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Benefit Analysis of Load-Flexibility from Consumer Energy Resources: Methodology Report

Prepared for the Australian Energy Market Commission

3 August 2023

ENERGEIA

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Executive Summary

This project is driven by Australian Energy Market Operator's (AEMO's) rule change request to the Australian Energy Market Commission (AEMC) (Flexible Trading Arrangements (Model 2) and Minor Energy Flow Metering in the National Electricity Market (May 22)). This rule seeks to enable consumers and the market to separate flexible CER and have them managed and recognised in wholesale market settlements if they choose. The AEMO model also allows for a consumer to contract with more than one financially responsible market participant (FRMP) if they choose to.[1]

The scope of this benefit and cost analysis aims to estimate the system and consumer benefits from incremental flexibility of consumer energy resources (CER). These can then be contrasted with any associated costs and breakeven adoption rates calculated (the amount of additional flexibility enabled by the rule change sufficient to cover costs). This will help inform the AEMC's consideration of a rule change to enable flexible loads to be managed independently of passive loads and to be able to reward consumers for doing so.

The analysis will model the outcome of CER load flexibility uptake and optimisation which aligns to AEMO's 2023 Inputs and Assumptions Report, most likely, the Step Change[2] scenario:

- **System Benefits** – Which will determine the value of the forecast system level load flexibility on reducing:
    - National Electricity Market (NEM) wholesale and ancillary service market costs,
    - NEM transmission and distribution costs, and
    - NEM carbon emissions from the electricity grid
- **Consumer Benefits** – Which will utilise a case study of the value of load flexibility to consumers for reducing their overall energy costs, including the cost of the CER flexibility, and the likely share of net benefits across value chain players.

The above outcomes will be modelled within a fit-for-purpose Excel-based tool that can estimate the material costs and benefits of flexible CER for the system and for consumers, and, crucially, enable the quantification of the benefits needed to be realized by a potential AEMC Rule change to be cost effective. The modelling will include the flexible load types and consumer segments outlined in this report across the NEM to 2050.

> It should be noted that the scope of this engagement is not to forecast the impact of a potential rule change on system costs, but to estimate the quantum of system benefits that load flexibility could potentially provide, and how large the benefits and uptake of load flexibility would need to be to justify the industry costs associated with a potential Rule change.

Delivering the key inputs needed to inform the AEMC's rule change requires the tool perform up to 4 key modelling outcomes, which are summarised below by project phase:

1. **Phase A.1** – Determine the incremental value of various CER load flexibility options in terms of benefits to the electricity system.

[1] AEMO rule change request, Appendix B HLD p. 42.

[2] AEMO. *2023 Inputs, Assumptions and Scenarios Report*. https://aemo.com.au/-/media/files/major-publications/isp/2023/2023-inputs-assumptions-and-scenarios-report.pdf?la=en

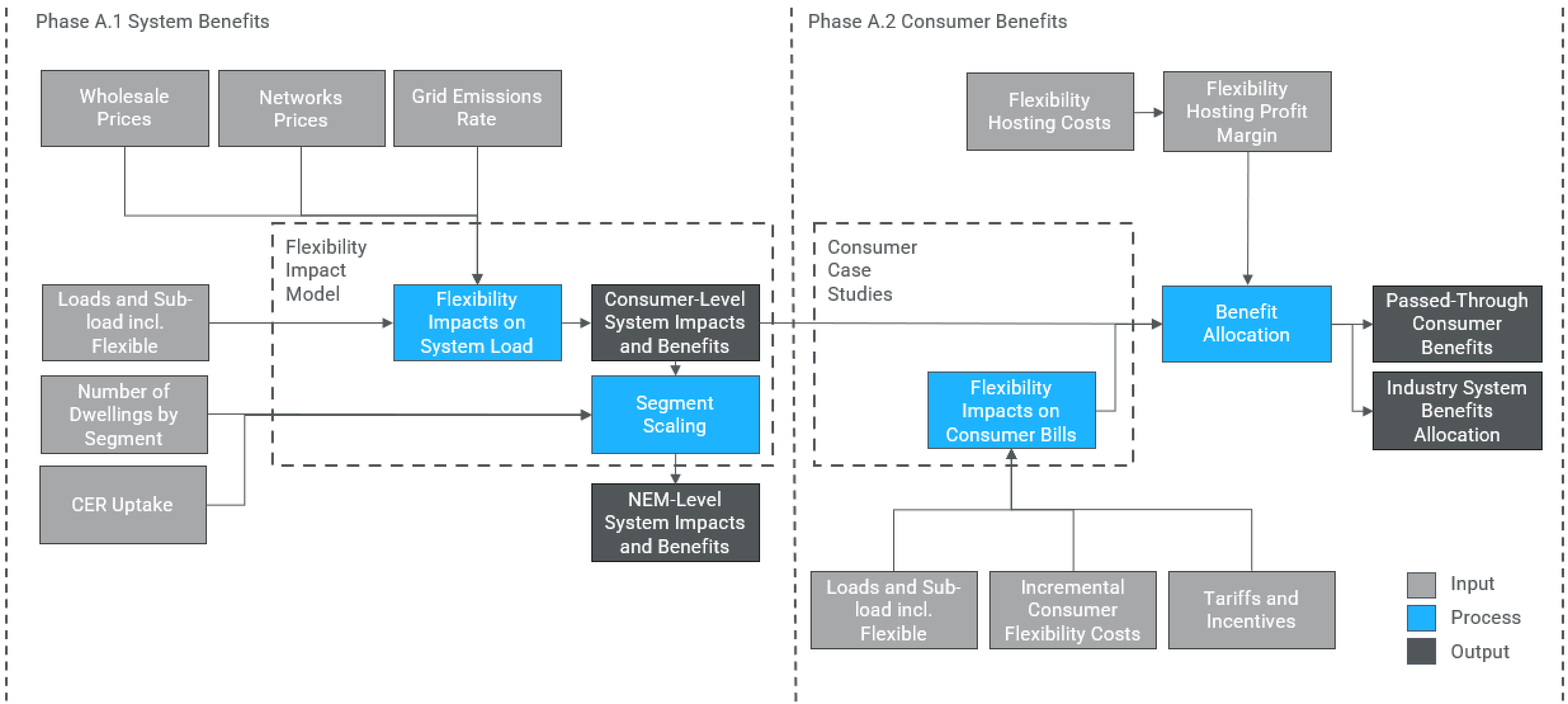
2. **Phase A.2** – Determine consumer-level benefits of CER flexibility by consumer segment and CER type utilising consumer case studies, determining the likely share of benefits by supply chain participant.
3. **Phase B.1** – Determine the trajectory of CER load flexibility uptake under a range of policy options, and the required threshold of incremental uptake to ensure load flexibility programs are feasible for all parties involved.
4. **Phase B.2** – Where the consumer benefits are sufficient, determine the impact of improved CER flexibility value for consumers on flexible CER device uptake.

Energeia is working with AEMC staff to continue to develop the following modelling methodology to achieve the key objectives and requirements and will consider all stakeholder feedback in further refining the methodology. The structure of Energeia's approach to this scope of work is contained within Phases A and B.

Below are a series of diagrams of Energeia's modelling approach to determining the current and potential volume and value of CER flexibility as well as the planned timeline of the analysis.

Phase A of the project focuses on capturing the benefits of flexible CER to consumers and the system. A block diagram of the Phase A modelling methodology can be seen in Figure E1.

Figure E1 – Phase A Block Diagram



Source: Energeia

The key modelling steps in the Phase A.1 methodology are:

1. **Flexibility Impacts on System Load –** Developing and modelling a set of representative consumer segments to utilise in modelling CER load flexibility, and its impact on consumer-level benefits for the wholesale, ancillary, transmission network, distribution network and carbon emissions costs, via a Flexibility Impact Model.
2. **Segment Scaling** – Applying the representative consumer-level system benefits to a NEM-wide level using key population statistics and CER uptake paths.

The key deliverable of Phase A.1 is NEM-Level system impacts of load flexibility by the key consumer segments and flexible loads modelled.

