Enhanced System Planning Project

C4NET | ESP Enhanced System Planning

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Abbreviations

DER	Distributed energy resources
EV	Electric vehicles
ICEV	Internal combustion engine vehicles
PV	Photovoltaics

Executive Summary

Purpose

Australia has committed to decreasing its carbon emissions and transitioning toward renewable energy technologies. The *primary aim* of this report was therefore to review potential policy-based levers that could help to accelerate the consumer adoption of three cleaner technologies that will be fundamental to reducing Australia's carbon emissions: electric vehicles/smart chargers, electrifying household gas appliances, and household batteries. A *secondary aim* of this report was to briefly summarise the various approaches that have been used to segment consumers when evaluating consumer perceptions of cleaner technologies.

These two aims – identifying policy-based levers and segmentation criteria – will feed-forward into follow-up research evaluating how consumers perceive and respond to technology-agnostic policies for motivating consumer adoption of cleaner technologies.

Approach

This report reviews relevant academic and industry research to evaluate the potential effectiveness of different policy-based levers in driving the adoption of cleaner technologies, with a stronger focus on recent (i.e., within the last 5 years) research that may have applicability to the Australian energy context.

Identified policy levers were:

+ *Grouped by the outcomes they are seeking to achieve.* Consumers tend to focus more on the outcomes of a policy (e.g., reducing purchase costs) than on the means of achieving those outcomes (e.g., subsidies vs. rebates vs. tax benefits). Placing the emphasis on the sought-after outcomes of policy therefore provides a better basis for evaluating how consumers perceive and respond to those outcomes within and across technologies.
+ *Evaluated on their alignment with consumer perceptions and motivations.* Policies designed to shape consumer adoption of cleaner technologies should seek to leverage and address issues of concern to consumers, and while consumer perceptions shift over time, inertia in consumer perceptions mean that current consumer concerns are likely to remain salient into the medium term.

Drawing on this approach, policy outcomes were evaluated on three dimensions:

+ *Alignment*, which is the extent to which the policy outcome aligns with consumers' perceptions and motivations.
+ *Efficacy*, which evaluates the effectiveness of the policies that have sought to achieve the desired policy outcome.
+ *Feasibility*, which evaluates the potential ease of implementing the policies or associated outcomes within an Australian context.

These dimensions were used to determine the policy outcomes that might be first-order candidates for accelerating the adoption of cleaner technologies in that, to effectively motivate consumer adoption, a given policy should address or leverage consumer issues, be effective enough to warrant investment, and be feasible to implement within the Australian context.

Key Findings

Policy Outcomes

Four policy outcomes were evaluated as having high alignment, efficacy, and feasibility:

+ *Reducing purchase costs* (indicative policy levers: subsidies, grants, rebates, and tax benefits).
+ *Reducing operating costs* (indicative policy levers: fees, tariffs structures, dynamic operating envelopes).
+ *Integrated infrastructure* (indicative policy levers: charging infrastructure, retrofitting buildings, distributed energy resource (DER) integration).
+ *Technology standards and mandates* (indicative policy levers: quotas, emission standards, phase-out dates).

These policy outcomes should form the basis of follow-up scenario-based studies aimed at evaluating how consumers perceive and respond to policies designed to achieve those outcomes.

Segmentation Variables

Understanding the variables with which to segment consumers is critical for identifying the differing needs and perceptions of consumers as they relate to the adoption of cleaner technologies. Based on an evaluation of the existing research, the following segmentation variables are recommended for inclusion in future research on consumer adoption of cleaner technologies:

+ Age.
+ Gender.
+ Location.
+ Cultural and linguistically diverse household status.
+ Financial wellbeing.
+ Dwelling ownership status.
+ Dwelling type.
+ Presence of DER.
+ Modes of transport.
+ EV ownership status.
+ Adopter category.
+ Environmental concern.

1 Background

Like many countries around the globe, Australia has committed to decreasing its carbon emissions and transitioning toward renewable energy technologies. For Australia, this will include finding ways to accelerate the adoption of:

+ Electric vehicles (EVs) and associated smart charger technology.
+ Electric appliances rather than those that rely on natural gas.
+ Household distributed energy resources (DERs) such as household battery storage.

Collectively, these technologies are henceforth referred to as 'cleaner technologies'.

While most developed economies will need to accelerate the transition to cleaner technologies if they are to meet their climate targets, there are several features of the Australian context that will make this transition particularly challenging. The Australian EV market, for instance, has not experienced the growth that has been observed in other markets, with EVs currently making up only 3.8% of new car sales in Australia (Purtill, 2023). This uptake lags significantly behind Europe, where approximately 20% of new car sales are EVs (Purtill, 2023). At the same time, for Australia to meet its 2050 net-zero emissions target, approximately five million households will need to be transitioned away from natural gas to electric for applications as varied as space heating, water heating, and cooking (Wood, Reeve, & Suckling, 2023). Finally, while household battery adoption is witnessing significant growth, with installations increasing by 55% to 47,000 in 2022 (Mercer, 2023), this number falls well short of the 3 million homes with rooftop solar photovoltaics (PV) that could potentially adopt batteries (DCCEEW, 2023).

Policy-based initiatives will likely be an important means for increasing customer adoption of EVs, accelerating the electrification of gas appliances, and enhancing the uptake of household batteries (Bohlmann, Inglesi-Lotz, & Bohlmann, 2022; Campbell et al., 2023; de Wilde & Spaargaren, 2019; Rakha, Moss, & Shin, 2018; Rietmann & Lieven, 2019). This report consequently provides a brief review of the various policy-based levers that have been employed to accelerate the adoption of these cleaner technologies.

A secondary aim of this report is to succinctly summarise the various approaches that have been used to segment consumers when evaluating consumer perceptions toward cleaner technologies. This overview of consumer segmentation approaches, in conjunction with the report's broader policy evaluation, will inform the next planned phase of research, which is to evaluate consumer perceptions of technology-agnostic policies for motivating consumer adoption of cleaner technologies.

2 Approach

2.1 Scope

Policies for accelerating the transition to cleaner technologies are rapidly evolving as:

+ Jurisdictions around the world experiment with different initiatives and learn from the experiences of others.
+ Cleaner technologies continue to be developed, necessitating new policies to accelerate their uptake and/or facilitate their integration into existing energy systems.

This report consequently reviews relevant academic and industry research to evaluate the potential effectiveness of different policy-based levers in driving the adoption of cleaner technologies, with a stronger focus on recent (i.e., within the last 5 years) research that may have applicability to the Australian energy context.

2.2 Evaluation Framework

One consequence of the rapidly evolving policy landscape is that many policy evaluations necessarily become highly granular, focusing on the effectiveness of one or a small number of policies in a single jurisdiction and with only a single technology (Palmer-Wilson, Bryant, Wild, & Rowe, 2022; Ransan-Cooper, Lovell, Watson, Harwood, & Hann, 2020; Say & John, 2021). By virtue of this granular focus:

+ It is not always readily apparent that **many policies** (e.g., subsidies, grants, rebates, tax benefits) are looking to achieve **similar outcomes** (e.g., reduce purchase costs). By extension, it is often difficult to identify which outcomes (e.g., reducing purchase costs vs. reducing operating costs) will receive greatest consumer acceptance, both to accelerate consumer adoption of cleaner technologies and from a perceived fairness perspective.
+ It is often difficult to identify which policy outcomes are **technology agnostic**; that is, applicable across multiple technologies. With a burgeoning number of cleaner technologies, understanding the policy outcomes that are likely to be effective across multiple technologies may simplify the policy development process by allowing the focus to turn to the most effective means for achieving those outcomes within the context of a specific technology. For example, if outcomes that are relevant across multiple technologies are identified (e.g., reducing purchase costs), technology-specific policies for achieving these more general outcomes can then be formulated (e.g., specific subsidies for EVs).

This review of potential policies for accelerating consumers' adoption of cleaner technologies consequently takes a unique approach by:

+ *Grouping policies by the outcomes they are seeking to achieve*. Consumers tend to focus more on the outcomes of a policy (e.g., reducing purchase costs) than on the means of achieving those outcomes (e.g., subsidies vs. rebates vs. tax benefits; Clinton & Steinberg, 2019; Gardiner, Schmidt, Heptonstall, Gross, & Staffell, 2020; Gong, Ardeshiri, & Hossein Rashidi, 2020). Placing the emphasis on the sought-after outcomes of policies therefore provides a better basis for evaluating how consumers perceive and respond to those outcomes within and across technologies. This is particularly pertinent given that a central aim of the review is to identify technology agnostic policy-based scenarios that will form the basis of a subsequent, consumer-focused evaluation.

- *Evaluating policy outcomes against their alignment with consumer perceptions and motivations.* Policies designed to shape consumer adoption of cleaner technologies should seek to leverage and address issues of concern to consumers (Gong et al., 2020). For example, all else being equal, a policy targeting an issue that is salient to only 20% of consumers will likely achieve a smaller net effect on cleaner technology adoption than one targeting an issue that is salient to 50% of consumers. While consumer perceptions shift over time, inertia in consumer perceptions mean that current consumer concerns are likely to remain salient into the medium term.

Drawing on this approach, identified policy outcomes were evaluated on three dimensions:

- **Alignment**, which is the extent to which the policy outcome aligns with consumers' perceptions and motivations.
- **Efficacy**, which examines the effectiveness of the policies that have sought to achieve the desired policy outcome.
- **Feasibility**, which considers the potential ease of implementing the policies or associated outcomes within an Australian context.

