORE CLARITY IS REQUIRED ON REGISTRATION OF CAPACITY IN MARKETS AND HOW TO DETERMINE DEMAND RESPONSE BASELINES

Determining an appropriate (fair, not able to be gamed) baseline, for rewarding delivered demand response, has been recognised as a major challenge: in Australia [36] for (i) the reliability and emergency reserve trading mechanism, and in the European Union [14], [27] for (ii) demand response in large commercial organisations and (iii) smart grids in general. A related observation is that the selection of a baseline scenario case for the analysis of economic benefits, through market simulation, is similarly challenging. An underdeveloped negotiation framework between utilities and developer proponents of distributed generation was identified in [29] as a barrier to distributed generation.

Barriers to market entry for demand management service providers [30] in the European Union include *prequalification criteria* and *lack of market framework for demand response services* [14]. In Australia, however, neither '*licensing requirements and standards for generators being complex & expensive'* nor '*the connection process being too complex'* were evaluated as among the most important barriers [29]. '*Market entry participation fees'* were regarded as a lower priority secondary barrier in the Netherlands [10].

3.5.3 ACCESS TO CAPITAL MAY BE AN ISSUE FOR HIGH CAPITAL COST INTERVENTIONS

Lack of *access to capital* is hypothesised in [21] as a general barrier which is classified under the financing barrier within the framework of [5]. Similarly '*liquidity constraints'* are cited by [28], and '*high upfront investment costs*' are cited by [25] for renewable energy. That utilities have more access to finance than demand management providers is a reasonably highly ranked priority in the Australian study [29]. However, not so highly ranked priorities are i) consumers and utilities requiring '*shorter payback for operations and maintenance* (such as investment in demand management) *than for additional supply*' and ii) *lack of capital, financiers, funds for demand management project proponents*.

3.6 COMMON SOCIAL, CULTURAL, BEHAVIOURAL BARRIERS

This section discusses cultural and behavioural barriers that apply across all stakeholder roles. Barriers that are specific to customers or end-users, including behavioural barriers are also treated in depth in [38] and in subsequent sections of this report.

While [22] recognises techno-economic barriers to flexible demand, such as lack of technical sensing and communication infrastructure, it concludes that greater barriers to widespread realisation originate from *organisational, institutional, and cultural* drivers (social, cultural and behavioural factors are the sixth category of [12]). Behavioural and social factors are characterised by [28] as departures from predictions of economic theory, but that are however explained by concepts from psychology [21] and other social sciences. These are further distinguished as follows. While behavioural or psychological phenomena relate primarily to that of individual choice, organisational or social phenomena are decisions made within the context of formal organisational groups or informal social groups with common cultural beliefs (what is true), attitudes (what is desirable) and practices (what is done). Social practice perspectives [39] place particular emphasis on practical activity in the context of the immediate material (technological, infrastructural, ecological) environment. Several alternative frameworks for explaining human behaviour are presented in [39]: cognitive dissonance, planned behaviour, normative conduct and habitual behaviour. The choice of framework influences suggested interventions for changing behaviour, and so to some extent the characterisation of barriers.

3.6.1 CULTURAL BIASES EXIST IN THE ELECTRICITY INDUSTRY

The *cultural beliefs or lack of appropriate knowledge and experience* of flexible demand technologies among customers is specifically mentioned [39] there is also a problem with *understanding* within the energy industry itself [21]. *Lack of experience, skills, expertise in demand management* in both electricity suppliers and demand management service providers were considered to be lower priority barriers by [29], although [25] identified *lack of skills* as an important barrier to commercialising renewable energy technology. Similarly [21] notes that there is a lack of *technological skills* in designing effective ecosystems of smart devices.

In contrast to ideal rationality, *bounded rationality* recognises people's limited ability to make optimal decisions within the context of complex circumstances, leading to key decision makers using heuristics or succumbing to inertia (not making any active decision) [28], [21], or being overly risk averse [25]. Other examples of behaviour that is not consistent with economic assumptions of ideal rationality are explained by [21]; i) the format that relevant information is provided in for ease of understanding, and ii) the trust by a recipient of relevant information in the source of that information which depends on iii) the credibility of the source.

Other behavioural factors include (individual, social or cultural) variation of norms, and inconsistency between implementing flexible demand and meeting other valued priorities. For example, both [29] and [37] identify concern that widespread uptake of distribution scale energy resources and time of use tariffs may merely shift the peak of electricity consumption to another time period, which may have as bad or worse environmental, or other, impacts. They suggest that concern about these other priorities may be another reason that demand response implementation is held back.

4. Role specific barriers

This section describes barriers that have been identified in the reviewed literature as especially salient to specific stakeholder roles. These roles have been grouped according to similarity of role.

4.1 Market Operator and Transmission and Distribution Network Operators

Section 5 of [20] is dedicated to a lengthy discussion of the evolving role of distribution networks to fully enable demand response markets. '*Immature technology*' was seen as an important barrier to the increased uptake of distributed energy resources (solar PV, batteries and electric vehicles) in Sweden [40], with *advanced protection tools to protect the grid from overvoltage* found to be moderately important within a five year time horizon. The following technological issues were found to be less important: '*advanced load control technologies*' and '*frequency regulation as a service from distribution system operators*'.

4.1.1 Network services need a supportive regulatory framework

'*Existing regulations and directives*' were seen to be relatively important [40], consistent with a concern that economic regulation in Finland '*favours network infrastructure over demand response investments*' [41], [34]), and that '*regulated network tariffs*' hamper the application of demand response incentives in the Netherlands [15]. Improving '*distribution system operator knowledge of new distributed energy solutions*' is recommended by [40].

