ACIL ALLEN CONSULTING

REPORT TO
AUSTRALIAN ENERGY REGULATOR
19 FEBRUARY 2020

VALUE OF CUSTOMER RELIABILITY

FOR WIDESPREAD AND LONG DURATION OUTAGES

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EXECUTIVE SUMMARY

The Australian Energy Regulator (AER) engaged ACIL Allen Consulting (ACIL Allen) to estimate the Value of Customer Reliability (VCR) for widespread and long duration outages (WALDO) for the National Electricity Market (NEM) jurisdictions,[1] using a macroeconomic modelling methodology supplemented by other appropriate approaches.

For the purposes of this analysis, a WALDO is defined as an outage ranging in severity from 1-2 Giga Watthours (GWh) to 15 GWh of unserved energy.[2]

In its instructions to ACIL Allen, the AER specified that WALDO VCRs are to be derived in this model by reference to the energy lost and not by direct reference to any specific site or location. Rather, the derived values are based on a synthesis of residential, commercial, industrial and social activity such as may be found in various regions of Australia within the NEM, but loosely informed by consideration of a range of potentially representative locations.

The intention of this work is to help guide the management of risk by NEM agencies by identifying the potential impact were a widespread or long duration outage event to occur. The AER does not consider any of the scenarios discussed herein are likely to occur.

This model does not attempt to model impacts from a natural disaster event; its usage is restricted to the impacts arising from events solely within the NEM.

Approach to modelling the WALDO VCR

As illustrated in Figure ES 1, the WALDO VCR comprises:

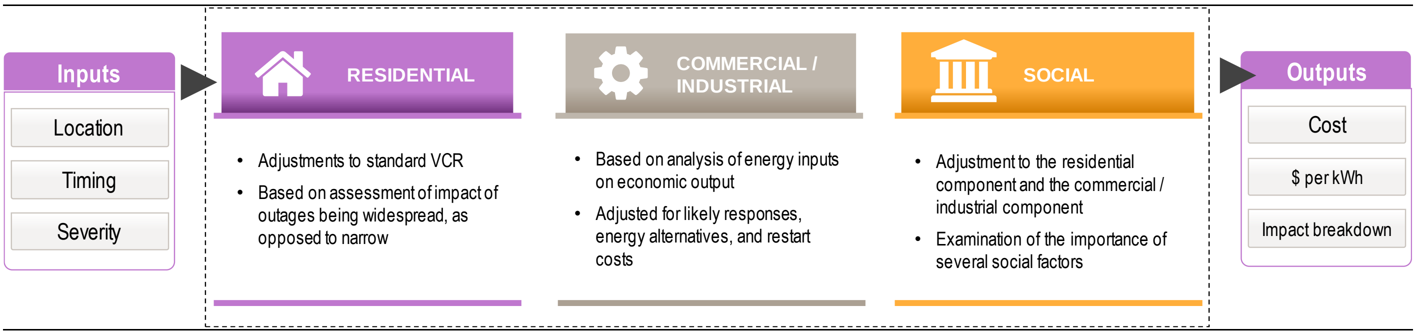
- a residential component
- a commercial / industrial component
- social costs associated with WALDOs.

Each component is estimated using a separate methodology and then combined into a single WALDO VCR for a given set of parameters in a MS Excel model.

[1] WALDO VCRs are not required for the Northern Territory

[2] Australian Energy Regulator, *Values of Customer Reliability, Final Decision*, November 2019, page 17

FIGURE ES 1 OVERVIEW OF THE WALDO VCR METHODOLOGY



SOURCE: ACIL ALLEN

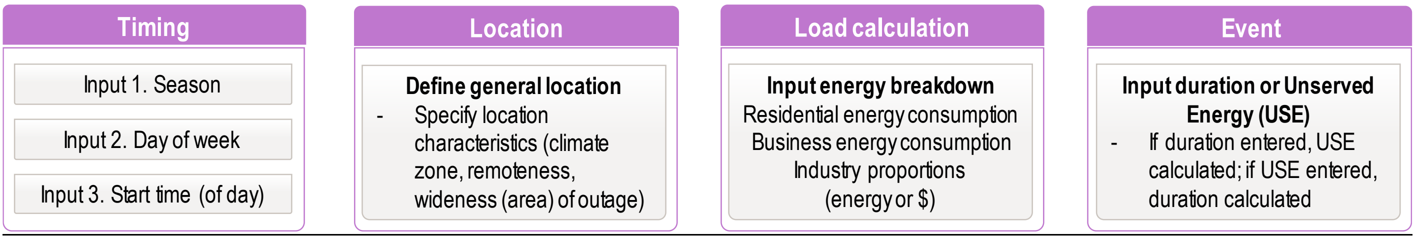
User inputs to the model

The WALDO VCR depends on the:

- timing of the outage
- location of the outage
- load impacted by the outage
- characteristics of the outage event.

These factors are provided as an input to the model, as illustrated at a high level in Figure ES 2.

FIGURE ES 2 USER INPUTS TO THE MODEL



SOURCE: ACIL ALLEN

Timing of the outage

The timing of the outage is specified by reference to:

- the season – summer or winter
- the day of the week – weekday or weekend
- start time – which indicates whether the outage occurs during peak time or off-peak time.

These parameters align with those used for the 'standard' VCRs which have been determined by the AER.[3]

Location

The location of the outage is specified by reference to the climate zone and the remoteness (CBD, suburban and regional). There are 19 combinations of climate zone and remoteness that align with the locations for the 'standard' VCRs which have been determined by the AER.

[3] Australian Energy Regulator, *Values of Customer Reliability – Final Decision*, December 2019

Load impacted by the outage

The residential and business load (in GWh per annum) is specified. The business load is further broken down by industry sector using the one digit Australian and New Zealand Standard Industrial Classification (ANZSIC), with a further disaggregation of the manufacturing sector into metal smelting and manufacturing excluding metal smelting, due to the unique characteristics associated with metal smelting.

Nature of the outage

The outage is specified in terms of the duration of the outage or the unserved energy. If the duration of the outage is specified, the unserved energy is calculated, and vice versa.

Residential component of the WALDO VCR

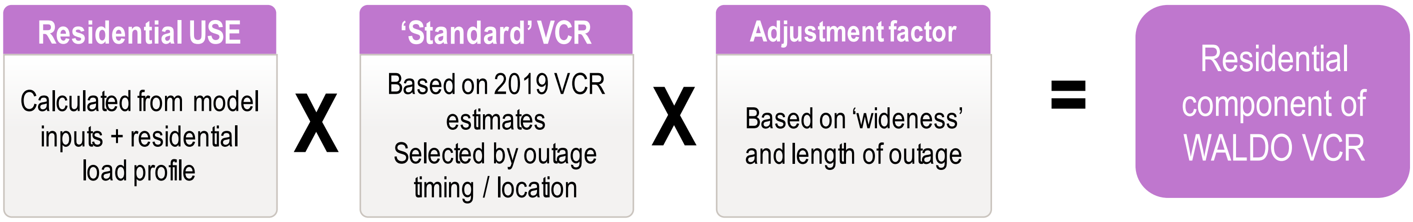
The residential component of the 'standard' VCR is based on the amount that individual households are prepared to pay to avoid an outage. Outages may typically span up to a few suburbs. It is therefore inherent in the estimates of the 'standard' VCRs that customers would have the option of travelling to a different location to spend their time (e.g. at a shopping centre or cinema), as the 'next best alternative' to being at home, or to buy meals.

A WALDO limits the ability of residential customers to do this, depending on how widespread the outage is. The result is that the 'standard' VCRs have been adjusted to account for these different financial and non-financial impacts on customers.

Additionally, the 'standard' VCR is based on an outage of up to 12 hours duration. A long duration outage could extend beyond 12 hours. In this case, the 'standard' VCRs are adjusted to account for the longer duration of the outage.

Figure ES 3 outlines the broad approach to estimating the residential impact of a WALDO – the unserved energy (USE) is multiplied by the 'standard' VCR (in dollars per kWh), which is multiplied by an adjustment factor that accounts for the WALDO being wider and /or longer than a 'standard' outage. The output is in dollars.

FIGURE ES 3 APPROACH TO CALCULATING THE WALDO VCR FOR RESIDENTIAL CUSTOMERS



SOURCE: ACIL ALLEN

Residential USE

The residential USE is calculated based on the residential load profile and the:

- annual energy consumption by the residential customers impacted by the outage
- timing of the outage (season, day of week and time of outage)
- duration of the outage.

The model includes a residential load profile for each climate zone, by summer and winter and by weekday and weekend.[4] These are based on metering data collected for the AER's energy consumption bill benchmarks and are the same as those used by the AER in calculating the 'standard' VCRs.

[4] The residential load profiles are provided as Appendix B.

'Standard' VCRs

The calculation of the WALDO VCR uses the 'standard' VCRs for residential customers that have determined by the AER for each location option (combinations of remoteness and climate zone) and for each timing option (season, day of week and 'peak' and 'off-peak' based on the time of day).[5]

The relevant 'standard' VCR(s) is used to calculate the residential component of the WALDO VCR. If more than one combination of remoteness and climate zone is selected, the model averages the 'standard' VCRs for each combination of remoteness and climate zone.

Adjustment factor

Two adjustment factors are used to calculate the WALDO VCR – one based on the wideness of the outage and one based on the duration of the outage.

We have assumed three levels of wideness:

1. outages with a radius less than 5 km, which have a wideness factor of 1.0 applied
2. outages with a radius between 5 km and 85 km, which have a wideness factor of 1.1 applied
3. outages with a radius greater than 85 km, which have a wideness factor of 1.3 applied.

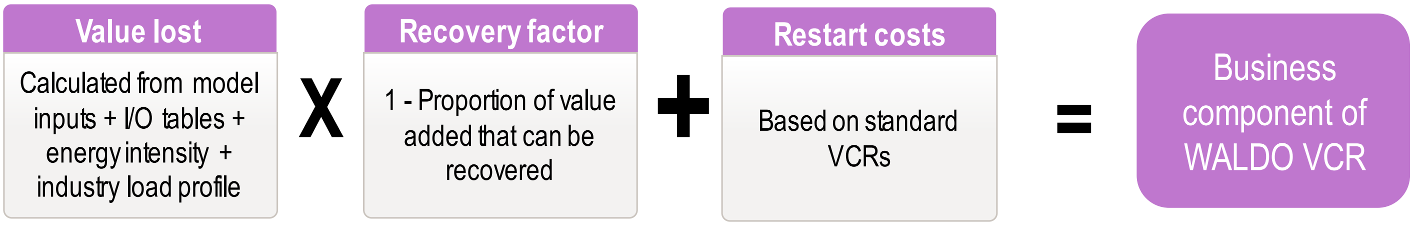
The wideness levels and multipliers have been informed by a literature review.

We fitted a logarithmic curve to each set of 'standard' VCRs for residential customers to extrapolate the four data points for outages longer than 12 hours.

Commercial/industrial component of the WALDO VCR

Figure ES 4 outlines the approach to calculating the commercial / industrial component of the WALDO VCR. The estimate is made for each industry sector by multiplying the potential economic value lost during the outage, as estimated using macroeconometric (Input-Output or I-O) modelling, by a recovery factor for that industry sector, and adding restart costs.

FIGURE ES 4 APPROACH TO CALCULATING THE WALDO VCR FOR COMMERCIAL / INDUSTRIAL CUSTOMERS



SOURCE: ACIL ALLEN

Potential economic value lost

The loss of power to a business 'turns off' value creation by that business. The potential economic value lost by each industry sector during a WALDO is estimated using I-O modelling.[6] The modelling considers the economic value lost by 20 industry sectors – 19 '2 digit' Australian and New Zealand Standard Industrial Classification (ANZSIC) sectors with metal smelting considered separately.

I-O tables, which are taken from the Input-Output tables in the Australian National Accounts, are used to estimate the impact on the businesses in the area directly impacted by the outage. Multipliers, which are calculated for CBD, suburban and regional areas based on the Input-Output tables for a sample of locations, account for the effects on upstream and downstream industries.

The I-O modelling assumes that the loss of economic value is temporary; that is, businesses will restart following the outage.

[5] The 'standard' VCRs are provided as Appendix C.
[6] Further information on I-O modelling is provided as Appendix D.

The estimate of the potential economic value lost also takes into account the following inputs:

- energy intensity by industry sector, which is calculated for each industry sector based on the Input-Output tables and assuming the value of electricity generated is $100 per MWh
- the load profile for each industry sector, which we have estimated for each industry sector[7]
- the following inputs to the model:
  - annual energy consumption or economic output by industrial customers in the scenario
  - timing of the outage (season, day of week and time of outage)
  - duration of the outage.

We have assumed that the load profile aligns with the profile of economic output, consistent with an assumption made in the development of a blackout simulator for the European Union.[8]

Recovery factors

The actual impact of an outage on the economy is based on how much economic activity can be recovered following an outage, for each industry sector. For example, manufacturers might schedule an additional shift so they incur overtime but not the total loss for the period of the outage. Similarly, and a wholesaler might be delayed in sending orders but none are foregone so the economic loss during the outage is largely recovered. However, lost accommodation nights cannot be readily recovered and a restaurant at full capacity will lose sales.

We assumed the recovery factor for each industry sector based on:

- the characteristics of the industry sector, such as the ability to continue production without an electricity supply, the ability to defer production, and the time to restore production following the restoration of supply
- the extent to which the industry sector has back-up generation installed.

Accordingly, recovery factors for each industry sector are set to one of four levels:

- low, which has a recovery factor of 0.1
- medium, which has a recovery factor of 0.5
- high, which has a recovery factor of 0.9
- smelted metals, for which we have assumed that, if the outage exceeds 4 hours, the metal pots will solidify, and the economic impact of the outage may persist for around three months.

Restart costs

After an outage occurs, there is a cost to restart a business. The literature review identified that the costs associated with long duration outages comprise three types of costs:

1. Fixed costs – these costs are incurred, regardless of the duration of the outage.
2. Flow costs – these costs are the value of lost opportunities arising from a lack of power. Flow costs may increase or decrease over time, depending on the extent to which activities can be deferred.
3. Stock costs – these costs occur after a period of time when stock (such as food) starts to spoil, but as time goes on, there is less stock to spoil, and the stock costs decline.[9]

We assumed that the fixed costs are the restart costs. We estimate the fixed costs by assuming that the ‘standard’ VCR for the first hour comprises the fixed costs and the flow costs, and the flow costs are the costs incurred for one hour based on the VCR for hours 6 to 12.

The ‘standard’ business VCRs have been determined by the AER for direct connect customers (industrial, metals, mines and services) and for non-direct customers (agricultural, commercial and industrial, by small/medium and large customers). The restart costs were calculated for each of these ‘standard’ business VCRs.

[7] The industrial load profiles are provided as Appendix E.
[8] Johannes Reichl, Michael Schmidthaler, *Methodology, Assumptions, and an Application of blackout-simulator.com*, Energie Institut, page 6
[9] For example, Sean Ericson, Lars Lisell, *A flexible framework for modelling customer damage functions for power outages*, Energy Systems (2018)

We proportioned the business load across these 'standard' VCR business categories to be able to allocate the restart costs to each of the 20 industry sectors.

Social costs

The final component of the WALDO VCR is the broader social impact of the outage, which captures the costs of WALDOs that are not captured through the residential and commercial / industrial components of the WALDO VCR.

The types of social costs that are incurred during a WALDO will vary depending on the remoteness of the outage. For example, the transportation impacts (congested roads, public transport inoperable) will be greater in urban areas than rural areas, but the animal welfare impacts will be greater in rural areas than in urban areas. Households in apartment buildings impacted by inoperable lifts are more likely to be in urban areas, and households reliant on water for pumping are more likely to be in rural areas.

The literature reviewed concludes that it is difficult to quantify the social costs as they are dependent on the specific circumstances of the outage and the socioeconomic conditions. Most of the literature reviewed references the costs associated with the 1977 blackout in New York City, which lasted for about 25 hours.

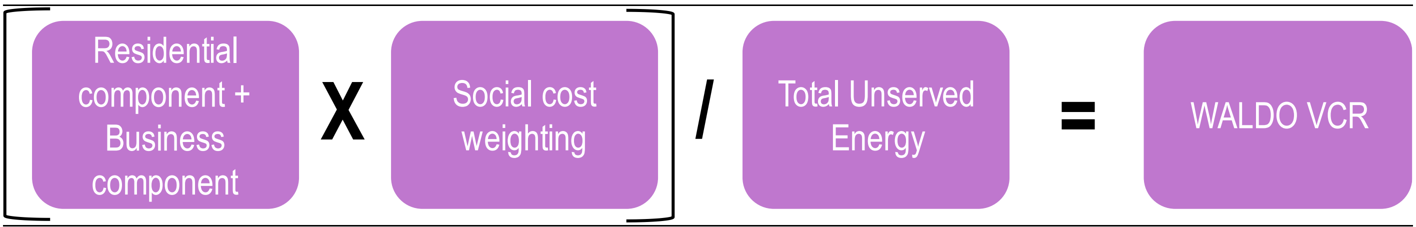
On the face of it, the ratio of indirect costs to direct costs was approximately 5, which is consistent with a 2014 estimate from insurance industry experts.[10] However, there are some costs that have been categorised as indirect that are included in the residential and commercial / industrial components of the WALDO VCR, and some costs associated with arson and looting that many studies attribute to the particular socioeconomic circumstances of New York at that time. If these costs are normalised, the costs that are not included in the residential and commercial / industrial components of the WALDO VCR are approximately 47 per cent of the costs that are included.

Given the uncertainty of the data on social costs, and the variability in the social costs based on the outage, location and socioeconomic conditions, we have applied a multiplier of 1.3 to the residential and commercial / industrial components of the outage costs (other than for metal smelting) for WALDOs to represent the social costs. No multiplier has been applied to the outage costs for metal smelting as we have assumed that the recovery factor for metal smelting provides for these costs.

Calculation of the WALDO VCR

The approach to calculating the WALDO VCR is set out in Figure ES 5. The outage costs incurred by residential and commercial / industrial customers during a WALDO are summed, multiplied by the social cost weighting and divided by the total unserved energy.

FIGURE ES 5 CALCULATION OF WALDO VCR



SOURCE: ACIL ALLEN

[10] Hugh Byrd, Steve Matthewman, *Exergy and the City: the Technology and Sociology of Power (Failure),* Journal of Urban Technology (2014)

Modelling the WALDO VCR

The WALDO VCR model was used to:

— estimate the WALDO VCR for three scenarios:
  – regional Victoria on a winter weekend commencing at 5 pm, with an unserved energy of 1 GWh
  – suburban Queensland on a summer weekday commencing at 7 am, with an unserved energy of 7 GWh
  – South Australia on a summer weekday commencing at 7 am, with an unserved energy of 14 GWh.

— test the sensitivity of the results to changes in the timing of the outage (the season, day of the week and start time).

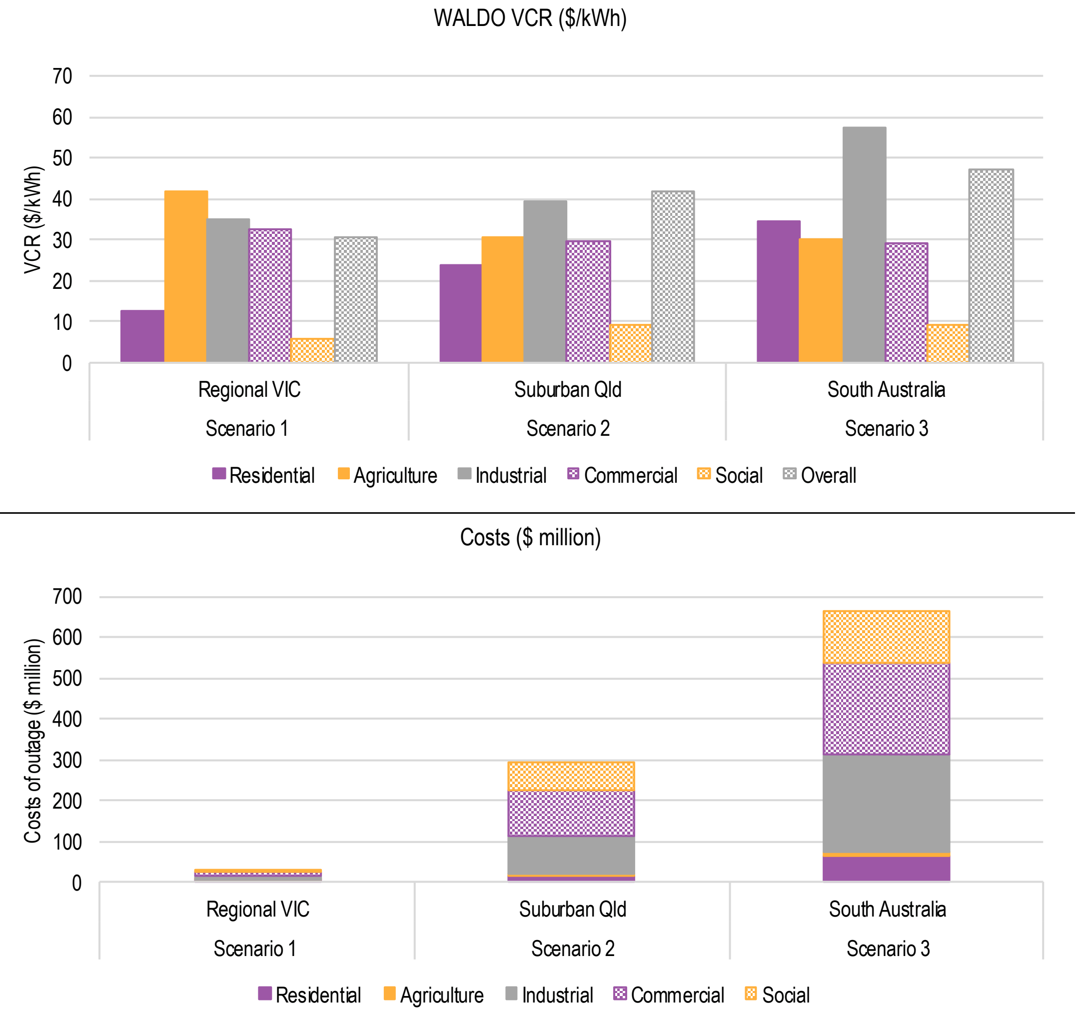
These scenarios are presented in the report for illustrative purposes only.