3 Policy Review

To help structure the review, policies were grouped into five broad categories:

+ Incentivising cleaner technologies financially.
+ Disincentivising non-clean technologies financially.
+ Incentivising cleaner technologies by reducing consumer effort.
+ Technology standards and mandates.
+ Increasing consumer trust for cleaner technologies.

Within each category sits a set of policy outcomes and levers, each of which are examined in turn.

3.1 Incentivising Cleaner Technologies Financially

The total cost of ownership encapsulates both **purchase** and **operating** costs. **Purchase** costs are the initial cost of buying cleaner technology (Coffman, Bernstein, & Wee, 2017) as well as any taxes, registration fees, and installation costs associated with purchase (Nadel, 2019; Rousseau et al., 2015). **Operating** costs involve ongoing electricity consumption costs alongside any other costs incurred in using or maintaining the technology, such as (in the context of EVs) insurance costs, maintenance costs, and road taxes (Franzò, Nasca, & Chiesa, 2022; Tidemann, Bradshaw, Rayner, & Cheung, 2022; Tidemann, Rayner, & Cheung, 2022).

As shown in Figure 1, this report clusters the various policies that have been used to financially incentivise the adoption of cleaner technologies into the following outcomes:

+ **Reduce purchase costs** (policies: subsidies, grants, rebates, replacement programs, tax benefits).
+ **Facilitate purchases** (policies: concessional financing).
+ **Reduce operating costs** (policies: toll fees, EV charging fees, gas disconnection fees, tariff structures, dynamic operating envelopes).

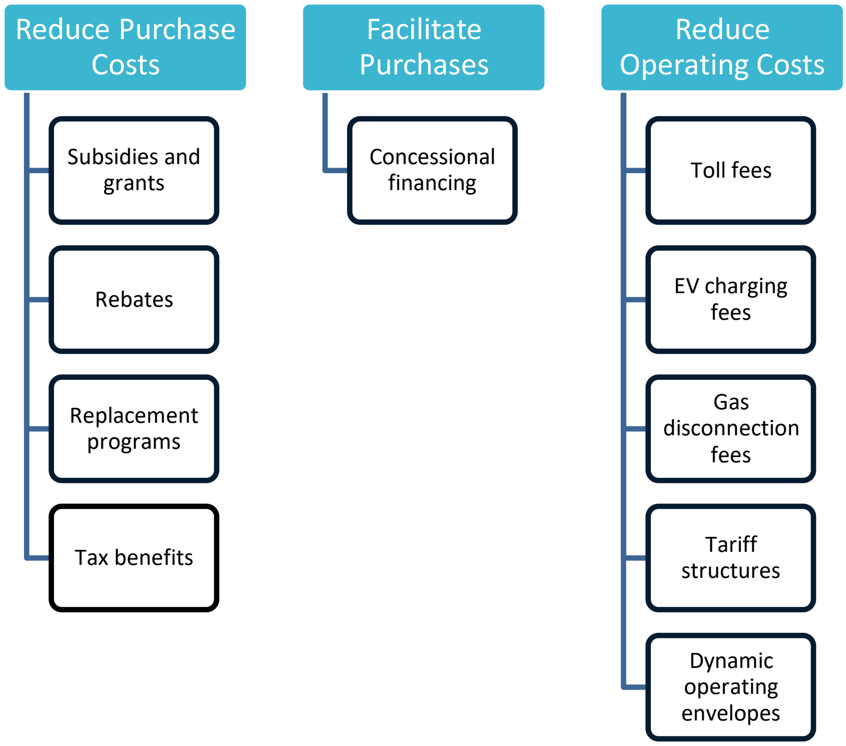

Figure 1. Financial incentives for adopting cleaner technologies.

3.1.1 Reducing Purchase Costs

A range of policy mechanisms are available to reduce the upfront costs associated with purchasing cleaner technologies. For example, **subsidies** are a "direct or indirect payment to individuals or firms, usually in the form of a cash payment from the government or a targeted tax cut", while **grants** are a "gift to an individual or company that does not need to be paid back" (Investopedia, 2023a, 2023b). Conversely, **rebates** are partial refunds that are provided after the purchase of technology, with the aim of reducing potential cost-related barriers to adoption (Best, Kent, & Lee, 2023; Clinton & Steinberg, 2019). Finally, **replacement programs**, which typically use subsidies or rebates, are also used to encourage the replacement of fossil fuel-dependent technologies with electric alternatives (Sheldon & Dua, 2019).

3.1.1.1 Alignment

In a survey of Australian consumers who indicated that their next car purchase would not be an EV, the most commonly cited barrier (59%) to purchasing an EV was price (Stolper, Diseris, & Di Benedetto, 2023). Cost-related concerns were also identified as a barrier to electrifying gas appliances by 43% of Australian consumers who felt negative about electrifying their home (Stolper et al., 2023). Similarly, a survey of households in regional and rural Victoria found that the biggest perceived barrier to joining a battery-focused virtual power plant was the cost of purchasing the necessary hardware (Newton, 2023). Policies that reduce the price of these cleaner technologies are therefore likely to address fundamental barriers to their adoption.

3.1.1.2 Efficacy

Electric Vehicles

Subsidies can reduce the upfront cost of purchasing EVs, accelerating the financial break-even point between EVs and their Internal Combustion Engine Vehicle (ICEV) counterparts (Ghasri, Ardeshiri, & Rashidi, 2019; Sahoo, Harichandan, Kar, & S, 2022; Santos & Rembalski, 2021). A recent UK-based study, for instance, analysed the total cost of ownership for different vehicle types, including ICEVs, plug-in hybrids, and EVs, over the period 2017 – 2020 (Santos & Rembalski, 2021). This research concluded that the purchase price of vehicles significantly influenced the total cost of ownership, and that subsidies targeting plug-in hybrids and EVs were essential for accelerating their adoption. This report further suggested that EVs should receive more subsidies, as this support would accelerate EV adoption, especially for consumers concerned about upfront costs (Santos & Rembalski, 2021).

Rebates may also be effective in promoting the adoption of EVs. One study from the US showed that purchase rebates significantly increased new EV registrations at a rate of approximately 8% per USD$1,000 of incentive offered, irrespective of the make of EV (Clinton & Steinberg, 2019). This study also found that between 2011 and 2015, purchase rebates led to an approximate 11% rise in overall new EV registrations (Clinton & Steinberg, 2019).

Some jurisdictions have also introduced **replacement programs** that use targeted subsidies or rebates to encourage the replacement of ICEVs with EVs. California's 'Replace Your Ride' program, for instance, offered targeted subsidies to lower-income households for retiring old vehicles and acquiring cleaner ones (Sheldon & Dua, 2019). An evaluation of the program found that it promoted clean vehicle adoption, with evidence indicating that a significant portion of EV purchases in 2015 had occurred as a result of the policy (Sheldon & Dua, 2019). However, modelling of a similar replacement program proposed in the US suggests that linking EV subsidies to the replacement of an ICEV may deter some households from participating, and that offering a straight EV subsidy may be more effective (Ankney & Leard, 2022).

Tax-related subsidies in the EV context include waiving a variety of taxes, including **tax exemptions** on EV ownership-related duties (Norwegian EV Association, ND) and EV purchase **tax credits** as direct reductions in income tax owed (IRS, 2023; Williams & Anderson, 2022). In Norway, tax incentives in the form of purchase tax and value added tax exemptions have been identified as critical to accelerating EV purchases, with more than 80% of EV owners considering these tax benefits as having been critical to their EV adoption (Bjerkan, Nørbech, & Nordtømme, 2016). In the US, for every USD$1,000 tax credit given for purchasing an EV, there is an associated 2.6% rise in EV registrations (Jenn, Springel, & Gopal, 2018). Similarly, in India, tax waivers and exemptions were found to be critical to motivating consumer adoption of EVs by minimising EVs' price premium relative to ICEVs (Sahoo et al., 2022).

Tax-related subsidies reforms do not have to directly target consumers to still have an influence on consumer adoption of EVs. In Australia, for instance, one solution that has been proposed for boosting Australia's lagging EV uptake is to implement tax reforms like those that have been introduced in Europe (Mortimore, Kraal, Lee, Klemm, & Akimov, 2022). This would include changing federal taxation laws to encourage fleet managers to opt for EVs over ICEVs, which would have the effect of providing consumers with more affordable EVs once those fleet vehicles enter the second-hand market (Mortimore et al., 2022).

Electrification

Under the 2022 Inflation Reduction Act, the Biden Administration introduced **rebates** to help US households transition to clean, energy-saving appliances such as heat pumps (The White House, 2023). Evaluations of similar schemes suggest that such rebates are likely to be effective, with a number of studies highlighting the positive impact of rebates on appliance electrification (Nadel, 2020; Walker, Less, & Casquero-Modrego, 2022). For example, one study conducted in North Carolina found that rebates of USD$300 – $450 per heat pump increased adoption by 13% in a year (Shen, Qiu, Liu, & Patwardhan, 2022). However, this research also demonstrated that high-income households were more sensitive to rebates than low-income households, perhaps because such rebates do not completely nullify the financial barriers to adoption.