4.2 Retailers

Market structure barriers might be described as the *electric retail utility* (*market*) *environment* [26], leading to a situation where flexible demand and energy efficiency solutions are in opposition to the prevailing business model [42]. Other market barriers for retailers, distinct from market structure, include *the institutional inertia* (*of the retailer*) [42]. In certain markets, retail price *regulation* hampers the use of incentives for flexible demand [41] (Table 1).

4.2.1 Retailers face high transaction costs and end-user apathy

Limited technical potential was raised as a barrier to the supply of flexible load products in Queensland, Australia [42], though the market supply of distributed energy resource technologies was not regarded as a limiting factor in Sweden [40]. Economic barriers identified as relevant to retailers include *high transaction costs* in general, including more *complex* measurement and customer interaction requirements [42], one such example being that rewarding flexible demand might require a *new system for customer billing* [15].

Cultural and behavioural factors affecting retailers include low customer awareness and fear of damage to reputation caused by customer perception that the retailer is unable to deliver supply at peak times [42].

Reference [43] found a lack of expertise in flexible demand markets amongst retailers. The corresponding transaction costs of developing knowledge and expertise in a new area are a disincentive. Furthermore, up-front costs of investing in a demand management solution with a customer creates a risk of not realising that investment if the contractual relationship with the customer is of insufficient duration. A typical payback period for a demand response investment is 24 months, whereas a retail supply contract may last only 6 months. An option for overcoming this barrier is to engage in separate contracts for demand response and electricity supply.

4.3 Customers & End Users

The customer perspective on demand side flexibility is dealt with in detail by [14]. Technical barriers to flexible demand pertinent to customers include *lack of standardisation and interoperability* of the technology that delivers flexible demand devices [14], *lack of availability of technology* in general and *information feeds* in particular [23]. The capabilities of the existing information technology infrastructure, however, are regarded as sufficient for Canada's public power utilities [44].

4.3.1 Customer savings may not be material to overall financial consideration

In many cases it is difficult to make a positive *business case* to invest in flexible demand [44] that is adequately material. Current *regulatory and tariff structures* may be insufficiently attractive to encourage electrical demand response, particularly for residential customers [24]. Insufficient incentives [27], [14] or potential savings [23] are frequently cited as a major barrier to demand response. [41] refers to *limited and uncertain benefits.*

Barriers that may or may not reflect efficient markets include *high transaction costs*, *unequal access to capital* of customers compared to (energy) companies [42]. [23] mentions '*technology cost and financing*'. Barriers impacting on customers' access to flexible demand markets include general *market immaturity*, *inefficient prices* for various aspects of electricity supply, and *split incentives* [42].

4.3.2 A range of behavioural factors impact on customer perceptions

The interaction between the requirements of flexible demand with *user routines and activities* may result in *inconvenience* to the customer [27]. Indeed, there is an inherent conflict between the customer's goals of demand satisfaction at will and the load flexibility required to minimise investment in electrical power infrastructure. [41] recognises that *changing patterns of electricity consumption* is inherently difficult. For business customers, flexible demand presents a risk of *business interruptions*, giving rise to *product quality concerns* [44].

Data security and privacy concerns regarding the collection of smart meter data are raised by [15] and [14], including uncertainty over how to administer consumer consent to make their data available to service providers.

Behavioural factors should be considered in the design of demand side policies and flexible demand programs. These are treated in depth in [38]. Beyond lack of customer awareness of their options [14], other behavioural barriers of interest include general *lack of interest* in customers about energy [41], *response fatigue* in changing usage patterns, and *satisficing behaviour* [23], which can explain the persistence of *habits*, or *status quo bias* and *behavioural inertia* [38]. [45] finds that response fatigue can be ameliorated by using smart domestic appliances (dishwashers, washing machines, clothes dryers and hot water) with automated response.

Difficulties in choosing flexible demand products may result from customer *lack of awareness* [14], [38] and inadequate consumer knowledge [23]. However *lack of awareness* of flexible demand was not a found to be a barrier in [44] for any of the three customer categories surveyed in Canada: large (managed account) electricity customers, smaller commercial customers and domestic customers. Required skills and training of the customer [44] are also dismissed as major barriers. Instead *tariff complexity* [44], *choice overload*, and the challenges of *intertemporal trade-off evaluation* [38], may hamper customer choice.

Examples of bounded rationality among customers may include the *sunk cost fallacy* and *inaccurate perceptions of self-efficacy* [38], and other relevant factors that motivate behavioural change (or stasis) include social norms and cognitive dissonance. [29] mentions '*public resistance to time of use meters and tariffs'* in Australia, a concern reinforced by [10] as being a social barrier in the Netherlands.

4.4 Aggregators and Intermediaries

Intermediaries are described as "a crucial entity to gather the flexibility from many small sources and facilitate active participation of DER" [46]. Considering the industrial sector in particular, [47] notes several barriers that can be overcome or ameliorated by intermediaries. Most of these are likely to be applicable to commercial and residential sectors, including identifying sources of flexible demand potential, and overcoming behavioural factors to realise it. Particularly important for smaller customers, intermediaries can permit hedging risk and enable economies of scale and scope (eg aggregation and value stacking). This may reduce transaction costs associated with participation in one or more electricity markets. [20] discusses the importance of enabling of effective participation of intermediaries in the electricity market, and outlines details of what this entails. It holds that this is the first necessary stage of three stages to the implementation of a fully responsive smart grid.

Reference [46] reviews mostly theoretical studies investigating various aspects of the feasibility of intermediaries that offer flexible demand aggregation, addressing primarily technical barriers. Technical barriers to the emergence of intermediary energy traders include *lack of smart meters*, and lack of other sensors to conduct *measurement for verification of performance* [48].