They should not be interpreted as any reflection of any assessment that has been undertaken that these scenarios are more likely to occur than any other outage scenarios.

Results from modelling the scenarios

The estimated WALDO VCR, and the estimated cost of the outage, for each of the scenarios is illustrated in Figure ES 6 and set out in Table ES 1.

FIGURE ES 6 ESTIMATED WALDO VCR AND OUTAGE COSTS FOR EACH OF THE THREE SCENARIOS ($2019)



SOURCE: ACIL ALLEN ANALYSIS BASED ON WALDO VCR MODEL

TABLE ES 1 ESTIMATED WALDO VCR AND OUTAGE COSTS FOR EACH OF THE THREE SCENARIOS ($2019)

	Scenario 1 – Regional Victoria	Scenario 2 – Suburban Queensland	Scenario 3 – South Australia
WALDO VCR ($/kWh)			
Residential	12.4	23.8	34.7
Agricultural	41.8	30.8	30.2
Industrial	35.0	39.6	57.4
Commercial	32.5	29.8	29.3
Social	5.7	9.1	9.1
Overall	**30.5**	**41.6**	**47.3**
Cost of outage ($ million)			
Residential	5.3	16.1	65.5
Agricultural	1.3	2.6	9.4
Industrial	9.4	92.6	237.0
Commercial	8.9	116.1	224.6
Social	5.7	63.9	126.2
Total	**30.5**	**291.3**	**662.8**

SOURCE: WALDO VCR MODEL

The unserved energy for the regional Victorian outage is significantly less than the unserved energy for the suburban Queensland outage, which is significantly less than the unserved energy for the South Australian outage. As a consequence, the outage costs associated with the regional Victoria outage are significantly less than for the suburban Queensland outage, which are significantly less than for the South Australian outage.

The overall WALDO VCR is less for the regional Victoria outage than for the suburban Queensland outage, which is less than the WALDO VCR for the South Australian outage. The residential VCR in regional Victoria is lower than in suburban Queensland and South Australia, and represents a higher proportion of the outage costs. This is partly offset by a higher agricultural VCR in regional Victoria which represents a higher proportion of the outage costs than in suburban Queensland and South Australia.

The overall WALDO VCR for the South Australian outage is higher than for the outages in regional Victoria and suburban Queensland. This is because:

— the outage is over a larger area and therefore there is a higher wideness factor that is applied to the 'standard' VCR for residential customers

— the outage is shorter than the outage in regional Victoria (the VCR generally decreases as the outage gets longer).

The WALDO VCR for industrial customers in South Australia is higher than for industrial customers impacted by the outage in suburban Queensland, which is higher than for industrial customers impacted by the regional Victoria outage. The differences in the WALDO VCR are attributable to the different composition of the industrial sector in each of the three scenarios.

Results from modelling the sensitivities

The sensitivity testing indicates that the outage costs associated with WALDOs are higher on weekdays than on weekends, higher for outages during peak times rather than off-peak times, and similar in summer and winter.

The WALDO VCRs do not necessarily follow this same pattern. For example, the outage costs for industrial customers during the South Australian outage were higher for an outage on a weekday rather than a weekend, but the WALDO VCR was higher on the weekend rather than on a weekday. This is because the unserved energy for manufacturing customers during an outage on the weekend is significantly lower than on a weekday, which increases the VCR. This is offset in part by the mining load which is the same each day, but with a higher unserved energy on the weekend because the outage would be of 9 hours duration if it occurred on a weekend with total unserved energy of 14 GWh, compared to 5½ hours duration if it occurred on a weekday with the same total unserved energy.

Findings

The modelling of the scenarios and sensitivities has demonstrated that the WALDO VCR is dependent on:

— the characteristics of the load – the proportion of the residential customer load to the business customer load, the breakdown of load by industry sector, and the profile of that load over the day and week
— the characteristics of the outage, in particular whether the outage occurs on a weekend or a weekday, what time the outage commences and the duration of the outage
— the wideness of the outage – the wider the outage, the higher the wideness factor that is applied to the residential load.

The WALDO VCR appears to be similar regardless of whether the outage occurs in summer or winter. This is because the business load is higher than the residential load, and for the purposes of the modelling has been assumed to be the same in winter and in summer.

The results from the WALDO VCR model need to be treated with care as there are a number of assumptions that have been made. In particular:

1. the multiplier that is applied for social costs
2. the multipliers that are applied for the wideness of the outage
3. the industry recovery factors
4. the industrial load profiles.

Further research is recommended to better inform these settings in the model.

Other than the industrial load profiles, the model has been set up so that these factors can readily be updated as more information becomes available.[11] In addition, it has been set up to readily change:

— the proportion of business customers that are direct connected versus not direct connected
— the breakdown of direct connected customers
— the ratio of large to small business customers that are not direct connected
— the constraints that are placed on the model:
  – the minimum outage duration
  – the minimum and maximum unserved energy.

[11] The industrial load profiles can also be changed, but not as readily as the other factors.

1 INTRODUCTION

The Value of Customer Reliability (VCR) seeks to reflect the value that customers place on the reliability of their electricity supply. It is a critical input into identifying efficient levels of network expenditure.

VCRs were first estimated by the former Victorian electricity transmission planner, VENCorp, in 1997 with updates in 2002 and 2007. In 2012, Oakley Greenwood prepared VCRs for New South Wales for the Australian Energy Market Commission (AEMC).

In 2009, the Australian Energy Market Operator (AEMO) was established, subsuming VENCorp as well as the National Electricity Market Management Company (NEMMCO) and a number of other jurisdictional market operators. In 2013, AEMO commenced a review to develop VCRs that could be applied across the National Electricity Market (NEM). The objectives of the review included to reconcile the VCRs that had been estimated for Victoria and NSW, to update the Victorian VCRs, and to develop VCRs for each NEM region.

The AEMO published a set of VCRs in September 2014, which included weighted average VCRs[12] for:

— residential customers by NEM region
— businesses by sector – agriculture, commercial, industrial and direct connected customers.

Despite undertaking this review, AEMO did not have formal responsibility for determining VCRs and updating them. In December 2017 the COAG Energy Council proposed a rule change to give formal responsibility for determining VCRs to the Australian Energy Regulator (AER). A new rule was approved on 5 July 2018 that requires the AER to, among other things:

— develop, publicly consult on, and publish a methodology for estimating the VCRs on a consistent basis across the NEM and the Northern Territory
— publish the first set of VCRs using this methodology by 31 December 2019
— ensure the methodology and VCRs are fit for purpose for any current and potential range of uses of VCRs.

The AER commenced its review of VCRs on 19 October 2018 and published its final report on 18 December 2019. The final report sets out VCR values for unplanned outages of up to 12 hours in duration (i.e. standard outages) for the NEM and the Northern Territory.

[12] VCRs for outages of duration less than 1 hour, between 1 and 3 hours, 3 and 6 hours, and between 6 and 12 hours were weighted.

1.1 VCRs for widespread and long duration outages

To ensure that the methodology for estimating VCR values is fit for purpose for any current and potential applications of VCRs, the AER is seeking to separately estimate VCRs for a subset of widespread and long duration outages (WALDOs). These VCRs may have applications in:

reviews of the system restart standard, declaration of protected events and 'resilience' measures coming out of the AEMC Black System Event review.[13]

The AER's final decision on the methodology for estimating VCRs concluded that a set of WALDO VCR cost curves are to be estimated using a macroeconomic modelling methodology supplemented by other appropriate approaches. It also defined a WALDO as an outage ranging in severity from 1-2 Giga Watthours (GWh) to 15 GWh of unserved energy.[14]

1.2 Purpose and structure of this report

The AER engaged ACIL Allen Consulting (ACIL Allen) to develop WALDO VCR cost curves for the NEM jurisdictions.[15] The purpose of this document is to:

— set out the methodology for developing a model to determine these cost curves (in chapter 2)
— present the results from the model for three scenarios (in chapter 3).

In its instructions to ACIL Allen, the AER specified that WALDO VCRs are to be derived in this model by reference to the energy lost and not by direct reference to any specific site or location. Rather, the derived values are based on a synthesis of residential, commercial, industrial and social activity such as may be found in various regions of Australia within the NEM, but loosely informed by consideration of a range of potentially representative locations.

The intention of this work is to help guide the management of risk by NEM agencies by identifying the potential impact were a widespread or long duration outage event to occur. The AER does not consider any of the scenarios discussed herein are likely to occur.

This model does not attempt to model the impacts of a natural disaster event (such as storms or bushfires) that may cause widespread and long duration outages. Rather, its usage is restricted to modelling the impacts arising solely from interruptions to the supply of electricity.

[13] Australian Energy Regulator, *Values of Customer Reliability, Final Decision*, November 2019, page 19
[14] ibid, page 17
[15] WALDO VCRs are not required for the Northern Territory

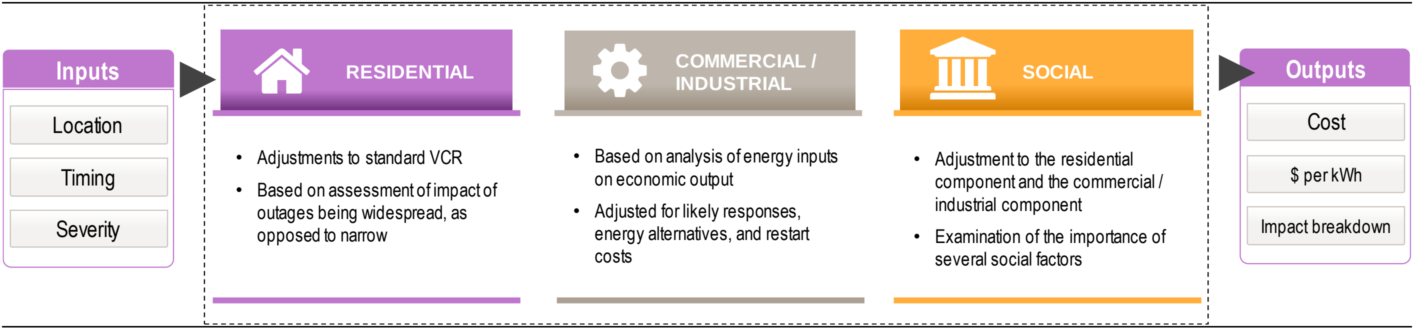
2 APPROACH TO MODELLING THE WALDO VCR

This chapter sets out the methodology for calculating the WALDO VCR. As illustrated in Figure 2.1, the WALDO VCR comprises:

— a residential component
— a commercial / industrial component
— social costs associated with WALDOs.

Each component is estimated using a separate methodology and then combined into a single WALDO VCR for a given set of parameters in a MS Excel model.

FIGURE 2.1 OVERVIEW OF THE WALDO VCR METHODOLOGY



SOURCE: ACIL ALLEN

The user inputs to the model are described in section 2.1. The methodology for estimating the residential component of the WALDO VCR is described in section 2.2 and for the commercial / industrial component in section 2.3. The methodology for estimating the social costs associated with WALDOs is described in section 2.4. The calculation of the WALDO VCR is described in section 2.5.

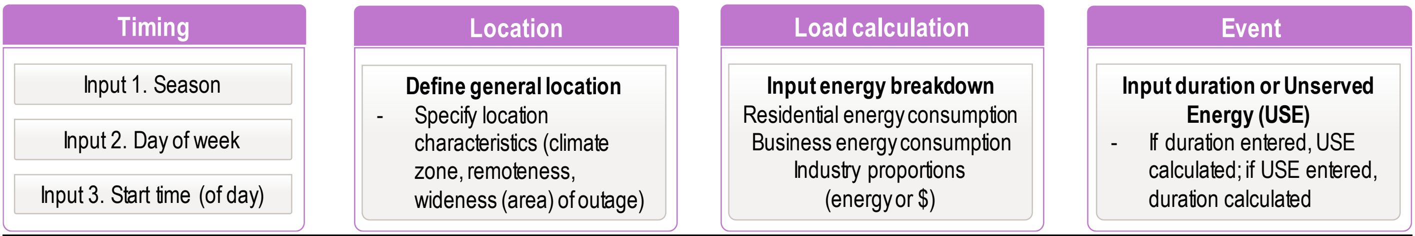
2.1 User inputs to the model

The WALDO VCR depends on the:

— timing of the outage
— location of the outage
— load impacted by the outage
— characteristics of the outage event.

These factors are provided as an input to the model, as illustrated at a high level in Figure 2.2. The inputs are described in further detail in the following sections.

FIGURE 2.2 USER INPUTS TO THE MODEL



SOURCE: ACIL ALLEN

2.1.1 Timing of the outage

The WALDO VCR will depend on the timing of the outage as the energy that will be unserved during the outage will depend on the season, the day of the week and the time of day. The inputs to the model for the timing of the outage are summarised in Table 2.1.

TABLE 2.1 USER INPUTS – TIMING OF OUTAGE

Input	Input options
Season	Summer Winter
Day of week	Weekday Weekend
Start time	A time during the day in one hour blocks

SOURCE: EMAIL FROM JAMES CRITICOS DATED 15 OCTOBER 2019

The timing inputs inform how much load is affected by the outage, which impacts the duration of the outage or the unserved energy applicable to the calculation of the WALDO VCR.

As discussed below, the impact of a WALDO on residential customers is calculated by adjusting the ‘standard’ VCR curves. The model references different ‘standard’ VCRs that have been determined by the AER using survey techniques, depending on the selected timing of the WALDO. Specifically, the WALDO VCRs for residential customers are calculated from:

— peak VCR curves (for which some or all of the outage occurs between 7 – 10 am or 5 – 8 pm)
— off-peak VCR curves (for which all of the outage occurs between 10 am – 5 pm or between 8 pm – 7 am).

Accordingly, the input options for the season and the day of the week are consistent with those used by the AER to determine the ‘standard’ VCRs.

2.1.2 Location of the outage

Climate zone and remoteness

The location of the WALDO is specified in a generic manner that aligns with the location parameters for the ‘standard’ VCRs. In addition, there are separate input options for the CBD area of each capital city in the NEM.

The location is a combination of the climate zone and remoteness as summarised in Table 2.2.

The user is able to enter multiple combinations of climate zone and remoteness. Where multiple combinations of climate zone and remoteness are entered, the model assumes that the characteristics of the load and outage are the same in each combination of climate zone and remoteness. For example, if two combinations of climate zones and remoteness are entered, then it is assumed that half of the total load impacted by the outage is in each combination of climate zone and remoteness, and that the industry structure is the same in each.

If the characteristics of each combination of climate zone and remoteness are quite distinct, then the model should be run separately for each combination and the results aggregated.

TABLE 2.2 USER INPUTS – LOCATION OF OUTAGE

Input	Input options	
	Climate zone	Remoteness
Location	1	Regional Australia
	2	CBD Brisbane
	2	Suburban Australia
	2	Regional Australia
	3 & 4	Regional Australia
	5	CBD Sydney
	5	Suburban New South Wales
	5	CBD Adelaide
	5	Suburban South Australia
	5	Regional Australia
	6	CBD Melbourne
	6	Suburban Victoria
	6	Suburban New South Wales
	6	Regional Australia
	7	CBD Canberra
	7	CBD Hobart
	7	Suburban Australia
	7	Regional Australia

Notes:

1. The climate zones are mapped for Australia and each State and Territory and can be found at the Australian Building Code Board's, Climate Zone map: Australia Wide, https://www.abcb.gov.au/Resources/Tools-Calculators/Climate-Zone-Map-Australia-Wide
2. Unless otherwise specified, "regional" includes inner regional, outer regional and remote

SOURCE: EMAIL FROM JAMES CRITICOS DATED 15 OCTOBER 2019

Wideness (area) of the outage

The size of the area impacted by the outage (the level of wideness) will also impact the WALDO VCR. The model provides three input options for the level of wideness, as set out in Table 2.3. These input options were informed by a literature review. Our approach to literature reviews is set out Box 2.1 and the papers reviewed are summarised in Appendix A.

TABLE 2.3 USER INPUTS – SIZE OF AREA IMPACTED BY THE OUTAGE

Input	Input options
Area impacted by outage	1. Radius of impacted area < 5 km 2. Radius of impacted area between 5 and 85 km 3. Radius of impacted area > 85 km

SOURCE: ACIL ALLEN

BOX 2.1 OUR APPROACH TO UNDERTAKING LITERATURE REVIEWS

The first step we undertake to conduct literature reviews is to determine the parameters of the review to ensure that it is targeted appropriately and addresses the issues raised. The review covered both national and international literature, and included peer reviewed and grey literature. Other key considerations for the literature search included:

- definition of search terms, including date of publication inclusion and exclusion criteria
- data sources
- search methodologies
- assessment of the quality of evidence
- other recently published literature reviews.

A literature review framework was developed that clearly articulated the parameters of the review, including defining search terms and databases, as well as our approach to analysing the literature. Search databases included:

ABI Inform Professional – multidisciplinary business research database.

British Libraries Inside Conference – details of papers given at congresses, symposiums, conferences, expositions, workshops, and meetings received at the British Library Document Supply Centre.

Business & Industry – facts, figures and key events dealing with companies, industries and markets at an international level.

Current Contents – bibliographic coverage of articles in every leading journal in the sciences, social sciences, arts and humanities worldwide.

Econlit – Economic development, history, macroeconomics, microeconomics – journal articles, books and dissertations.

Ei EnCompassLIT – coverage of literature related to the petroleum, petrochemical, natural gas, and energy related industries.

FDAnews – U.S. and international regulatory, legislative, and business news and information for those companies and organisations that are regulated by the FDA and the European commission.

Gale Group PROMT – multiple-industry database providing broad, international coverage of companies, products, markets and applied technologies for a wide range of industries.

Gale Group Trade & Industry Database – multi-industry database covering international company, industry, product, and market information.

Inspec® – bibliographic database, worldwide literature on physics, electrical & electronic engineering, computer & control engineering, information technology and mechanical, manufacturing and production engineering.

ProQuest Dissertations & Theses Professional – dissertations and theses, the official digital dissertations archive for the Library of Congress and the database of record for graduate research.

ProQuest Professional Newsstand – leading newspapers and wires from the US and around the world. Many titles are in full text, with in-depth coverage of each issue, and indexing for companies, industries, people and geographies.

SciSearch – an international, multidisciplinary index to the literature of sciences.

The information identified by the search was reviewed to extract and synthesise the information that is of most relevance to addressing the issues raised.

Two studies reviewed quantified a higher willingness to pay for widespread outages – one study identified the willingness to pay (WTP) to avoid an outage that covered three provinces in Austria (rather than one that affected one's own street/road)[16], while the second study identified the WTP to avoid an outage that affected the whole country (rather than a residential street only).[17]

Austria has nine provinces ranging in size from 415 square km to 19,178 square km. The three smallest contiguous provinces have an area of around 23,000 square km which equates to a radius of around 85 km. The highest level of wideness is therefore for outages that cover an area with a radius greater than 85 km.

The AER's choice modelling tested two levels of the area impacted by an outage – local and "widespread", which is defined as a few adjacent suburbs or a regional town. The lowest level of wideness is for the local outages, during which customers will have no more than 5 km to travel to get to an unimpacted area. The middle level of wideness is for those outages that are between the lower and upper levels, that is, the impacted area has a radius between 5 and 85 km.

2.1.3 Load impacted by the outage

The WALDO VCR depends on the load that is impacted by the outage. The model requires that the characteristics of the load impacted by the outage be entered.

At the highest level, the annual energy consumption for residential customers and for business customers in the area impacted is entered (in GWh per annum).

The business customer load is then disaggregated by industry sector. The industry sectors align with the one digit Australian and New Zealand Standard Industrial Classification (ANZSIC) codes, with a further disaggregation of the manufacturing sector into metal smelting and manufacturing except metal smelting, due to unique characteristics associated with metal smelting.

The business customer load can be disaggregated based on electricity consumption or by economic output. The breakdown of the business customer load by economic output is pre-populated based on the combination of climate zone and remoteness. These have been derived from Australian Bureau of Statistics (ABS) tables and census data.

The load characteristic inputs retrieve and weight the relevant load profiles for residential and industrial customers that are used to calculate the:

— amount of unserved energy, if the nature of the outage is defined by reference to the outage duration, or
— duration of the outage, if the nature of the outage is defined by reference to the unserved energy.

The load information to be entered into the model is set out in Table 2.4.

TABLE 2.4 USER INPUTS – LOAD IMPACTED BY THE OUTAGE

Input	Input options
Residential customer load in the location impacted	Annual energy consumption (in GWh per annum)
Business customer load in the location impacted	Annual energy consumption (in GWh per annum)
Breakdown of industrial load by industry sector	Flag – breakdown entered in terms of % of energy consumed or % of economic output The user inputs the data at an aggregated level (i.e. by one-digit ANZSIC) as well as for metal smelting, using the industrial load sectors as set out below.

[16] Johannes Reichl, Michael Schmidthaler, Friedrich Schneider, *The value of supply security: The costs of power outages to Austrian households, firms and the public sector*, Energy Economics 36 (2013) 256-261
[17] Johannes Reichl, Michael Schmidthaler, *Methodology, Assumptions, and an Application of blackout-simulator.com*, Energie Institut

Input	Input options
	Industry sector
Business load sectors	Agriculture, forestry and fishing
	Mining
	Manufacturing, excluding metal smelting
	Metal smelting
	Electricity, gas, water and waste services
	Construction
	Wholesale trade
	Retail trade
	Accommodation and food services
	Transport, postal and warehousing
	Information, media and telecommunications
	Financial and insurance services
	Rental, hiring and real estate services
	Professional, scientific and technical services
	Administrative and support services
	Public administration and safety
	Education and training
	Health care and social assistance
	Arts and recreation services
	Other services

SOURCE: EMAIL FROM JAMES CRITICOS DATED 15 OCTOBER 2019

The percentages for each industry sector must sum to 100 per cent. An error message is displayed if they do not.

2.1.4 The nature of the outage

The WALDO VCR is based on the nature of the outage.