Rebates also appear to be critical in the Australian context. A report by the Climate Council explains that the success of electrification efforts, like the ACT Government's Sustainable Household Scheme, relied on providing financial incentives (Climate Council, 2022). These incentives included rebates as well as concessional financing (see Section 3.1.2) to ensure strong participation from low-income households and small businesses (Climate Council, 2022). The Victorian Energy Upgrades program also offers rebates of up to AUD$2,600 to Victorians replacing gas heating and cooling systems with efficient electric alternatives (DELWP, 2022a). Additional rebates are also available through the scheme for replacing gas hot water systems and gas cooktops (DEECA, 2023a; DELWP, 2022a). In 2021 alone, this program facilitated over 650,000 energy efficiency upgrades in 413,249 households and businesses, resulting in anticipated savings of 7.5 million tonnes of greenhouse gases and 7.7 gigawatt hours of energy over the upgrades' lifetime (Essential Services Commission, 2022).

Subsidies or rebates that are offered as part of **replacement programs** can also expedite the transition to electrification, as evidenced by US-based heat pump incentive programs (Ankney & Leard, 2022; Sheldon & Dua, 2019). States like Maine, Massachusetts, Vermont, and the Northwest, for instance, achieved significant success by incentivising the purchase of heat pumps through replacement programs (Nadel, 2019). Incentives for recycling or disposing of old appliances can also promote electrification by encouraging the replacement of outdated, energy-intensive appliances with modern, energy-efficient electric alternatives (Diawuo, Pina, Baptista, & Silva, 2018; Hammerle & Burke, 2022).

Battery

Several studies have evaluated the effect of **subsidies** on the adoption of household batteries. One analysis, which evaluated household decision-making in Italy, found that subsidies played a crucial role in making household battery systems financially viable (Cucchiella, D'Adamo, & Gastaldi, 2017). The analysis concluded that subsidies enhance the return of such investments, ultimately motivating consumers to adopt household batteries for energy storage (Cucchiella et al., 2017). A similar conclusion was made through a simulation model evaluating the potential influence of subsidies on the mass market adoption of batteries in Queensland over the 2006 – 2036 time period (Agnew, Smith, & Dargusch, 2019). In one of the simulation scenarios, a subsidy offering up to AUS$1,000 for adopting a small battery (i.e., 5 kWh) was found to achieve a battery adoption rate of 55%, substantially higher than the 42% adoption rate modelled in the base scenario where no subsidies were offered (Agnew et al., 2019).

To date, various Australian jurisdictions have implemented battery subsidy schemes. As two examples:

- The Home Battery Scheme in South Australia offered up to AUD$6,000 off the cost of a home battery system until it was discontinued in June 2022 due to lower uptake of the scheme than the government initially anticipated (Carroll, 2022; Cassidy, 2022).
- In the Northern Territory, the Home and Business Battery Scheme offers a grant of AUD$450 per kilowatt hour of usable battery capacity, up to AUD$6,000, for eligible homeowners, businesses, and not-for-profit organizations (NTGOV, 2023).

Rebates can boost customer adoption of household batteries by making the initial investment more affordable (Best et al., 2023; Comello & Reichelstein, 2019). For example, rebates offered as part of California's Self Generation Incentive Program, along with other federal-level incentives like the Investment Tax Credit, have been credited with synergistically combining to drive consumer adoption of energy storage devices like household batteries (Comello & Reichelstein, 2019).

Within Australia, rebates have also been found to significantly influence battery adoption (Best et al., 2023). The Victorian state government, for example, introduced rebates in 2019 to promote home battery adoption, and a study examining battery adoption data from June 2020 to March 2021 found that postcodes with earlier access to these rebates demonstrated 58% higher battery uptake, presumably because residents in those postcodes had more time to plan for their battery investments (Best et al., 2023). However, from 1 July 2023, these rebates transitioned to an interest-free loan program (SolarVictoria, 2023), and the impact of this interest-free program on rates of battery adoption in Victoria have yet to be determined empirically.

In the US, various state-level **tax credit schemes** have been identified as helping to increase adoption of household batteries. For example, and as identified earlier in this section, the synergistic combination of California's Self Generation Incentive Program (a rebate scheme) and a federal tax credit has proven effective in incentivising significant investments in behind-the-meter battery storage (Comello & Reichelstein, 2019). Indeed, the primary deterrent for a household in California installing an arbitrarily large storage system is the risk of losing the full federal tax credit, which becomes unavailable when the energy storage capability surpasses 12.2 kWh (Comello & Reichelstein, 2019), highlighting the impact of such schemes in shaping consumer adoption decisions.

3.1.1.3 Feasibility

Reducing purchase costs through **subsidies** tend to be popular, with 80% of respondents in a recent survey of 3,804 Canadian homeowners supporting or strongly supporting purchase subsidies for home decarbonisation activities (Odland, Rhodes, Corbett, & Pardy, 2023)3.1.1.2. Similarly, a stated preference survey conducted among 1,076 residents of New South Wales found that the most favoured one-off financial incentive for EVs was receiving a **rebate** on the upfront cost of purchase (Gong et al., 2020). As highlighted in Section 3.1.1.2, jurisdictions across Australia have already introduced subsidies and rebate programs to support the adoption of cleaner technologies, indicating that they are already part of the established playbook of policies being used to accelerate the consumer adoption of these technologies.

3.1.2 Facilitating Purchases with Concessional Financing

Concessional financing involves providing loans below market rates, which can be useful for motivating the adoption of more expensive technologies when high interest rates might otherwise deter potential borrowers (Climate Council, 2022). Thus, while subsidies, grants, and targeted tax schemes aim to reduce the initial purchase of cleaner technologies, the aim of concessional financing is to make it easier for consumers to access the credit they require to afford high initial purchase outlays.

3.1.2.1 Alignment

As outlined in Section 3.1.1.1, cost is a significant barrier for adopting cleaner technologies. While concessional financing may not reduce those costs, it can make it easier for households to finance these purchases. Moreover, income-based disparities are already starting to emerge in the ownership profile of EVs, with those deemed financially vulnerable in one Australian survey substantially less likely to own an EV (4%) than their financially non-vulnerable counterparts (9%; Stolper et al., 2023). More affordable financing options may therefore be especially important for supporting the adoption of cleaner technologies among low-income households.

3.1.2.2 Efficacy

Electric Vehicles

Concessional finance schemes do not appear to be widely available for motivating the purchase of EVs, perhaps because personal financing is already available for consumer vehicles. However, some traditional credit providers offering loans at attractive market rates – such as Macquarie in Australia – have developed personal car loans specifically for the EV market (Macquarie, 2023), suggesting that private solutions to the issue of providing attractive financing for EVs may emerge over time.

Electrification

Concessional financing is one potential driver for motivating the electrification of gas appliances (Climate Council, 2022; Crowe, 2022). Indeed, in the US, loans offering below-market interest rates are commonly offered to incentivise residential heat pump installations (Shen et al., 2022). However, consumers appear to prefer other financial incentives over concessional financing. A study conducted in North Carolina, for instance, found that a rebate of USD$300 – $450 per heat pump was more effective at motivating heat pump adoption than two loan programs with below-market annual interest rates of 3.9% and 9% (Shen et al., 2022).

Battery

Concessional financing may also play a role in motivating customer adoption of batteries given that the current purchase costs for adopting household batteries are sizeable. In the UK, for example, **interest-free loans** were part of a broader package of financial measures that were deemed essential to making residential storage a profitable investment for customers (Gardiner et al., 2020).

In Australia, **concessional financing** has also been identified as motivating the adoption of cleaner technologies, including household batteries (Climate Council, 2022; Crowe, 2022). To illustrate, the Queensland Government implemented the "Interest Free Loans for Solar and

Storage Scheme," offering interest-free loans of up to AUD$6,000 for eligible battery storage systems, while NSW's Empowering Homes Program provided similar interest-free loans of up to AUD$9,000 for battery systems (Esplin & Nelson, 2022). The popularity of these interest-free loans became evident as the Queensland government had to allocate additional grants and interest-free loans for battery storage systems following the near depletion of the original budget allocation within two weeks of its announcement (Maisch, 2018). Of note, other financial approaches to minimising cost as a barrier to adoption have started to transition to the use of concessional financing. In Victoria, for instance, the Solar Battery rebate scheme recently transitioned to an **interest-free loan** scheme (SolarVictoria, 2023).

3.1.2.3 Feasibility

Loans and financing to facilitate home decarbonisation tend to be reasonably popular, with 64% of respondents in a survey of 3,804 Canadian homeowners supporting or strongly supporting such initiatives (Odland et al., 2023). Moreover, many Australian jurisdictions currently offer concessional financing for the electrification of gas applications and for purchasing batteries (see Section 3.1.2.2). Thus, concessional financing would appear to be a feasible policy outcome.

3.1.3 Reducing Operating Costs

Various policy mechanisms exist to reduce the ongoing operating costs associated with cleaner technologies. Such policy mechanisms include **road toll charges** for EVs, which can be reduced or offset relative to ICEVs, as well as **free or discounted charging**. For electrification, **addressing gas disconnection fees** and the strategic use of **tariff structures** are potential policy mechanisms, with tariff structures also applying to battery storage.