Reference [49] distinguishes three categories of sources of profit for intermediaries. Unlocking *fundamental value* is desirable, these are improvements to net social economic value that are aligned with intermediary incentives. Some sources of profit for intermediary might be merely *transitory*, owing to a relatively temporary market disequilibrium. These might be available initially to kick-start the market for intermediaries, but they will disappear over time due to competitive pressure once solutions have been implemented. Finally, some source of profits for intermediaries are categorised as *opportunistic*, where the profit motive for intermediaries are misaligned with economic efficiency, a case of "perverse incentives" representing an enabler of intermediaries rather than addressing a barrier. [49] notes that a challenge for regulators is to develop a market framework for intermediaries that facilitates fundamental value while discouraging opportunistic profits, and a challenge for all market actors is to recognise the temporary nature of the transitory sources.

4.4.1 Aggregators require a level playing field with other actors in the market

In the European Union important (market and regulatory) barriers include *lack of level playing field for actors that are independent of energy suppliers* [46]. In Finland [41], *market rules prevent participation of aggregated loads* in wholesale, balancing and capacity markets. [50] recommends that intermediaries should be *recognised by regulators as having a role that is distinct from both generators and retailers*, as well as other actors in the energy market, and [41] recommends that regulations should prevent electricity suppliers from requiring their consent before their customers can enter into a contractual arrangement with an intermediary. However, [41] also notes that customers and aggregators may alternatively gain an unfair advantage over retailers, if they can optimise their demand response after the spot prices are settled, whereas retailers are required to estimate the flexibility in advance during bidding process (see also reference to information asymmetries recognised by [27] in determining demand baselines and [51] in the manufacturing sector).

It is noted [29] that retailers have alternative means beyond demand management to manage exposure to the wholesale market through ownership of generation assets and use of financial instruments to reduce risk. This results in difficulties for non-retailer service providers or intermediaries to access the wholesale market [29]. On the other hand [19] finds, based on a survey within the Australian industry sector, that the ability of intermediaries to provide demand response directly to the wholesale energy market is not a high priority barrier for industrial demand response.

Market rules such as minimum bid size and duration, and penalties for non-supply [48] [37], can discourage the market entry of intermediaries. [41] points to a '*lack of standardised processes between balance responsible parties and intermediaries'* and recalls the '*underdeveloped negotiation framework between utilities and developer proponents of distributed generation'* in Australia [29].

The desirability of *cross border regulatory harmonisation in the EU* is also mentioned by [48]. [52] notes that, in Germany, intermediaries lack a clearly defined role in the energy market and are discouraged from participating by the strong requirements for guaranteeing their services, on pain of financial penalties. Another barrier in participation is the long lead time (one week) required to submit their bids to the market, which exceeds the time horizon of their forecast accuracy. There are further challenges to determining how intermediary performance would be measured for verification, and the relationship between the technical demand response activation mechanism and the settlement of a price.

Reference [26] notes that intermediaries are subject to barriers that are similar to those for retailers, such as being subject to stringent regulations that limit business model options, or lacking a market to trade in (some jurisdictions manage ancillary services outside the market framework, unlike the National Electricity Market [53] and Wholesale Electricity Market [54]). Also, similar to the barrier identified for retailers, a contract with an industrial sector flexible demand provider may require a minimum duration to justify any upfront investment in automation and control equipment.

Finally, the complexity of solving "global" optimisation problems [46] will tend to result in system operators selecting a satisficing solution, that is one that satisfies the most important constraints but achieves only a close to optimum (such as minimum cost) rather than a strictly optimum value. Any given suboptimal satisficing operational setting, particularly when the net system suboptimality cost is relatively immaterial, could well significantly disadvantage particular market actors (particularly intermediaries).

5. End use Market Segments

This section presents barriers that have been identified in the reference material as applying to specific end-use segments: the industrial sector & large customers, the commercial sector & medium scale customers, and the residential sector & small customers. It finds that more significant barriers to flexible demand are largely similar or analogous across the industrial, commercial and residential sectors. Cost, concern about disruption to existing practices, and insufficient incentives are a barrier to flexible demand for all customer sectors. A significant barrier to improving incentives seems to be network tariff mispricing and regulatory barriers appear consistently as a significant theme. The main differences by sector are that larger customers will be relatively less affected by "transaction costs" than smaller ones. Factors for the larger customers will be more likely to be due to internal organisational decision-making structures, and individual behavioural factors more relevant to residential and small commercial customers.

5.1 Industry Sector and Large Customers

The review article [55] lists 42 references relevant to drivers and barriers for demand management in the manufacturing sector. Costs are a universal concern, with *economic barriers* ([56] (for the food industry) and additional investment costs [57] (for manufacturing companies in Southern Germany) expressed for the more general industrial sector (in Australia) as both *technology costs* and challenges of *establishing a business case* [19]. [44] shows that battery costs and developing the business case are among the most significant barriers to investment in batteries by large customers in their Canadian survey. Absence of *reliable assessments of the benefits of demand response* [58] and *uncertainty regarding future revenues and costs* (in part related to policy uncertainty in Australia) [43] are also significant. [19] reinforces concerns in Australia regarding *uncertain revenue*.

Financial barriers [58], including competition for scarce capital [43], limit the implementation of demand response. Knowledge-based barriers [58], such as lack of access to specialist energy knowledge and expertise [43] applies to the industry sector in particular, as it does more generally across commercial and residential customers.

5.1.1 Cost reflective options are often not offered, and a fair proportion of value created from flexible demand may not be passed through, to industry

A *restrictive regulatory framework* limits the scope for demand response [57], as does the uncertainty of commercial viability where *future regulations are not known*. '*Regulatory barriers*' [58] and "legislative and regulatory" barriers in the international food industry [56], are represented as *limitations of market regulations*, such as '*utilities face conflicting incentives that discourage network savings*' [58]. Due to *limited transparency on network projects*, *limited competitive pressures for demand management services*, retailers may effectively charge *high margins to customers who wish to exploit demand management* capability to access the wholesale market [43].