The unserved energy during an outage is a function of the duration of the outage, as well as the timing and load characteristics. The user can enter into the model either the duration of the outage (in hours) or the unserved energy. The model will calculate the unserved energy if the duration of the outage is entered, or will calculate the duration of the outage if the unserved energy is entered.

The minimum duration of the outage that can be entered is currently set to 3 hours, although this could be changed in the future, if required. If the duration of the outage entered (or calculated) is shorter than the minimum duration, an error message is displayed.

The model currently assumes that a business will restart after an outage occurs, which is most likely to be the case if the outage is less than a week. If the outage duration entered (or calculated) is longer than a week, a warning message will be displayed. The maximum outage duration that can be entered is currently set to three months. If the duration of the outage entered (or calculated) is longer than the maximum duration, an error message is displayed.

In practice, the duration of the outage is not the same for all customers in the area impacted by the outage – the supply of electricity is generally progressively restored to customers over time. We have assumed a Pareto distribution with the supply restored to 80 per cent of customers within *x* hours after the outage commences and the supply to the remaining 20 per cent of customers restored over a longer period of time.

For the purposes of this analysis, we assume that the supply to all customers is restored within *x* hours. Accordingly, the duration of the outage that is input into the model represents the duration of the outage experienced by customers representing 80 per cent of the total load impacted.[18]

If the duration of the outage is input, the model calculates the Unserved Energy (USE) based on the duration of the outage, the annual energy consumption and the load profiles, using the approach as described in section 2.2 for the residential load and as described in section 2.3 for the commercial / industrial load.

The USE must be within the range of 1 – 15 GWh, although this range could be readily changed in the future. If the USE calculated is outside this range, an error message is displayed.

If the USE is input, the duration of the outage is calculated based on the USE, the annual energy consumption and the load profiles. The valid ranges for the USE and duration of outage will be as per above, with error messages displayed if they are outside the valid ranges.

2.1.5 Model input screen

An example of the model input screen is provided as Figure 2.3.

[18] The model could be run twice (or more times) – once for an outage representing the experience of 80 per cent of customers and a second time for an outage representing the experience of 20 per cent of customers, and then aggregating the results.

FIGURE 2.3 MODEL INPUT SCREEN

VCR for Widespread And Long Duration Outages

Control sheet

Step 1. Select timing

Season of outage	Winter
Start day:	Weekend
Start time:	5:00 PM

Step 2. Select location / area
Location

Location	Climate zone	Selection
Regional Australia	1	No
CBD Brisbane	2	No
Suburban Australia	2	No
Regional Australia	2	No
Inner and outer regional Australia	3 & 4	Yes
CBD Sydney	5	No
Suburban New South Wales	5	No
CBD Adelaide	5	No
Suburban South Australia	5	No
Regional Australia	5	No
CBD Melbourne	6	No
Suburban Victoria	6	No
Suburban New South Wales	6	No
Regional Australia	6	No
CBD Canberra	7	No
CBD Hobart	7	No
Suburban Australia	7	No
Regional Australia	7	No

Area of outage	Widespread (e.g. more than 85 km radius)

Step 3. Describe load
High level sector energy usage

Sector	Annual energy consumption (in GW
Residential	500
Business	1500

Industry breakdown
Breakdown by: Economic output

Industry	ANZSIC code	Economic output	Suggested values
Agriculture, forestry and fishing	1	19%	19%
Mining	2	30%	30%
Manufacturing, excluding Metal smelting	3	6%	6%
Metal smelting	3	0%	0%
Electricity, gas, water and waste service:	4	8%	8%
Construction	5	10%	10%
Wholesale trade	6	3%	3%
Retail trade	7	3%	3%
Accommodation and food services	8	2%	2%
Transport, postal and warehousing	9	3%	3%
Information, media and telecommunication	10	1%	1%
Financial and insurance services	11	2%	2%
Rental, hiring and real estate services	12	1%	1%
Professional, scientific and technical servi	13	2%	2%
Administrative and support services	14	2%	2%
Public administration and safety	15	3%	3%
Education and training	16	3%	3%
Health care and social assistance	17	3%	3%
Arts and recreation services	18	0%	0%
Other services	19	1%	1%
Total		**100%**	100%

Industry	Proportion large business
Agriculture	83%
Industrial	94%
Commercial	84%

Step 4. Describe event

Input type:	Unserved energy	
Amount:	5	GWh

Event characteristics		
Unserved energy	5	GWh
Outage duration	24.5	hours

Error messages: *None*

SOURCE: WALDO VCR MODEL

2.2 Residential component of the WALDO VCR

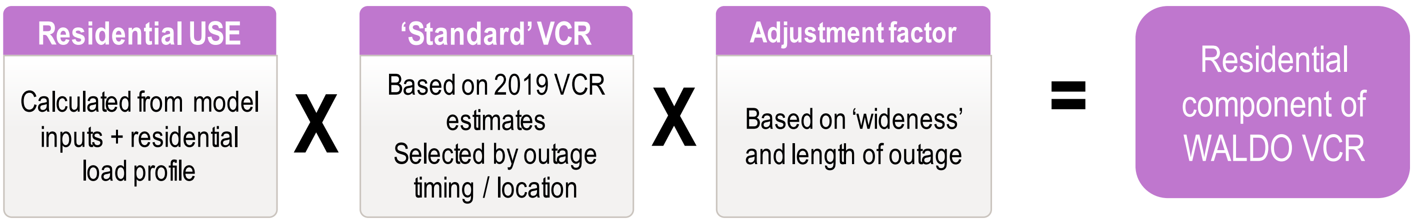
The residential component of the 'standard' VCR is based on the amount that individual households are prepared to pay to avoid an outage. Outages may typically span up to a few suburbs. It is therefore inherent in the estimates of the 'standard' VCRs that customers would have the option of travelling to a different location to spend their time (e.g. at a shopping centre or cinema), as the 'next best alternative' to being at home, or to buy meals.

A WALDO limits the ability of residential customers to do this, depending on how widespread the outage is. The result is that the 'standard' VCRs have been adjusted to account for these different financial and non-financial impacts on customers.

Additionally, the 'standard' VCR is based on an outage of up to 12 hours duration. A long duration outage could extend beyond 12 hours. In this case, the 'standard' VCRs are adjusted to account for the longer duration of the outage.

Figure 2.4 outlines the broad approach to estimating the residential impact of a WALDO – the unserved energy is multiplied by the 'standard' VCR (in dollars per kWh), which is multiplied by an adjustment factor that accounts for the WALDO being wider and /or longer than a 'standard' outage. The output is in dollars.

FIGURE 2.4 APPROACH TO CALCULATING THE WALDO VCR FOR RESIDENTIAL CUSTOMERS



SOURCE: ACIL ALLEN

Each of the factors that contributes to the residential component of the WALDO VCR is discussed in the following sections.

2.2.1 Residential USE

The residential USE is calculated based on the residential load profile and the following user inputs to the model:

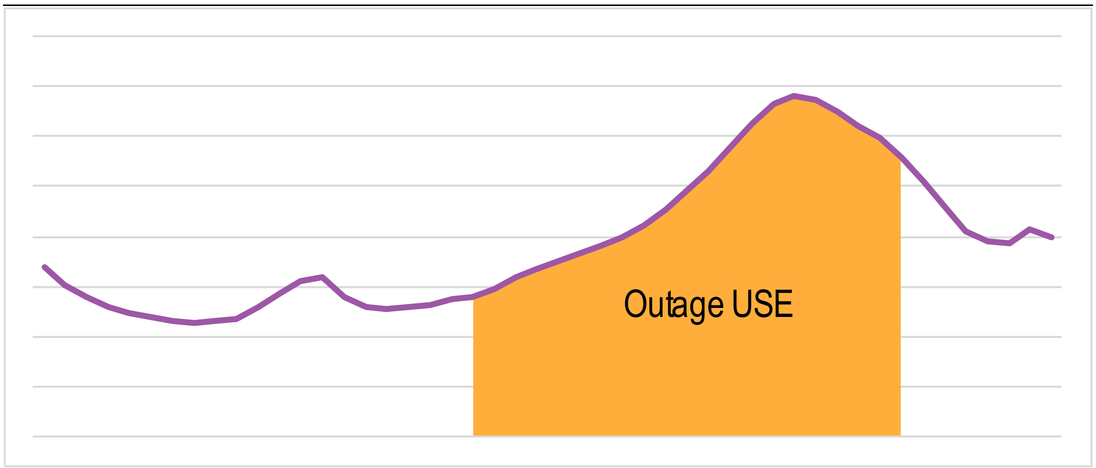
- annual energy consumption by the residential customers impacted by the outage
- timing of the outage (season, day of week and time of outage)
- duration of the outage.

The model includes a residential load profile for each climate zone, by summer and winter and by weekday and weekend. These are based on metering data collected for the AER's energy consumption bill benchmarks and are the same as those used by the AER in calculating the 'standard' VCRs. The residential load profiles for each climate zone are illustrated in Appendix B.

The residential load profile is scaled by the annual energy consumption of the residential customers impacted by the outage. A section of the residential load profile is then identified to correspond with the timing of the outage and duration of the outage. The energy represented by this section of the load profile is the residential USE.

Figure 2.5 provides an example of the selection of a section of a residential load profile.

FIGURE 2.5 EXAMPLE OF THE SELECTION OF A SECTION OF THE LOAD PROFILE



SOURCE: ACIL ALLEN

2.2.2 'Standard' VCRs

The model includes a 'standard' VCR for residential customers for each location option identified in Table 2.2 (combinations of remoteness and climate zone) and for each timing option identified in Table 2.1 (season, day of week and 'peak' and 'off-peak' based on the time of day). The set of 'standard' VCRs for residential customers that have been determined by the AER are provided as Table C.1 in Appendix C.

The relevant 'standard' VCR(s) is used to calculate the residential component of the WALDO VCR. If more than one combination of remoteness and climate zone is selected, the model averages the 'standard' VCRs for each combination of remoteness and climate zone.

2.2.3 Adjustment factor

The adjustment factor in the calculation of the WALDO VCR for residential customers comprises two components – one based on the area impacted by the outage (the wideness) and the second based on the duration of the outage.

Area impacted by the outage

As discussed in section 2.1.2, two studies reviewed quantified a higher willingness to pay for widespread outages – one study identified that the WTP to avoid an outage that covered three provinces in Austria (rather than one that affected one's own street/road) is 26.75 per cent higher[19], while the second study identified that the WTP to avoid an outage that affected the whole country (rather than a residential street only) is 32.7 per cent higher.[20]

We have nominated three levels for the area impacted by the outage, as set out in Table 2.3**.** Based on the literature reviewed, we assumed that the multiplier that applies to the 'standard' VCR for residential customers for a relatively localised outage (impacted area has a radius less than 5 km) is 1.0 and for a widespread outage (radius of impacted area is greater than 85 km) is 1.3.

We used our judgement to assign a multiplier of 1.1 for outages with an area impacted that lies between these two levels.

The multipliers that we have assumed for the size of area impacted by the outage are set out in Table 2.5. These multipliers could be readily updated in the model in the future if research is undertaken to identify an Australian-specific multiplier.

[19] Johannes Reichl, Michael Schmidthaler, Friedrich Schneider, *The value of supply security: The costs of power outages to Austrian households, firms and the public sector*, Energy Economics 36 (2013) 256-261

[20] Johannes Reichl, Michael Schmidthaler, *Methodology, Assumptions, and an Application of blackout-simulator.com*, Energie Institut

TABLE 2.5 MULTIPLIER – SIZE OF AREA IMPACTED BY THE OUTAGE

Area impacted	'Standard' VCR multiplier
1. Radius of impacted area < 5 km	1.0
2. Radius of impacted area between 5 and 85 km	1.1
3. Radius of impacted area > 85 km	1.3

SOURCE: ACIL ALLEN

Duration of the outage

Studies have identified that the costs associated with long duration outages comprise three types of costs:

1. Fixed costs – these costs are incurred, regardless of the duration of the outage. Estimates for short duration outages provide a proxy for these costs.
2. Flow costs – these costs are the value of lost opportunities arising from a lack of power. Flow costs may increase or decrease over time, depending on the extent to which activities can be deferred, but only for a period of time, and the ability to adapt.
3. Stock costs – these costs occur after a period of time when stock (such as food) starts to spoil, but as time goes on, there is less stock to spoil, and the stock costs decline.[21]

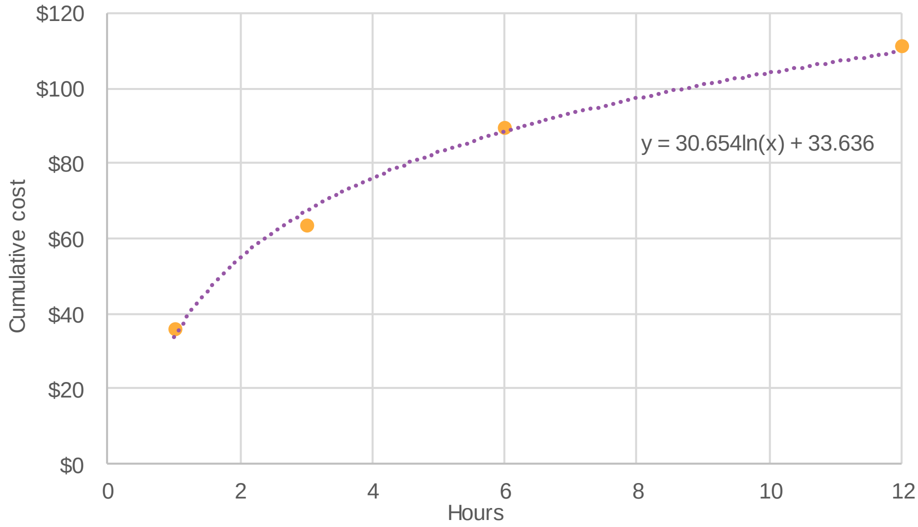
The costs associated with an outage are therefore high for a short duration outage during which the fixed costs and flow costs are incurred. The flow costs are sustained throughout the outage, with the stock costs increasing as stock spoils and then decreasing to zero when all stock is spoilt. The resulting non-linearity in the costs occurred over time has been identified in a number of studies.

For the purposes of our analysis, we assume that when the duration of an outage exceeds 12 hours, the costs incurred are the costs associated with a 12 hour outage plus the flow costs for the remaining duration of the outage.

We analysed each set of 'standard' VCRs for residential customers to determine the flow costs that are incorporated in them to determine the VCRs for long duration outages. We did this by fitting a logarithmic curve to the four data points associated with the 'standard' VCRs for residential customers. The data points were the total outage costs associated with the VCR for 0-1 hour, the VCR for 1-3 hours, the VCR for 3-6 hours and the VCR for 6-12 hours, assuming a 1 kW load, as illustrated in Figure 2.6.

[21] For example, Sean Ericson, Lars Lisell, *A flexible framework for modelling customer damage functions for power outages*, Energy Systems (2018)

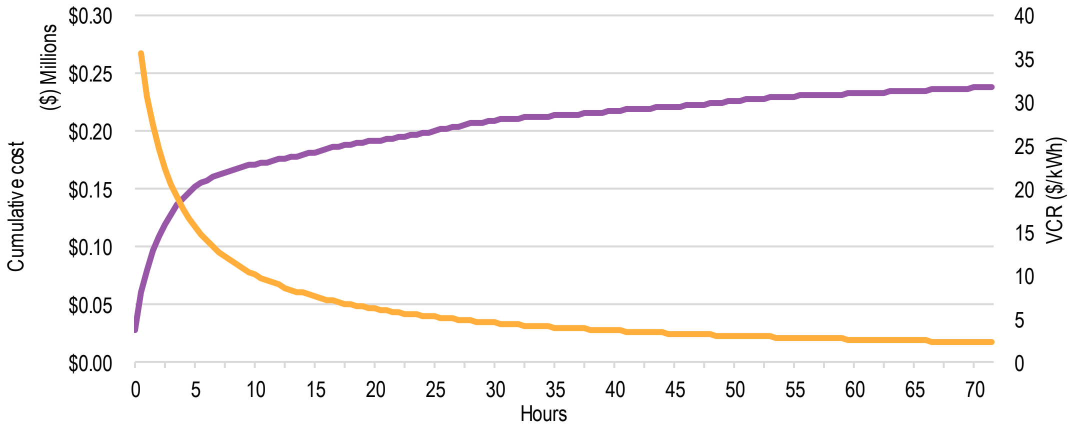
FIGURE 2.6 TOTAL COSTS ASSOCIATED WITH AN EXAMPLE SET OF 'STANDARD' VCRs



SOURCE: ACIL ALLEN ANALYSIS

For each set of 'standard' VCRs, we then projected the total costs forward over a three month period based on the logarithmic curve, assuming a 1 kW load and calculated the VCR for each hour (after 12 hours) by dividing the total costs by the duration. The resultant long duration VCRs for the example set of 'standard' VCRs (in Figure 2.6) based on a 1 kW load are illustrated in Figure 2.7 (up to 70 hours). This illustrates the declining growth in the outage costs over time and the declining VCR.

FIGURE 2.7 TOTAL COSTS AND LONG DURATION VCRs FOR THE EXAMPLE SET OF 'STANDARD' VCRs



SOURCE: ACIL ALLEN ANALYSIS

2.3 Commercial / industrial component of the WALDO VCR

The loss of power to a business 'turns off' value creation by that business, with flow on impacts to businesses upstream and downstream. The commercial and industrial component of the WALDO VCR estimates the potential wider economic impact of longer duration outages through macroeconomic modelling. We have also accounted for the likely behaviour of businesses to recover some of the value of their lost output following an outage and the costs to restart production following an outage.

The literature review identified that there are three types of macroeconomic models that have been used to estimate the broader economic impact of outages on the commercial / industrial sector – Computable General Equilibrium (CGE) models, Input-Output (I-O) models and macroeconometric models. The three different forms of models are described in Box 2.2.

I-O models are simpler than CGE models, but do not capture the substitution effects that are captured in CGE models. However, substitution is less likely to occur in the short run, which is the timeframe under consideration for an outage.

Given the range of assumptions that have been made to estimate the WALDO VCRs, we are of the view that the simplicity of the I-O modelling is appropriate for this purpose. The model is therefore based on I-O modelling.

BOX 2.2 DESCRIPTION OF THE DIFFERENT FORMS OF MODELS

Input-Output (I-O) models represent all inter-industry relationships or flows in an economy, i.e., how the outputs of industries are used as inputs to others, and the overall outputs of consumer goods (or "final demand") produced by all industries, as systems of linear equations—the system of industry transactions is represented in matrix form. The key technical feature of I-O models is the assumption of fixed coefficients or proportions determining input-output relations between industries. That is, the amount of input X that is required to produce a unit of output Y by a given industry does not change according to scale, or through substitution with different inputs depending upon relative prices changes, or as a result of, for example, technological change. Essentially for this reason, the basic I-O accounting framework does not represent the actions that firms might take in order to adapt to the loss of electricity.

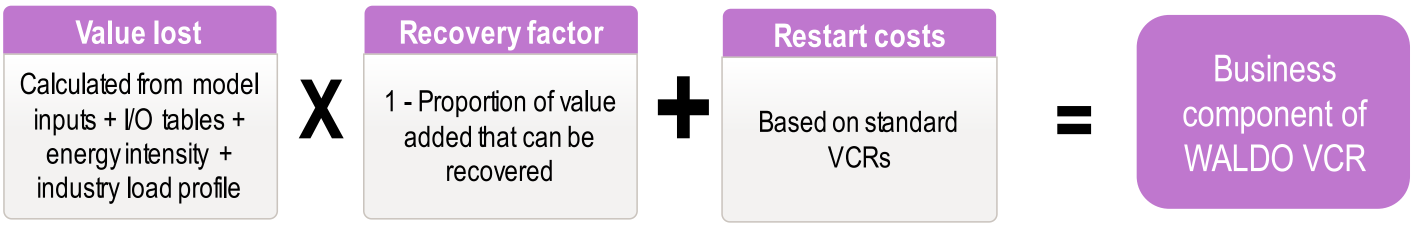
CGE models represent in simplified but explicit form all supplies and demands in an economy and both their direct and indirect market interactions. Supply and demand are determined by the economic (optimising) choices of consumers and firms. CGE models are therefore based on microeconomic principles; they are complete numerical representations of economies in the form of systems of non-linear algebraic equations or related mathematical structures. By contrast to I-O models, the input-output relations among industries are non-linear and to a degree flexible, a function of technology assumptions, prices and other factors.

Macro-economic models are systems of statistical forecasting equations, with parameters statistically estimated on historical times series data. These have most commonly used to represent national economies and to study inflation and other monetary phenomena as well as aggregate (un)employment. However, they have also been used to analyse regional-level economies. Unlike most computational economic models (including CGE), they do not explicitly represent the decision-making behaviour of consumers or firms, nor the equilibration of supply and demand in markets.

SOURCE: ALAN SANSTAD, REGIONAL ECONOMIC MODELING OF ELECTRICITY SUPPLY DISRUPTIONS: A REVIEW AND RECOMMENDATIONS FOR RESEARCH, ENERGY ANALYSIS & ENVIRONMENTAL IMPACTS DIVISION (2016)

Figure 2.8 outlines the approach to calculating the commercial / industrial component of the WALDO VCR. The estimate is made for each industry sector by multiplying the potential economic value lost during the outage, as estimated using I-O modelling, by a recovery factor for that industry sector, and adding restart costs. Each of these factors is discussed in the following sections.

FIGURE 2.8 APPROACH TO CALCULATING THE WALDO VCR FOR COMMERCIAL / INDUSTRIAL CUSTOMERS



SOURCE: ACIL ALLEN

2.3.1 Potential economic value lost

The potential economic value lost by each industry sector during a WALDO is estimated using I-O modelling based on:

— I-O tables
— multipliers
— energy intensity by industry sector
— the load profile for each industry sector
— the following user inputs to the model:
  – annual energy consumption or economic output by industrial customers in the scenario
  – timing of the outage (season, day of week and time of outage)
  – duration of the outage.

The I-O modelling assumes that the loss of economic value is temporary; that is, businesses will restart following the outage.

I-O tables

The model includes a set of I-O tables to estimate the potential value lost by the business directly impacted by the outage.