3.1.3.1 Alignment

In one recent Australian survey, various reductions in ongoing operating costs were commonly identified by potential EV purchasers as explaining their desire to purchase an EV, with 51% believing they were cost effective to run, 36% believing they were cost effective to maintain, and 36% believing that petrol/diesel were becoming too expensive (Stolper et al., 2023). For the electrification of gas appliances, reduced energy bills were the second most commonly cited reason (18%) that consumers who felt positive about electrifying more homes gave to justify this perception (Stolper et al., 2023). Finally, another recent survey of Australian consumers found that decreasing their power bill was the single biggest motivator for joining a battery-focused virtual power plant (Newton, 2023). Collectively, these findings suggest that efforts to further reduce ongoing operating costs may be instrumental in motivating consumer adoption of these cleaner technologies.

3.1.3.2 Efficacy

Electric Vehicles

Toll charges – such as fees levied for using certain roads or bridges – are commonly used to fund infrastructure construction and maintenance. In some countries, exemptions allow EVs to access tolled infrastructure for free or at reduced rates, with EV drivers in Norway paying 50% to 100% less than what ICEV owners pay (Figenbaum, 2022; Hardman, 2017). **Free or discounted charging** at EV charging stations may also influence customer adoption of EVs, although the longer-term economic sustainability of such measures has been questioned

(Bonges & Lusk, 2016; Chakraborty, Bunch, Lee, & Tal, 2019). For example, Chakraborty et al. (2019) found that when workplace charging is free, EV drivers' likelihood of charging from their workplace increases, with commensurate decreases in intended home and public charging, highlighting the impact of such incentives on consumer adoption.

Electrification

Australian gas retailers charge different fees for:

- Disconnecting a household from the gas network, which involves locking the household's gas meter and closing their account ($38 - $68).
- Permanently abolishing the household's gas connection, which involves removing the meter and the pipes the connect the meter to the gas network ($750 - $1,100; Wood et al., 2023).

Consumers have reported being confused about these different options or of not even being aware that a cheaper option existed, which may act as a disincentive for households to disconnect from the gas network (Wood et al., 2023). Addressing ambiguity around **gas disconnection fees**, and by extension helping households avoid the average $1 daily gas supply charge, may therefore help to further tip the economic scales in favour of households fully electrifying their homes (Wood et al., 2023).

Implementing different **tariff structures** that encourage consumers to use their electric appliances in the middle of the day – when power generated from solar PV is plentiful – has also been advanced as a means for reducing the ongoing operating costs of electric appliances while simultaneously reducing pressure on the grid (Tidemann, Rayner, et al., 2022).

Battery

Various **tariff structures** have been identified as influencing – both positively and negatively – the adoption of household batteries (Jacob John, Gatumu, Newton, Rotman, & Weber, 2023; Say & John, 2021). Say and John (2021), for instance, modelled potential rates of residential rooftop PV and battery adoption in Western Australian across 2018 – 2037 under different feed-in tariff rates. Underpinning this modelling were a range of key assumptions, including that retail usage charges would increase by 5% per year, battery purchase costs would decrease by 8% per year, and flat tariff structures that remained static over the course of a day would remain the norm. According to their modelling, the take-up of household batteries dropped markedly once the value of the feed-in tariff rates exceeded 50% of retail usage charges, with these tariff rates instead motivating greater grid export activity through rooftop PV. The highest rates of battery take-up were instead modelled to occur with zero feed-in tariff rates, with households in this scenario adopting batteries to minimise their electricity bills by maximising the self-consumption of stored power.

Introducing **dynamic operating envelopes**, which provide households with flexible limits on the amount of electricity they can export to the grid (ARENA, 2022; Azim et al., 2023), may also have an effect. One study, which modelled a peer-to-peer trading scheme featuring a dynamic operating envelope, found that the scheme significantly reduced electricity costs for prosumers (i.e., consumers who transition from being passive electricity consumers to active participants, producing and exporting their generated energy) while also improving network efficiency (Azim et al., 2023). Separately, the Battery Storage and Grid Integration Program found that dynamic operating envelopes improve cost-effectiveness and enhance network visibility, enabling customers to maximise returns by allowing DER like a battery to actively engage in the energy market (BSGIP, 2022). Since cost savings and better financial returns are key contributors to the adoption of DER, the introduction of dynamic operating envelopes could potentially influence customer adoption of household batteries (Chapman et al., 2021; Newton, Jacob John, Weber, & Rotman, 2022).

3.1.3.3 Feasibility

As the examples in Section 3.1.3.2 indicate, tariff structures are already being used in Australia to motivate certain forms of consumption behaviour, suggesting that at least some of the policy options available for reducing ongoing operating costs are immediately feasible.

3.2 Disincentivising Non-Clean Technologies Financially

Consumers make choices within a competitive marketplace. Thus, while increasing the relative attractiveness of cleaner technologies through various financial measures may be one approach to accelerating the adoption of cleaner technologies (see Section 3), so too may decreasing the relative attractiveness of non-clean technologies.

As shown in Figure 2, this report clusters the various policies that have been used to financially disincentivise the adoption of non-clean technologies into the following outcomes:

+ **Increase purchase costs** (policies: taxes).
+ **Increase operating costs** (policies: taxes, fuel mandates, fossil fuel subsidies).

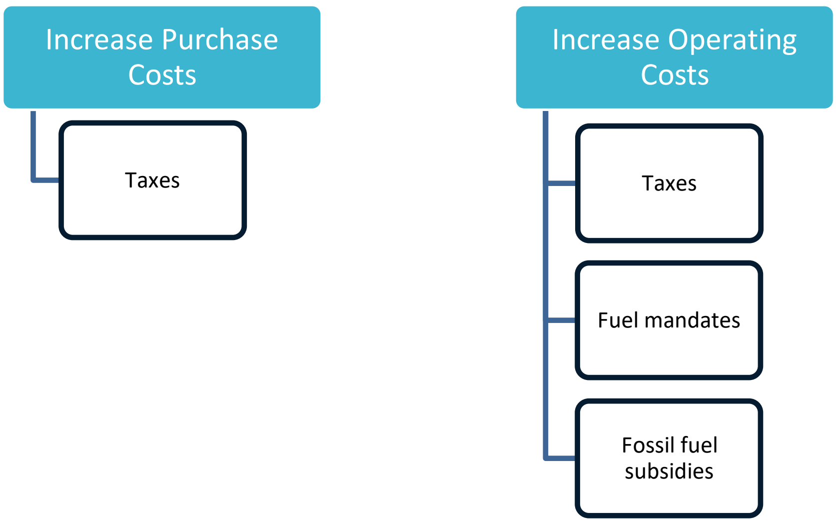

Figure 2. Financial disincentives for adopting non-clean technologies.

3.2.1 Increasing Purchase Costs

Increasing the cost of adopting non-clean technologies – such as by preferentially **taxing** those technologies – can help to reduce the price disparity that may otherwise exist between these non-clean technologies and their cleaner technology counterparts.

3.2.1.1 Alignment

As outlined in Section 3.1.1.1, the cost of purchasing cleaner technologies like EVs, electric appliances, and household batteries are routinely cited as one of the main barriers to doing so. Equalising the price differential between these cleaner technologies and their non-clean competitors by making the equivalent non-clean technologies more expensive would likely address this issue, albeit in a manner that might make the broader product category more unaffordable for a greater proportion of consumers than is currently the case.

3.2.1.2 Efficacy

Electric Vehicles

EV policy experts from across the five Nordic countries (Iceland, Finland, Denmark, Sweden and Norway) were asked to identify potential policies for increasing EV adoption (Kester, Noel, Zarazua de Rubens, & Sovacool, 2018). Increasing the cost of ICEVs was one of the mechanisms advocated by this group, with one policy – elevating **purchase taxes** on ICEVs – seen as helping to address the relative perception that EVs are more costly to purchase than ICEVs (Kester et al., 2018). In support of this recommendation, Norway employs a tax strategy that favours low and zero-emission vehicles by imposing higher **purchase taxes** on high-emission cars and lower purchase taxes on environmentally friendly ones (Norwegian EV Association, ND). The purchase tax for new cars is determined by weight, CO_2, and NO_x emissions, with a progressive structure that makes large, high-emission vehicles more expensive (Norwegian EV Association, ND).

Electrification

No policy initiatives were identified that involved increasing the purchase cost of gas appliances.

Batteries

Not directly applicable given that the non-clean technology with the greatest overlapping set of benefits (diesel generators) has insufficient market penetration to justify a targeted policy response.

3.2.1.3 Feasibility

In a recent representative survey of 1,954 Australians, the single greatest concern identified by respondents was 'cost of living', with 77% indicating that they were either extremely or very concerned about this issue (Stolper et al., 2023). Policy initiatives that contribute to these cost-of-living pressures by increasing the price of certain products are therefore unlikely to receive widespread support, making their implementation unlikely.

3.2.2 Increasing Operating Costs

The operating costs of non-clean technologies can also be made more unattractive to consumers through a range of policy mechanisms, including introducing **higher taxes** for more polluting sources of energy, introducing **fuel mandates** that require producers to change the composition of fuel sources to include cleaner (and more costly) ingredients, and reducing or eliminating **fossil fuel subsidies**.

3.2.2.1 Alignment

As outlined in Section 3.2.1.3, the rising cost-of-living is a considerable source of concern in Australia (Stolper et al., 2023). Against this backdrop, households may be especially attentive to alternatives that would allow them to avoid increased operating costs for fundamental technologies like transport (EVs) and heating (electrification of gas appliances).