More *innovation in the market* is required [59] (for smart grids), which would allow better *access to energy market revenue streams* for demand management services from Australian industry [43]. At present, *supply agreements and tariffs* do not provide clients with *sufficient incentive* to implement demand response, nor are they appropriately *reflective of marginal costs of electricity supply* [43]. *Time-based tariffs* in general are reported to lack widespread implementation in the industrial sector [58]. Market participation rules in Australia may discourage demand response service providers due to onerous *notice periods and terms of participation* (such as firmness of commitment) [43]. Requirements of flexible demand programs, and aggregation requirements may be too difficult to meet, or participation in existing energy efficiency programs may unnecessarily prevent additional participation flexible demand potential [58]. Reference [51], also focussing on the industry sector, notes concerns that "Information asymmetries and complex opportunity costs may yield severe economic gaming problems on markets".

5.1.2 LOAD FLEXING IN THE INDUSTRY SECTOR CAN IMPACT ON PRODUCTION

Industrial customers tend to be wary of flexible demand due to the potential impacts of the interruption of supply [44]. Potentially negative effects can occur both during and after a supply interruption [51] and include possibly negative effects on underlying production processes, "loss of production, damage to machines, increased waste, reduced profits, missing production, additional maintenance work" or the loss of reputation due to reduced product quality. Flexible operation may result in increased mechanical wear and increased maintenance expenses. Product quality is one of the highest concerns [44], and this is reiterated in [56] for the food processing industry as "perception of potential impact on food processing effectiveness and quality of final products".

Accordingly the capacity of existing sites to implement change to flexible operations that might permit the realisation of load flexibility represents a common barrier identified by [43]. [51] warns that industrial production process may be complex systems with high dependencies, and so may be error-prone under a change in operational logistics. In the food processing industry, in particular, the complexities of some food processing chains, "with cascade, intermittent and inter-connected processes", require particular attention to the "quality of final product, safety issues, and process effectiveness" [56]. Where processes are complex it may be difficult to change them to realise greater load flexibility. [43] claims that the value that could be delivered by price-responsive demand, and by fast responding storage, is not fully optimised by existing demand response programs.

Larger and industrial customers who face higher costs will be more motivated to consider load flexibility [22]. "However, unless an obligation to reduce demand is imposed, even large industrial customers do not see load management as a priority".

Reference [57] highlights '*uncertain savings* or *cost savings that are too low*' for manufacturing in southern Germany. '*Low priority given to energy matters*' is further confirmed in [19] as a barrier to industrial demand response in Australia. However, the time and effort required to manage an industrial response programme was found to be not a significant barrier [19], nor was the administrative burden a significant barrier in a European study of industrial demand response [58].

Reference [57] conducted further investigation of barriers to load shifting in the manufacturing industry, including grouping barriers into correlated clusters, potentially defining categories from empirical data rather than expert interpretation. It also disaggregated results for customers by a) strategic value of electricity to their business and b) by production logistics categories. It suggests that customers with higher absolute electricity costs are somewhat more concerned than those with lower costs about the uncertainty of cost savings from load shifting. It also finds that customers with higher relative electricity costs are more concerned about regulatory restrictions, and customers with higher absolute electricity usage are more concerned about regulatory uncertainty than their lower electricity intensity and absolute usage counterparts. Companies with continuous production processes report generally lower barriers to load shifting than those with batch and just-in-time processes. Companies with batch processes are more concerned, and those with continuous processes are less concerned, about the potential for load shifting to interfere with personnel planning. The relative priority of energy management among company managers is a greater barrier for companies with just-in-time production.

Intermediaries have the potential to address barriers to flexible demand in industry [47] by realising some economies of scope and the enabling of value stacking, some hedging of risk, and alleviating wholesale market transaction costs. Intermediaries have expertise in identifying sources of flexible demand potential, and can assist in overcoming organisational inertia to realise it. However, [49] warns that some intermediary sources of incentives may be temporary, and some impacts could be contrary to economic efficiency.

5.2 Commercial sector and medium scale customers

5.2.1 Smaller energy savings from smaller site loads makes the business case more difficult

Costs are identified by [44] as an important barrier for both demand response and energy storage for medium scale commercial customers. Similarly, for small companies in the services sector, flexible demand measures were assessed as costly by [60]. Hidden costs of flexible demand response (including capital, production, transaction costs, and activation processes) are mentioned in [61] as barriers in the commercial sector. In one survey, the challenges of making a business case were found to be a high priority barrier for the commercial sector [19].

Small companies, particularly in the services sector, may find demand response financially uninteresting due to low energy consumption [60]. Consequently, there may be low motivation to understand flexible demand opportunities for residential and small commercial customers whose electricity costs are a small proportion of total expenditure.

5.2.2 Behavioural factors, misaligned incentives and perceived risks of disruption are a significant barrier in the commercial sector

Supply interruptions are listed as a higher priority concern by medium scale Canadian customers in [44]. The risks of disruption may be perceived to be higher owing to unfamiliarity [61], and subject to limitations imposed by the social practices, including the habitual timing of business activities, of end users. As for large and industrial customers, medium scale customers [44] and commercial customers [57] may be impacted by lower product quality.

Common behavioural barriers, such as bounded rationality, inertia/ status quo bias, and organisational decision complexity are confirmed as applying also to commercial customers [61]. Energy is found to be a low priority concern in general [61] and in the services sector in particular [60].

In commercial buildings, a significant barrier to both energy efficiency and flexible demand is that design incentives are misaligned. [62] details a wide range of issues including split incentives between the end-user (who should want low operating costs) and the building designer and developer (who often aim for low construction cost). Fourteen different phases across the design, build and operate lifetime of commercial buildings are examined, with misaligned incentives identified in each phase.