The value added and economic output (Australian production) for each of the industry sectors was taken from the Input-Output tables in the Australian National Accounts. The value added was calculated as a percentage of the economic output for each industry sector, as set out in Table 2.6. The same percentages were used in each location combination of remoteness and climate zone.

TABLE 2.6 VALUE ADDED AS A PROPORTION OF OUTPUT, BY INDUSTRY SECTOR

Industry sector	Value added	Economic output	Value added as a % of economic output
Agriculture, forestry and fishing	$47,868	$102,069	47%
Mining	$134,325	$222,390	60%
Manufacturing	$101,759	$343,542	30%
Electricity, gas, water and waste services	$300	$687	44%
Construction	$43,893	$109,032	40%
Wholesale trade	$134,196	$428,504	31%
Retail trade	$69,606	$134,334	52%
Accommodation and food services	$75,916	$124,758	61%
Transport, postal and warehousing	$41,102	$85,831	48%
Information, media and telecommunications	$83,053	$180,433	46%
Financial and insurance services	$43,883	$102,661	43%
Rental, hiring and real estate services	$153,106	$243,510	63%
Professional, scientific and technical services	$53,090	$105,227	50%
Administrative and support services	$117,804	$228,904	51%
Public administration and safety	$56,176	$93,751	60%
Education and training	$92,653	$149,071	62%
Health care and social assistance	$83,346	$121,521	69%
Arts and recreation services	$119,265	$172,917	69%
Other services	$14,082	$37,495	38%

SOURCE: ACIL ALLEN ANALYSIS BASED ON DATA IN 5209.0.55.001 AUSTRALIAN NATIONAL ACCOUNTS: INPUT-OUTPUT TABLES, 2016-17, TABLE 8

The value added and economic output were escalated from 2016-17 to September 2019 dollars using the Consumer Price Index (All Groups, weighted for eight capital cities).

Multipliers

The model also includes a set of multipliers to estimate the impact on businesses upstream and downstream of the business directly impacted by the outage.

The multipliers that were used in the model were derived by first calculating the multipliers by industry sector for a number of locations across different climate zones and remoteness, as set out in Table 2.7.

TABLE 2.7 LOCATIONS FOR WHICH MULTIPLIERS CALCULATED

State	Area	Remoteness	Climate zone
New South Wales	State-wide		
	Sydney CBD	CBD	5
	Broken Hill	Regional Hill	4
	Wagga Wagga	Regional	4
Queensland	State-wide		
	Brisbane CBD	CBD	2
	Gold Coast	Suburban	2
	Rockhampton	Regional	2
South Australia	State-wide		
	Mt Gambier	Regional	6
Tasmania	State-wide		
	Hobart	Regional	7
Victoria	State-wide		
	Melbourne CBD	CBD	
	Geelong	Suburban	6
	Bendigo	Regional	6

SOURCE: ACIL ALLEN

Our analysis indicated that the multipliers varied by industry sector and were relatively similar for a given remoteness, regardless of the climate zone. We therefore calculated three multipliers for each industry sector – one for each of CBD, metropolitan and regional – by averaging the multipliers in the relevant locations.

While the multipliers could be estimated with a greater level of accuracy, the accuracy with which they have been calculated for the purposes of the model at this time is proportional to the accuracy associated with the model as a whole.

The multipliers that were used are set out in Table 2.8.

TABLE 2.8 MULTIPLIERS USED IN THE WALDO VCR MODEL, BY INDUSTRY SECTOR

Industry sector	CBD	Suburban	Regional
Agriculture, forestry and fishing	0.25	0.21	0.20
Mining	0.10	0.12	0.15
Manufacturing	0.19	0.19	0.18
Electricity, gas, water and waste services	0.12	0.15	0.11
Construction	0.36	0.13	0.16
Wholesale trade	0.12	0.11	0.13

Industry sector	CBD	Suburban	Regional
Retail trade	0.09	0.09	0.11
Accommodation and food services	0.15	0.14	0.15
Transport, postal and warehousing	0.17	0.12	0.13
Information, media and telecommunications	0.11	0.13	0.16
Financial and insurance services	0.05	0.12	0.09
Rental, hiring and real estate services	0.14	0.09	0.09
Professional, scientific and technical services	0.09	0.10	0.13
Administrative and support services	0.07	0.09	0.11
Public administration and safety	0.08	0.08	0.10
Education and training	0.08	0.07	0.07
Health care and social assistance	0.07	0.07	0.07
Arts and recreation services	0.10	0.13	0.15
Other services	0.00	0.10	0.10

SOURCE: ACIL ALLEN ANALYSIS BASED ON DATA IN 5209.0.55.001 AUSTRALIAN NATIONAL ACCOUNTS: INPUT-OUTPUT TABLES, 2016-17, TABLE 8

Scaling the I-O tables to the location impacted by the outage

To calculate the commercial / industrial component of the WALDO VCR, the economic output by industry sector in the area impacted by the outage is required so that the data in the I-O tables can be scaled to the location that is impacted by the outage. To do this, the user inputs into the model either:

— the economic contribution of each industry to the scenario (as a percentage), or
— the energy consumed by each industry (as a percentage).

Both of these data points are required in the model, but the user is only required to input one, while the other is calculated in the model, as discussed below.

Calculating the economic output by industry sector from the industry breakdown of economic contribution

If the contribution by each industry sector is input as *a percentage of economic output* by industry sector, the *level of economic output* for each sector is calculated using the total level of business energy consumption in the location impacted by the outage (which is entered by the user) and the energy intensity (which is discussed in the following section). The user is required to input the total energy consumption for business customers in the location impacted by the outage.

The economic output by industry sector for the location is calculated by:

1. multiplying the percentage of economic output by industry sector by the energy intensity for that industry sector (MWh per dollar output)
2. scaling that energy consumption based on the total energy consumption by the business customers in the location impacted by the outage, to derive the energy consumed by each industry sector
3. multiplying the energy consumed by each industry sector by the energy intensity for that industry sector.

Calculating the economic output by industry sector from the industry breakdown of energy consumption

If the contribution by each industry sector is input as a *percentage of energy consumption* by industry sector, the energy consumption for each sector is calculated by multiplying the percentage consumption by the total business consumption. This is then converted to economic output by industry sector using the energy intensity ratios discussed in the following section.

Energy intensity

The energy intensity is the relationship between the energy consumption and economic output.

We have estimated the energy intensity by industry sector using data from the Australian National Accounts. The Australian National Accounts include:

— the value of electricity that is generated as an input for each industry sector
— the value of the output (Australian production).

We have assumed that the value of electricity generated is $100 per MWh, and then calculated the electricity generated (in MWh) as a function of the value of the output. The energy intensity factors we have used are set out in Table 2.9.

TABLE 2.9 ENERGY INTENSITY BY INDUSTRIAL LOAD SECTOR

Industrial load sector	Energy intensity (MWh per $millions of output)
Agriculture, forestry and fishing	24.8
Mining	73.2
Manufacturing, excluding Metal smelting	63.4
Metal smelting	194.7
Electricity, gas, water and waste services	142.4
Construction	5.5
Wholesale trade	23.3
Retail trade	55.6
Accommodation and food services	68.7
Transport, postal and warehousing	21.2
Information, media and telecommunications	23.9
Financial and insurance services	6.3
Rental, hiring and real estate services	63.9
Professional, scientific and technical services	15.0
Administrative and support services	7.1
Public administration and safety	81.1
Education and training	13.9
Health care and social assistance	14.2
Arts and recreation services	14.5
Other services	11.4

SOURCE: ACIL ALLEN ANALYSIS BASED ON DATA IN 5209.0.55.001 AUSTRALIAN NATIONAL ACCOUNTS: INPUT-OUTPUT TABLES, 2016-17, TABLE 8

Load profiles

The model includes load profiles (how energy is consumed across the year) for each industry sector identified in Table 2.4, by weekday/weekend. We developed a set of synthetic load profiles for each industry sector, which was informed by energy data collected for some sectors, other publicly available information and our judgement as to the likely load profile. The industrial load profiles are illustrated in Appendix E. Given the assumptions made to develop the synthetic load profiles, we have not differentiated the load profile by climate zone or by season.

The load profiles are scaled by the annual energy consumption by the customers in that industry sector that are impacted by the outage. A section of each industrial load profile is identified to correspond with the timing of the outage and duration of the outage. The energy represented by this section of the profile is the USE for that industry sector (refer to Figure 2.5).

We have assumed that the energy consumption profile aligns with the profile of economic output. This helps to identify the potential impact on the economy associated with the outage experienced by that industry sector. This assumption is consistent with an assumption made in the development of a blackout simulator for the European Union. Reichl and Schmidthaler noted that:

… electricity is an essential input for value added, and that hours without electricity supply deal damage even when happening during non-productive hours. Such damages stem from e.g. inoperable cooling appliances or safety facilities.[22]

2.3.2 Recovery factor

The actual impact of an outage on the economy is based on how much economic activity can be recovered following an outage, for each industry sector. We assumed the recovery factor for each industry sector based on:

— the characteristics of the industry sector, such as the ability to continue production without an electricity supply, the ability to defer production, and the time to restore production following the restoration of supply

— the extent to which the industry sector has back-up generation installed.

Recovery factors for each industry sector are set to one of four levels:

— low – the sector has no back-up generation and the production that is lost during the outage largely cannot be recovered following the outage

— medium – the sector loses some but not all production, through the use of back-up generation and/or recovery of some production following the outage

— high – either the sector has sufficient back-up generation to continue operation for the entirety of the outage and / or the production that is lost during the outage can be fully recovered following the outage

— smelted metals – if back-up generation is not installed and the outage exceeds four hours, then the model assumes that metal pots will solidify and the economic impact of the outage may persist for around three months.

The recovery level assigned to each industry sector, and the values that are assigned to each level, are set out in Table 2.10. The model has been set up so that these values can be readily updated in the future.

[22] Johannes Reichl, Michael Schmidthaler, *Methodology, Assumptions, and an Application of blackout-simulator.com*, Energie Institut, page 6

TABLE 2.10 RECOVERY FACTOR

Recovery level	Industry sectors	Proportion of value that can be recovered
Low	Electricity, gas, water and waste services Accommodation and food services Information, media and telecommunications Financial and insurance services Public administration and safety Arts and recreation services	0.1
Medium	Agriculture, forestry and fishing Mining Manufacturing, excluding metal smelting Construction Wholesale trade Retail trade Transport, postal and warehousing Rental, hiring and real estate services Professional, scientific and technical services Administrative and support services Health care and social assistance Other services	0.5
High	Education and training	0.9
Smelted metals (with no back-up generation)		[1 - 3 months / duration of interruption (in months)]

SOURCE: ACIL ALLEN ASSUMPTION

There has inevitably been some averaging in assigning a level to an industry sector. For example, if the production that is lost during the outage by an industry sector cannot be recovered, then that sector has been assigned a level of low (that is, the proportion of value that can be recovered is 0.1). However, if 50 per cent of that sector has back-up generation installed which can supply electricity through the period of the outage, then that sector has been assigned a level of medium instead (that is, the proportion of value that can be recovered is 0.5).

The recovery factors are currently set so that they are the same, regardless of the duration of an outage. The model could be set up in the future so that they are varied over time. However, this implies a higher level of accuracy in the results than has been modelled.

2.3.3 Restart costs

After an outage occurs, there is a cost to restart a business. We estimated the restart costs from the 'standard' VCRs for businesses, other than those in the metal smelting sector.

The recovery factor for the metal smelting sector has been calculated in a different way to the other sectors as it is assumed that there will be a period over which economic value added will be lost due to the solidification of metal pots. There will be some value added associated with the work required to restore production. We have therefore assumed that the restart costs offset the value added during recovery phase and so we have not accounted for any additional restart costs.

As discussed in section 2.2, the costs associated with long duration outages comprise three types of costs:

1. Fixed costs – these costs are incurred, regardless of the duration of the outage. Estimates for short duration outages provide a proxy for these costs.
2. Flow costs – these costs are the value of lost opportunities arising from a lack of power. Flow costs may increase or decrease over time, depending on the extent to which activities can be deferred, but only for a period of time, and the ability to adapt.
3. Stock costs – these costs occur after a period of time when stock (such as food) starts to spoil, but as time goes on, there is less stock to spoil, and the stock costs decline.

We assumed that:

- the fixed costs are the restart costs
- the 'standard' VCR for the first hour comprises the fixed costs and the flow costs
- the flow costs are the costs incurred for one hour based on the 'standard' VCR for hours 6 to 12.

The AER determined 'standard' VCRs for the following groups of business customers:

- not direct connected
  - agricultural – small/medium and large
  - industrial – small/medium and large
  - commercial – small/medium and large
- direct connected
  - services
  - industrial
  - metals
  - mines.

The 'standard' VCRs for business customers are provided in Table C.2 in Appendix C.

Table 2.11 sets out the correlation between the industry sectors and the groupings for the 'standard' VCRs for business customers.

TABLE 2.11 CORRELATION BETWEEN INDUSTRY SECTORS AND THE 'STANDARD' VCRs

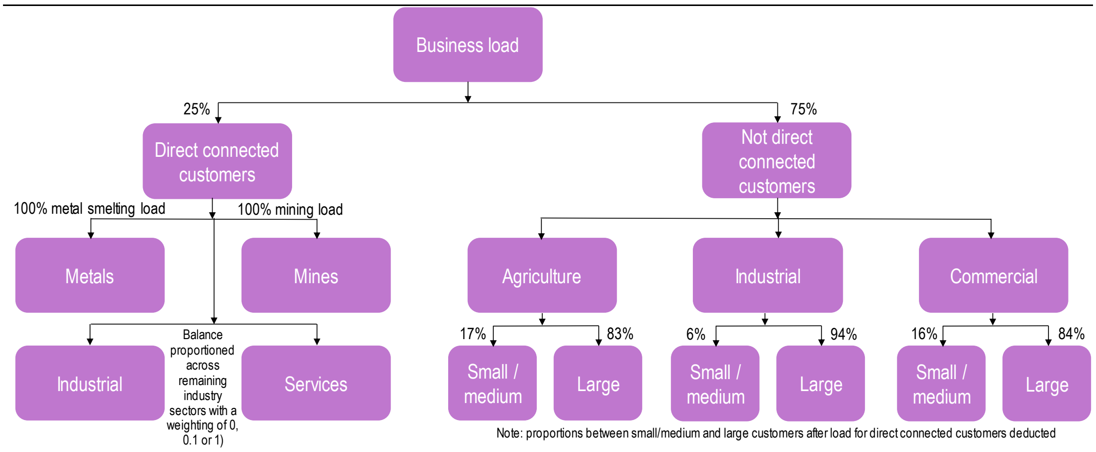
Industry sector	Not direct connected	Direct connected
Agriculture, forestry and fishing	Agricultural	Services
Mining	Industrial	Mines
Manufacturing, excluding Metal smelting	Industrial	Industrial
Metal smelting	Industrial	Metals
Electricity, gas, water and waste services	Commercial	Services
Construction	Commercial	Services
Wholesale trade	Commercial	Services
Retail trade	Commercial	Services
Accommodation and food services	Commercial	Services
Transport, postal and warehousing	Commercial	Services
Information, media and telecommunications	Commercial	Services
Financial and insurance services	Commercial	Services
Rental, hiring and real estate services	Commercial	Services
Professional, scientific and technical services	Commercial	Services
Administrative and support services	Commercial	Services

Industry sector	Not direct connected	Direct connected
Public administration and safety	Commercial	Services
Education and training	Commercial	Services
Health care and social assistance	Commercial	Services
Arts and recreation services	Commercial	Services
Other services	Commercial	Services

SOURCE: ACIL ALLEN

We have proportioned the business load across the 'standard' business VCRs as illustrated in Figure 2.9.

FIGURE 2.9 PROPORTIONING BUSINESS LOAD ACROSS 'STANDARD' VCRs



SOURCE: ACIL ALLEN BASED ON INFORMATION PROVIDED BY THE AER

The business load is proportioned between small/medium and large customers that are not direct connected, and direct connected customers, based on information provided by the AER. We have assumed that 75 per cent of the business load is used by customers that are not direct connected and 25 per cent is used by customers that are direct connected.

We have assumed that the proportion of the business load that is used by small/medium or large business customers that are not direct connected is as set out in Table 2.12. These proportions are applied to each industry sector within the relevant grouping.

TABLE 2.12 PROPORTION OF BUSINESS LOAD FOR CUSTOMERS THAT ARE NOT DIRECT CONNECTED

Grouping	Small/medium	Large
Agriculture	0.17	0.83
Industrial	0.06	0.94
Commercial	0.16	0.84

SOURCE: AER

We have assumed that the business load for direct connected customers is proportioned across the industry sectors by assuming that:

— 100 per cent of the business load for metal smelting and mining is by direct connected customers

— none of the business load for the following sectors is by direct connected customers:

  – retail trade
  – accommodation and food services
  – financial and insurance services

  - rental, hiring and real estate services
  - administrative and support services
  - health care and social assistance
  - arts and recreation services
  - other services

We have then assumed that the balance of the business load that is used by direct connected customers is proportioned to the remaining industry sectors with the following weightings applied to the energy used in those sectors:

- a weighting of 1 for manufacturing, excluding metal smelting
- a weighting of 0.1 for:
  - agriculture, forestry and fishing
  - electricity, gas, water and waste services
  - construction
  - wholesale trade
  - transport, postal and warehousing
  - information, media and telecommunications
  - professional, scientific and technical services
  - public administration and safety
  - education and training.

2.4 Social costs

The final component of the WALDO VCR is the broader social impact of the outage, which captures the costs of WALDOs that are not captured through the residential and commercial / industrial components of the WALDO VCR. The types of costs considered here include the:

- financial cost of managing social responses to an outage (e.g. increased crime)
- financial and non-financial costs for consumers being unable to access the services they had originally organised to access.

The non-financial costs for consumers are primarily related to *organised* activities, rather than activities that are undertaken by the consumer *in response to* an outage. For example, the disbenefit that a consumer experiences from having a knee operation may include the pain and discomfort associated with waiting for their re-scheduled procedure, and the financial costs of additional medications and travel.

Examples of social costs might include:

- **Emergency and essential services –** police would need to prioritise responses as traffic congests, public transport halts, security systems fail, public lighting fails and opportunistic crime rises; hospitals will have to cancel elective surgery and procedures, and will be put under strain with an increase in traffic accidents caused by the congestion, and prison inmates may be confined to cells. Fire alarm systems may be inoperable and firefighting may be hampered in those areas where some electricity is required to pump water. Goods and services requiring a controlled environment, such as pharmaceuticals, the blood bank, and frozen samples, may be impacted. There may also be safety concerns with fallen power lines.
- **Transport** – traffic would congest with traffic lights and ventilation fans in tunnels inoperable, petrol stations would close, train and tram services would halt, potentially stranding many passengers and air travel may be limited. There may be major delays at airports, with ripple effects through the entire network.
- **Communications –** mobile phones, computers and handheld devices that are the mainstay of modern communications may run out of charge and/or be inoperable as communication towers power down when (if) back-up batteries are depleted. This would disrupt people broadly, including preventing them from contacting emergency services, and will impact on the operation of emergency services that depend on telecommunications.
- **Commercial sector –** banking operations including ATMs and EFTPOS machines will be significantly impacted; businesses and shopping centres are likely to close early without access to electricity for air

conditioning or to operate emergency exits and fire alarm systems. The impact of this reaches beyond lost commerce to include loss in activity through shopping etc. Lights and lifts would fail, potentially trapping people in office or other buildings or forcing them to use stairs to exit (not an option for people with reduced mobility). Entertainment venues will close with commercial impact, but also loss of entertainment to would be patrons.

— **Commercial and industry sector** – in addition to the costs identified through the macroeconomic modelling, there may be additional costs associated with materials loss/spoilage and equipment damage, which are not reflected in the restart costs.
— **Households and individuals** – most households would be unable to perform their usual routines which, for some, causes increased tension and may result in increased levels of violence. The vulnerable (the very young, elderly and people with chronic or serious health conditions) will be at risk generally, but also due to lack of cooling or heating. Depending on time and duration, food may spoil and be discarded. At the extreme, there have been deaths reported during electricity outages due to lack of cooling, heating, inoperability of medical support equipment or spoilt food.[23] Residents in apartment buildings may be impacted by inoperable lifts and water pumps.
— **Animal welfare** – animals will also be at risk. Sensitive processes include incubation, milking, pumping, heating, air-conditioning and refrigeration. Impacts may be felt on farms and at veterinary hospitals and in other contexts.

The types of social costs that are incurred during a WALDO will vary depending on the remoteness of the outage. For example, the transportation impacts will be greater in urban areas than rural areas, but the animal welfare impacts will be greater in rural areas than in urban areas. Households in apartment buildings are more likely to be in urban areas, and households reliant on water for pumping are more likely to be in rural areas.

The literature reviewed concludes that it is difficult to quantify the social costs as they are dependent on the specific circumstances of the outage and the socioeconomic conditions. Most of the literature reviewed references the costs associated with the 1977 blackout in New York City, which lasted for about 25 hours. The costs associated with that blackout are summarised in Table 2.13. These are identified in the literature as direct and indirect costs.

TABLE 2.13 COSTS ASSOCIATED WITH 1977 NEW YORK CITY BLACKOUT

Impact areas	Direct cost ($ million)		Indirect cost ($ million)	
Businesses	Food spoilage Wages lost Securities industry Banking industry	1.0 5.0 15.0 13.0	Small businesses Emergency aid (private sector)	155.4 5.0
Government (Non-public services)			Federal Assistance Programs New York State Assistance Program	11.5 1.0
Consolidated Edison (electricity authority)	Restoration costs Overtime payments	10.0 2.0	New capital equipment (program and installation)	65.0
Insurance			Federal crime insurance Fire insurance Private property insurance	3.5 19.5 10.5
Public Health Services			Public hospitals – overtime, emergency room charges	1.5

[23] For example, Royal Academy of Engineering, *Counting the cost: the economic and social costs of electricity shortfalls in the UK: a report for the Council for Science and Technology*, (2014) and Office of Technology Assessment, *Physical vulnerability of electric systems to natural disasters and sabotage*, Congress of the United States, June 1990

Impact areas	Direct cost ($ million)		Indirect cost ($ million)	
Other public services	Metropolitan Transportation Authority (MTA) revenue:		MTA vandalism	0.2
			MTA new capital equipment required	11.0
	Losses	2.6	Red Cross	0.01
	MTA overtime and unearned wages	6.5	Fire Department overtime and damaged equipment	0.5
			Police Department overtime	4.4
			State Courts overtime	0.5
			Prosecution and correction	1.1
Westchester County	Food spoilage	0.25		
	Public services equipment damage, overtime payments	0.19		
Totals		***55.54***		***290.16***

SOURCE: OFFICE OF TECHNOLOGY ASSESSMENT, PHYSICAL VULNERABILITY OF ELECTRIC SYSTEMS TO NATURAL DISASTERS AND SABOTAGE, CONGRESS OF THE UNITED STATES, JUNE 1990, PAGE 33

On the face of it, the ratio of indirect costs to direct costs was approximately 5, which is consistent with an estimate from insurance industry experts.[24]

There are some costs that have been categorised as indirect that are included in the residential and commercial / industrial components of the WALDO VCR, in particular, the costs for small businesses. Additionally, there are some costs associated with arson and looting that many studies attribute to the particular socioeconomic circumstances of New York at that time.