3.2.2.2 Efficacy

Electric Vehicles

Rising fuel prices can increase the operating costs of ICEVs, potentially increasing consumer demand for EVs. For instance, research conducted in Kuwait found that fuel price increases of 50-99% would prompt 23% of respondents to seriously consider purchasing EVs (Ottesen, Banna, & Alzougool, 2022). Policies that increase fuel prices may therefore be a useful means for encouraging the adoption of EVs. Two policy mechanisms available for achieving this outcome – increasing existing **fuel taxes** and implementing a **carbon tax** – were both seen by Nordic EV policy experts as increasing the perceived favourability of EVs relative to their ICEV competitors (Kester et al., 2018). Similarly, a choice experiment conducted in China found that both **carbon taxes** and **personal carbon trading** – a method of providing citizens with 'credits' for how much carbon they can consume before incurring a cost, and which they can sell or trade – would encourage the adoption of EVs, with personal carbon trading being relatively more effective compared to carbon taxes (Li et al., 2019).

Fossil fuel subsidies could also be targeted to increase the operating costs of ICEVs. For example, the Malaysian government is currently considering changes to its fossil fuel subsidies, which in 2022 accounted for 7% of total government expenditure (Yeann, 2023). Proposed changes include removing fuel subsidies for households within the top 20% income bracket, which would increase the operating costs of ICEVs and further build the economic case for adopting an EV (Yeann, 2023). While Australian fossil fuel subsidies are not (currently) directly targeted towards reducing cost of living pressures at the fuel pump, 80% of the Australian Federal Government's fossil fuel spending was allocated to gas and oil in 2022-23 (Campbell et al., 2023), suggesting that reducing or removing these subsidies may also increase ICEV operating costs (Baršauskaitė, 2022; Ouyang & Lin, 2014).

Electrification

Renewable natural gas mandates, which require a certain proportion of natural gas to be sourced from renewable sources like biomass, would likely increase the price of natural gas (Dunsky, 2021). Given that Australian households can already enjoy substantial annual savings – ranging from AUD$336 to AUD$1,311 – for transitioning to all-electric home appliances (Tidemann, Bradshaw, et al., 2022), the introduction of such mandates may further motivate households to electrify their existing gas appliances by increasing the operating costs associated with using gas appliances (Dunsky, 2021).

The Dutch model of **energy taxation** also plays a crucial role in the Netherlands' transition to electric appliances. The country uses a system where gas and electricity are taxed at separate rates across five brackets based on the volume of consumption, with lower-volume consumers, like households, paying higher rates than high-volume users, like industries (CE Delft, 2022). To minimise the country's CO_2 emissions, the Dutch government has decided to incrementally increase gas taxes while simultaneously decreasing electricity taxes, resulting in a net decrease in energy costs for households and small businesses that transition to electricity. For example, these alterations have led to the total lifetime cost of a gas boiler surpassing that of a heat pump (Lockwooda, Devenisha, & Kerrb, 2022).

The Australian Federal Government's fossil fuel subsidies ultimately serve to artificially reduce fossil fuel costs, and redirecting these **fossil fuel subsidies** to renewable sources of energy or to cleaner technologies could increase the economic favourability of those technologies, which would further motivate consumers to electrify their gas appliances. However, while the shifting of fossil fuel subsidies to renewables has been examined across multiple studies (Baršauskaitė, 2022; Ouyang & Lin, 2014), research on the consequences and efficacy of such swaps for increasing the rate of electrification remains limited.

Battery

Not directly applicable given that the non-clean technology with the greatest overlapping set of benefits (diesel generators) has insufficient market penetration to justify targeted policy responses, although changing existing fuel taxes, ending fossil fuel subsidies, or introducing a carbon tax would likely have similar effects to those for ICEVs and gas appliances.

3.2.2.3 Feasibility

Policy approaches that increase operating costs through mechanisms such as **carbon taxes** or **renewable natural gas mandates** tend not to receive widespread public support, with only 47% (carbon taxes) or 49% (renewable natural gas mandates) of respondents in a recent survey of 3,804 Canadian homeowners supporting such approaches (Odland et al., 2023). Within the Australian context, the fraught history of the carbon pricing scheme introduced in 2011 by the Gillard government and repealed in 2014 by the Abbott government make it unlikely that another equivalent carbon pricing scheme will be introduced in the foreseeable future (Garnaut, 2023; Ludlow, 2019). Thus, while approaches that shift the economic calculus towards transitioning to cleaner technologies by making non-clean technologies more expensive may be effective, the political calculus for introducing such mandates is likely to be less favourable.

Although policymakers may be hesitant to abruptly remove **fossil fuel subsidies** due to potential adverse effects, a socio-technological perspective suggests leveraging international support to finance renewable energy deployment and foster local renewable technology supply chains and job opportunities as an alternative pathway to transition away from fossil fuel subsidies (Schmidt, Matsuo, & Michaelowa, 2017).

3.3 Incentivising Cleaner Technologies by Reducing Consumer Effort

Consumers are strategic in the use of their limited time and resources and, all else being equal, will typically prefer more convenient offerings that provide the same set of outcomes for less effort (Yan & Murray, 2022). Reducing the burden of effort associated with using and maintaining new energy technologies may consequently increase the motivation to adopt those technologies.

As shown in Figure 3, this report clusters the various policies that have used effort-reducing incentives to encourage the adoption of cleaner technologies into the following outcomes:

+ **Preferential access** (policies: preferential lane access, parking benefits, traffic restriction exemptions).
+ **Integrated infrastructure** (policies: availability of charging infrastructure, building retrofits, DER integration).
+ **Incentivising retailers** (policies: EV incentive schemes for dealers).

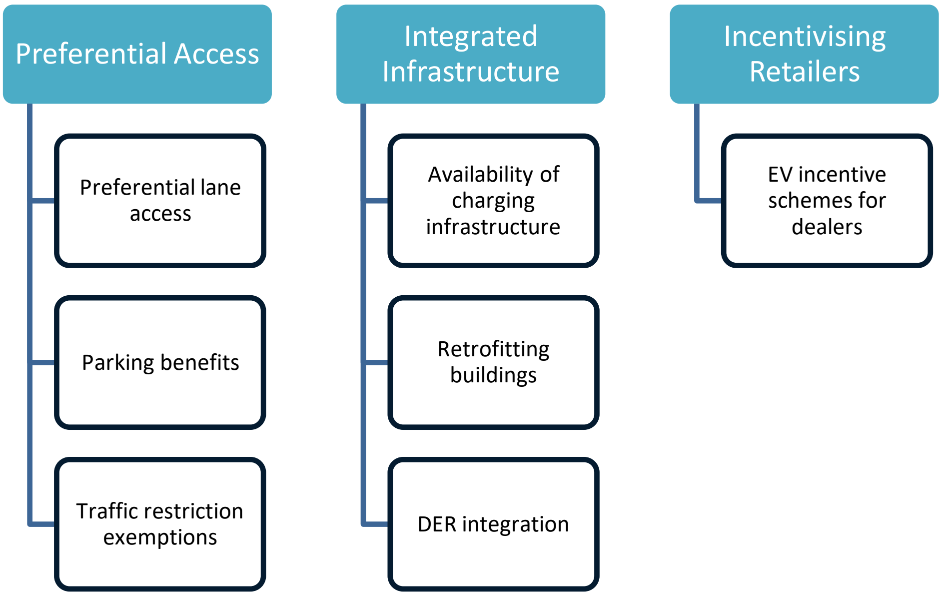

Figure 3. Effort-based incentives for adopting cleaner technologies.

3.3.1 Preferential Access

Providing adopters of cleaner technologies with preferential access to otherwise restricted benefits – such as **preferential lane access** or **traffic restriction exemptions** – reduces the effort in using those technologies and, by extension, may help to drive their adoption.

3.3.1.1 Alignment

Consumers have limited time and energy to expend, and so will often select options that require less effort to access or that simplify otherwise effortful tasks (Yoon, Ma, & Rhodes, 2015). However, it can be difficult to appropriately evaluate the importance that pre-adoption consumers attach to effort reduction activities because the pains of effort are often difficult to assess until during or after adoption. In line with this, Australian consumers rated the importance of one effort-related outcome (reducing life admin) as the lowest of six energy service-related outcomes (Newton et al., 2022).

3.3.1.2 Efficacy

Electric Vehicles

Providing **preferential lane access** to EV users has been evaluated as one potential means for reducing the effort of using an EV. One US study observed that allowing EVs access to high-occupancy vehicle ("carpool") lanes significantly contributed to EV adoption in locations with high traffic density (Jenn et al., 2018). For example, in California, where major cities have similar traffic density and commute times to Melbourne and Sydney (TomTom Traffic Index, 2022), allowing EVs to access high-occupancy vehicle lanes increased EV registration rates by an estimated 46% (Jenn et al., 2018). Similarly, among Norwegian respondents who believed that a single incentive would motivate them to adopt an EV, 18% indicated that that motivating incentive would be allowing EVs access to bus lanes (Bjerkan et al., 2016).

Parking benefits have also been examined as a potential means for motivating the uptake of EVs, although the efficacy of such initiatives is less certain. For example, a Chinese study found that providing parking benefits for EV owners had no effect on promoting EV sales (Qiu, Zhou, & Sun, 2019), although this study did not detail what type of parking benefits were examined, which may be critical given that other studies have found a stronger effect from providing free parking than providing a 50% discount on parking (Langbroek et al. 2016). Potentially contributing to this variability is that, just as the efficacy of providing preferential lane access depends on traffic density (Hardman, 2019), the efficacy of providing parking benefits may similarly depend on the broader availability of parking.