Lack of availability of energy management tools is not a significant barrier [60], nor lack of awareness of such technologies [57]. Lack of customer skills is not seen as a major barrier in the commercial sector in Australia [19], employees are perceived to not need training in Canada [44], or convincing in the services sector [60]. Image is not seen as a barrier [44], indeed [60] claims that image effects are not significant in the decision process. Decision complexity is not perceived to be a barrier [44], access to external capital access is adequate, and data security issues are not a concern [57].

5.2.3 LACK OF STANDARDS AND INTEROPERABILITY ISSUES IMPACT ON SCALABILITY IN THE COMMERCIAL SECTOR

"*Technical standardisation and interoperability* are seen as challenges by [59] for smart grid technologies, with [58] finding the same for demand response, noting the '*limitations of open standards*' and the '*variety of measurement and verification mechanisms*'. Improvements to *building management systems*, *data management systems* and *data quality* is required to improve the prospects of renewable energy and load management in Australia [43]. *Demand control technology* also needs improvement: for example, to aggregate load response across dozens of separate sites [43]. The interactions between *automated demand response, battery storage and automated generation* in smart grids also need improved management and technical control [59].

Refrigeration and air conditioning is considered in detail in [3], where the most relevant barriers include lack of technical knowledge and lack of experience by customers. The split-incentives commonly identified between users and owners is also applicable to these cooling technologies, as well as challenges associated with fair attribution and sharing of net cost savings and risks.

5.3 GOVERNMENT CUSTOMERS

Local, State and Federal governments in Australia have a significant portfolio of commercial and institutional buildings and they have significant purchasing power as a major tenant in CBDs across Australia. State and Federal Governments agreed to lead by example in their own buildings under the National Energy Productivity Plan [63]. Reference [64] suggested that they may need to develop improved strategies for collaborating with energy service companies, to counteract the challenges of institutional barriers. However, competing priorities will remain a major barrier.

5.3.1 GOVERNMENT BUILDING PORTFOLIOS COULD INFLUENCE THE MARKET BUT MUST OVERCOME INTERNAL PURCHASING/ DECISION MAKING BARRIERS

Reference [65] found that formal institutions and collectives tend to face different barriers, compared to individuals, to the implementation of environmentally beneficial and smart energy efficiency technologies. For formal institutions (such as corporations or government departments), barriers include lack of clear definition of requirements, institutionally embedded decision-making processes that are often informed by other priorities, and departmental silos. Similarly, collective decision-making institutions such as business associations and community groups struggle with perceptions of risk and uncertainty, and technical and operational restrictions on managing energy technologies.

5.4 Residential Sector and small customers

Reference [15] describes numerous potential barriers, in the residential sector, to the implementation of flexible demand via dynamic network pricing or direct load control in the Netherlands. A *lack of suitable appliances* is a barrier to direct load control. Regulation creates further barriers because (i) dynamic network tariffs are not permitted by the regulations and (ii) regulation *obstructs the distribution system operator* from involvement with customers and (iii) regulation defines unhelpful *criteria in the imbalance market*. Furthermore, after flexible demand reforms are implemented, *new demand peaks* may be created. For direct load control, low prices on the balancing market are insufficient to make a business case, and benefits to the distribution network are uncertain. The system operator would also face a less predictable income distribution. Additional administrative costs would be incurred because a new billing system is required. However, even if the required regulatory reforms were implemented, [22] claims that despite "currently dealing with large numbers of customers, ISO/RTOs are not equipped to deal with individual residential and small commercial customers".

The following were found to not be significant barriers in the scenario in [15]: inaccuracies in forecasting and uncertainties in balance, a requirement for new smart meters, or the fact that dynamic network tariffs might lead to higher costs for large users.

5.4.1 Lifestyle typologies and demographics may be required to segment and attract customers in the Residential Sector

It appears that residential customers in the Netherlands are not very interested in dynamic network tariffs [15]. This is consistent with recent Australian survey results [19] which identifies customer engagement interest as an ongoing challenge. Given the reasonably small proportion of total household expenditure, motivation for consumers to understand time-varying pricing (and other mechanisms that might encourage flexible loads) is low [22].

However, several studies indicate that it is useful to differentiate consumers in the residential sector, in order to tailor offerings to match customer values. Reference [66] distinguishes Australian potential customers of demand response along two dimensions of social values: "horizontal" versus "vertical" as a guiding principle of interpersonal social relations and the relative importance of "individualist" versus "collectivist" interests. Also applied to Australian consumers, reference [67] identifies the social categories of "settlers", "prospectors" and "pioneers", in describing their attitudes to innovative technologies and practices. In a study of attitudes to smart grids, [68] classifies consumers into four categories according to principal motivating attitudes as "economist", "technician", "environmentalist" or "compromiser". [69] identified that '*how incentives were framed'* to consumers was found to influence consumer decisions. However [70] warns, in their systematic review, that typically available demographic characteristics of residential customers were not always accurately predictive of their engagement with demand response.

5.4.2 Changing consumer consumption patterns is difficult without automation

Several Australian references [39], [71] make the point that household electricity consumption is merely one aspect of lifestyle, which is embedded within an interacting ecosystem of social practices that is co-created with an existing habitat, with established rhythms and routines of social activity organised across time and space. In practice, realising electricity consumption flexibility represents a behavioural change that may require significant modification of inter-related patterns of activity if the change is to persist. Similar arguments have been applied in the United Kingdom context [72]. The interaction between flexible demand and user routines and activities is found to represent a potential barrier across the numerous studies reviewed in [70], which notes that whether demand response is implemented manually or automatically is less important to its successful implementation, and it is more likely to be facilitated if it is less disruptive to existing routines. Analogous findings hold for the industrial and commercial sectors. In Israel [69], it was noted that the groups showing the greatest acceptance of the new technologies included not only the young (who are frequently early adopters of social innovations in general) but also the observant Jewish community, as it made it easier "to avoid contradicting [a] religious prohibition" against electricity use on the Sabbath. This suggests that if a behavioural innovation facilitates meaningful social objectives, novelty alone is not a strong barrier to uptake.