If we assume that:

— the small business costs of $155.4 million, which have been classified as a direct cost, are included in the commercial / industrial component of the WALDO VCR

— the indirect costs incurred by the electricity authority are $65.0 million and these are included in the commercial / industrial component of the WALDO VCR

— half of the remaining indirect costs incurred are associated with arson and looting,

the indirect costs that not included in the residential and commercial / industrial components of the WALDO VCR are approximately 47 per cent of the direct costs that are included in the residential and commercial / industrial components of the WALDO VCR.

We have applied the social costs as a multiplier on the residential component and commercial / industrial component of the WALDO VCR.

Given the uncertainty of the data on social costs, and the variability in the social costs based on the outage, location and socioeconomic conditions, we have applied a multiplier of 1.3 to the residential and commercial / industrial components of the outage costs for WALDOs (other than for metal smelting) to represent the social costs. No multiplier has been applied to the outage costs for metal smelting.

The social cost multiplier could be readily updated in the model in the future if research is undertaken to identify a more contemporary Australian-specific multiplier.[25]

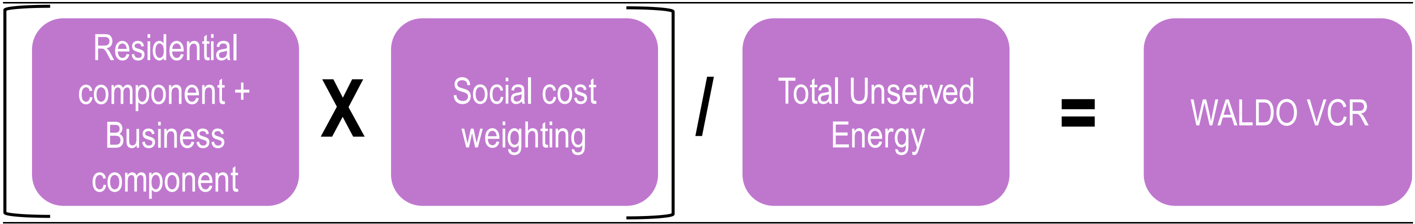
2.5 Calculation of the WALDO VCR

The approach to calculating the WALDO VCR is set out in Figure 2.10. The outage costs incurred by residential and commercial / industrial customers during a WALDO are summed, multiplied by the social cost weighting and divided by the total unserved energy.

[24] Hugh Byrd, Steve Matthewman, *Exergy and the City: the Technology and Sociology of Power (Failure),* Journal of Urban Technology (2014)

[25] It has been commented that the costs associated with Victoria's 2009 Black Saturday bushfires that were identified by the Royal Commission into the bushfires could be used to inform the social cost multiplier. However, those costs relate to the bushfires rather than the loss of electricity. It has also been commented that the number of excess deaths following the 26 January – 1 February 2009 heatwave in Victoria could also be used. However, similarly, these excess deaths largely relate to the prevailing weather conditions rather than the loss of electricity.

FIGURE 2.10 CALCULATION OF WALDO VCR



SOURCE: ACIL ALLEN

The residential component of the WALDO VCR (in dollars) is calculated in accordance with section 2.2, the commercial / industrial component of the WALDO VCR (in dollars) is calculated in accordance with section 2.3 and the social cost weighting is calculated in accordance with section 2.4. The calculation of the residential USE is discussed in section 2.2 and the calculation of the USE for each industry sector is discussed in section 2.3.

The outputs of the model are:

1. residential component of the WALDO VCR
2. commercial / industrial component of the WALDO VCR, by agriculture, industrial and commercial customers
3. social costs of the WALDO
4. overall WALDO VCR.

Each of these outputs are presented in dollars per kWh.

We have also presented the results as a cost in dollar terms.

There are two outputs screens – a detailed output screen and a summary output screen that also includes the key inputs to the model. An example of the detailed output screen is provided as Figure 2.11, and the summary output screen is provided as Figure 2.12.

If the WALDO VCR for a particular outage is to be estimated from multiple runs of the model, the outage costs and the unserved energy should be aggregated, and the WALDO VCR recalculated. The WALDO VCRs should not be aggregated.

FIGURE 2.11 EXAMPLE OF THE DETAILED OUTPUT SCREEN

VCR for Widespread And Long Duration Outages

VCR Outputs

Residential Component

Residential USE	0.36	GWh
WALDO VCR cumulative cost	$7.54	$million
Residential VCR	$20.79	$/kWh

Business component

	Industry	Sector	Output lost per day ($m)	Daily energy (GWh)	Outage output lost ($m)	Value added lost ($m)	Recovery factor	Outage VA ($m)	Multiplier	Multipler VA ($m)	Total Industry VA ($m)	Restart costs ($m)	USE (GWh)	Business VCR ($/kWh)
1	Agriculture, forestry and fishing	Agriculture	$9.39	0.233	$0.76	$0.36	0.5	$0.18	0.20	$0.15	$0.33	$1.07	0.019	$74.86
2	Mining	Industrial	$12.19	0.892	$1.78	$1.07	0.5	$0.54	0.14	$0.24	$0.78	$2.21	0.130	$23.00
3	Manufacturing, excluding Metal smeltin	Industrial	$4.78	0.303	$1.01	$0.30	0.5	$0.15	0.18	$0.19	$0.34	$3.24	0.064	$55.67
3a	Metal smelting	Industrial	$0.43	0.083	$0.06	$0.03	NA	$39.13	0.18	$0.01	$39.14		0.012	$3,214.58
4	Electricity, gas, water and waste servic	Commercial	$5.09	0.725	$0.95	$0.38	0.1	$0.34	0.13	$0.12	$0.46	$4.84	0.135	$39.38
5	Construction	Commercial	$10.35	0.057	$1.19	$0.37	0.5	$0.19	0.14	$0.17	$0.36	$0.31	0.007	$101.30
6	Wholesale trade	Commercial	$3.56	0.083	$0.50	$0.26	0.5	$0.13	0.12	$0.06	$0.19	$0.57	0.012	$65.00
7	Retail trade	Commercial	$5.46	0.304	$0.74	$0.45	0.5	$0.23	0.10	$0.07	$0.30	$2.63	0.041	$71.00
8	Accommodation and food services	Commercial	$4.45	0.305	$0.94	$0.45	0.1	$0.41	0.15	$0.14	$0.54	$2.51	0.065	$47.22
9	Transport, postal and warehousing	Commercial	$5.04	0.107	$0.70	$0.32	0.5	$0.16	0.12	$0.09	$0.25	$0.81	0.015	$71.26
10	Information, media and telecommunicati	Commercial	$2.18	0.052	$0.42	$0.18	0.1	$0.16	0.14	$0.06	$0.22	$0.36	0.010	$58.05
11	Financial and insurance services	Commercial	$3.43	0.022	$0.62	$0.39	0.1	$0.35	0.10	$0.06	$0.41	$0.14	0.004	$141.88
12	Rental, hiring and real estate services	Commercial	$2.87	0.183	$0.37	$0.19	0.5	$0.09	0.09	$0.03	$0.13	$1.33	0.024	$61.91
13	Professional, scientific and technical ser	Commercial	$3.65	0.055	$0.49	$0.25	0.5	$0.13	0.12	$0.06	$0.18	$0.32	0.007	$68.86
14	Administrative and support services	Commercial	$1.84	0.013	$0.25	$0.15	0.5	$0.07	0.10	$0.02	$0.10	$0.08	0.002	$100.08
15	Public administration and safety	Commercial	$3.56	0.289	$0.48	$0.30	0.1	$0.27	0.09	$0.04	$0.31	$1.71	0.039	$52.05
16	Education and training	Commercial	$3.03	0.042	$0.41	$0.28	0.9	$0.03	0.07	$0.03	$0.06	$0.25	0.006	$54.07
17	Health care and social assistance	Commercial	$6.07	0.086	$1.17	$0.81	0.5	$0.40	0.07	$0.08	$0.48	$0.60	0.017	$64.94
18	Arts and recreation services	Commercial	$1.44	0.021	$0.29	$0.11	0.1	$0.10	0.14	$0.04	$0.14	$0.15	0.004	$68.99
19	Other services	Commercial	$2.88	0.033	$0.59	$0.30	0.5	$0.15	0.10	$0.06	$0.21	$0.24	0.007	$67.02
	Total business		$91.70	3.888	$13.71	$6.94		$43.20		$6.30	$44.93	$23.38	0.618	$110.61
	Total business (excl. smelting)		$91.27	$3.80	$13.65	$6.92		$4.07		$6.29	$5.78	$23.38	0.605	$48.18

Sector	Value added lost ($m)	Restart cost ($m)	USE (GWh)	VCR ($/kWh)
Agriculture	$0.33	$1.07	0.019	$74.86
Industrial	$40.26	$5.45	0.206	$221.39
Commercial	$4.34	$16.86	0.392	$54.02

Social component

Social multiplier:	1.3	
Social cost	$11.01	$million
Social VCR	$11.37	$/kWh

Overall

Total USE	0.98	GWh
Total cost	$86.86	$million
Overall VCR	$88.62	$/kWh

Total cost summary

	Total cost ($m)	WALDO VCR ($/kWh)
Residential	$7.54	$20.79
Agriculture	$1.40	$74.86
Industrial	$45.71	$221.39
Commercial	$21.20	$54.02
Social	$11.01	$11.37

SOURCE: WALDO VCR MODEL

FIGURE 2.12 EXAMPLE OF THE SUMMARY OUTPUT SCREEN

VCR for Widespread And Long Duration Outages

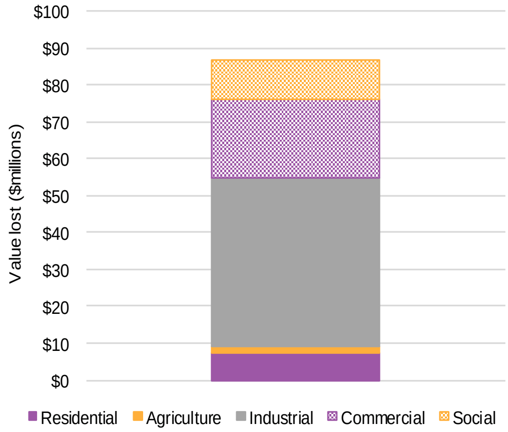
Scenario summary

Season	Winter
Day type	Weekend
Start time:	5:00 PM
Location	Suburban New South Wales CZ6, Regional Australia CZ6
Area	Moderate (e.g. between 5-85 km radius)
Annual energy consumption (GWh	2500
Proportion residential:	20%

Business characteristics	Economic share	Proportion direct connect	Proportion large business
Agriculture	6.9%		83%
Industrial	22.1%		94%
Commercial	71.0%		84%

Event characteristics		
Unserved energy	1	GWh
Outage duration	3.5	hours
Peak / Off peak	Peak	

	Total cost ($m)	WALDO VCR ($/kWh)
Residential	$7.54	$20.79
Agriculture	$1.40	$74.86
Industrial	$45.71	$221.39
Commercial	$21.20	$54.02
Social	$11.01	$11.37
Overall	**$86.86**	**$88.62**



SOURCE: WALDO VCR MODEL

3 MODELLING THE WALDO VCR

The WALDO VCR model described in chapter 2 was used to estimate the WALDO VCR for three scenarios, and to test the sensitivity of the results to changes in the timing of the outage.

The scenarios and sensitivities are described in section 3.1. The results from the modelling of the scenarios are presented in section 3.2 and of the sensitivities in section 3.3. The results are compared with the 'standard' VCRs in section 3.4. Key findings from the modelling of the scenarios are discussed in section 3.5.

These scenarios are presented in the report for illustrative purposes only.

They should not be interpreted as any reflection of any assessment that has been undertaken that these scenarios are more likely to occur than any other outage scenarios.

3.1 Description of the scenarios and sensitivities

The model was used to calculate the WALDO VCR for three scenarios specified by the AER. The key characteristics of the three scenarios are summarised in Table 3.1.

One of the scenarios modelled is an outage in South Australia. South Australia has five combinations of climate zones and remoteness:

— 3 & 4 / Regional Australia
— 5 / CBD Adelaide
— 5 / Suburban South Australia
— 5 / Regional Australia
— 6 / Regional Australia.

Where there are multiple combinations of climate zones and remoteness, the model averages the parameters for each combination of climate zone and remoteness. For the purposes of the modelling, we have assumed that South Australia comprises three combinations of climate zone and remoteness – those in climate zone 5 – as the other three combinations of climate zone and remoteness are likely to make a small contribution to the WALDO VCR for this scenario.

To estimate a more accurate value of the WALDO VCR for the South Australian outage, the model would be run five times – once for each combination of climate zone and remoteness.

TABLE 3.1 CHARACTERISTICS OF THE SCENARIOS MODELLED

	Scenario 1 – Regional Victoria	Scenario 2 – Suburban Queensland	Scenario 3 – South Australia
Timing of outage			
Season	Winter	Summer	Summer
Day of week	Weekend	Weekday	Weekday
Start time	5 pm (peak)	7 am (peak)	7 am (peak)
Location			
Climate zone / remoteness	6 / Regional Australia	2 / Suburban Australia	5 / CBD Adelaide 5 / Suburban South Australia 5 / Regional Australia
Area impacted	Medium	Medium	Large
Residential load impacted	258 GWh pa	1,176 GWh pa	3,877 GWh pa
Business load impacted	774 GWh pa	5,881 GWh pa	11,631 GWh pa
Business composition by industry sector	As suggested by the model based on the inputs and National Accounts	As suggested by the model based on the inputs and National Accounts	As suggested by the model based on the inputs and National Accounts
Nature of the outage	USE = 1 GWh Duration = 10.5 hours	USE = 7 GWh Duration = 5.5 hours	USE = 14 GWh Duration = 5.5 hours

Note: Duration of the outage is calculated based on unserved energy, timing of outage and load profile

SOURCE: AUSTRALIAN ENERGY REGULATOR

For each of the scenarios, we have not changed the default breakdown of the industry sectors between small/medium and large business customers. The proportions are as set out in Table 2.12.

The model was also used to test the sensitivity of the WALDO VCR to changes in the inputs to these scenarios, in particular to the time at which the outage commences – in summer compared to winter, a weekday compared to the weekend, and at different times of the day. The sensitivities that have been modelled are summarised in Table 3.2.

TABLE 3.2 SENSITIVITIES MODELLED

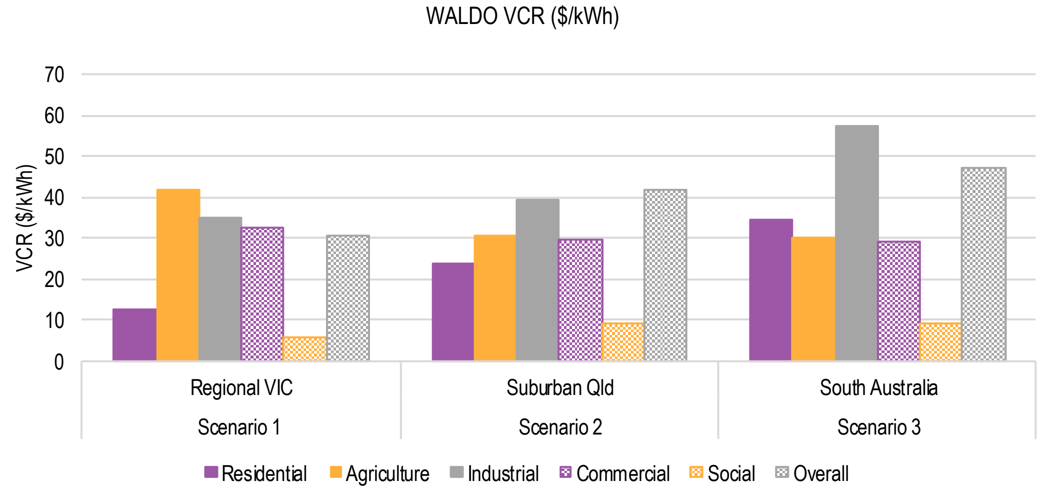
Scenario / sensitivity	Season	Day of week	Start time
Scenario 1 – Regional Victoria	Winter	Weekend	5 pm (peak)
Sensitivity 1A – summer	Summer	Weekend	5 pm (peak)
Sensitivity 1B – weekday	Winter	Weekday	5 pm (peak)
Sensitivity 1C – off-peak	Winter	Weekend	8 pm (off-peak)
Scenario 2 – Suburban Queensland	Summer	Weekday	7 am (peak)
Sensitivity 2A – winter	Winter	Weekday	7 am (peak)
Sensitivity 2B – weekend	Summer	Weekend	7 am (peak)
Sensitivity 2C – off-peak	Summer	Weekday	8 pm (off-peak)
Scenario 3 – South Australia	Summer	Weekday	7 am (peak)
Sensitivity 3A – winter	Winter	Weekday	7 am (peak)
Sensitivity 3B – weekend	Summer	Weekend	7 am (peak)
Sensitivity 3C – off-peak	Summer	Weekday	8 pm (off-peak)

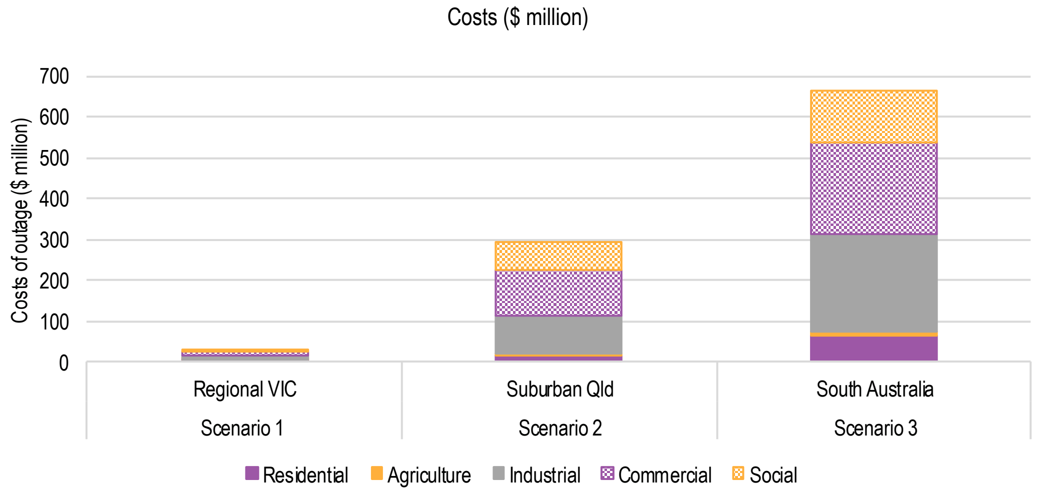
SOURCE: ACIL ALLEN

3.2 Results from modelling the scenarios

The estimated WALDO VCR, and the estimated cost of the outage, for each of the scenarios is illustrated in Figure 3.1 and set out in Table 3.3.

FIGURE 3.1 ESTIMATED WALDO VCR AND OUTAGE COSTS FOR EACH OF THE THREE SCENARIOS ($2019)





SOURCE: ACIL ALLEN ANALYSIS BASED ON WALDO VCR MODEL

TABLE 3.3 ESTIMATED WALDO VCR AND OUTAGE COSTS FOR EACH OF THE THREE SCENARIOS ($2019)

	Scenario 1 – Regional Victoria	Scenario 2 – Suburban Queensland	Scenario 3 – South Australia
WALDO VCR ($/kWh)			
Residential	12.4	23.8	34.7
Agricultural	41.8	30.8	30.2
Industrial	35.0	39.6	57.4
Commercial	32.5	29.8	29.3
Social	5.7	9.1	9.1
Overall	**30.5**	**41.6**	**47.3**

	Scenario 1 – Regional Victoria	Scenario 2 – Suburban Queensland	Scenario 3 – South Australia
Cost of outage ($ million)			
Residential	5.3	16.1	65.5
Agricultural	1.3	2.6	9.4
Industrial	9.4	92.6	237.0
Commercial	8.9	116.1	224.6
Social	5.7	63.9	126.2
Total	**30.5**	**291.3**	**662.8**

SOURCE: WALDO VCR MODEL

The unserved energy for the regional Victorian outage is significantly less than the unserved energy for the suburban Queensland outage, which is significantly less than the unserved energy for the South Australian outage. As a consequence, the outage costs associated with the regional Victoria outage are significantly less than for the suburban Queensland outage, which are significantly less than for the South Australian outage.

The overall WALDO VCR is less for the regional Victoria outage than for the suburban Queensland outage, which is less than the WALDO VCR for the South Australian outage. The residential VCR in regional Victoria is lower than in suburban Queensland and South Australia, and represents a higher proportion of the outage costs. This is partly offset by a higher agricultural VCR in regional Victoria which represents a higher proportion of the outage costs than in suburban Queensland and South Australia.

The overall WALDO VCR for the South Australian outage is higher than for the outages in regional Victoria and suburban Queensland. This is because:

— the outage is over a larger area and therefore there is a higher wideness factor that is applied to the 'standard' VCR for residential customers

— the outage is shorter than the outage in regional Victoria (the VCR generally decreases as the outage gets longer).