Certain jurisdictions around the world have also introduced **traffic restriction exemptions for EVs**. In London, for example, ultra-low emissions zones have been introduced such that ICEVs travelling through such zones incur the London congestion charge. Low emission vehicles are exempt from such charges, enhancing the relative attractiveness of EVs over ICEVs. One study, for instance, found a positive correlation between proximity to these zones and registrations of hybrid EVs, demonstrating the effectiveness of such measures in encouraging the adoption of low emission vehicles (Morton, Lovelace, & Anable, 2017). Certain regions in China have introduced even more stringent traffic restrictions, with the use of vehicles on certain days of the week effectively banned based on, for example, the last digit of the vehicle's licence plate (Hu, Yang, Sun, & Zhang, 2021; Lu, Yao, Jin, & Pan, 2020). Within such jurisdictions, **traffic restriction exemptions for EVs** would make it more convenient and attractive for consumers to choose EVs over ICEVs, increasing rates of EV adoption (Hu et al., 2021; Lu et al., 2020).

Electrification

No policy initiatives were identified that involved providing consumers who had electrified their gas appliances with preferential access to otherwise restricted effort-reducing benefits.

Battery

No policy initiatives were identified that involved providing consumers who had adopted household batteries with preferential access to otherwise restricted effort-reducing benefits.

3.3.1.3 Feasibility

Policies that reduce effort by giving consumers who have adopted cleaner technologies preferential access to otherwise restricted benefits vary in their likelihood to be feasibly implemented in the Australian context. For instance, the vast majority (>70%) of Australians live in urban areas (ABS, 2018), providing traffic conditions that could make effort reduction incentives such as preferential lane access and parking incentives appealing to consumers. At the same time, Australia does not have a history of implementing traffic restrictions based on emissions or vehicle registration status, making such regulations potentially challenging to implement.

3.3.2 Integrated Infrastructure

Initiatives that better integrate cleaner technologies into legacy systems – and in the process, reduce consumer effort – have also been explored for their influence on consumer adoption. Such integration seeks to address challenges such as the availability of **charging infrastructure** for EVs, **retrofitting** buildings for electrification, and enhancing **DER integration** for more effective battery management and utilisation.

3.3.2.1 Alignment

A common barrier to the adoption of new energy technologies is the concern that they will not seamlessly integrate into existing infrastructure, thereby creating inconvenience for consumers. For example, in a recent survey of Australian residents, the second, third, and fourth most cited barriers to adopting an EV all related to concerns about charging, including the prevalence of EV charging stations (2nd, 40%), running out of charge while driving (3rd, 34%), and the driving range of EVs (4th, 33%; Stolper et al., 2023). Policies that can better integrate cleaner technologies into existing infrastructure may therefore help to address these concerns and, in the process, minimise the longer-term effort in using these technologies. Indeed, one Australian survey found that infrastructure investment would likely have a greater impact on EV adoption decisions than reducing vehicle costs (Broadbent, Metternicht, & Drozdzewski, 2019).

3.3.2.2 Efficacy

Electric Vehicles

Charging infrastructure is crucial for EV adoption as it addresses range anxiety – that is, the fear of being stranded with an empty battery – while also providing convenient access to charging options (Goel, Kumar, Parayitam, & Luthra, 2023; Morrissey, Weldon, & O'Mahony, 2016). Policies can address this by incentivising the expansion and development of a widespread and easily accessible charging network (Goel et al., 2023; Morrissey et al., 2016). In this vein, **increasing access to private charging infrastructure** may influence the adoption of EVs, although how consumers respond to such initiatives is influenced by where they typically park their vehicle (Patt, Aplyn, Weyrich, & van Vliet, 2019). For example, for those who routinely park their vehicle on the street, the provision of free street chargers equalised their willingness to purchase an EV relative to those who owned a dedicated parking space but would have a more moderate influence on drivers who routinely park their vehicle in shared parking lots or garages (Patt et al., 2019).

The availability and functionality of public charging infrastructure are considered critical to EV adoption and have prompted various policy-based mechanisms to address such factors (Fabianek & Madlener, 2023; Kim, Oh, Park, & Joo, 2018). For example, a new law passed by the EU in July 2023 requires the **installation of interoperable fast-charging stations along highways** at 60km intervals by the end of 2025 so that all EVs, irrespective of make, have better access to charging infrastructure (Bennett, 2023).

The increasing adoption of EVs also presents challenges and opportunities for power systems (Daina, Sivakumar, & Polak, 2017). One significant challenge is the potential surge in peak power demand if EV charging coincides with existing demand peaks (Philip, Lim, & Whitehead, 2022; Wu et al., 2022), necessitating the development of **smart charging solutions** to ensure that EV charging is optimised to align with broader patterns of electricity demand (Daina et al., 2017). A choice experiment with early and potential EV adopters revealed their willingness to participate in various smart charging solutions (Kubli, 2022). Relative to a base scenario (home charging for 6 hours, with a guarantee that 50% of the EV's maximum driving range be available after half the charging period), Kubli (2022) found that consumers:

+ Were prepared to pay more to achieve a guarantee that 95% of their EV's maximum range would be available after half of the charging period had elapsed.
+ Would expect to pay less if they were charging away from home.

Early and potential EV adopters may therefore be prepared to engage with smart charging options that limit when or how their EV is charged, provided they are compensated accordingly. Similarly, in a separate study, monetary incentives were found to drive interest in participating in a smart charging program that shifted energy demand from EVs to off-peak hours among current and interested EV drivers (Wong, Shaheen, Martin, & Uyeki, 2023). Other initiatives, such as providing free smart charging equipment and guaranteeing minimum battery levels, were also found to encourage participation in this smart charging program (Wong et al., 2023).

Electrification

Heat pumps can be installed in most UK homes, but their adoption is hindered by higher installation costs, linked partially to the necessity for extra **retrofitting** compared to gas boilers (UK Parliament, 2023). The availability of property-specific advice on retrofit options, costs, benefits, financing, and finding installers, as offered by Home Energy Scotland, has consequently played a crucial role in addressing these retrofitting-related changes, which in turn has driven consumer adoption (UK Parliament, 2023). Similarly, the Republic of Ireland has experienced success through their One Stop Shop program, which seeks to minimise the effort of retrofitting electric appliances by bringing energy assessments, grants and financing support, project management, tradespeople support, and quality assurance into a single, consolidated service (SEAI, 2023). A study analysing retrofitting interventions in France, Germany, and Finland also highlighted the need for innovative strategies that would make building retrofitting more efficient (Pardo-Bosch, Cervera, & Ysa, 2019). This study focused particularly on the role of policymakers in providing funding schemes, promoting risk-sharing and guaranteed savings, and actively involving owners in strategies to increase homeowner participation in retrofit initiatives.

Battery

In surveys and interviews examining residential battery storage, consumers report a preference for ease of operation (e.g., set and forget settings; Agnew and Dargusch (2017); Jacob John et al. (2023). One means for achieving such ease of operation is through the use of home energy management systems, which can help households manage their electricity needs by effectively integrating their DER (Lokeshgupta & Sivasubramani, 2019). A current challenge, however, is the lack of interoperability between DER, with closed device ecosystems often making it difficult or impossible for households to effectively leverage all their DER through a single home energy management system (Sträuli, Kuiper, Rakotojaona, Lacroix, & Lelong, 2022). However, current international standards, such as IEEE 1547-2018, provide a potential starting point for developing open standards to facilitate interoperability across DER (Sträuli et al., 2022).

3.3.2.3 Feasibility

Initiatives like the $70m Driving the Nation funding pool announced in 2023 (ARENA, 2023) demonstrate that there is already appetite among government stakeholders to expand the availability of public EV infrastructure in Australia. Activities that provide integrated infrastructure to support the uptake of cleaner technologies would therefore appear to be feasible within the Australian policy context.

3.3.3 Incentivising Retailers

Purchase choices are often shaped by the interactions that consumers have with retailers and installers, so aligning these diverse stakeholders to facilitate cleaner technology adoption may prove impactful. Such initiatives would also reduce the effort that might otherwise be placed on consumers to investigate, understand, and evaluate complex technologies.

3.3.3.1 Alignment

Car dealers can play a critical role in shaping how consumers evaluate the vehicles that are available for sale (Matthews, Lynes, Riemer, Del Matto, & Cloet, 2017), yet these dealers are not always incentivised to promote EVs, particularly given that EVs sales reduce an important aftersales revenue stream (i.e., ongoing car servicing) for many car dealerships (Fischer, Kramer, Maurer, & Mickelson, 2021; Hanley, 2023). At the same time, a recent survey of Australian consumers found that 24% of those who were negatively disposed towards purchasing an EV cited insufficient knowledge about EVs as contributing to this reticence (Stolper et al., 2023). Incentivising retailers and associated stakeholders to promote cleaner technologies more actively could address both issues.

3.3.3.2 Efficacy

Electric Vehicles

One study, which drew on the experiences of 20 mystery shoppers tasked with evaluating the experience of purchasing EVs in Canada, found that salespeople with positive attitudes towards EVs and having EVs available on-site for test-driving were significant predictors of a successful sale (Matthews et al., 2017). Policy recommendations emerging from the study included modifying the structure of existing **EV incentive schemes** so that dealers were more strongly motivated to advocate for EVs over ICEVs, and developing training programs for EV dealers to ensure they are providing consumers with accurate information about EVs (Matthews et al., 2017).