The key modelling steps in Phase A.2 methodology are:

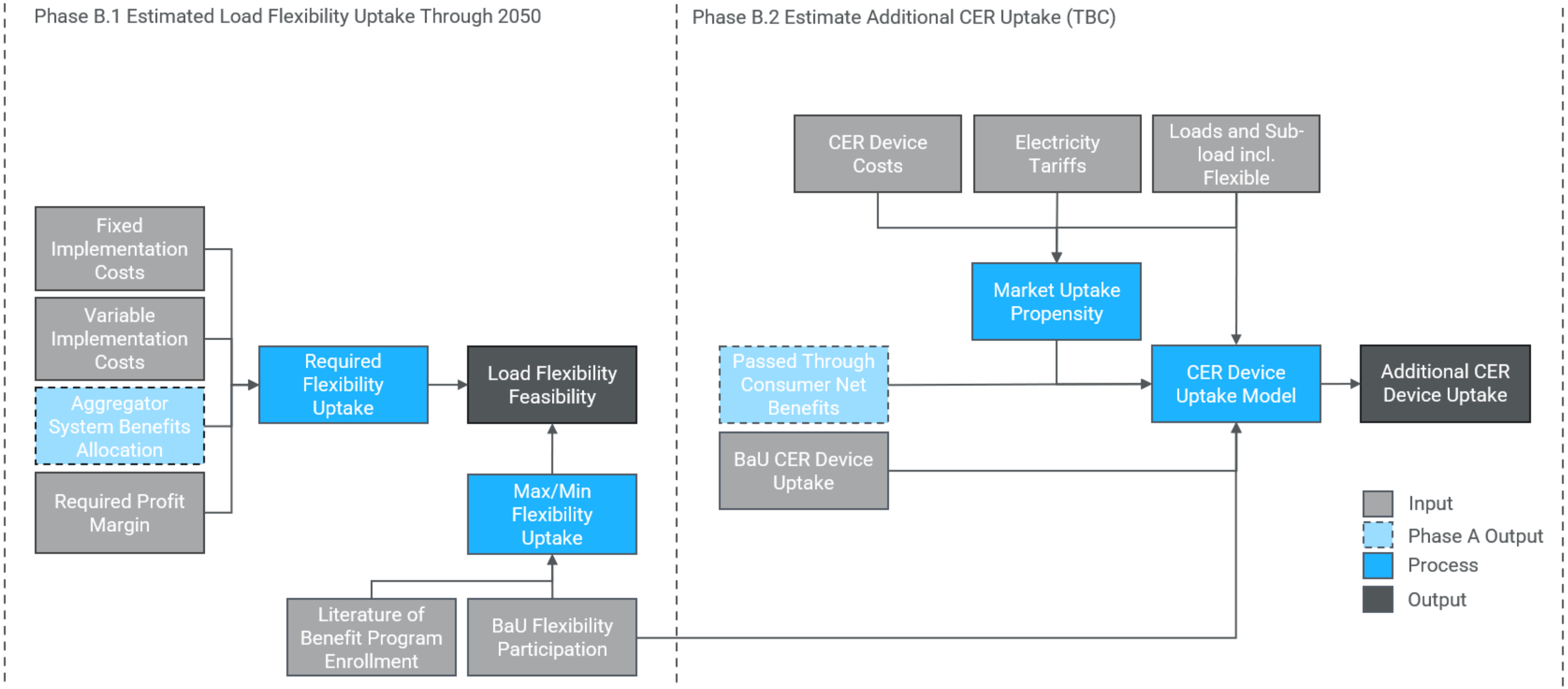
1. **Flexibility Impacts on Consumer Bills** – Modelling of the potential costs of facilitating CER load flexibility to consumers, utilising a case study approach. This will determine the costs of incremental load flexibility on a consumer segment basis when allocating net system benefits to participating consumers.
2. **Benefit Allocation** – Modelling of the total net benefits to supply chain participants, including networks, generators, retailers, aggregators and consumers including the unavoidable costs associated with providing flexible load hosting and management.

The key deliverable of Phase A.2 is an estimate of the slice of the total system benefits that aggregators would require to provide load flexibility services and that will be needed for consumers to justify a rule change. Passed through benefits to industry by supply chain are also developed, as a key linkage between Phase A and Phase B.

Phase B of the project builds on Phase A by determining the net impact of the policy on CER flexibility benefits, CER flexibility net benefits allocation and flexible CER and CER flexibility program uptake. A block diagram of the Phase B modelling methodology is given in Figure E2.

Phase B.2 will optionally be modelled resulting from the level of benefits that can be accrued by a consumer.

Figure E2 – Phase B Block Diagram



Note: BaU = Business as Usual
Source: Energeia

The key modelling steps in the Phase B.1 methodology are:

1. **Required Flexibility Uptake** – Characterising the minimum required flexibility uptake threshold to induce aggregator participation in load flexibility including implementation costs, required profit margins, available aggregator benefits.
2. **Min/Max Flexibility Uptake** – Identifying potential adoption pathways through the review of information found in the academic and industry literature. This will be considered alongside the level identified based on rule change costs and net benefits.

The key output of Phase B.1 is an assessment of load flexibility feasibility by consumer and flexible load segment modelled, based on required flexibility uptake threshold for net benefits and min/max flexibility uptake characterisation.

Where the magnitude of potential benefits identified in the above work for a given CER flexibility option are significant, Phase B.2 may be undertaken. The key processes in the Phase B.2 methodology are:

1. **Market Uptake Propensity** – Establishing the relationship between return on investment and uptake of energy cost saving measures from a consumer's perspective based on historic uptake of solar PV.
2. **CER Device Uptake Model** – Modelling the incremental impacts of a potential rule change on CER uptake by applying the uptake relationship to the consumer segments and CER technologies, given the calculated passed-through consumer benefits.

The final outcome of Phase B.2 is the estimated additional CER device uptake resulting from the additional value of load flexibility passed through to the consumer.

Table E1 shows the indicative modelling timeline. Energeia will deliver Phase A and Phase B of the modelling in an iterative process with the AEMC.

Table E1 – Indicative Modelling Timeline

Stage	Timeline
Commission publishes directions paper	3 August 2023
Stakeholder submissions due	14 September 2023
Stakeholder forums workshops	Late September and October 2023
The Commission publishes a draft determination and may publish a draft rule	Dec 2023
Stakeholder submissions due	Late January 2023
The Commission publishes a final determination and final rule (if any)	March/April 2024

Source: AEMC

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1. Background

This study is feeding into an AEMC Unlocking CER Benefits through flexible trading rule change. This rule change is one of the many CER implementation reforms seeking to better integrate CER into the National Electricity Market (NEM). visibility and control, AEMC Rule Change

The Australian Energy Market Operator's (AEMO's) rule change request to the Australian Energy Market Commission (AEMC) (Flexible Trading Arrangements (Model 2) and Minor Energy Flow Metering in the National Electricity Market (May 22)), seeks to enable end users to separate their controllable electrical resources and have them managed independently from their passive load without needing to establish a second connection point.[3] The AEMO model also allows for a consumer to contract with more than one financially responsible market participant (FRMP) if they choose to.[4]

This rule change is one of the many CER implementation reforms underway. Other rule changes and reviews which may influence the analysis of this engagement. These include but are not limited to:

- Integrating Price-Responsive Resources into the NEM
- Review of the Regulatory Framework for Metering Services
- Review into CER Technical Standards
- Consumer Protections for Future Energy Services
- Development of Interoperability Policy
- Review of the Regulatory Framework for Flexible Export Limit Implementation
- Network Visibility for the Market

A summary of each of these are provided in the AEMC Directions Paper for this rule change.

[3] https://www.aemc.gov.au/sites/default/files/2022-05/ERC0346%20Rule%20change%20request%20pending.pdf

[4] AEMO rule change request, Appendix B HLD p. 42.

2. Scope and Approach

The AEMC engaged Energeia to develop and configure a tool to enable them to better understand the magnitude of benefits of incremental load flexibility to the NEM and its consumers from CER devices that can separately receive market signals/pricing for wholesale, network and/or ancillary services.

The following section outlines the scope and approach of this project.

2.1. Scope

This scope of this benefit and cost analysis aims to estimate the system and consumer benefits from incremental flexibility of consumer energy resources (CER)[5]. These can then be contrasted with any associated costs and breakeven adoption rates calculated (the amount of additional flexibility enabled by the rule change sufficient to cover costs). This will help inform the AEMC's consideration of a Rule change to enable flexible loads to be managed independently of passive loads and to be able to reward consumers for doing so.

The analysis will model the outcome of CER load flexibility uptake and optimisation which aligns to AEMO's 2023 Inputs, Assumptions and Scenarios Report, most likely, the Step Change[6] scenario:

- **System Benefits** – Which will determine the value of the forecast system level load flexibility on reducing:
    - NEM wholesale and ancillary service market costs,
    - NEM transmission and distribution costs, and
    - NEM carbon emissions from the electricity grid
- **Consumer Benefits** – Which will utilise a case study of the value of load flexibility which will be received by consumers for reducing their overall energy costs, including the cost of the CER, and the likely share of net benefits across value chain players.