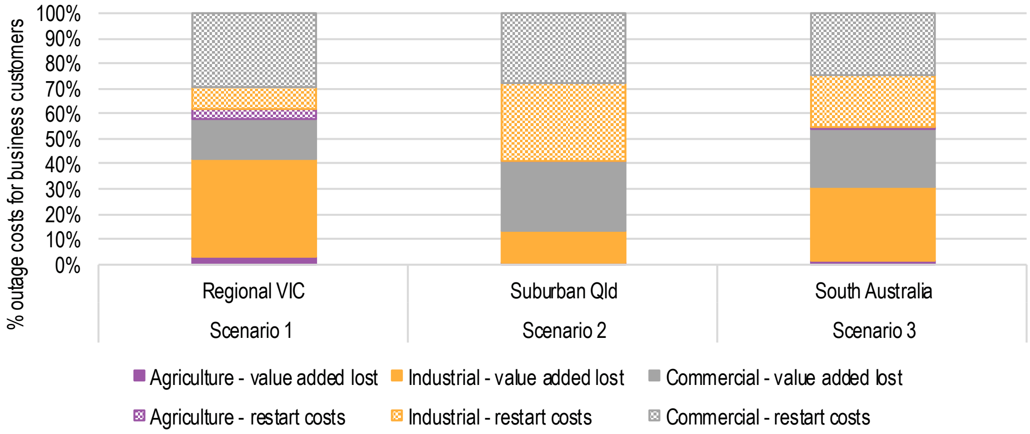
The WALDO VCR for industrial customers in South Australia is higher than for industrial customers impacted by the outage in suburban Queensland, which is higher than for industrial customers impacted by the regional Victoria outage. The differences in the WALDO VCR are attributable to the different composition of the industrial sector in each of the three scenarios.

The VCR for mining is lower than for manufacturing. The proportion of mining is greatest in regional Victoria, which lowers the WALDO VCR, and lowest in suburban Queensland. The VCR for metal smelting is significantly higher than for mining and manufacturing. While the proportion of metal smelting is low in all three scenarios, it is higher in regional Victoria and South Australia, which increases the WALDO VCR, than in suburban Queensland. The WALDO VCR for metal smelting is higher in South Australia and suburban Queensland because the outage is shorter than in regional Victoria.

Figure 3.2 illustrates the breakdown of the outage costs for business customers for each of the scenarios. It illustrates that the outage costs for agricultural customers are relatively low across all three scenarios, and that the value added lost by industrial customers is proportionally much lower in suburban Queensland than in regional Victoria or South Australia.

The restart costs represent a higher proportion of the costs for business customers impacted by the outage in suburban Queensland than customers impacted by the other outages. This is because the restart costs are lower in mining than the other industrial sectors and there is very little mining in suburban Queensland.

FIGURE 3.2 BREAKDOWN OF THE COSTS OF AN OUTAGE FOR BUSINESS CUSTOMERS ($2019)



SOURCE: ACIL ALLEN BASED ON WALDO VCR MODEL

3.3 Results from modelling the sensitivities

The results from the modelling of the sensitivities are presented for each scenario in the following sections. The sensitivity of the estimates of the WALDO VCR and outage costs to changes in the timing of the outage (season, day of the week and time of the day) are tested.

3.3.1 Scenario 1: Regional Victoria

The sensitivity of the estimated WALDO VCR, and the estimated cost of the outage, for scenario 1 (regional Victoria) is illustrated in Figure 3.3 and set out in Table 3.4.

The overall WALDO VCR and outage costs are slightly higher in summer than in winter and higher on weekdays than on weekends. The overall VCR and outage costs are lower when the outage occurs during off-peak times than when it occurs during peak times.

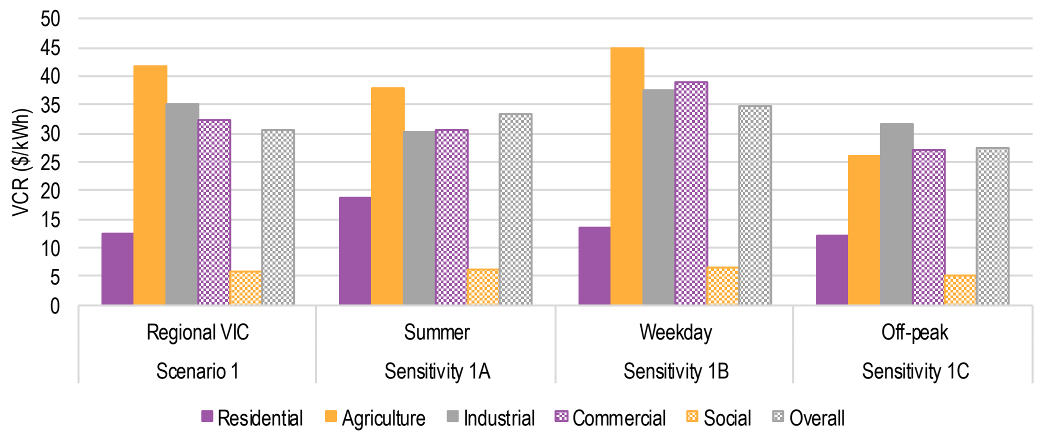
The residential WALDO VCR is higher in summer than in winter driven by a higher ‘standard’ VCR for residential customers in summer than in winter.

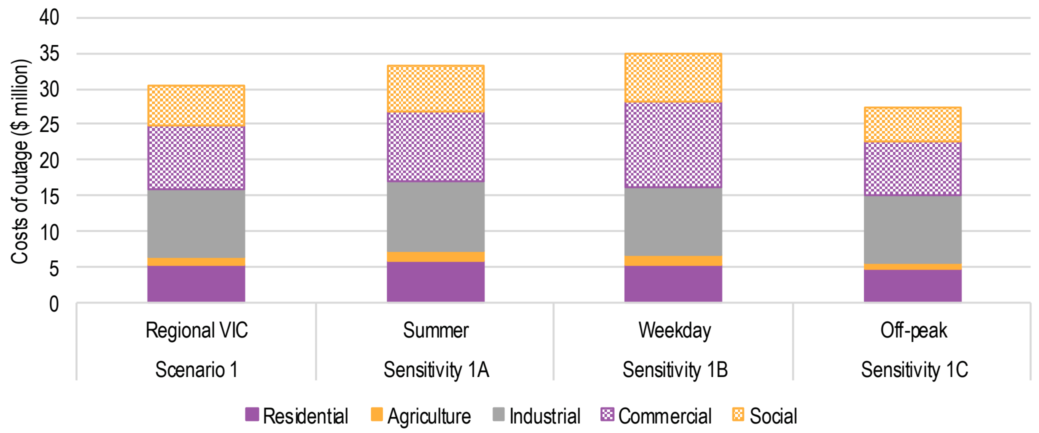
The industrial WALDO VCR is lower in summer than in winter because, for the same total unserved energy, the duration of the outage is longer in summer than in winter. The industrial load is the same in winter as in summer and so the unserved energy for industrial customers is higher in summer than in winter, reducing the VCR.

The commercial WALDO VCR is higher on a weekday than on a weekend because the restart costs are higher relative to the value added lost on a weekday because the outage is shorter in duration.

The agricultural WALDO VCR is higher on a weekday than on a weekend because the unserved energy is lower on a weekday than the weekend because the outage is shorter in duration.

FIGURE 3.3 SENSITIVITY OF THE ESTIMATED WALDO VCR AND OUTAGE COSTS FOR SCENARIO 1 (REGIONAL VICTORIA) ($2019)





SOURCE: ACIL ALLEN ANALYSIS BASED ON WALDO VCR MODEL

TABLE 3.4 SENSITIVITY OF THE ESTIMATED WALDO VCR AND OUTAGE COSTS FOR SCENARIO 1 (REGIONAL VICTORIA) ($2019)

	Scenario 1 – Regional Victoria	Sensitivity 1A – summer	Sensitivity 1B – weekday	Sensitivity 1C – off-peak
Characteristics of outage				
Season	Winter	Summer	Winter	Winter
Day of week	Weekend	Weekend	Weekday	Weekend
Timing	Peak	Peak	Peak	Off-peak

	Scenario 1 – Regional Victoria	Sensitivity 1A – summer	Sensitivity 1B – weekday	Sensitivity 1C – off-peak
WALDO VCR ($/kWh)				
Residential	12.4	18.8	13.3	12.1
Agricultural	41.8	37.7	44.8	26.0
Industrial	35.0	30.1	37.4	31.7
Commercial	32.5	30.5	38.8	27.1
Social	5.7	6.3	6.7	5.0
Overall	**30.5**	**33.2**	**34.8**	**27.5**
Cost of outage ($ million)				
Residential	5.3	5.9	5.5	4.7
Agricultural	1.3	1.4	1.2	0.9
Industrial	9.4	9.8	9.5	9.4
Commercial	8.9	9.8	11.9	7.5
Social	5.7	6.3	6.6	5.0
Total	**30.5**	**33.2**	**34.8**	**27.5**
Duration of outage (hours)				
	10.5	13.0	9.5	12.5

SOURCE: WALDO VCR MODEL

3.3.2 Scenario 2: Suburban Queensland

The sensitivity of the estimated WALDO VCR, and the estimated cost of the outage, for scenario 2 (suburban Queensland) is illustrated in Figure 3.4 and set out in Table 3.5.

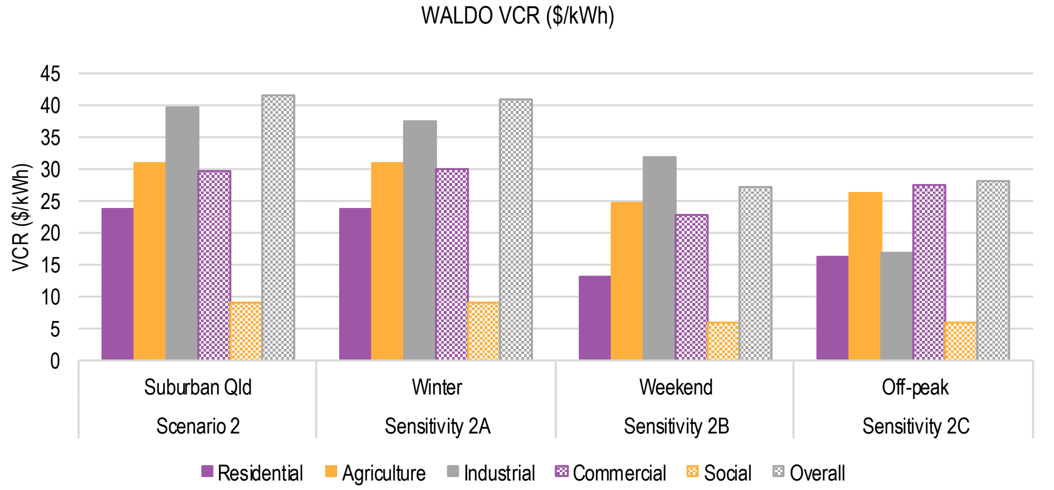
The overall WALDO VCR and costs for the outage in suburban Queensland are similar if the outage occurs in summer or in winter, but substantially lower if the outage occurs on a weekend rather than a weekday and during off-peak times rather than peak times.

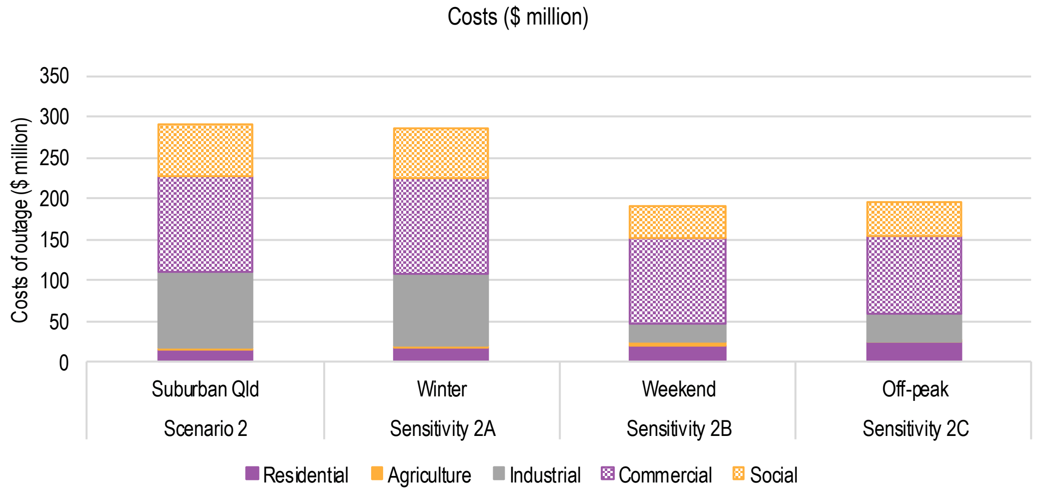
The WALDO VCRs for each sector follow a similar pattern, although the difference between the WALDO VCR for outages occurring during peak and off-peak times is greater for industrial customers and less for commercial customers. This outcome arises because of the differences in the start time for the outage, the duration of the outage and the load profile.

When the outage is assumed to start during a peak time, it starts at 7am and lasts for 5½ hours (until 12.30pm). When the outage is assumed to start during an off-peak time, it starts at 8pm and lasts for 12½ hours (until 8.30am the next morning). The load profile for manufacturing, for example, is such that it is low overnight, ramps up from around 5am to a peak around 1pm and then declines to a low level at around 5pm.

When the outage is assumed to start at 7am, the load for manufacturing would otherwise have been high during the entire period of a 5½ hour outage. When the outage is assumed to start at 8pm, the load for manufacturing would have otherwise been low for 9 hours of the 12½ hour outage, but then substantially higher for the last 3½ hours of the outage.

FIGURE 3.4 SENSITIVITY OF THE ESTIMATED WALDO VCR AND OUTAGE COSTS FOR SCENARIO 2 (SUBURBAN QUEENSLAND) ($2019)





SOURCE: ACIL ALLEN ANALYSIS BASED ON WALDO VCR MODEL

TABLE 3.5 SENSITIVITY OF THE ESTIMATED WALDO VCR AND OUTAGE COSTS FOR SCENARIO 2 (SUBURBAN QUEENSLAND) ($2019)

	Scenario 2 – Suburban Queensland	Sensitivity 2A – winter	Sensitivity 2B – weekend	Sensitivity 2C – off-peak
Characteristics of outage				
Season	Summer	Winter	Summer	Summer
Day of week	Weekday	Weekday	Weekend	Weekday
Timing	Peak	Peak	Peak	Off-peak

	Scenario 2 – Suburban Queensland	Sensitivity 2A – winter	Sensitivity 2B – weekend	Sensitivity 2C – off-peak
WALDO VCR ($/kWh)				
Residential	23.8	23.8	13.1	16.2
Agricultural	30.8	30.8	24.8	26.3
Industrial	39.6	37.7	31.9	16.8
Commercial	29.8	30.0	22.6	27.6
Social	9.1	9.0	5.8	6.0
Overall	**41.6**	**41.0**	**27.3**	**28.0**
Cost of outage ($ million)				
Residential	16.1	16.5	20.5	24.4
Agricultural	2.6	2.6	4.0	1.4
Industrial	92.6	88.0	23.0	34.2
Commercial	116.1	116.8	103.0	94.1
Social	63.9	62.8	40.8	41.9
Total	**291.3**	**286.7**	**191.3**	**196.0**
Duration of outage (hours)				
	5.5	5.5	10.0	12.5

SOURCE: WALDO VCR MODEL

3.3.3 Scenario 3: South Australia

The sensitivity of the estimated WALDO VCR, and the estimated cost of the outage, for scenario 3 (South Australia) is illustrated in Figure 3.5 and set out in Table 3.6.

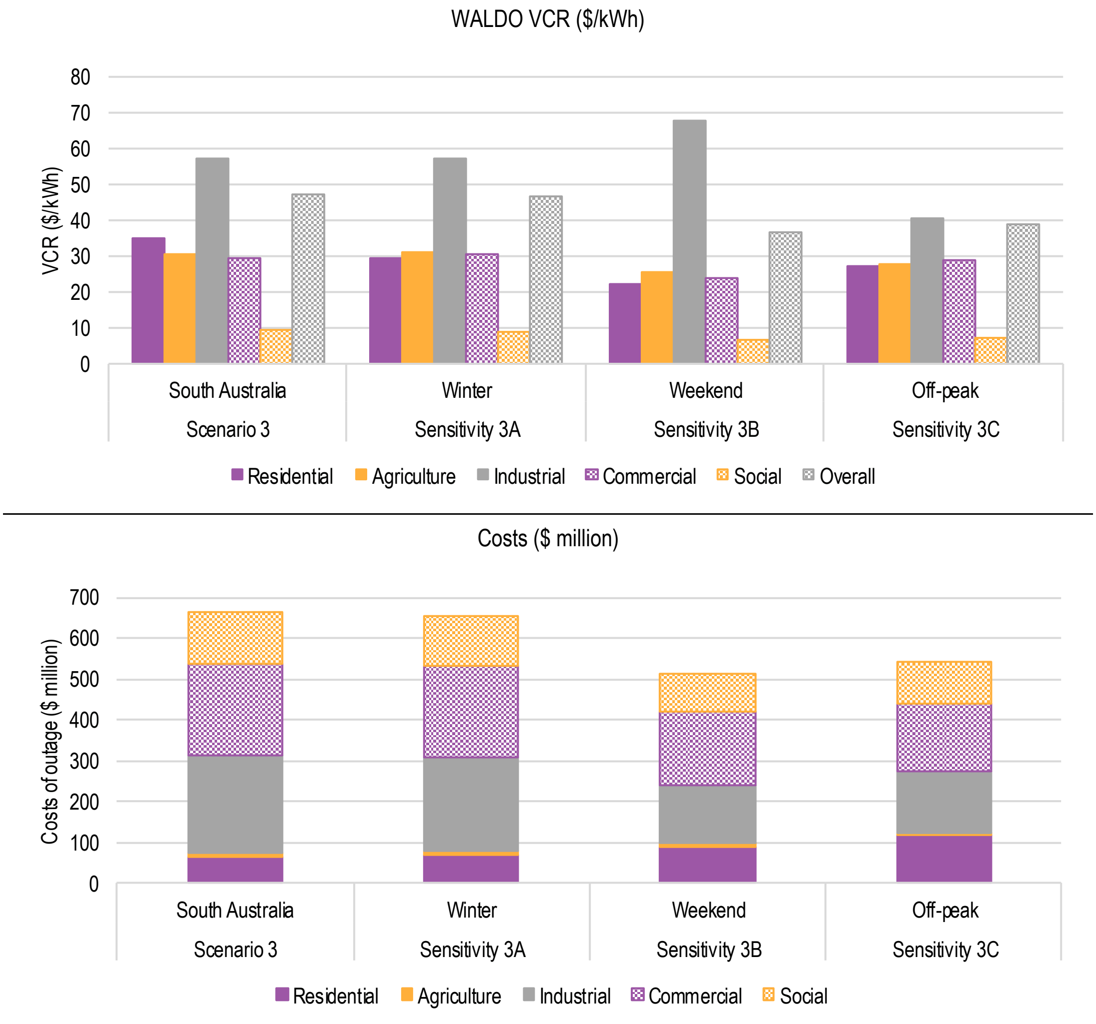
The overall WALDO VCR and outage costs are similar for outages occurring in winter and in summer, and lower for outages occurring on the weekend than on a weekday, and for outages starting in an off-peak time rather than a peak time.

The costs for residential customers are higher when an outage occurs during an off-peak time than during a peak-time. This is because the outage that was assumed to start during the peak time commenced at 7am, at the beginning of a work day when the load for business customers is increasing, while the outage that was assumed to start during the off-peak time commenced at 8pm, when the load for business customers is relatively low. As a consequence, the outage is of 5½ hours in duration when it starts at 7am with total unserved energy of 14 GWh and is of 11½ hours in duration when it starts at 8pm with the same total unserved energy. The costs for residential customers of an 11½ hour outage are substantially higher than for a 5½ hour outage.

The difference between the WALDO VCRs is not as significant because the unserved energy for residential customers during an 11½ hour outage is also much higher than during a 5½ hour outage.

The WALDO VCRs by sector do not necessarily follow the same pattern as for the overall WALDO VCRs. For example, the outage costs for industrial customers during the South Australian outage were higher for an outage on a weekday rather than a weekend, but the WALDO VCR was higher on the weekend rather than on a weekday. This is because the unserved energy for manufacturing customers during an outage on the weekend is significantly lower than on a weekday, which increases the VCR. This is offset in part by the mining load which is the same each day, but with a higher unserved energy on the weekend because the outage would be of 9 hours duration if it occurred on a weekend with total unserved energy of 14 GWh, compared to 5½ hours duration if it occurred on a weekday with the same total unserved energy.

FIGURE 3.5 SENSITIVITY OF THE ESTIMATED WALDO VCR AND OUTAGE COSTS FOR SCENARIO 3 (SOUTH AUSTRALIA) ($2019)



SOURCE: ACIL ALLEN ANALYSIS BASED ON WALDO VCR MODEL

TABLE 3.6 SENSITIVITY OF THE ESTIMATED WALDO VCR AND OUTAGE COSTS FOR SCENARIO 3 (SOUTH AUSTRALIA) ($2019)

	Scenario 3 – South Australia	Sensitivity 3A – winter	Sensitivity 3B – weekend	Sensitivity 3C – off-peak
Characteristics of outage				
Season	Summer	Winter	Summer	Summer
Day of week	Weekday	Weekday	Weekend	Weekday
Timing	Peak	Peak	Peak	Off-peak

	Scenario 3 – South Australia	Sensitivity 3A – winter	Sensitivity 3B – weekend	Sensitivity 3C – off-peak
WALDO VCR ($/kWh)				
Residential	34.7	29.5	22.4	27.3
Agricultural	30.2	30.8	25.2	27.8
Industrial	57.4	57.4	67.7	40.6
Commercial	29.3	30.2	24.1	29.0
Social	9.1	8.9	6.6	7.1
Overall	**47.3**	**46.8**	**36.5**	**38.6**
Cost of outage ($ million)				
Residential	65.5	69.7	86.6	117.9
Agricultural	9.4	9.2	13.6	4.3
Industrial	237.0	229.7	137.9	153.3
Commercial	224.6	229.7	181.8	166.7
Social	126.2	124.3	91.2	97.9
Total	**662.8**	**654.7**	**511.1**	**540.1**
Duration of outage (hours)				
	5.5	5.5	9.0	11.5

SOURCE: WALDO VCR MODEL

3.4 Comparison of WALDO VCRs to 'standard' VCRs

Table 3.7 compares the WALDO VCRs for the three scenarios modelled to the 'standard' aggregate VCRs as published by the AER.