5.4.3 Financial benefits, risk management, ease-of-use and trust are important factors for consumers

Financial and environmental benefits were found to be the most common motivations for involvement in demand response, and of these, *financial motivations were typically given the greatest weight* [70]. This is consistent with results for Australian households [19] that *technology costs*, and having *sufficient incentive* are higher priority barriers to demand response. Access to the wholesale market was found to be a reasonably important motivation for Australian households to engage in demand response, and lack of access a corresponding barrier. In the Canadian context *cost* was the highest priority barrier to both flexible demand and investment in batteries [44], with the second priorities being (i) potential impacts on *comfort* for flexible demand and (ii) having the available *space* for battery installation. In the Netherlands, *Uncertain benefits to consumers* was confirmed as a barrier to demand response [15]. Considering automation and direct load control in the United Kingdom [73], key consumer concerns included maintaining levels of *comfort*, concern over the *timing* of the demand response and financial concerns, *spending*. In Israel [69], engagement as a prosumer was not seen to contribute to national energy priorities such as affordability and energy independence, and there was a perception of low public support to reduce electricity demand.

Familiarity and trust were found to be important factors in predicting household demand response across a review of numerous studies [70], with low trust in the institutions overseeing the necessary technologies confirmed as a barrier to households taking on more of a prosumer role [69] in Israel. Customer relations is recognised as a critical barrier in [14], emphasising the need for consumer protection regulations. More specifically [74] recommends that retailers and intermediaries should be obliged to provide disaggregated billing information, and offer low-cost options for consumers to switch among providers. It also recommends that non-discriminatory access to relevant data by market actors should be enforced, and customers should have access to independent mechanisms for resolving disputes with intermediaries.

Consumers had *privacy and data access* concerns [15] in the Netherlands, and *privacy and health concerns about smart meters* [69] in Israel. In addition to fears of *loss of comfort*, negative perceptions held by Canadian consumers included fears of *loss of privacy and control*, expressed in a United Kingdom study as a consumer concern with *autonomy*, while *perceived risk and perceived control* was confirmed in [70] as a significant factor in general in residential customer engagement in demand response. *Complexity and effort* were also found to be generally major factors [70]. [69] found consumers in Israel were consistently unenthusiastic about allowing household appliances to be controlled remotely to achieve load shifting, instead preferring to respond personally to information communicated by the grid via smart controls. This suggests a preference for control (autonomy) over limited effort.

6. Prioritising Barriers

A systematic process for prioritising barriers, and its application (to several dozen barriers to flexible demand in three European countries) is described by [16]. The paper includes suggested assessment criteria, processes for eliciting assessment from relevant experts, and for aggregating individual assessments into summary assessments and recommendations. A similar process of identifying barriers and solution opportunities is provided by [10], emphasising a focus on *system impact* and *ease of implementation*.

Criteria for barriers that are higher priority to address include: barriers

- to higher, rather than lower, value and quantity of technical potential,
- that are common (similar) to a broader, rather than narrower, scope of sources of technical potential,
- to potential sources that are less likely to be hindered by other significant, or intractable barriers,
- that are more likely to be otherwise neglected by other initiatives,
- that are easier (lower cost, lower risk) to address, for example being low cost to trial and easily replicable and scalable,
- barriers for which it is easier to measure removal or the impact of removal.

When selecting barriers to focus on finding opportunities for, it is important to be aware of not only the scale of the technical potential that the barrier in question affects, but also on how much additional potential is likely to be realised if the barrier is successfully addressed. This suggests that it is important to be mindful of the impact of other barriers affecting the same potential sources (recall the barrier pyramid in Figure 1 above). Addressing a significant technical barrier will have limited impact if regulatory barriers, that are also in effect, are likely to remain prohibitive. Conversely, but more obviously, addressing a barrier to a source of flexible demand that is largely already realised will also have limited impact. Considering these two conditions suggests that technical potential that are currently subject to neither too few barriers, nor too many, may be more fruitful for seeking barrier removal opportunities (see Figure 4).