The above outcomes will be modelled within a fit-for-purpose excel-based tool that can estimate the material costs and benefits of flexible CER for the system and for consumers, and, crucially, enable the quantification of the benefits needed to be realized by a potential AEMC Rule change to be cost effective. The modelling will include the flexible load types and consumer segments outlined in this report across the NEM to 2050.

> It should be noted that the scope of this engagement is not to forecast the impact of a potential Rule change on system costs, but to estimate the quantum of system benefits that load flexibility could potentially provide and how large these benefits and the consumer allocation would need to be to justify the industry costs associated with a potential Rule change.

The following section outlines Energeia's approach to determining the volume and value of load flexibility.

[5] CER for the purposes of the rule change request is defined in Chapter one of the Directions Paper.

[6] AEMO. *2023 Inputs, Assumptions and Scenarios Report*. https://aemo.com.au/-/media/files/major-publications/isp/2023/2023-inputs-assumptions-and-scenarios-report.pdf?la=en

2.2. *Energeia's Approach*

Delivering the key inputs needed to inform the AEMC's rule change requires the tool to perform up to 4 key modelling outcomes, which are summarised below by project phase:

1. **Phase A.1** – Determine the incremental value of various CER load flexibility options in terms of benefits to the electricity system.
2. **Phase A.2** – Determine consumer-level benefits of CER flexibility by consumer segment and CER type utilising consumer case studies, determining the likely share of benefits by supply chain participant.
3. **Phase B.1** – Determine the trajectory of CER load flexibility uptake under a range of policy options, and the required threshold of incremental uptake to ensure that load flexibility programs are feasible for all parties involved.
4. **Phase B.2** – Where the consumer benefits are sufficient, determine the impact of improved CER flexibility value for consumers on flexible CER device uptake.

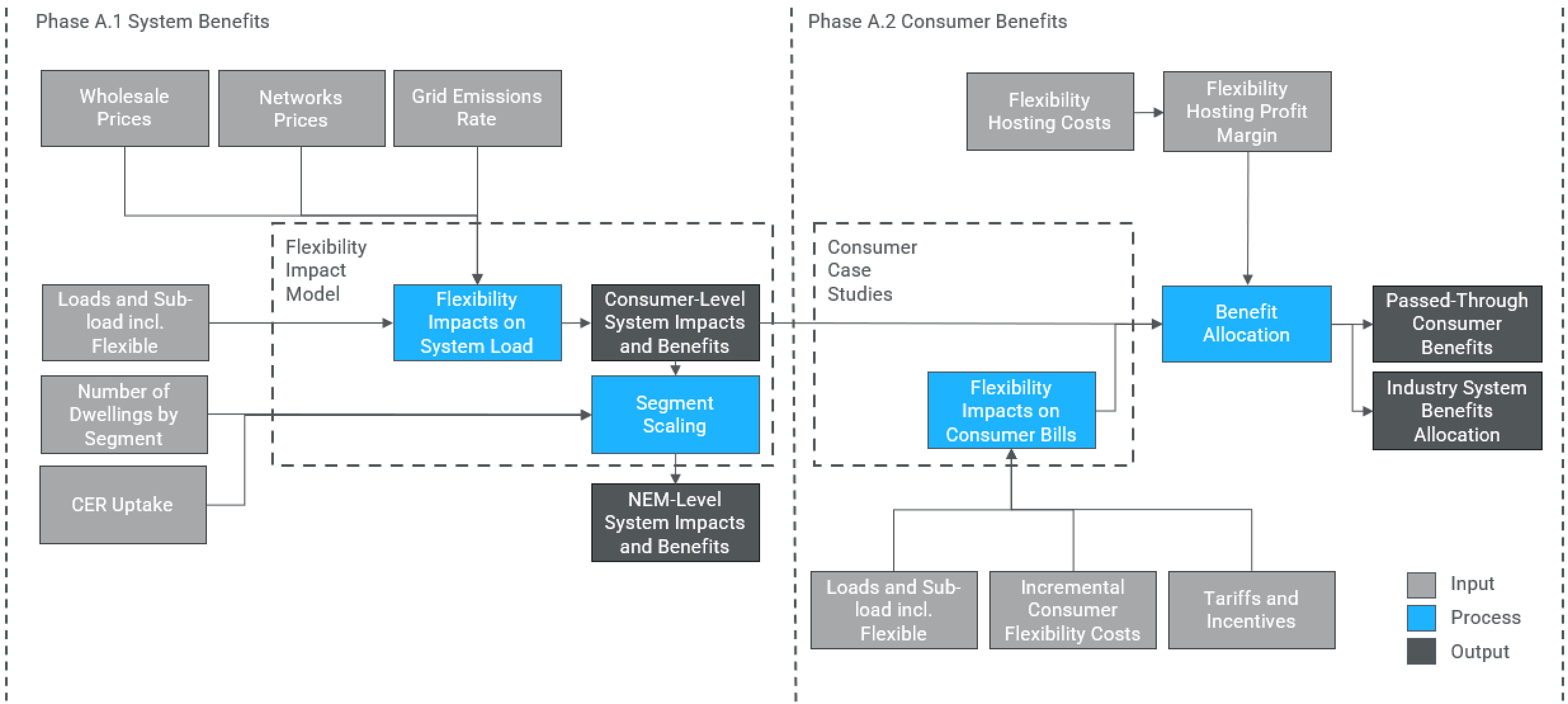
Energeia is working with AEMC staff to continue to develop the following modelling methodology to achieve the key objectives and requirements and will consider all stakeholder feedback in further refining the methodology.

2.2.1. Overview

Below are a series of diagrams of Energeia's modelling approach to determining the current and potential volume and value of CER flexibility, as well as the planned timeline of the analysis.

Phase A of the project focuses on capturing the benefits of flexible CER to consumers and the system. A block diagram of the Phase A modelling methodology can be seen in Figure 1 below.

Figure 1 – Phase A Block Diagram



Source: Energeia

The key modelling steps in the Phase A.1 methodology are:

1. **Flexibility Impacts on System Load –** Developing and modelling a set of representative consumer segments to utilise in modelling CER load flexibility, and its impact on consumer-level benefits for the wholesale, ancillary, transmission network, distribution network and carbon emissions costs, via a Flexibility Impact Model.
2. **Segment Scaling** – Applying the representative consumer-level system benefits to a NEM-wide level using key population statistics and CER uptake paths.

The key deliverable of Phase A.1 is NEM-Level system impacts of load flexibility by the key consumer segments and flexible loads modelled.

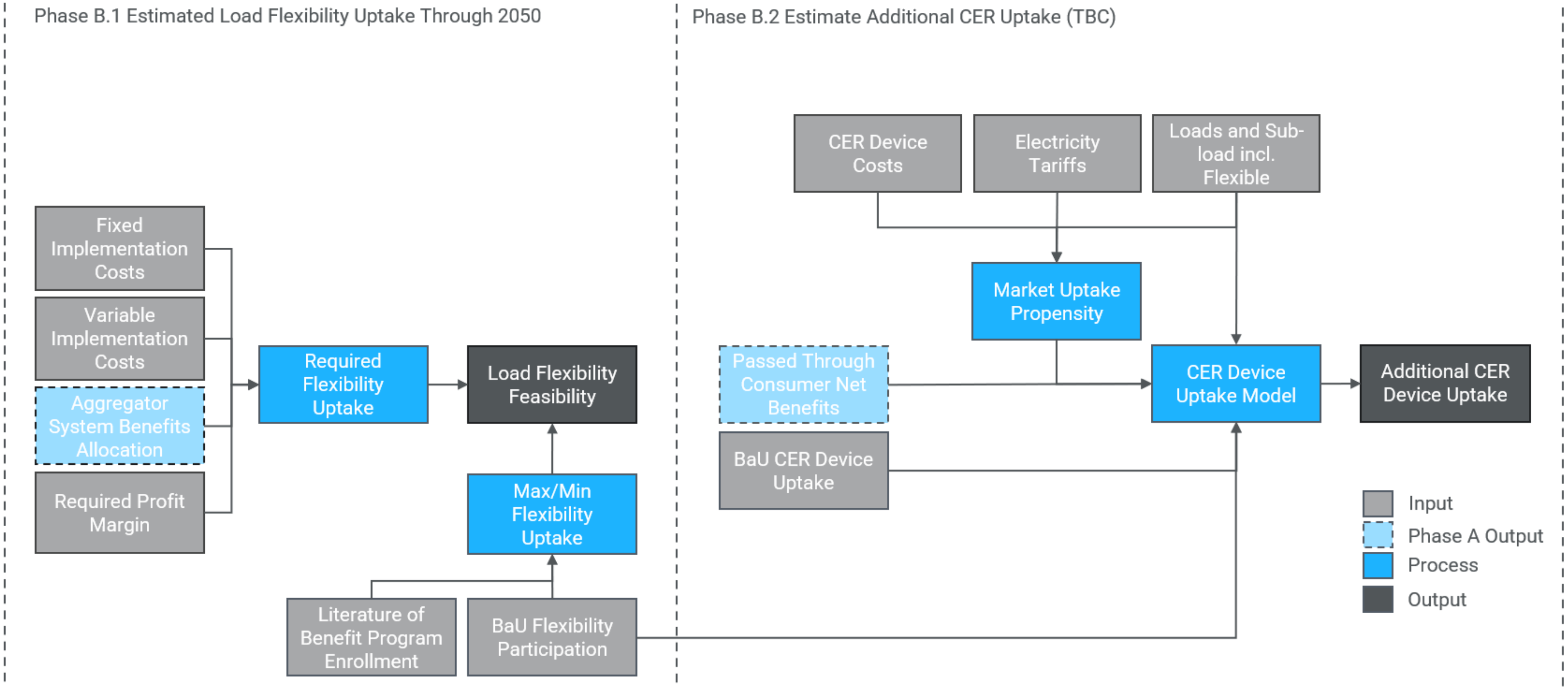
The key modelling steps in Phase A.2 methodology are:

1. **Flexibility Impacts on Consumer Bills** – Modelling of the potential costs of facilitating CER load flexibility to consumers, utilising a case study approach. This will determine the costs of incremental load flexibility on a consumer segment basis when allocating system benefits to participating consumers.
2. **Benefit Allocation** – Modelling of the total benefits to supply chain participants, including networks, generators, retailers, aggregators and consumers. It will account for the unavoidable costs associated with providing flexible load hosting and management, such as potential customer retail bill impacts or the fixed and variable costs associated with establishing and operating a load flexibility program for an aggregator.

The key deliverable of Phase A.2 is an estimate of the slice of the total system benefits that an aggregator would require to provide load flexibility. Passed through benefits to industry by supply chain are also developed, as a key linkage between Phase A and Phase B.

Phase B of the project builds on Phase A by determining the net impact of the policy on CER flexibility benefits, CER flexibility net benefits allocation and flexible CER and CER flexibility program uptake. A block diagram of the Phase B modelling methodology is given in Figure 2. Phase B.2 will optionally be modelled resulting from the level of benefits that can be accrued by a consumer.

Figure 2 – Phase B Block Diagram



Note: BaU = Business as Usual
Source: Energeia

The key modelling steps in the Phase B.1 methodology are:

1. **Required Flexibility Uptake** – Characterising the minimum required flexibility uptake threshold for net benefits through including implementation costs and available aggregator benefits.
2. **Min/Max Flexibility Uptake** – Identifying potential adoption pathways through the review of information found in the academic and industry literature. This will be modelling alongside the level identified based on rule change costs and net benefits.

The key output of Phase B.1 is an assessment of CER load flexibility feasibility by consumer and flexible load segment considered, based on required flexibility uptake threshold for net benefits and min/max flexibility uptake characterisation.

Where the magnitude of potential benefits identified in the above work for a given CER flexibility option are significant, Phase B.2 will be undertaken. The key processes in the Phase B.2 methodology are:

1. **Market Uptake Propensity** – Establishing the relationship between return on investment and uptake of energy cost saving measures from a consumer's perspective based on historic uptake of solar PV.
2. **CER Device Uptake Model** – Modelling the incremental impacts of a potential rule change on CER uptake by applying the uptake relationship to the consumer segments and CER technologies, given the calculated passed-through consumer benefits.

The final outcome of Phase B.2 is the estimated additional CER device uptake resulting from the additional value of load flexibility passed through to the consumer.

2.2.2. Phase A.1

The following section outlines the key inputs and methods of Phase A.1, which determines system benefits of load flexibility.

Flexibility Impacts on System Load

To quantify system level impacts, load flexibility through either shifting or shedding will be applied to each load profile to optimise its shape with respect to system outcomes, categorised as minimising wholesale costs, ancillary service costs, and transmission and distribution network infrastructure costs.

Wholesale and ancillary cost impacts will be based on 30-minute 2022 Regional Reference Prices (RRP) and ancillary services prices by state. Transmission and distribution costs will be estimated by the change in system peak and minimum demand multiplied by the associated Long-Run Marginal Cost (LRMC). The impact on grid emissions will also be accounted for, though not explicitly optimised.

The above methodology will result in a value of total benefits accrued for a single consumer, which will then be scaled to a NEM-level basis in the following step.

Segment Scaling

The above analysis requires extrapolation from the representative consumer basis to a NEM-wide basis, split by state. Scaling of each representative consumer will be based on population statistics for the consumer segment each year.

Population statistics will be determined using AEMO's 2023 Inputs, Assumptions and Scenarios Report, most likely, the Step Change scenario[7] in terms of the number of:

- premises,
- flexible appliance, equipment, and electric vehicle (EV) charger stock,
- average load by consumer segment and appliance, equipment, and sub-load, and
- flexibility program adoption

Load flexibility will be reported at the state, consumer, and load type by year.

2.2.3. Phase A.2

The following section outlines the key inputs and methods of Phase A.2, which will determine the level of benefits that can be expected to flow to consumers from load flexibility.

Flexibility Impacts on Consumer Bills

Energeia will utilise a series of consumer case studies to model the costs or benefits to consumer bills that will be accrued from load flexibility using a bottom-up model of representative, 30-minute consumer loads by end use and technology. The selection of these representative consumers and the different variation of load flexibility that are proposed to be modelled for each CER is discussed in more detail in Section 3.1.

Unmanaged load profiles for these CER sub-loads will be estimated based on data from the Residential Baseline Study 2022[8], or if not available, from End-Use Load Profiles for the U.S. Building Stock[9], matched to the relevant Australian climate.

Consumer bill impacts for each case study will be estimated based on the impact of changes in load due to load flexibility on consumer bills based on the most popular Time-of-Use (ToU) tariff in the state, as well as their overall costs including the cost of load flexibility technology and any costs associated with the provision of flexibility services.

In the following stage, this will be compared to the total value to be earned on a system-basis, as calculated from Phase A.1, as a constraint to how system benefits must be allocated to consumers in order to induce participation.

Benefit Allocation

Using the understanding of the consumer costs and benefits of CER load flexibility through the case studies, the allocation of the remaining benefits to the other market participants will be estimated by considering any flexible hosting costs and profit margins that are likely to be required to induce participation from aggregators. Profit margin requirements could be estimated through a case study of typical retailer costs compared to consumer bills.

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[7] AEMO. *2023 Inputs, Assumptions and Scenarios Report*. https://aemo.com.au/-/media/files/major-publications/isp/2023/2023-inputs-assumptions-and-scenarios-report.pdf?la=en

[8] https://www.energyrating.gov.au/industry-information/publications/report-2021-residential-baseline-study-australia-and-new-zealand-2000-2040

[9] https://www.eia.gov/consumption/commercial/data/2018/index.php?view=consumption

The above methodology will result in an estimate of potential benefits allocations of load flexibility for each segment to be modelled. These allocations will then be taken forward into Phase B of the analysis.

2.2.4. Phase B.1

The following section outlines the key inputs and methods of Phase B.1, which will seek to determine the feasibility of load flexibility programs being implemented from a given policy option.

Required Flexibility Uptake

The implementation of a load flexibility program from an aggregator's perspective involves both fixed and variable costs, as well as a required return on investment. Based on the benefit allocation calculated in Phase A.2, this model will calculate whether the BaU level of flexibility uptake assumed would be enough to ensure the viability of a given CER load flexibility program, or what the minimum uptake threshold of additional load flexibility for that CER device would need to be.

The various implementation costs for a load flexibility program will be estimated through desktop research and stakeholder feedback.

Min/Max Flexibility Uptake

To determine whether the flexibility uptake threshold is feasible, a minimum and maximum level flexibility uptake for a given consumer segment will be estimated, utilising the BaU flexibility uptake as the minimum level, i.e. additional benefits unlocked through a policy change can only serve to increase consumer participation.

To characterise a max participation trajectory, a literature review of studies into the uptake propensity of consumers into programs where the magnitude of costs and benefits align to the modelling outcomes in Phase A.2 will be undertaken. The findings will be used to determine the potential additional uptake of a given load flexibility program, based on the net consumer benefits calculated.

2.2.5. Phase B.2

The following section outlines the key inputs and methods of the final phase, which will determine the additional CER device uptake resulting from load flexibility benefits, should a sufficient magnitude of benefits exist to enable this analysis.