The 'standard' aggregate VCR for residential customers in climate zone 6 regional is much higher than the WALDO VCR for residential customers under scenario 1 due to the differences in the timing and the duration of the outages.

The 'standard' VCR is effectively a weighted average of outages occurring in summer and in winter, on weekdays and weekends, and during peak and off-peak times, and of durations 0-1 hours, 1-3 hours, 3-6 hours and 6-12 hours. Scenario 1 occurred on a weekend in winter and was of duration 10 hours. The 'standard' VCR is lower in winter than summer, lower on weekends than weekdays and decreases as the duration increases. Accordingly, the WALDO VCR for residential customers under scenario 1 is much less than the 'standard' aggregate VCR for residential customers in climate zone 6 regional.

The 'standard' aggregate VCR for residential customers in climate zone 2 CBD and suburban is 3.7 per cent lower than the WALDO VCR for residential customers under scenario 2 primarily due to the 10 per cent wideness factor applied to calculate the WALDO VCR, offset by the duration of the outage being longer than the average outage duration (with a lower VCR).

Similarly, the 'standard' aggregate VCR for residential customers in climate zone 5 CBD and suburban South Australia is 4.4 per cent lower than the WALDO VCR. In addition to the wideness factor and the longer duration of the outage, the scenario includes residential customers in climate zone 5 regional, for which the 'standard' aggregate VCR is lower than for residential customers in climate zone 5 CBD and suburban South Australia.

The 'standard' aggregate VCR for agricultural customers is lower than the WALDO VCR for agricultural customers in regional Victoria (scenario 1) and higher than for agricultural customers in suburban Queensland (scenario 2) and South Australia (scenario 3). The WALDO VCR for agricultural customers in regional Victoria (scenario 1) is higher than for agricultural customers in suburban

Queensland and South Australia because the restart costs are relatively high relative to the value added lost for scenario 1 compared to scenarios 2 and 3. The value added that is lost under scenario 1 is low relative to scenarios 2 and 3 because of the timing of the outage – scenario 1 commences at the end of the day when the load (and therefore the value added) is low while scenarios 2 and 3 start at the beginning of the day when the load (and therefore the value added) is high.

The VCR is calculated by dividing the outage costs by the unserved energy. If the unserved energy is relatively low (or high), the VCR is relatively high (or low).

There are four 'standard' aggregate VCRs that correspond to the WALDO VCR for industrial customers – the 'standard' aggregate VCRs for industrial customers that are directly connected and for direct connected customers that are industrial, metals and mines. The four 'standard' aggregate VCRs vary within a range from $19.86/kWh to $117.99/kWh. The WALDO VCRs lie within this range.

The differences between the WALDO VCRs are due to the different composition of industry in each of the scenarios and the different timing of the outages, which affects the unserved energy, as discussed in section 3.2.

The 'standard' aggregate VCRs for commercial customers are very different depending on whether the commercial customer is direct connected or not. The WALDO VCRs lie within this range. The WALDO VCRs vary less for commercial customers across the scenarios than for other types of customers.

The WALDO VCR includes a social component that is not included in the 'standard' aggregate VCRs.

TABLE 3.7 COMPARISON OF THE ESTIMATED WALDO VCRs TO THE 'STANDARD' VCRs ($2019)

	Scenario 1 – Regional Victoria	Scenario 2 – Suburban Queensland	Scenario 3 – South Australia	'Standard' aggregate VCRs
Residential ($/kWh)				
Climate zone 6 regional	12.4			21.77
Climate zone 2 CBD & suburban		23.8		22.95
Climate zone 5 CBD & suburban SA			34.7	33.23
Climate zone 5 regional				24.57
Business ($/kWh)				
Agricultural	41.8	30.8	30.2	37.87
Industrial	35.0	39.6	57.4	63.79
Direct connect – industrial				117.99
Direct connect – metals				19.86
Direct connect – mines				35.16
Commercial	32.5	29.8	29.3	44.52
Direct connect – services				10.54
Social ($/kWh)				
	5.7	9.1	9.1	N/A

SOURCE: WALDO VCR MODEL; AER, VALUES OF CUSTOMER RELIABILITY – FINAL DECISION, DECEMBER 2019, PAGES 14, 17-18

3.5 Findings

The modelling of the scenarios and sensitivities has demonstrated that the WALDO VCR is dependent on:

- the characteristics of the load – the proportion of the residential customer load to the business customer load, the breakdown of load by industry sector, and the profile of that load over the day and week
- the characteristics of the outage, in particular whether the outage occurs on a weekend or a weekday, what time the outage commences and the duration of the outage
- the wideness of the outage – the wider the outage, the higher the wideness factor that is applied to the residential load.

The WALDO VCR appears to be similar regardless of whether the outage occurs in summer or winter. This is because the business load is higher than the residential load, and therefore has a greater influence on the WALDO VCR, and for the purposes of the modelling the business load has been assumed to be the same in winter and in summer.

The results from the WALDO VCR model need to be treated with care as there are a number of assumptions that have been made. In particular:

1. the multiplier that is applied for social costs
2. the multipliers that are applied for the wideness of the outage
3. the industry recovery factors
4. the industrial load profiles.

Further research is recommended to better inform these settings in the model.

Other than the industrial load profiles, the model has been set up so that these factors can readily be updated as more information becomes available.[26] In addition, it has been set up to readily change:

- the proportion of business customers that are direct connected versus not direct connected
- the breakdown of direct connected customers
- the ratio of large to small business customers that are not direct connected
- the constraints that are placed on the model:
  - the minimum outage duration
  - the minimum and maximum unserved energy.

[26] The industrial load profiles can also be changed, but not as readily as the other factors.

APPENDICES

A LITERATURE REVIEW

Table A.1 summarises the literature reviewed.

TABLE A.1 SUMMARY FROM LITERATURE REVIEW

Ref.			Summary
2	Sunhee Baik, Alex Davis, Assessing the Cost of Large-Scale Power Outages to Residential Customers, Risk Analysis (2017)	Widespread, long duration outages Social costs	Widespread and long-lasting outages can have severe individual and societal impacts. Examples include the ice storm that hit southern Quebec, Ontario, and northern New York in 1998, leaving many customers without power for several weeks in the dead of winter (affecting 2.3 million people, economic losses of over $4 billion, and the loss of 44 lives), and the extensive outages along the East Coast after Hurricane Sandy (affecting more than 8 million people, economic losses of over $50 billion, and at least 147 direct deaths). These large outages are not limited to extreme weather events, but can also result from a large solar mass ejection (for example, the geomagnetic storm on the United States and Quebec power grids that caused a blackout in 1989), as well as physical and cyber attacks on grid infrastructure. The following table provides a list of services that will and will not work in homes and communities when the power is out for the entire region.

In your home		In community	
Will work	**Will not work**	**Will work**	**Will not work**
– Old style telephones that have a rotary dial. – Anything that runs on a battery, as long as the battery lasts (e.g., radios, flashlights, laptop computers, and cell phones). – Natural gas and all normal water and sewer services.	– New style telephones that include a plug to a power outlet. – All electrical appliances that cannot also run on batteries, including air conditioners and blowers that circulate air. – Cable and Internet service.	– Emergency service including 911 (via cell phone or rotary dial phone). – Hospitals, police stations, and other places that have back-up generators. – TV and radio stations (most have back-up generators). – Natural gas and all normal water and sewer services. – Bus service. – GPS service.	– Traffic signals. – Street lights. – Banks and ATMs. – Most gas stations (pumps need electricity). – Food stores (lights, refrigeration, and cash registers will not work). – Most restaurants (very few have back-up generators). – Elevators in buildings without back-up. – Ventilator fans and lighting in traffic tunnels. – Electric trolley service. – Airport major delays.

The study results suggest that the value of serving High Priority (HP) demands for a one-time 24-hour outage (M= $0.75/kWh) was significantly higher than that of Low Priority (LP) demands (M= $0.51/kWh).

If it is assumed that the cost of an outage increases proportionally to the duration, scaling the Sullivan et al. results to a 24-hour outage suggests a cost of $46. While the estimated cost is higher than this study's initial "sure" WTP for the full back-up service (M= $39), it is less than the number they got from the final stage (M= $51). Importantly, the increase comes from the HP demands, not from the LP demands.

Ref.			Summary
4	Alexis Blue, Assessing economic impacts of disruption to Oregon's energy infrastructure to enhance regional disaster resilience, WWU Graduate School Collection (2014) 321	Macroeconomic modelling	Using I-O modelling helped highlight sector dependencies that can be enhanced to improve regional disaster resilience.
6	Mark Burlingame, Patty Walton, NARUC and MDPSC cost-benefit analysis of various reliability improvement projects from the end users' perspective	Long duration outages	One of the primary questions investigated in this report is "What is the cost to a customer of a prolonged outage?" **Residential customers** The following costs were identified as hardships and costs of residential customers being without electricity: – Ruined food – probably the most common cost for residential customers in a prolonged outage is that of ruined food. According to the USDA, the refrigerator will keep food safe for up to 4 hours. According to a Con Edison study, the average values of food spoilage in a refrigerator and freezer for 12 or more hours ranged from $72 to $125. – Being without water (if on a well and septic system) – some rural customers would experience costs due to inoperable electric pumps for wells and septic systems. These costs include the purchase of drinking water. There is a possible cost of repairing septic systems due to "…wastewater collecting in the septic tank, treatment unit or dosing tank during the electrical outage. – Operating a home generator – many residential customers investigate the possibility of installing permanent back-up generation. – Hotel room – in cases of prolonged outages or due to damage to the home, customers may choose to relocate to a hotel. – Relocating a home-based business – many people work out of their homes. Home-based work requires a work-space, telecommunications, internet connection, filing and storage space and climate control. The research indicates that for the first few days of an outage, customers may not require a new workplace, and that a customer would return to work full-time after 5 days. – Accommodations for the elderly and disabled – the study used the cost of a hotel room as a proxy for the cost of relocating the elderly from residences or from assisted living. – Reduction in lost productivity, wages, and revenue to businesses – for workers who are paid hourly, lost wages become a very substantial cost. – Road/Transportation Disruption – customers who live in areas where travel becomes difficult or impossible due to downed power lines or inoperative traffic lights may be delayed in travel or find it necessary to detour around troubled areas. Traffic delays cost motorists $22 per hour delayed. If motorists must take a detour, the proxy used was the US Internal Revenue Service mileage allowance, which was $0.565/mile for 2013. – Other costs to maintain basic comfort and necessity levels in a residence, including gas lanterns, gas stoves, back-up battery supply for electronics, candles, ice and kerosene heaters. The survey showed that 75 – 80% of respondents listed "lost heat/air conditioning" and "spoiled food" as the "biggest hassles" customers face in a prolonged outage. Over half of respondents listed losing and/or resetting electronic devices as problematic followed closely by losing lighting.

Ref.	Summary
	Commercial customers The following costs were identified as hardships and costs of commercial customers being without electricity: – Ruined food for a food service, entertainment or accommodation business – the research indicated that the costs of food for accommodations and food service establishments varied between 25% and 38% of total revenues. – Being without water (if on a well and septic system for a small or rural business) – commercial customers operating on wells and septic systems are assumed to be small and rural. – Operating a back-up generator or microgrid. – Relocating a home-based business employees – if a company has employees working at home who are unable to continue doing so, then the company may need to provide temporary workspace for those displaced workers. – Reduction in lost productivity, wages, and revenue to businesses – firms unable to conduct normal business operations are subject to lost revenues. This is truer for businesses whose sales depend on day to day operations. Other firms may not be as vulnerable, such as those firms with longer sales cycles. – Other costs such as those related to equipment damage, other restart costs, miscellaneous costs, and back-up battery supply for electronics for up to 30 minutes. The commercial segment is diverse in size and type, whether it is segmented by revenues, employees or electricity consumption. This significantly affects individual direct costs. **Industrial customers** The following costs were identified as hardships and costs of industrial customers being without electricity: – Being without water and waste water treatment for industrial processes – onsite industrial water and waste water treatment is critically necessary for the following industrial processes: Iron and steel industry, Mines and quarries, Food industry, Pulp and paper industry, Chemicals industry, and Nuclear industry. – Operating a generator or micro grid – Reduction in lost productivity, wages, and revenue to businesses – Other costs such as materials loss/spoilage, other restart costs, and equipment damage. As with the commercial customer segment, industrial customers exhibit a vast degree of diversity in terms of energy consumption. Three sectors of the U.S. economy are particularly sensitive to power disturbances: – The digital economy (DE). This sector includes firms that rely heavily on data storage and retrieval, data processing, or research and development operations. Specific industries include telecommunications, data storage and retrieval services (including collocation facilities or Internet hotels), biotechnology, electronics manufacturing, and the financial industry. – Continuous process manufacturing (CPM). This sector includes manufacturing facilities that continuously feed raw materials, often at high temperatures, through an industrial process. Specific industries include paper; chemicals; petroleum; rubber and plastic; stone, clay, and glass; and primary metals.

Ref.			Summary
			– Fabrication and essential services (F&ES). This sector includes all other manufacturing industries, plus utilities and transportation facilities such as railroads and mass transit, water and wastewater treatment, and gas utilities and pipelines." EPRI determined that longer power outages created greater costs for businesses. **Value of lost load** For all customer segments, on a $/kW basis the first 6-8 hours are when costs rise at a logarithmic rate. After the first 6-8 hours, costs on a per kW basis level off, becoming primarily a function of the length of the outage. An approximate 24 hour outage cost could be determined by multiplying an 8 hour outage by 3 for residential customers. An 8-hour outage does not vary much in cost from a 24-hour outage for commercial customers.
7	Royal Academy of Engineering, Counting the cost: the economic and social costs of electricity shortfalls in the UK: a report for the Council for Science and Technology, (2014)	Social costs	Estimates of VoLL are highly sensitive to the characteristics of the outage, in particular the timing, duration, location. **Outage duration** For businesses, many short outages have a more pronounced impact than one long outage, whereas households are more affected by one long outage. Both households and businesses are very concerned about data loss and damage to computing equipment; it is worth noting that this can occur even if the outage is just for one second. One important point which was raised is that there may be 'critical thresholds' of duration, such as the time it takes for food to go off in a fridge, or for a generator to run out of diesel. **Social and political impacts** The study did not reveal any recent real-world examples of outages leading to considerable social unrest. The only example found was the Bronx riots in the 1970s, but the UK's previous experience of outages occurring over a large geographical area for 24 hours or more is so limited that projections cannot really be made with confidence. Nevertheless, demand for electricity is notoriously inelastic. Electricity shortfalls lead to rising prices, which could increase fuel poverty. Moreover, several respondents suggested that there is evidence that outages lead to considerable knock-on effects between sectors, especially as economies are now so interconnected. However, the knock-on effects are dependent on value chains; the higher up the value chain, the greater the impact to the economy as a whole. So for example, an outage at a company supplying vital components for a large manufacturing firm could have knock-on effects to all the companies in that supply chain, and in turn could have an impact on huge numbers of consumers; on the other hand, an outage at the end of the supply chain (for instance, a retail unit) would probably only affect the staff and users of that specific company The importance of 'tipping points' on the impacts of longer outages was discussed. Examples could include cash in circulation running out because of a lack of power for ATMs, or emergency back-up generators running out of diesel. Because of this, estimates from Europe have suggested that an outage of more than four days' duration would lead to highly unpredictable societal consequences. However, all these impacts would involve outages of 48 hours or more over a very large geographical area, a scenario that is highly unlikely and would only occur as the result of a low-probability/high-impact event or combination of events which would be impossible to predict. **Case studies** ***Case 1: Canada/Northeast US 2003:*** Area affected: eight US states, one Canadian province Number of people affected: ~50 million

Ref.	Summary
	Duration: between one and four days' blackout; rolling blackouts for up to a week in parts of Ontario Costs: between $4.5 billion and $8.2 billion, including $4.2bn in lost income to workers and investors, $15m to $100m in extra costs to government agencies, for instance due to overtime and emergency service costs, $1–2bn in costs to the affected utilities, and between $380m and $940m in costs associated with lost or spoiled commodities. The blackout happened after trading on the stock exchange had closed for the day, meaning that the impact on financial services from the blackout on Wall Street was limited. Cost data: good availability of data; poor reliability of estimates. This paper estimates lost earnings (using GVA data) and assumes a 5–10% spoilage rate for grocery store goods. Major impacts: high number of calls to 911; fires caused by candles; crime was lower than usual; minimal social unrest. *Impacts on society* The outage immediately affected water supplies and transportation. Subway systems halted and traffic became snarled. Freeways were tied up in Detroit, and the governor of Michigan had to attend an emergency meeting without the use of lights or computers. Altogether, over 1,000 flights were cancelled. Telephone services were severely disrupted, with disruption to mobile phones caused by a sudden surge of demand on the mobile networks. Cashpoints failed, meaning that people without cash couldn't access money to buy supplies of candles or batteries. Up to 11 deaths were linked to the blackout (numbers vary according to different news sources). Hospital admissions from respiratory attacks increased, and calls to 911 soared. However, hospitals managed to use back-up generators to maintain service. It is also worth noting that of the thousands of calls to 911, many were connected to people's initial fears of a terrorist attack, and the tripping out of alarm systems. There were reports of 300 fires caused by candles. There were some isolated (and unofficial) reports of looting; however, crime was minimal, and New York actually recorded a lower crime rate than usual. At first, residents were concerned that this was another terrorist attack. However, officials soon made announcements, and once residents' fears were allayed, and people realised that the kind of rioting and looting which had been experienced in the 1970s wasn't happening, there were reports of a 'party atmosphere' as residents went out into the streets. *Impacts on industry* – Daimler Chrysler: lost production at 14 plants. The company estimated that ~10,000 cars that were moving through the paint shops at the time of the outage had to be scrapped. – Ford: at one Ford plant, the outage caused molten metal to solidify inside one of the furnaces. It took them a week to repair the furnace. – Marathon Oil: a refinery had to be shut down. During this process, a small explosion was caused by the improper shutdown of a carbon monoxide boiler. As a precaution, a one mile strip around the compound was evacuated, including hundreds of residents. ***Case 4: Europe 2006:*** Area affected: 20 countries in Western and Eastern Europe and North Africa Number of people affected: ~15 million Duration: up to two hours Costs: no data available on overall economic costs; ~$100m costs to service industry in spoiled products

Ref.	Summary
	Cost data: very limited Major impacts: rescue services under strain due to tripping of alarm systems and people trapped in lifts; political debate over the future of European electricity transmission integration. *Impacts* – In Coburg, Germany, four men broke into a hardware store – In Cologne, 70 people were trapped for half an hour in a cable car above the Rhine – Der Spiegel reported that “rescue workers were in constant use”, partly due to the tripping of alarm systems – In France, firemen responded to around 40 calls from people stuck in lifts. There were long delays in rail transport, affecting about 100 trains mainly in Germany. Subways had to be evacuated. Costs to restaurants and bars in spoiled products and lost sales totalled around €100m. There were no reports of injuries due to the blackout. However, the impacts could have been greater had the blackout happened on a weekday. ***Case 5: Italy/Switzerland 2003:*** Area affected: Italy and parts of Switzerland Number of people affected: ~56 million Duration: between one-and-a-half and 19 hours Costs: economic impacts estimated at €1,182m Cost data: very limited Major impacts: around 30,000 people were trapped on trains and underground transport; up to four deaths (unofficial). The Italian power system faced its worst disruption in 50 years, which also affected parts of Switzerland with around 56 million people in total. The total energy not delivered was roughly 180GWh. The blackout happened overnight, meaning that impacts were less severe than they could have been otherwise. However, it was the night of the annual Nuit Blanche carnival in Rome, meaning that more people were on the streets at night than usual. 30,000 people were trapped on trains, and several hundred passengers were stranded on underground transit systems. The subway had to be evacuated. All flights were cancelled. Despite the disruption, the police reported no serious incidents; however, there were unofficial reports of three deaths attributed to the blackout, mostly elderly people falling down the stairs in the dark. Some news sites reported traffic chaos on the roads as traffic lights failed, possibly causing one death. Hospitals used back-up generators successfully, meaning that no hospital operations were affected ***Supplemental Case Somerset 2014*** 750,000 homes lost power, with electricity restored for 90% of those within a day.

Ref.			Summary
			The case studies indicate that social impacts are perhaps more limited than may have been expected; it appears as if the trend in a crisis is towards societal co-operation, and this study did not reveal evidence of an outage directly causing social unrest. However, the case studies illustrate that the longer-term impacts on both policy and the economy may be significant.
10	Sean Ericson, Lars Lisell, A flexible framework for modelling customer damage functions for power outages, Energy Systems (2018)	Long duration outages	Sustained loss of power can halt daily activities, lead to spoilage of food, disrupt industrial processes, and can lead to arson, looting, injury and death The authors categorise the types of costs a power outage can incur into three categories of costs: fixed costs which do not depend on outage duration, flow costs which accrue as outage duration increases, and stock costs which relate to the loss of a perishable inventory of goods. Some costs, such as damage to machinery, occur immediately while other costs, such as food spoilage take time to begin accruing. Therefore, a clear understanding of how different types of outage costs vary over time is integral to accurately estimating the effect of outage duration on total outage cost. Most studies do not estimate costs for outages exceeding 8 hours in duration and almost no study estimates costs for outages exceeding 24 hours. Survey estimates therefore have limited applicability to estimating outage costs from extreme events, such as hurricanes, which can have impacts lasting for several days or weeks. **Fixed** costs include shutdown costs and startup costs which do not depend on outage duration. Some examples include computer data loss, damage to machinery, system reboot times, and process interruption resulting in failed output. Estimates for short duration outages can be used as a proxy for fixed costs. **Flow** costs are the value of lost opportunities resulting from a lack of power. Some examples of flow costs include loss of emergency services, suffering due to disabled health equipment, costs of lost utility services (street lights, water treatment, etc.), lost worker and machinery productivity, lost business revenues, diesel fuel costs for back-up systems, loss of leisure time, discomfort from lack of heating or air conditioning. Flow costs can increase, remain constant or decrease over time depending on the ability to substitute production or adapt to the outage. Businesses that can shift workers to activities which do not require electricity, or can make up for lost production by increasing output in subsequent periods will likely have increasing flow costs over time. This is due to the diminishing ability to substitute production as outage duration increases. On the other hand, customers with the ability to adapt, such as by bringing back-up generators on-line, or customers who can change location, such as residential customers who may leave the house until power is restored, may expect flow costs to decrease over time. **Stock** costs are damages that occur due to spoilage, expiration or vandalism. While a flow cost such as lost worker productivity can occur in multiple periods, once an item spoils it will not spoil again in later periods. Some examples of spoilable stock include patient morbidity or mortality due to lack of power, clean-room contamination due to lack of ventilation, stolen or broken assets due to looting and vandalism, food spoilage, steel cooling, and missing contract obligations. Oftentimes the time at which a stocks spoils is unknown and different stocks, such as various food products, spoil at many different times. Products are more likely to spoil as the outage duration increases, but as time goes on there is also less stock that can spoil. The authors assumed that 10% of the value of work in progress can spoil, 50% of the stock spoils within the first 4 hours and 90% of the stock spoils within the first 8 hours of a power outage. These assumptions coincide with a manufacturing plant which requires raised or lowered temperature for production, or whose production process is time sensitive.