Electrification

While incentives are often used to shape consumer behaviour, they can also be used to influence the activities of various supply chain actors, including manufacturers, retailers, and distributors (de la Rue du Can, Leventis, Phadke, & Gopal, 2014). In 1993, for instance, Sweden initiated a technology procurement program for ground source heat pumps to foster the development of innovative, high-quality products (de la Rue du Can et al., 2014; Kiss, Neij, & Jakob, 2012). The program connected buyers and manufacturers to lower development risks by also utilising an advanced heat pump specification co-created by purchasers, specialists, and the Swedish Agency for Economic and Regional Growth (Kiss et al., 2012). The program was therefore key to kickstarting a new market.

The Victorian Energy Upgrades initiative provides another example of how programs targeting various stakeholders in the supply chain may shape broader retailer behaviour (DEECA, 2023b). As part of the initiative, energy retailers are required to purchase a certain number of Victorian Energy Efficiency Certificates each year to meet emission targets set by the Victorian Government. These Certificates are generated whenever Victorian households undertake subsidised energy efficiency improvements through the program, such as replacing gas appliances with an electric equivalent. Manufacturers and accredited retailers, in turn, are motivated to participate in the program because of the demand the scheme can generate. In this way, multiple market participants are motivated to act in ways that support the electrification of gas appliances.

However, while governments can promote the shift to efficient electric appliances, gas companies may seek to negate this shift. For example, the Australian gas retailers Jemena and Multinet offer financial incentives for connecting to the gas network and replacing appliances (Vorrath, 2023). Likewise, Australian Gas Networks offer up to $250 rebate for each new natural gas home appliance installed (AGN, 2023).

Battery

No policy initiatives seeking to incentivise retailers to promote battery storage options were identified through this review.

3.3.3.3 Feasibility

The experience of the Victoria Energy Upgrades program (DEECA, 2023) suggests that initiatives to incentivise retailers to promote cleaner technologies have the potential to be effectively implemented in an Australian context.

3.4 Technology Standards and Mandates

As shown in Figure 4, various standards and mandates have been proposed to support the phase-in of cleaner technologies (and by extension, the phase-out of fossil fuel-dependent technologies), including **setting quotas**, **emission standards**, and **phase-out dates**.

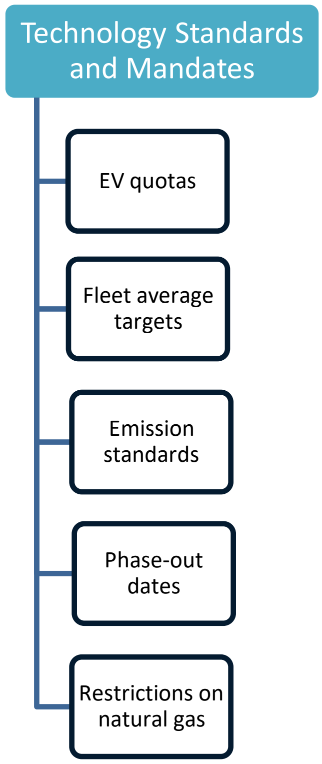

Figure 4. Standards and mandates for increasing the adoption of cleaner technologies.

3.4.1.1 Alignment

Some consumers attend to future technology trends when making current technology purchase decisions. For example, 38% of Australians who expressed an interest in adopting an EV cited "It's the way of the future" as one of the reasons underpinning their interest (Stolper et al., 2023). In that same survey, 22% of Australians interested in adopting an EV also highlighted concerns about the future availability of petrol/diesel as motivating this interest (Stolper et al., 2023). Signalling that certain fossil fuel-dependent technologies will be phased out over the medium term may therefore provide an additional motivational impetus for some consumer cohorts to adopt cleaner technologies well in advance of that phase out.

3.4.1.2 Efficacy

Electric Vehicles

Several approaches are available to support the gradual phase-out of ICEVs. One approach is to introduce **EV quotas** for automakers, which mandate a minimum (and growing) percentage of EV sales each year to avoid financial penalties (Campbell, 2023). Several countries and states have implemented such mandates. For example, California's Zero-Emission Vehicle regulation sets ambitious goals for emissions reduction, aiming for 100% zero-emission and clean plug-in hybrid-electric vehicles in the state by 2035 (CARB, 2023; IEA, 2021). Similarly, beginning in 2026, Canadian automakers will be required to offer 20% zero-emission vehicles in their new passenger vehicle lineup, escalating to 60% by 2030 and reaching 100% by 2035 (CEC, 2023).

Fleet average targets, which include a requirement for automakers to achieve a minimum (and growing) level of average fuel efficiency or greenhouse gas emissions across the fleet of vehicles they sell in a specific market, can incentivise automakers to produce and sell more EVs (Lee, 2020; Uyttebroeck, 2020). Introducing **stringent emissions standards** for ICEVs, as seen in Norway, the European Union, and China, can also indirectly influence customer adoption of EVs by encouraging automakers to focus on developing more low emission vehicles, including EVs (Corradi, Sica, & Morone, 2023; Theilen & Tomori, 2023; Wangsness, Proost, & Rødseth, 2020).

Although the number of EVs in Australia nearly doubled in 2022, EV adoption rates in Australia still lag global figures (EVC, 2022). Contributing to this may be the lack of stringent fuel-efficiency standards in Australia, which has established a perverse disincentive for car manufacturers to sell their best EVs in Australia as doing so would reduce the (limited) stock they have available to achieve fleet emission average targets in other markets (Purtill, 2023).

Policy makers may also seek to directly restrict sales of ICEVs. Legislative action banning the immediate sale of ICEVs is rare and mostly non-binding, with countries instead relying on targets and pledges to phase-out ICEVs by some future date (Burch & Gilchrist, 2020). The UK government, for example, has indicated that it will **gradually prohibit the sale of new petrol and diesel cars** (Tiwari, Aditjandra, & Dissanayake, 2020). The ban was originally proposed to take full effect by 2040, but modelling showed that such a ban would have little impact on accelerating EV adoption as most consumers would have already chosen an EV by then (Lee & Brown, 2021). The ban was consequently brought forward to 2030 as modelling showed that this would accelerate rates of EV adoption, leading to approximately 96% of all cars on the road being fully electric by 2045 (Lee & Brown, 2021).

Electrification

Successful **restrictions on natural gas usage** have been introduced in several countries. In the Netherlands, a significant step was taken to transition away from natural gas by amending the Gas Act to prevent new houses and buildings from being connected to the gas grid (Van't Hof, 2018). Similarly, several US cities have banned natural gas connections in new buildings (Kim, 2023; Raguso, 2019), while numerous jurisdictions in the EU are now enacting comparable ordinances to promote all-electric construction as an alternative to natural gas (Nadel, 2019). In 2023, Victoria became the first jurisdiction in Australia to ban gas connections for all new homes (HIA, 2023). The ban, which will take effect from January 2024, will require all new builds to rely exclusively on electric appliances (HIA, 2023).

Battery

Not directly applicable given that the non-clean technology with the greatest overlapping set of benefits (diesel generators) has insufficient market penetration to justify a targeted policy response.

3.4.1.3 Feasibility

The Australian Government is currently considering legislating fuel efficiency standards for vehicles (DITRDCA, 2023). Moreover, given that the Victorian Government recently became the first jurisdiction in Australia to ban gas connections to new residential builds (see Section 3.4.1.2), there is some prospect that policies to support the phase-out of fossil fuel-dependent technologies could be introduced.

3.5 Increasing Consumer Trust for Cleaner Technologies

Trust can play an important role in the adoption of technologies, particularly those that are novel or depend on third-party providers to operate (Slade, Dwivedi, Piercy, & Williams, 2015). Policies have consequently been proposed or introduced to address issues relating to trust (see Figure 5), typically through various forms of **certification**.

Figure 5. Trust-related policies to encourage the adoption of cleaner technologies.

3.5.1.1 Alignment

A study of Australian consumers found that most (61%) were unsure whether they could trust a third-party aggregator to actively manage their battery in the context of a virtual power plant (Newton et al., 2022). This highlights the role that trust can play in considerations around whether to adopt cleaner technologies or the services that emerge to support the integration of those technologies into the grid.

3.5.1.2 Efficacy

Electric Vehicles

International standards like ISO 15118 and ISO 21434 have been designed to protect EV owners from a range of issues, including cybersecurity threats (Sunderland, 2022). For example, ISO 15118 defines a bi-directional vehicle-to-grid communication interface for electric vehicles, including features like secure communication. Similarly, ISO 21434 outlines cybersecurity measures for road vehicles' development lifecycle to counter emerging cyber threats in vehicle communication and updates (Sunderland, 2022). Although these standards are voluntary, some EV manufacturers have started designing their processes to be compliant with these standards (Abuelsamid, 2022; DEKRA, 2023). However, changes in technology mean that even EV automakers that adhere to them may still leave consumers vulnerable due to the rapidly evolving nature of cybersecurity threats (Johnson, Berg, Anderson, & Wright, 2022).