Market Uptake Propensity

Energeia will develop a flexible resource uptake model which will utilise the historical relationship between CER uptake and consumer return-on-investment (ROI) to forecast future CER uptake in response to calculated changes in ROI.

The model will use historical solar PV installations to characterise the relationship between return on investment and uptake as it is an investment decision that does not impact a consumer's utility, like that of adopting load flexibility. ROI will be calculated based on historic tariffs and total system installation costs.

This modelling will result in a parameterised relationship between return on investment and the consumers' likelihood of uptake of a cost-saving energy device.

CER Device Uptake Model

Utilising the determined uptake parametrisation, Energeia will apply each CER flexibility consumer ROI based on the determined additional passed-through consumer benefits, and the additional costs to the consumer compared with selecting a similar device which does not allow for load flexibility.

The additional value can be used to determine the marginal uptake impact of separating CER. Energeia will produce a forecast of CER uptake inclusive of the marginal uptake of CER uptake in addition to the BaU, due to the Rule change unlocking additional load flexibility benefits.

2.3. Key Modelling Limitations

The following modelling simplifications were implemented to make the resulting model parsimonious and tractable. However, the modelling methodology is, in our view, fit-for-purpose given the scope and purpose of the project to inform the AEMC regarding the indicative size of the load flexibility market and to provide an indicative estimate of the required Rule change impacts needed to cover the implementation costs.

- Energeia carried out an analysis of end use load magnitudes by consumer segment and a review of third-party load flexibility assessments to inform our proposed scoping of flexible loads to be included in the modelling, which was then validated with the AEMC team. The findings are shown in Section 3. Not all consumer segments and flexible load technologies are included in the modelling due to the probability of the technology to be a significant source of flexibility, and quality of information available.
- 30-minute profiles are used despite market settlement moving to 5-minutes. While 5-minutes is important for several reasons including greater accurate of faster response resources, it is in our view unlikely to be justified given the indicative nature of this work.
- While the impacts by representative consumers will be scaled to represent the population accurately, there is a possibility that the use of representative consumers could exaggerate peak and minimum demand impacts, potentially overstating the impacts of load flexibility due to load homogeneity. However the impacts of this are likely to be mitigated by the fact that consumers face the same incentives for load flexibility, and that aggregated load flexibility seeks to homogenise consumer loads in any case.
- The modelling method contains interactions between consumer behaviour and the wholesale and FCAS markets as well as transmission and distribution networks to determine the value of load flexibility. However there will be no feedback loop between electricity wholesale market outcomes and load flexibility. The modelling captures first order wholesale market effects of avoided RRP cost, the second order effects will be determined by an allocation of value across the stakeholders, including consumers.
- Modelling of grid impacts will be undertaken on a network-wide basis. The modelling assumes a continuous benefit from reducing peak and increasing minimum demand, based on the associated LRMC for thermal and voltage upgrades. In reality, the benefit will depend on the quantum required, available and associated cost. While the impacts will vary within networks this should give a relatively unbiased view of network wide benefits.

More detailed and complex modelling is recommended in the future to gain a clearer understanding of the potential benefits on a more granular basis.

2.4. Timeline

Figure 3 shows the indicative modelling timeline. Energeia will deliver Phase A and Phase B of the modelling in an iterative process with the AEMC.

Table 1 – Indicative Modelling Timeline

Stage	Timeline
Commission publishes directions paper	3 August 2023
Stakeholder submissions due	14 September 2023
Stakeholder forums workshops	September and October 2023
The Commission publishes a draft determination and may publish a draft rule	Dec 2023
Stakeholder submissions due	Late-January 2023
The Commission publishes a final determination and final rule (if any)	March/April 2024

Source: Energeia

3. Key Data Sources and Assumptions

The following sections describe Energeia's key inputs and assumptions that will feed into the previously described modelling methodologies.

3.1. Scope of Flexible Loads Considered

Energeia carried out an analysis of end use load magnitudes by consumer segment and a review of third-party load flexibility assessments to inform our proposed scoping of flexible loads to be included in the modelling, which was then validated with the AEMC team.

Table 1 outlines the range of flexible loads and consumer segmentations initially incorporated as part of our analysis and the resulting scope, designed to capture the most significant flexible loads[10].

Table 2 – Initial Scope of Flexible Loads

Consumer Type	Appliances	Flexibility Options
Residential and Small Business	Water Heating	Shift Shed
	Heating, Ventilation and Air Conditioning (HVAC)	Shift Shed
	Pools / Spas	Shift Shed
	Lighting	✕
	Cooking	✕
	Solar PV	Shed
	Battery	Shift
	EV Charging and Discharging	Shift Shed
	Refrigeration	✕
Large Business**	Water Heating	Shift Shed
	HVAC*	Shift Shed
	Pools / Spas	✕
	Lighting	✕
	Cooking	✕
	Solar PV	Shed
	Battery	Shift
	EV Charging and Discharging	Shift Shed
	Refrigeration*	Shift Shed

* Will vary by type of consumer
** Does not include industrial consumers
Source: Energeia

It's important to note that upon discussion with the AEMC, industrial consumers were deemed out of scope as they are already strongly involved in the market with regards to their flexibility (registered loads etc.).

10 Load shifting refers to moving electricity consumption from one time period to another. Load shedding refers to reducing/removing electricity consumption.

3.1.1. Load Magnitude by End Use

Energeia conducted a quantitative analysis of estimated building end uses by consumer segment to identify the highest consumption end uses in the NEM states. This analysis provides insight into the existing resource potential.

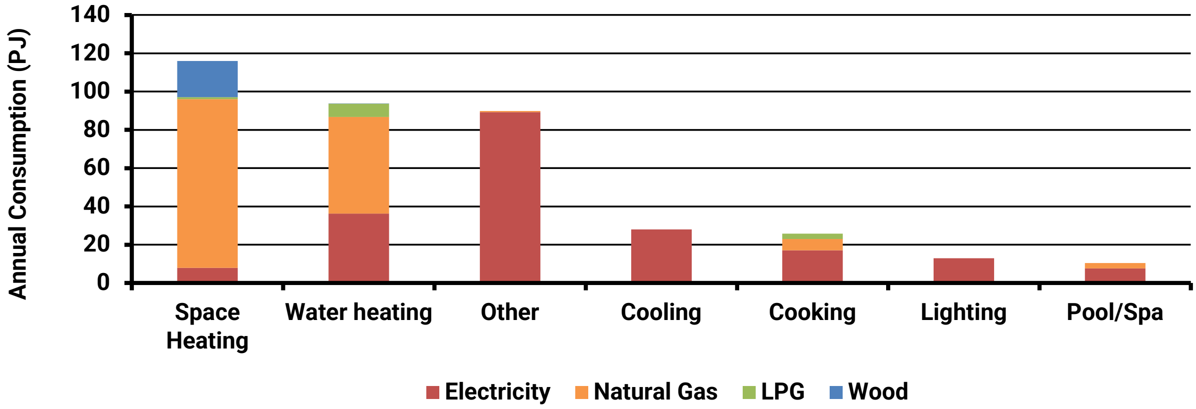
The capabilities for each end use to be utilised as a flexible resource is discussed in Section 3.1.2.

Residential Buildings

Energeia sourced data from the 2021 Residential Baseline Study[11] to identify the most significant residential end uses by consumption.

As shown in Figure 4, space heating and water heating are responsible for the most significant end use consumption in the NEM states, with most of this energy being provided by natural gas. 'Other' end uses are also a significant source of load but are not further considered due to the lack of information regarding the nature of the load.

Figure 3 – NEM Residential End Use Consumption by Fuel Type

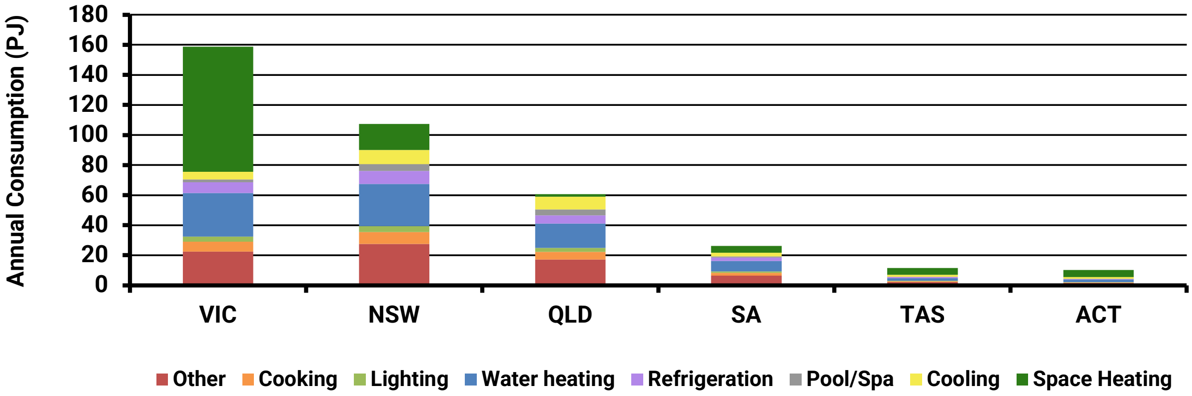


Source: EnergyConsult (2022), Energeia

Figure 5 shows consumption by NEM state and end use. Victoria leads with an extreme, predominantly gas-fuelled space heating load. The other states show expected breakdowns based on their differing climates and populations.