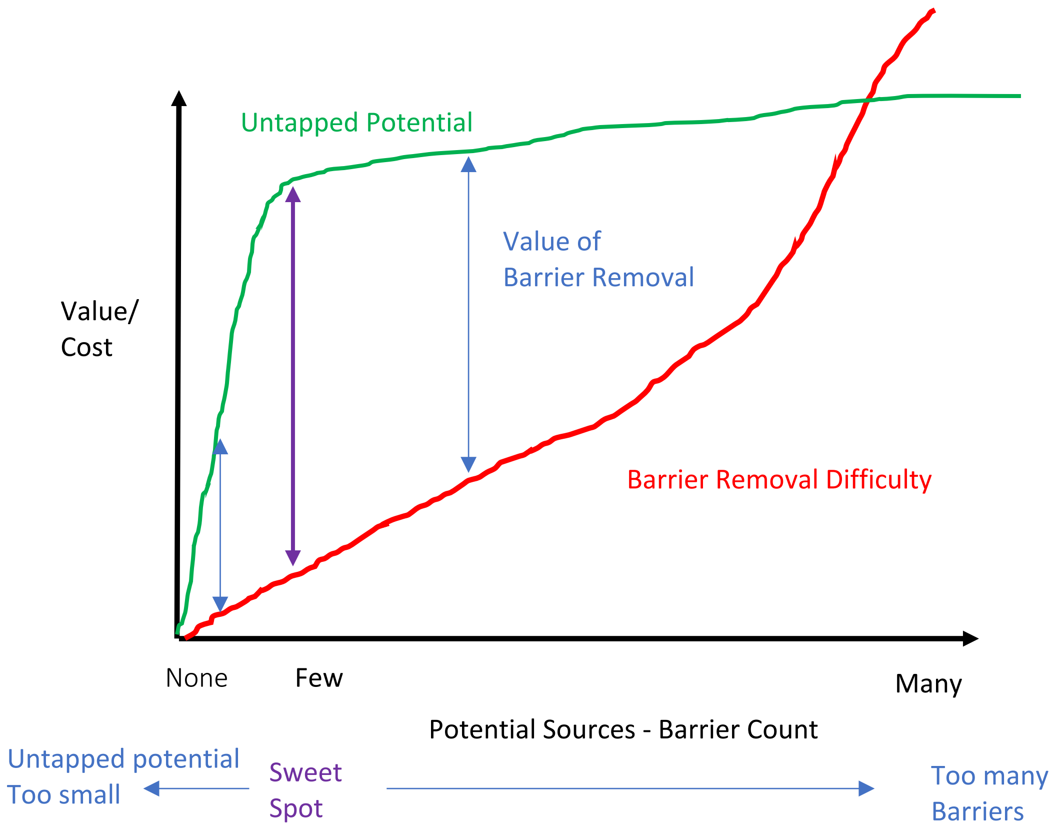

Figure 4: The net effect of barrier removal

It is finally worth noting that the staged approach in [20] looks promising for simplifying the complexity of the barrier landscape. Rather than trying to identify (and tackle) as many possible barriers with corresponding enablers to arrive at an idealised end state, the paper suggests dividing the problem into dependency stages (three, in this case).

- Actions to be completed first, that will move the industry to a well-described pathway milestone "*Stage 1: Intermediary trading enabled*". The hypothesis is that some benefits from completing that milestone will already be realised by significantly progressing that stage.
- Developments that aren't necessary for the first stage, but will move the industry to a second milestone, though still not the ultimate end goal "*Stage 2: Role of DNSPs evolved*" to take more responsibility for economically efficient day to day operations, eventually feeding into more sophisticated planning assessments that recognise the role of intermediaries and demand response. Again, some additional benefits should be realised by each stage – it is hoped that it is not necessary to reach Stage 3 being complete before any benefits can be seen.
- Changes that aren't necessary for the completion of stage 2, but that can realise benefits now that stage 2 is well progressed – "*Stage 3: Flexible demand fully integrated*"

Another way of breaking down the "big" problem may be to consider the realisation of a narrow category of unrealised potential, such as all industrial sector RERT technical potential, or VPP battery RTPV 'hosting capacity' maximisation. Both breakdown strategies are compatible with each other.

7. Summary and Conclusion

A comprehensive literature review of barriers would identify all the numerous general barrier categories, and all the specific barriers relevant to each category. However, many of those barriers would be irrelevant to a particular source of flexible demand potential, and such a review would be complex, repetitive, and difficult to absorb. Hence this review attempts to simplify the literature into a reduced number of key attribute dimensions.

A summary of the key findings is provided in Table 1 (prior to the introduction) and is further summarised in Figure 5 below. Table 1 is rolled up from the titles of each of the subsections (the heading names in blue font).

Economics and Incentives

- Lack of price signals
  - Fixed price retail tariffs
  - No market for network services
- Uncertain business case
  - Volatile, immature markets
- Upfront cost
  - transaction/ customer acquisition costs
  - equipment/technology costs

Cultural & Behavioural

- Electricity industry inertia
- End-user disinterest
  - awareness
  - perceived risk
  - complexity and competing priorities
  - purchasing processes and preferences

Technology

- Cost/lack of metering
- Difficulty with information management
- IT, cyber-security and interoperability issues
- The industrial process isn't able to flex

Other

- Arduous regulatory requirements to participate
- Achieving scale and firmness at specific locations
- Operational control of assets when value stacking
- Market transparency/ lack of competition

Figure 5: Summary of Key Barriers to Flexible Demand

These key findings are expanded somewhat as follows.

Under common barriers, it is found that

- Technical and Technology Barriers: More (and improved) metering is required for network visibility, for verification and financial settlement. Additional communications connectivity, decision and control integration, and automation is required to integrate end-user devices with markets for firm flexible demand capacity. To fulfill the needs of the various applications of flexible demand in the electricity industry, a high proportion of loads with responsiveness capability is required.
- Economic Barriers: For every stakeholder, there is a need for more certainty in order to justify investment in demand flexibility. More clarity is also required on how to determine demand response baselines. For high capital cost interventions, access to the required capital may be an issue.
- Market Structure and Regulatory Barriers: Many markets that would support demand flexibility are either absent or lack transparency and so potential buyers of flexible demand lack strong incentives to do so. More clarity on the role and priorities of regulators, and better coordination of the activities of regulatory bodies are required. Existing regulations, including technical standards, tend to favour historical, and now

incumbent, technical solutions. Various energy policy targets could support demand flexibility. More clarity is required on the registration of flexible demand capacity in markets, which would improve market transparency and improve commercial certainty of returns to investment in flexible demand.

- Cultural Barriers: Significant cultural biases exist in the electricity industry, which are not necessarily recognised by regulators working on the assumption that market behaviour is economically rational. Inertia or status quo bias can affect customers, retailers, networks, market operators, and regulators. Institutional structures, by definition, impose some degree of inertia, and the relationships and interactions among stakeholders will tend to become somewhat institutionalised, as way to manage coordination complexity. Cultural and institutional inertia are mutually reinforcing.