Electrification

Building certifications emphasise the sustainability of buildings, focusing particularly on their environmental, social, and economic impacts (Chi, Chi, Xu, & Kennedy, 2022; Nygaard, 2023). These certifications can also influence consumer trust. For example, in one study, the presence of a green building certification increased participants' trust in the green performance of that building (Chi et al., 2022), highlighting the utility of such schemes for addressing trust-related issues (Darnall, Ji, & Vázquez-Brust, 2018). Energy certifications for buildings, like that offered by Leadership in Energy and Environmental Design (Liu et al., 2018) may therefore address consumer trust-related issues that might exist around the electrification of gas appliance. Such certifications are, however, voluntary (EPA, 2023). Moreover, certifications such as these can give rise to risks around greenwashing, where a product is inaccurately portrayed as sustainable, often to exploit consumers' growing demand for sustainable products (Nygaard, 2023).

Battery

The Victorian Government has implemented several trust-building mechanisms and protections for DERs (DELWP, 2022b), including the banning of door-to-door sales of solar products (effective from 1 September 2021) and the introduction of a Code of Conduct (effective from 1 July 2022) for businesses supporting the Victorian Energy Upgrades rebate scheme (DELWP, 2022b). Moreover, a national New Energy Tech Consumer Code (effective from 1 February 2023), which is administered by the Clean Energy Council, has also been introduced to build consumer confidence in approved sellers (NETCC, 2022). These mechanisms highlight some of the approaches that have been introduced to protect consumers as they look to purchase DER like household batteries (DELWP, 2022b).

3.5.1.3 Feasibility

Initiatives to increase consumer trust for cleaner technologies are already in motion within the Australian context, including the implementation of international standards and building certifications. Such initiatives are therefore feasible.

4 Comparing the Efficacy of Different Policy Outcomes

4.1 Background

Drawing on the literature reviewed in the preceding sections, each identified policy outcome was evaluated in Table 1 on three dimensions:

+ **Alignment**, which is the extent to which the policy outcome aligns with consumers' perceptions and motivations.
+ **Efficacy**, which refers to the effectiveness of the policies that have sought to achieve the desired policy outcome.
+ **Feasibility**, which refers to the potential ease of implementing the policies or associated outcomes in an Australian context.

These dimensions were used in determining the policy outcomes that might be first-order candidates for accelerating the adoption of cleaner technologies in that, to effectively motivate consumer adoption, a given policy should address or leverage consumer issues, be effective enough to warrant investment, and be feasible to implement within the Australian context.

4.2 Recommendation

Through this evaluative process, four first-order policy outcomes were identified:

+ Reduce purchase costs.
+ Reduce operating costs.
+ Integrated infrastructure.
+ Technology standards and mandates.

These outcomes should form the basis of follow-up studies evaluating whether policies aimed at achieving these outcomes would influence consumer adoption of cleaner technologies.

Table 1. Evaluation of policy outcomes for accelerating the adoption of cleaner technologies.

Policy outcome	Alignment	Efficacy	Feasibility
Incentivising cleaner technologies financially			
Reducing purchase costs	High	High	High
Facilitating purchases with concessional financing	Medium	Medium	High
Reducing operating costs	High	High	High
Disincentivising non-clean technologies financially			
Increasing purchase costs	High	High	Low
Increasing operating costs	High	High	Low
Incentivising cleaner technologies by reducing consumer effort			
Preferential access	High	Medium	Medium
Integrated infrastructure	High	High	High
Incentivising retailers	Medium	Medium	High
Technology standards and mandates	High	High	High
Increasing consumer trust	High	Medium	High

5 Consumer Segmentation

5.1 Background

Consumers are not a monolith, and the transition to cleaner technologies will consequently vary across different consumer segments. For example:

+ Some consumer segments will likely be faster than others to adopt cleaner technologies (Newton et al., 2022; Pardy, Rhodes, & Jaccard, 2022; Smith, Olaru, Jabeen, & Greaves, 2017).
+ The values and motivations held by different consumer segments may influence how they respond to specific policy initiatives designed to accelerate the adoption of cleaner technologies (Gong et al., 2020; Odland et al., 2023; Selvakkumaran & Ahlgren, 2019; Yan & Murray, 2022).

Understanding the variables on which to segment consumers is therefore important for identifying the differing needs and perceptions of consumers as they relate to the adoption of cleaner technologies.

5.2 Review and Evaluation

A review of the segmentation variables used in recent Australian studies to examine consumer perceptions and responses to cleaner technologies was conducted. Focus was restricted to Australian studies to ensure that the segmentation variables ultimately selected through this evaluation process were appropriate to Australia's sociocultural context. The results of this review are presented in Table 2.

Table 2. Segmentation variables used in Australian research examining consumer adoption of cleaner technology.

Segmentation variable	EVs					Elect.		Battery		
	[1]	[2]	[3]	[4]	[5]	[4]	[5]	[4]	[6]	[7]
Sociodemographic										
Gender	●	●	○		●		●			○
Age	●	○	○		●		●		●	●
Location				*	●	*	○	*	●	
Socioeconomic status										
Education	●	○	○		●					○
Income	●	○	○						○	○
Financial pressure				*		*		*		
Employment status	●	○			●					
Number of jobs			○							
Property variables										
Dwelling ownership status	●			*	●	*		*	○	
Dwelling type	●	○		*		*		*	○	
Dwelling value									○	
Presence of DER									●	●

Segmentation variable	EVs					Elect.		Battery		
	[1]	[2]	[3]	[4]	[5]	[4]	[5]	[4]	[6]	[7]
Frequency of power outages										○
Household composition	●			*		*		*		○
Recently moved									●	
Transport variables										
Daily distance travelled		○								
Modes of transport		●								
Frequency of using EVs			●							
Psychographic										
Adopter category										●
Excitement using new tech			○							
Political ideology										○
Environmental concern			●							

Table notation: ● = significant segmentation variable; ○ = non-significant segmentation variable; * = no significance testing; blank = not examined/reported

Summarised studies: [1] = Gong et al. (2020); [2] = Loengbudnark, Khalilpour, Bharathy, Taghikhah, and Voinov (2022); [3] = Smith et al. (2017); [4] = ECA (2022); [5] = Stolper et al. (2023); [6] = Best et al. (2023); [7] = Newton et al. (2022)

Demographic variables were the primary means for segmenting consumers, which is unsurprising given the ease of identifying such variables and – by extension – the ease of leveraging them in non-research contexts. Of these:

- **Gender**, **age**, and **location** were regularly found to segment consumers based on their perceptions of, or adoption intention towards, cleaner technologies, highlighting their potential utility as segmentation variables.
- Variables relating to socioeconomic status were captured in a variety of ways, including traditional approaches (**education**, **income**, **employment status**) as well as various indicators of financial wellbeing (**financial pressure**, **number of jobs**). While there was some variability in the predictive utility of these segmentation variables, examining indicators of financial wellbeing are likely to be important from an equity perspective for ensuring that marginalised or vulnerable segments of the community are not left behind in the transition to cleaner technologies (see Hammerle & Burke 2022 and 2023).
- Several property-related variables were measured, with some assessing macro characteristics (**dwelling ownership status**, **dwelling type**, **dwelling value**) and others examining how the property interfaced with energy systems (**presence of DER**, **frequency of power outages**) or socio/family dynamics (**household composition**, **recently moved**). Although there was some variability in their predictive utility across studies, macro characteristics like dwelling ownership status and dwelling type appeared to be important. These variables also reflect the control (or lack thereof) that residents have to adopt certain cleaner technologies, further warranting their use as segmentation variables. Presence of DER also emerged as a significant predictor of adoption-related outcomes in the two studies that evaluated this segmentation variable, suggesting that it too has potential utility as a segmentation variable.

- Transport-related variables (**daily distance travelled**, **modes of transport**, **frequency of using EVs**) were used in two of the five studies examining EV-related adoption issues. Of these variables, two were identified as significant: modes of transport and frequency of using EVs. Both are likely to have utility in terms of evaluating the centrality of vehicle-based modes of transport to consumers' current lifestyle (modes of transport) and the importance that consumers attach to associated technologies like smart chargers (EV ownership status).

Alongside these sociodemographic segmentation variables were a smaller set of psychographic segmentation variables (**adopter category**, **excitement using new technology**, **political ideology**, **environmental concern**). Psychographic variables were far less commonly assessed, potentially because they can be harder to leverage when the focus shifts from generating insights through research to applying insights in real-world contexts, where information to support the allocation of consumers to segments is more difficult to identify. Nevertheless, the two psychographic variables identified as significant (adopter category, environmental concern) represent potentially useful segmentation variables in that they:

- Provide insight into the perceptions of consumer cohorts beyond those of early adopters (adopter category).
- Determine the centrality of environmental motivations to perceptions and decisions about adopting cleaner technologies (environmental concern).

5.3 Recommendation

Drawing on the evaluation in Section 5.2, the following minimum segmentation variables are recommended for inclusion in future segmentation research on consumer adoption of cleaner technologies:

- Age
- Gender
- Location
- Financial wellbeing
- Dwelling ownership status
- Dwelling type
- Presence of DER
- Modes of transport
- EV ownership status
- Adopter category
- Environmental concern

Although it was not featured in any of the reviewed Australian studies, one final segmentation variable is also recommended for inclusion in future research: status as a culturally and linguistically diverse household. The rationale for its inclusion is to evaluate how minority or vulnerable communities respond to initiatives aimed at supporting the transition to cleaner technologies, particularly with a view to ensuring that these communities are not left behind in this transition.

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