[11] https://www.energyrating.gov.au/industry-information/publications/report-2021-residential-baseline-study-australia-and-new-zealand-2000-2040

Figure 4 – Residential End Use Consumption by NEM State



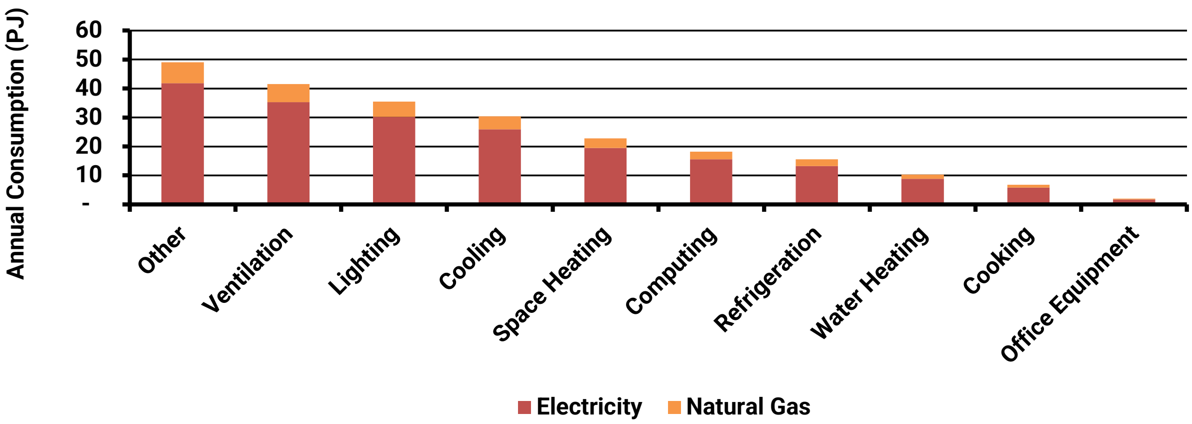
Source: EnergyConsult (2022), Energeia

Commercial Buildings

To the best of Energeia's knowledge, there is no publicly available dataset that estimates subload consumption by commercial building type in Australia. As such, Energeia estimated commercial subload energy consumption by fuel type and end use in NEM states by gathering commercial end use energy intensities, sourced from US data,[12] and applying them to Australian energy consumption by building type from the 2022 Commercial Buildings Energy Consumption Baseline Study.[13]

Figure 6 displays the total annual electricity and natural gas consumption by end use. 'Other' end uses provide the greatest source of consumption but as with the residential segment, these are out of scope, as are the more minor loads of computing and office equipment. Of the remaining loads, HVAC loads (space heating, cooling, and ventilation) are the most significant, alongside lighting – which Energeia deemed as inflexible (Table 1).

Figure 5 – NEM Commercial End Use Consumption by Fuel Type



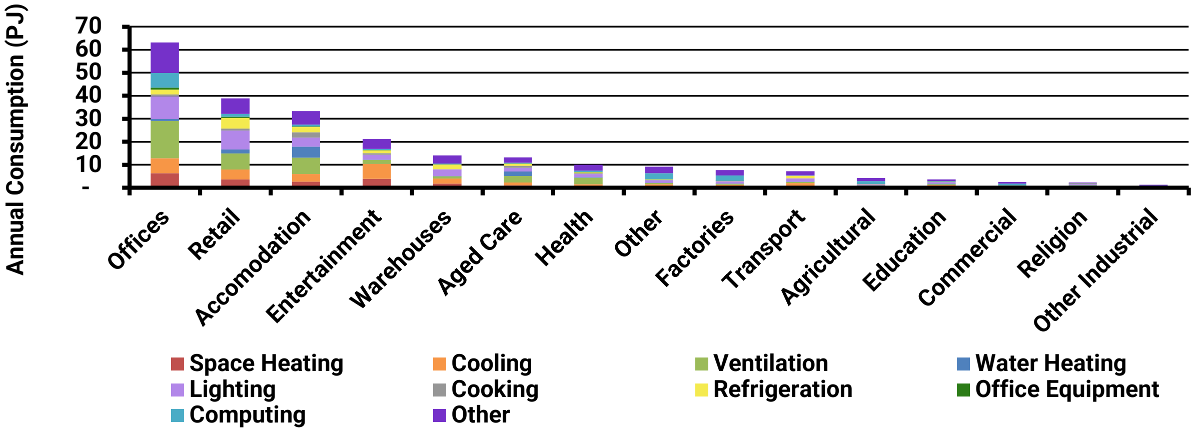
Source: Energy Information Administration (2018), DCCEEW (2022), Energeia

[12] https://www.eia.gov/consumption/commercial/data/2018/index.php?view=consumption

[13] https://www.energy.gov.au/publications/commercial-buildings-energy-consumption-baseline-study-2022

Figure 7 displays the end use consumption by building type, showing that office buildings are the dominant consumption source in the NEM states, followed by retail and accommodation. Although there is some variation between building types, HVAC loads and lighting are frequently the highest sources of consumption, consistent with the results in Figure 6.

Figure 6 – NEM Commercial End Use Consumption by Building Type



Source: Energy Information Administration (2018), DCCEEW (2022), Energeia

3.1.2. End Use Load Flexibility Potential

Energeia researched the latest research regarding load flexibility and found two key reports relevant to this study. The first is from the Reliable Affordable Clean Energy (RACE) for 2030 initiative and the second is from the Australian Renewable Energy Agency (ARENA) assessing the flexibility potential of different loads in the Australian context to supplement discussions with the AEMC on which loads to include in the modelling scope. This research was used to inform our final scoping of which end uses and technologies were likely to be the most significant for including in the study.

RACE for 2030 – Opportunity Assessment, Flexible Demand and Demand Control

RACE for 2030[14] commissioned an assessment of the prospective potential for commercial load flexibility by end use, with the aim of identifying priority research areas to assist in advancing flexible demand growth.

Assessments were completed using a semi-qualitative HUFF Matrix, which evaluates potential load flexibility using the following criteria:

- **Homogeneity:** How replicable is the solution?
- **Ubiquity:** How scalable is the solution?
- **Feasibility (techno-economic):** How cost effective if the solution?
- **Feasibility (realistic):** How well does the solution fit with the industry?

Each type of load was given a score of 1 to 3 for each of the HUFF criterion, where a higher score is more prospective based on a qualitative assessment. Scores were summed to produce a total ranging from 4 to 12. Each building type was also given a score of 1 to 3 for each criterion and

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[14] https://www.racefor2030.com.au/wp-content/uploads/2021/10/RACE-B4-OA-Final-report.pdf

summed. The summed load and building scores were multiplied to produce the final score in the matrix for each opportunity (hence the scores could range from 16 to 144).

The HUFF Matrix shown in Figure 8 rated HVAC and electrical storage as the most prospective forms of load flexibility in the commercial sector. Embedded generation, water heating, thermal storage, and refrigeration were also highly rated. Commercial EV flexibility was given the lowest rating.

Figure 7 – Commercial End Use HUFF Matrix

	HVAC	Heat pumps	Hot water	Thermal storage	Electric vehicles	Pool pumps	Embedded generation	Electrical storage	Refrigeration
Retail	70	56	63	63	35		63	70	
Offices	80	64	72	72	40		72	80	
Warehouses	80	64		72	40		72	80	72
Apartments	90	72	81	81	45	72	81	90	81
Public buildings	90	72	81	81	45		81	90	81
Data centres				63			63	70	
Supermarkets	90	72	81	81	45		81	90	81
Aquatic centres		72	81	81	45	72	81	90	

Source: RACE for 2030 (2021)

ARENA – Load Flexibility Study

ARENA[15] identified load flexibility as a focus area in their 2021 Investment Plan, leading them to produce their Load Flexibility Study. ARENA used PLEXOS[16] to model a range of scenarios through to 2040 and reported the magnitude of load flexibility by resource.