Considering barriers specific to particular stakeholders,

- Network services need a supportive regulatory framework to unlock potential savings offered by flexible demand solutions.
- Retailers and intermediaries (aggregators) face high transaction costs, end-user lack of interest, and time-scales for flexible demand investments that exceed typical energy supply contracts. Intermediaries in addition face competition from existing electricity supply companies with established customer relationships, and require a level playing field with other actors in the market.
- For customers, accessible savings may not be material relative to overall financial considerations. A range of behavioural factors impact on customer perceptions and willingness to explore demand flexibility, including long evolved ongoing patterns of behaviour. Choice and information overload, rather than lack of awareness can be a barrier in some circumstances.
    - For industrial customers, cost reflective options are often not offered and a fair proportion of value created from flexible demand may not be passed through. Load flexing in the industry sector can impact on production, and many customers are constrained by the limitations of legacy capital equipment and operational logistics that were designed for least cost rather than operational flexibility to enable agile business strategies. Because industrial processes are relatively heterogenous, flexible demand solutions are more commonly bespoke. Many industrial customers are not aware of the financial savings that can become be achieved through demand responsiveness and may overestimate the disruptiveness to business operations.
    - In the commercial sector, smaller energy savings from smaller site loads makes the business case more difficult. Behavioural factors, misaligned incentives and perceived risks of disruption are also significant barriers. Although the end-use processes in the commercial sector may be more homogenous than in industry, lack of technical standards and interoperability issues impact on scalability of flexible demand enabling technology. Government building portfolios could influence the market but must overcome internal purchasing and other barriers associated with decision making.
    - In the residential sector, lifestyle typologies and demographics may be required to segment and attract customers, as individual customers will tend to be too small to develop bespoke flexible demand options or suitable energy supply tariffs or deploy technology options. Changing consumer consumption patterns is difficult without automation or changes to lifestyles over the longer term. Financial benefits, trust, perceived risk and perceived control, complexity of energy decisions and effort are important factors for consumers.

The barrier taxonomy from [5] and described in Section 2.1 is confirmed in Sections 3-5 (and multiple applications in other references) as a usable classification scheme for the references identified. Most of the literature inspected, where barrier categorisation schema were presented or implied, were minor variants. Other taxonomies such as from [1] and that implied by [14] provide alternatives that are sufficiently interesting and distinct, that they may be useful in an ideation process barrier identification and opportunity prioritisation processes.

The notion in [20] of identifying dependency stages appears to be a useful way to address the complexity of barrier interaction. This idea hypothesises that some barriers (opportunities) can be broken down into smaller staged components, such that all barriers (opportunities) don't have to be addressed at once.

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APPENDIX: REVIEW METHOD DETAILS AND LIMITATIONS

Literature review research questions for initial reference identification

1. What barriers (including behavioural barriers) account for the most significant difference between the economic potential for exploiting flexible load opportunities and those that are realised?

- Do users participate directly, or are intermediaries required to drive uptake?
- What characterises successful commercial and industrial demand response customers and provider relationships?
- Are barriers general or specific to industries, technologies and/or companies? What are the relevant subcategories?

2. What is the stakeholder landscape for commercial and industrial flexible demand?

3. Which barriers are realistically susceptible to being removed / influenced to realise significant flexible load opportunities?

Keywords based on research question

Flexible Demand Keywords: demand response, demand management, demand-side management, flexible demand, flexible load, load shifting, load shedding, commercial, tertiary sector, industrial, secondary sector, industry sector, building, business, domestic/residential, end-use, energy service

Barriers Keywords: Barriers, challenges, technical, social, psychological, institutional, regulatory, economic, attitudes, motive, behaviour, "in practice", practical, empirical, potential gap, technical potential, economic potential, realistic potential, stakeholder, customer relationship, intermediary, aggregator

Keywords tags based on reference content

Architecture, Australia, Automation, Barrier Categories, Barriers, Behavioural, Buildings, Business Case, Case Study, Commercial, Customer, Economic Potential, Economics, Elasticity, FCAS, Incentive, Indicators, Industry, Interaction, Intermediary, International, Market Design, Market, Platform, Market Potential, Market Simulation, Measures, Methodology, Nongeneral, Other, Overview, Platforms, Policy, Potential, Products, Regulation, Reliability, Renewable, Residential, Review, Shift, Smart, Microgrid, Socioeconomic Equity, Stakeholder, Storage, Technical Potential, TOU, Value

Review limitations

There is a risk of bias based on barrier mentions as many of the references cite each other and refer to barriers that have been identified in their cited works. The extent of mutual citation is further biased in that many of the references were identified by snowballing, rather than relying solely on keyword searches in common databases. Broad search criteria were used to guarantee a large scope of initially identified references, making exhaustive analysis impractical, so there is selection bias based on author judgement regarding which references to prioritise in inclusion in this report where several references have similar content.

There has been some liberal reinterpretation of terminology in other papers and translation into a more consistent set of terms used in this review. This will disregard nuanced distinctions in the source material. In this discussion paper, words and phrases appear in italics to indicate that they are *closer to the original wording in the source material* rather than the more consistent terms promoted here.

The following translations from other jurisdictions have been used.

Balance Responsible Party (BRP)	Market Operator
Distribution System Operator (DSO)	Distribution Network Service Provider
Independent System Operator (ISO)	Market Operator
Regional Transmission Operator (RTO)	Transmission Network Service Provider
Transmission System Operator (TSO)	Transmission Network Service Provider
Utility	Retailer or Retailer and Network Service Provider

We recognise that these translations are not exact. Although many functions and responsibilities for similarly named organisations broadly overlap across most jurisdictions, there are also invariably exception in the details.