Figure 9 shows results by scenario, each indicating the total modelled load flexibility contributions by resource. Across all the scenarios, residential EV charging and hot water heating were significant contributors to flexible load, with minor contributions from residential pool pumps. The High DER Uptake scenario showed battery as the largest flexible load. On the commercial side, water heating provided the most flexible load. Other resources were modelled to be relatively negligible.

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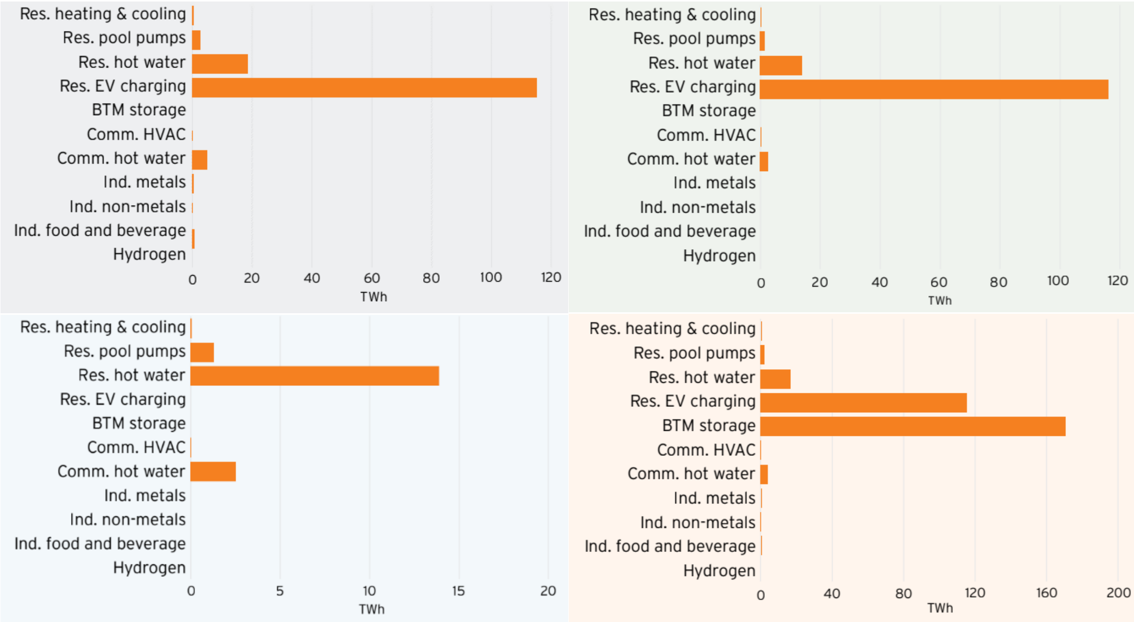
[15] https://arena.gov.au/assets/2022/02/load-flexibility-study-technical-summary.pdf

[16] PLEXOS is a specialised market simulation software, https://www.energyexemplar.com/plexos

Figure 8 – Modelled Flexible Load by Scenario (2021-2040)



Scenarios: Baseline (top left), High EV Uptake (top right), Electrification (bottom left), High DER Uptake (bottom right)
Source: ARENA (2022)

3.1.3. Proposed Subload Inclusions

Table 2 outlines the resulting proposed scope of flexible loads to be included in the modelling, which has been refined from the original scope in Table 1.

It is important reiterate that the objective of this project is not to model every flexible load option, but rather to estimate the quantum of system benefits that added load flexibility could potentially provide and how large these benefits and the consumer allocation would need to be to justify the industry costs associated with a potential Rule change, as well as to determine if there are any broad opportunities that may be particularly attractive for policymakers and regulators to focus on.

Table 3 – Proposed Scope of Flexible Loads

Category	Sub Load	Estimated Total Energy Consumption/Generation (PJ, 2023)	Load Flexibility Ranking	Include/Exclude?	Flexibility Options
Residential and Small Business	Space Heating	121.2	Medium	✗	Shift Shed
	Water Heating	96.1	High	✓	Shift Shed
	Solar PV	82.6	High	✓	Shed
	Space Cooling	34.9	Medium	✗	Shift Shed
	Cooking	25.7	Low	✗	✗
	Refrigeration	15.5	Low	✗	✗
	Lighting	12.9	Low	✗	✗
	Pools / Spas	10.3	High	✓	Shift Shed
	Ventilation	9.5	Medium	✗	Shift Shed
	Battery	8.0	High	✓	Shift
	EV Charging EV Discharging	1.0	High	✓	Shift Shed
Large Business	Solar PV	82.6	High	✓	Shed
	Ventilation	32.0	Medium	✓	Shift Shed
	Lighting	27.3	Low	✗	✗
	Space Cooling	23.5	Medium	✗	Shift Shed
	Space Heating	17.6	Medium	✗	Shift Shed
	Refrigeration	12.0	High	✓	✗
	Water Heating	7.9	High	✓	Shift Shed
	Battery	8.0	High	✓	Shift
	Cooking	5.2	Low	✗	✗
	EV Charging EV Discharging	1.0	Low	✗	Shift Shed
	Pools / Spas	0.0	High	✗	Shift Shed

* Does not include industrial consumers
** NEM state totals. Residential and commercial splits of EV, PV and battery are TBD
Source: Energy Information Administration (2018), DCCEEW (2022), AEMO (2023), Energeia

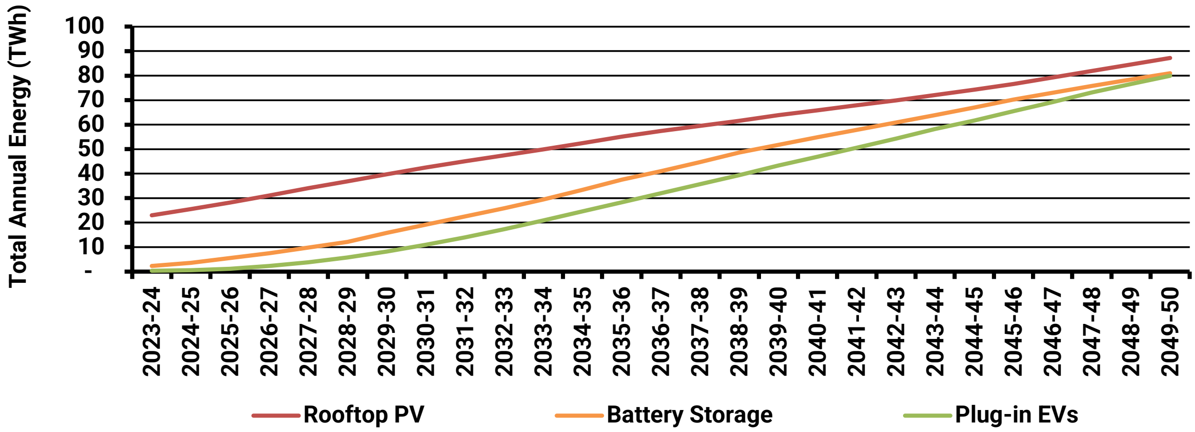
More detailed explanations for the notable inclusions and exclusions are as below:

- Space heating, cooling and ventilation are excluded as they are not expected to be a practical source of flexibility due to the lack of centralised control and smart home thermostats in Australia. Electrification of heating may increase ability of control in the future, and thus in future iterations, this assumption should be revisited. Additionally, ARENA did not find these loads to be significant flexibility resources in their modelling (See Figure).
- Refrigeration is also excluded from the residential and small business segment for similar reasons regarding lack of opportunity and materiality of flexibility. Refrigeration is included in the large business segment as they are not expected to have the same degree

of conflict and have been identified as potentially flexible loads by RACE for 2030 (See Figure).

- Battery and EV flexibility is included despite current uptake levels being low, as they are expected to grow in uptake in future and are highly flexible resources. Figure 10 shows the forecast uptake from AEMO's Draft Integrated System Plan (ISP) Inputs, Assumptions and Scenarios Report (IASR) 2024[17].

Figure 9 – Total Energy by CER, 1.8°C Orchestrated Step Change



Source: AEMO (2022)

Another key finding of the analysis and validation with the AEMC was that modelling of small and large businesses would be represented by the following key building types:

- Offices
- Retail
- Accommodation
- Entertainment
- Warehouses
- Health

These categories were selected due to these commercial building types having the highest total consumption across the NEM (see Figure 7), therefore representing most of the system.

[17] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/2023-inputs-assumptions-and-scenarios-consultation/draft-2023-inputs-and-assumptions-workbook.xlsx?la=en

3.2. Data Sources and Assumptions

This section presents a detailed list of key data sources and assumptions Energeia proposes to use, categorised by modelling phase.

3.2.1. Phase A.1

Table 4 – List of Phase A.1 Modelling Inputs and Assumptions

Input Category	Input	Source	Publication Date
Loads and Subloads	Residential Subload Shapes	2021 Residential Baseline Study for Australia and New Zealand for 2000 — 2040 (EnergyConsult)	2022
	Commercial Subload Shapes	End-Use Load Profiles for the U.S. Building Stock (NREL)	2021
	US Weather Data	End-Use Load Profiles for the U.S. Building Stock (NREL)	2021
	AU Weather Data	Visual Crossing	2023
	Typical Annual Residential Appliance Usage	2021 Residential Baseline Study for Australia and New Zealand for 2000 — 2040 (EnergyConsult)	2022
	Typical Annual Commercial Appliance Usage	Energeia Modelling via 2018 CBECS Survey Data (EIA) and Commercial Buildings Energy Consumption Baseline Study 2022 (SPR)	2018, 2022
Wholesale Prices	Electricity Price by Interval	2022 Regional Reference Prices by State (NEMWeb via UNSW NEMOSIS)	2022
	Ancillary Services Price by Interval	2022 Frequency-Controlled Ancillary Service Prices by State (NEMWeb via UNSW NEMOSIS)	2022
	Electricity Price Forecast	AEMC	TBC
	FCAS Price Forecast	AEMC	TBC
Network Costs	Peak Demand LRMC	DNSP Tariff Structure Statements (Ausgrid, UED, SAPN, Energex and TasNetworks)	2017-2022
	Peak Voltage LRMC	Energeia Modelling	2023
Grid Emissions	Grid Emission Intensities	AEMC	TBC
Segment Scaling	Residential Consumers by Segment	2021 Residential Baseline Study for Australia and New Zealand for 2000 — 2040 (Energy Consult)	2022
	Commercial Consumers by Segment	Commercial Buildings Energy Consumption Baseline Study 2022 (SPR)	2022
	Aggregate Residential Consumption by Segment	2021 Residential Baseline Study for Australia and New Zealand for 2000 — 2040 (Energy Consult)	2022
	Aggregate Commercial Consumption by Segment	Energeia Modelling via 2018 CBECS Survey Data (EIS) and Commercial Buildings Energy Consumption Baseline Study 2022 (SPR)	2018, 2022
	Small vs. Large Commercial Consumer Split	DNSP RIN Category Analysis (various)	2022
	Residential Consumer Growth Forecast	Energeia Modelling via 2022 Macroeconomic Projections Report (BIS Oxford) and Census of Population and Housing (ABS)	2022, 2022
	Commercial Consumer Growth Forecast	Energeia Modelling via 2022 Macroeconomic Projections Report (BIS Oxford) and Census of Population and Housing (ABS)	2022, 2022
Historical CER Uptake	Residential Appliance Uptake by Segment	2021 Residential Baseline Study for Australia and New Zealand for 2000 — 2040 (Energy Consult)	2022
	Commercial Appliance Uptake by Segment	Commercial Buildings Energy Consumption Baseline Study 2022 (SPR)	2022
	Residential Solar PV Uptake by Segment	Energeia Modelling via PV Postcode Data (APVI)	2022
	Commercial Solar PV Uptake by Segment	Energeia Modelling via PV Postcode Data (APVI)	2022
	Residential Battery Uptake by Segment	Energeia via 2022 NEM ISP	2022

	Commercial Battery Uptake by Segment	Energeia via 2022 NEM ISP	2022
	Residential EV Uptake by Segment	Energeia Modelling via vFacts (FCAI)	2022
Base CER Flexibility Forecast	Residential Appliance Uptake by Segment	2021 Residential Baseline Study for Australia and New Zealand for 2000 — 2040 (Energy Consult)	2022
	Commercial Appliance Uptake by Segment	Energeia Modelling via Commercial Buildings Energy Consumption Baseline Study 2022 (SPR)	2022
	Residential Solar PV Uptake by Segment	Energeia via NEM IASR Step Change Scenario	2022
	Commercial Solar PV Uptake by Segment	Energeia via NEM IASR Step Change Scenario	2022
	Residential Battery Uptake by Segment	Energeia via NEM IASR Step Change Scenario	2022
	Commercial Battery Uptake by Segment	Energeia via NEM IASR Step Change Scenario	2022
	Residential EV Uptake by Segment	Energeia via NEM IASR Step Change Scenario	2022
	Flexibility Participation Rate Forecast	Energeia via NEM IASR Step Change Scenario	2022

Note: CBECS – Commercial Buildings Energy Consumption Survey, EIA – Energy Information Administration, NREL – National Renewable Energy Laboratory, SAPN – South Australia Power Networks, UED – United Energy Distribution, UNSW – University of New South Wales
Source: Energeia

3.2.2. Phase A.2

Table 5 – List of Additional Inputs Required for Phase A.2

Input Category	Input	Source	Publication Date
Flexibility Hosting Profit Margins	Residential Retail Tariffs	Time of Use Energy Tariffs in Ausgrid, UED, SAPN, Energex and TasNetworks	2023
	Small Commercial Retail Tariffs	Time of Use Energy Tariffs in Ausgrid, UED, SAPN, Energex and TasNetworks	2023
	Large Commercial Network Tariffs	Default Large Consumer Network Tariff	2023
	Residential Network Tariffs	Time of Use Energy Tariffs in Ausgrid, UED, SAPN, Energex and TasNetworks, from Pricing Proposal	2023
	Small Commercial Network Tariffs	Time of Use Energy Tariffs in Ausgrid, UED, SAPN, Energex and TasNetworks, from Pricing Proposal	2023
	Electricity Price by Interval	2022 Regional Reference Prices by State (NEMWeb via UNSW NEMOSIS)	2022
	Retailer Costs	Residential Electricity Price Trends Report (AEMC)	2016-2022
	Electricity Consumption Load Profile	As per Residential and Commercial Subload Profile data	
CER Flexibility Hosting	Flexibility Hosting Costs by Segment	Desktop Research and Stakeholder Feedback	
CER Benefits Allocation	Producer/Consumer Surplus	Academic Literature	

Source: Energeia

3.2.3. Phase B.1

Table 6 – List of Additional Inputs Required for Phase B.1

Input Category	Input	Source	Publication Date
CER Flexibility Implementation Costs	Flexibility Implementation Costs by Segment	Desktop Research and Stakeholder Feedback	
Program Enrolment	Propensity of Consumers to Enrol in Benefit Programs	Academic Literature	

3.2.4. Phase B.2

Table 7 – List of Additional Inputs Required for Phase B.2

Input Category	Input	Source	Publication Date
Electricity Prices	Historic Retail Electricity Price	Residential Electricity Price Trends Report (AEMC)	2016-2022
	Forecast Electricity Price	NEM ISP 2023 residential retail price index (AEMO)	2022
	Historic Feed-In Tariffs	Historic Retailer Tariff Publications by State (Retailer Websites)	2016-2022
	Forecast Feed-In Tariffs	Energeia Modelling based on CECV (AER)	2023
Solar PV System Prices	Historic PV System Costs	SolarQuotes	2022
	Forecast PV System Costs	GenCost 2022-23 (CSIRO)	2022
	STC Values	Clean Energy Regulator	2023
Average Solar PV System Size	Historic Average Solar PV System Installed	PV Postcode Data (APVI)	2023
	Forecast Average Solar PV System Installed	Energeia Assumption based on NEM ISP IASR (AEMO)	2022
Consumer Load	Electricity Consumption Load Profile	As per Residential and Commercial Sub load Profile data	
	Solar PV Load Trace	PVWatts (NREL)	2023
Appliance Costs	Base Equipment and Installation Costs	Appliance Retailer Websites	
	Base Equipment and Installation Cost Forecast	Desktop Research of Trade and Consumer Websites	
	Load Flexibility Enablement Costs	Regulation Impact Statement for Decision: 'Smart' Demand Response Capabilities for Selected Appliances (E3)	2019

Source: Energeia, Note: CSIRO – Commonwealth Scientific and Industrial Research Organisation

Energeia's mission is to empower our clients by providing the evidence-based advice using the best analytical tools and information available

Heritage

Energeia was founded in 2009 to pursue a gap foreseen in the professional services market for specialist information, skills and expertise that would be required for the industry's transformation over the coming years.

Since then the market has responded strongly to our unique philosophy and value proposition, geared towards those at the forefront and cutting edge of the energy sector.

Energeia has been working on landmark projects focused on emerging opportunities and solving complex issues transforming the industry to manage the overall impact.

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