Ref.			Summary
			Fixed damages lead to a high initial cost, and stock spoilage results in incremental costs increasing from hours 1 to 4. As the outage duration increases however, the effect of spoilage reduces and incremental costs begin to decline, due to the fact that there is less and less stock to spoil.
11	Joseph Eto, Et al, Scoping study on trends in the economic value of electricity reliability to the US economy (2001)	Widespread long duration outages	Reports on the costs of large outage events are not well documented; they are often developed based on applying rules of thumb derived from existing studies extrapolated to a current situation. There have been few systematic studies of the costs of actual large-scale outages. Studies of hypothetical outages are typically organized in ways that appear to support extrapolation of outage costs to the preparation of aggregate estimates of these costs. Insurance claims for "data losses" are a growing issue.
13	ICF Consulting, The economic cost of the blackout (2003)	Widespread long duration outages	An analysis done on the 1977 outage in New York City that resulted in a loss of more than 5,000 MW and lasted for 25 hours estimated that the direct cost was about $0.66/kWh (for example, losses due to spoilage, and lost production and wages), and an indirect cost of $3.45/kWh (due to the secondary effects of the direct costs).
15	Michael Schmidthaler, Johannes Reichl, Assessing the socio-economic effects of power outages ad hoc	Long duration outages	Sectors that are particularly vulnerable to long duration outages are the semiconductor industry, papermaking and data-generating processes.
16	Thomas Schroder, Wilhelm Kuckshinrichs, Value of lost load: an efficient economic indicator for power supply security? A literature review, Frontiers in energy research (2015)	Social costs	**Technical and systemic characteristics** The consequences for electricity customers (material damage, costs) are not usually affected by the cause of the interruption and are contingent on how much they depend on electricity as well as how long they are being interrupted. The consequences are affected by the factors influencing the outage, which are inherent to each individual case. The character of the individual factors and their combination determine the extent of the consequences. Each outage, therefore, represents a unique event that affects electricity customers to different extents. The factors influencing the blackout are divided into the subcategories of "technical factors," "load-side factors," and "social factors" The **technical factors** describe the framework conditions constraining the interruption, the characteristics of which are decisive for the consequences of a blackout. The **load-side factors** concern the effects that exacerbate the damage arising as a consequence of the structure of the electricity customer affected. In this respect, the customers' pattern of electricity use is also decisive. The load-side factors are naturally determined by the technical factors. Finally, the **social factors** describe the influences that affect the consequences of the blackouts but which are difficult to assess objectively. These are mainly culturally related differences in the economic and social structures of different regions, which lead to differences in power supply security. The cultural factors cannot be modelled appropriately.

Factors influencing power interruptions		
Technical factors	**Load-side factors**	**Social factors**
– Duration – Region – Frequency – Time – Dimension – Advance warning – Accustomed level of supply security	– Type of electricity customer – Number of customers affected and level of dependence on electricity – Degree to which process steps can be substituted – Existence of standby power supply	Special cultural and social features

Time characteristics

The duration of an interruption of the power supply is an essential influencing factor

Cost categories for damage and mitigation

Direct damage costs are taken to mean those that are incurred directly by the company or the individual affected. For example, loss of production can be regarded as direct damage for the manufacturer. This loss of production then makes itself felt as indirect damage for other companies in the form of delayed deliveries. Mitigation costs are understood, for example, as costs for the procurement and operation of standby generators.

Structure of damage and mitigation costs					
Economy (industry, commercial users)			**Private industries**		
Damage costs		Mitigation costs	Damage costs		Mitigation costs
Direct	Indirect		Direct	Indirect	
a) Opportunity costs of idle resources – labor, country, capital, profits (b) Production holdups and restart times (c) Adverse effects and damage to capital goods, data loss	(a) Delayed deliveries along the value chain (b) Damage for consumers if the company produces an end product (c) Costs/benefits for some manufacturers (d) Health and safely aspects	Procurement of standby generators, batteries, etc. Investments in grid construction via charges (network tariffs)	(a) Restrictions on activities, lost leisure, stress (b) Financial costs – damage to premises and real estate, food spoilage, data loss (c) Health and safely aspects	Restrictions on acquisition of goods Costs for other private individuals and companies	Procurement of standby generators, batteries, etc. Investments in grid construction via charges (network tariffs)

Ref.			Summary
			(d) Health and safely aspects
18	Jeffrey Simonoff et al, Electricity case: statistical analysis of electric power outages, Published Articles and papers (2005) Paper 162	General	An analysis of events reveals that customer losses were higher for events caused by natural disaster, crime, unknown causes, and third party, and lower for incidents resulting from capacity shortage, demand reduction, and equipment failure, holding all else in the model fixed.
19	Michael Sullivan et al, Pacific Gas & Electric company's 2012 value of service study (2012)	Long duration outage	See Table 1-2 below. The report tabulates the cost per outage by region and customer class, for outages of duration 5 minutes, 1 hour, 4 hours, 8 hours and 24 hours. They illustrate that the cost per event increases as the duration increases, but the increase is non-linear.

Table 1-2:
2012 Cost per Outage Event Estimates by Region and Customer Class

Region	Outage Duration	Residential ($/Event)	SMB ($/Event)	Large Business ($/Event)	Agricultural ($/Event)
Bay Area	5 minutes	$8.18	$585.2	$761,784	$124.1
	1 hour	$13.22	$2,679.4	$861,359	$299.3
	4 hours	$19.59	$6,607.7	$1,073,743	$2,512.2
	8 hours	$26.63	$16,463.6	$1,080,310	$4,866.9
	24 hours	$37.83	$33,780.9	$2,252,293	$8,392.1
Non-Bay Area	5 minutes	$6.96	$159.0	$24,308	$147.5
	1 hour	$10.71	$973.9	$54,970	$461.6
	4 hours	$14.89	$2,761.1	$113,746	$1,201.5
	8 hours	$19.79	$4,435.0	$147,383	$2,496.6
	24 hours	$26.03	$8,514.5	$615,402	$5,763.9
All	5 minutes	$7.41	$379.8	$454,675	$146.1
	1 hour	$11.89	$1,848.8	$449,655	$453.5
	4 hours	$16.82	$4,774.3	$596,675	$1,230.7
	8 hours	$22.89	$10,568.7	$617,196	$2,549.4
	24 hours	$31.67	$21,339.4	$1,472,497	$5,842.4

Ref.			Summary
23	Executive office of the President, Economic benefits of increasing electric grid resilience to weather outages, The White House (2013)	Widespread long duration outages Social costs	Between 2003 and 2012, an estimated 679 widespread power outages occurred due to severe weather. Power outages close schools, shut down businesses and impede emergency services, costing the economy billions of dollars and disrupting the lives of millions of Americans. **Case Study: Superstorm Sandy** Superstorm Sandy made landfall near Atlantic City, New Jersey as a post-tropical cyclone on October 29, 2012 and then continued northwest over New Jersey, Delaware and Pennsylvania. The storm damaged 650,000 homes and knocked out power for 8.5 million customers. Sandy directly caused the deaths of 72 people in the United States and an estimated $65 billion in damages. Sandy indirectly caused the death of another 87 people, 50 of which were attributed to power outages. Numerous senior citizens without heat died from hypothermia while other victims died of carbon monoxide poisoning due to improperly vented generators **Case Study: Hurricane Irene** Hurricane Irene made landfall near Cape Lookout, North Carolina on August 27, 2011 as a category one hurricane and then continued north-eastward making a second landfall near Atlantic City, New Jersey. More than 6.5 million people in the United States lost power during Hurricane Irene, which includes over 30 percent of the people living in Rhode Island, Connecticut and Maryland. Irene caused the death of 41 people in the United States and resulted in $15.8 billion in total damages **Outage distribution data** All of the fourteen storm-outage-profiles resemble one another, even though they range in duration from 3 to 20 days. The number of customers affected rises sharply in the first few hours of the event and peaks 15 to 25 percent into the total duration. Power is restored to a majority of customers relatively quickly, however a substantial number of customers remain without power long after the event begins. **Social costs** The estimates in this report are based on private costs borne by customers who lose power. In addition to private costs, outages also produce externalities – both pecuniary and nonpecuniary. For example, outages that limit air transport produce negative network externalities throughout the country. Generally speaking, the costs of major outages are borne not only by those without power, but also by the millions of people inconvenienced in other ways. Some of the lost GDP arising from storms is made up later by overtime hours, additional hiring, and additional consumption. These additional expenditures counteract the negative effect of the storm on GDP, but they do not increase welfare. Essentially, GDP is higher after a homeowner restocks the refrigerator – but the homeowner is worse off for having to do so. Many of these additional benefits of grid resilience constitute positive externalities – societal benefits beyond the direct costs avoided by electric customers. For example, power outages can hinder public safety since police, firefighters and emergency medical personnel struggle to provide assistance during outages (Sullivan et al. 2009). Manufacturing businesses far removed from an outage may face economic costs if their supply chains are disturbed. Online businesses engaged in long-distance transactions may also be negatively affected by reduced internet traffic.
24	US Department of Energy, Valuation of energy security for the United States, Report to Congress (2017)	Macroeconomic models	Models of the whole economy of a country or other region can be used to estimate the economy-wide effects of power outages.

Ref.		Summary
	Long duration outages	**CGE models** – the parameters in CGE models are typically set at levels intended for estimating long-run equilibrium effects. In a power outage, however, firms are limited to the substitutions they can make quickly. The CGE model is likely to overestimate the amount of substitution that would occur and thus underestimate the cost to the economy from the outage. Similarly, production functions in CGE models are typically estimated from long-term data and are therefore likely to overestimate the amount of adjustment that would occur in response to an outage. That, too, is likely to cause CGE models to underestimate the cost to the economy from the outage. CGE models could be adapted to better estimate the effects of resilience on the costs of power outages. However, it appears that at present, no empirical estimates exist of short term substitution elasticities or production functions that capture the effect of short-term shocks. **Input-out models** – typical input-output models assume that a fixed amount of each input is needed to produce the output of each sector, so it effectively assumes that all elasticities of substitution are zero. The real elasticities of substitution within days or weeks are closer to zero than are the real elasticities of substitution within years, so this assumption of fixed input requirements may be less of a weakness in simulating a power outage than in simulating longer-lasting phenomena. **Macroeconometric models** – as in CGE models, the estimates of relationships in such models are generally long-run relationships, while the economy-wide effects of an outage usually result from short-run relationships. Standard CGE, input-output, and macroeconometric approaches do not account for costs other than lost production, and in accounting for lost production, assume that the amount of production lost is equal only to the amount that would have occurred during the time of the outage. This is true of proxy methods as well. In fact, there are other costs, and production may be disrupted for longer than the outage lasts. **A hypothetical long duration outage** Sullivan and Schellenberg (2013) offer an instructive survey-based study of the estimated costs of a long electricity supply outage. It is similar to the short-term work of Sullivan et al. (2009, 2015), but considers outages lasting 1 day to 7 weeks.

Table 4.4. Total estimated direct and indirect costs of hypothetical San Francisco outages, by duration (millions of U.S.$)

Outage Duration	Total Direct Outage Cost	Range of Total Indirect Outage Costs	
		Low (Direct Cost x 0.5)	High (Direct Cost x 2.0)
24 hours	$125.7	$62.9	$251.4
4 days	$407.4	$203.7	$814.8
3 weeks	$1,417.0	$708.5	$2,833.9
7 weeks	$2,922.6	$1,461.3	$5,845.2

***Source*: Sullivan and Schellenberg (2013)**

The shortest outages have the highest estimated cost per unserved kWh. The estimated cost per kWh is approximately half as large in a 7-week outage as in a 1-day outage.

Ref.			Summary
25	Ian Wing, Adam Rose, Economic consequence analysis of electric power infrastructure, US DoE (2018)	Macroeconomic modelling Resilience	Sanstad (2016) and others have reviewed various modelling approaches to estimating the economy-wide (typically at the regionbal level) impacts of electricity outages. The general leaning of these assessments is that CGE models are the preferred approach. Input-output (I-O) models are limited by their inherent linearity, lack of behavioral content and absence of considerations of prices and markets. CGE models are able to maintain the best features of I-O models—sectoral detail and ability to trace interdependencies—while overcoming these limitations. The most recent advances in modelling the economic consequences of electricity disruptions relates to various types of resilience. The focus here shifts to the customer side, since there are so many more tactics available, and they are much less costly. For example, a good deal of conservation more than pays for itself (energy efficiency), back-up generators are relatively inexpensive, shifting production to other facilities that have electricity as well as excess capacity is relatively inexpensive, as is recapturing lost production at a later date by working overtime and extra shifts. Moreover, most of these tactics need not be put in place before the outage, but can simply be implemented on an as-needed basis once an outage occurs. Other tactics include use of inventories, input substitution, and relying more on imported goods from other regions or countries. The studies all found that resilience substantially moderates losses.
29	Sinan Kufeloeglu, Matti Lehtonen, Interruption costs of service sector electricity customers, a hybrid approach, Electrical Power and Energy Systems 64 (2015) 588-595	Social costs	The direct impacts of interruptions include the direct effects of power cuts that cause economic losses such as sales loss, lost manufacturing, interruption of services, suspension of transportation, spoiled materials, damages on the electric equipment and on electronic data, other damages and accidents resulted from interruptions or, worst of all, injuries and deaths. The analysis of these events is relatively easy when they are compared to the indirect impacts. The indirect effects of power outages compose of arsons, looting, public disorder and crimes due to blackouts, possible sharp increases in the insurance rates, property losses, overtime payments, cancellation of social activities, lost tax revenues, the costs for recovering from looting and so on. The economic worth of the indirect impacts can be much higher than that of direct ones.
31	Kristina H. LaCommare, Joseph H. Eto, Cost of power interruptions to electricity consumers in the United States (US), Energy: The International Journal (2006)	Long duration outages	Residential-sector costs of reliability events include elements such as the cost of consumable goods (e.g. flashlights and candles) and inconvenience costs (e.g. resetting clocks, changing plans, and coping with inconvenience, fear, anxiety, etc.). A subtle issue that is gaining recognition is that business losses are not always directly proportional to the duration of a reliability event.
32	Peter Larsson, Alan Sanstad,, Kristina LaCommare, Joseph Eto, Frontiers in the Economics of Widespread, Long-Duration Power Interruptions: Proceedings from an Expert Workshop, Lawrence Berkeley National Laboratory (2019)	Resilience Macroeconomic modelling	There are two types of resilience in response to widespread, long-duration power outages: (1) “static” resilience, which has to do with efficient use of readily available resources in the short term (i.e., hours, days) after the outage occurs, such as rescheduling production once a disruption occurs; (2) what they call “dynamic” resilience, which refers to the efficient use of resources that enable an economy to recover from an outage over time, such as making investments to replace damaged equipment or structures during the ensuing weeks, months, and years. Important outage impact categories include the loss of human life, the migration of affected populations and firms, and other longer-term effects. CGE modelling is in general the preferred macroeconomic method because of its capacity to represent customers’ adaptive behavior (i.e., resilience, mitigation) in the face of power outages, while also acknowledging the usefulness of I/O for practical reasons, particularly ease-of-use, relatively low expense (compared to CGEs), and validity for estimating first-order direct impacts.

Ref.			Summary
			There are trade-off between CGE and I/O models, including pragmatic considerations such as usability and cost, where I/O models have an advantage, and completeness of the representations of economies and the capacity to analyse resilience mechanisms, a strength of the CGEs. The value of relatively simpler models was also reiterated.
34	Pedro Linares, Luis Rey, The costs of electricity interruptions in Spain. Are we sending the right signals? Economics for Energy (2012)	Social costs	The consequences of electricity interruptions can be classified in three categories: – Direct economic impacts – loss of production, restart costs, equipment damage, raw material spoilage – Indirect economic impacts – the cost of income being postponed, the financial cost of loss of market share – Social impacts – uncomfortable temperatures at work/home, loss of leisure time, risk to health and safety Not all electricity interruptions have the same consequences. Social and indirect economic impacts are larger when interruptions are unexpected. Likewise long interruptions have mainly direct economic impacts. The impact of electricity interruptions will vary by industrial sector. Electricity is essential for some activities such as textiles and, on the other hand, construction can be active without electricity. The costs related to equipment damage and start-up costs are fixed, independently of the length of the interruption, and therefore, a short interruption may cause higher costs in the industrial sector than in the rest of the sectors.
35	Evan mills, Richard Jones, An Insurance Perspective on U.S. Electric Grid Disruption Costs, The Geneva Papers on Risk and insurance – Issues and Practice 41(4) (2016) 555-586	Widespread long duration outages	Electricity service disruptions have important direct links to insured risks such as property damages and business interruptions, as well as indirect links to events such as civil unrest and vandalism during blackouts. For a variety of reasons, insured losses represent only a portion of total economic losses. These factors include incomplete penetration of insurance, deductibles, limits, and exclusions among those who are insured. In addition to standard property damages, liability claims may also be made (Blume and Holmer 2013), among which are environmental liability claims stemming from disruptions in wastewater treatment or pollution controls dependent on electricity for pumping, communications, and control systems (NIST 2015). A wide variety of adverse healthcare outcomes have also been associated with power outages. Only two events (the 1977 New York City Blackout and the 2003 Northeast Blackout) have been recorded and quantified by the U.S. insurance industry's central loss tracking system. **1977 New York City blackout** – the total economic costs were $1,348 million (2014 dollars). Public and private insurance mechanisms each participated in shouldering the costs, amounting to $131 million, or 10% of the $1.35 billion total economic impact. Second-order impacts (in this case fires and looting) resulted in substantial additional insured losses. Formal or informal limits on coverages attenuated the level of paid claims. **2003 Northeast Blackout** – left almost 20% of the U.S. population in darkness for periods ranging from hours to days. Within 8 minutes, the outage took the equivalent of 62 billion watts of power offline (more than 500 generating units at 265 sites, including 10 nuclear plants), in the process impacting 50 million people across 8 states and large parts of Ontario Canada (U.S.-Canada Power System Outage Task Force 2004). Power was largely restored in the U.S. within 30 hours (an important consideration in light of waiting-period deductibles), but took significantly longer in parts of Canada. Total economic cost estimates range from $4 to $10 billion (U.S.-Canada Power System Outage Task Force 2004), with $6 billion ($7.7B in 2014 dollars) quoted by the U.S. Department of Energy as the central estimate. One source states that the costs could have been twice as high had it not occurred late in the working week.

Ref.			Summary
			Examples of specific impacts include: – Daimler Chrysler: production disruption at 14 of 31 plants, e.g., 10,000 vehicles stranded in the painting assembly line were scrapped. Direct costs not reported. – Ford Motor Company: solidified molten metal in furnace created a one-week disruption. Direct costs not reported. – Marathon Oil Corporation: Emergency shutdown procedures triggered boiler explosion, followed by evacuation of hundreds of residents. Direct costs not reported. – Nova Chemicals Corp. Business disruptions reduced earnings by $10 million at 7 facilities. – Duane Reade Inc. Drugstore chain closed all of its 237 stores, losing $3.3M in sales. – Airports. Closed in 13 locations, with 1000 flights cancelled. Direct costs not reported. – New York City: $250M in frozen and perishable food destroyed, among other losses.
36	Aaron Praktiknjo, Stated preferences based estimation of power interruption costs in private households: an example from Germany, Energy 76 (2014) 82-90	Long duration outages	In the case of the longer-term interruptions, the impact of household income on the costs of an interruption increases from 17 percent (4 hour interruption) to 33 percent (1-day interruption) and to 36 percent (4- day break). Possibly, the influence of income on the interruption costs further increases with the duration of the interruption, because households with higher income are probably more likely willing to pay a higher amount to avoid loss of comfort or they demand higher compensation payments in order to relinquish on comfort.

Ref.	Summary

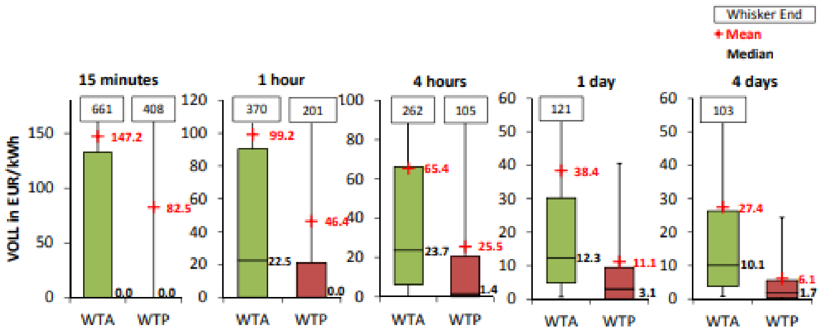


Fig. 5. Distribution of WTA and WTP-based VOLL in EUR/kWh.

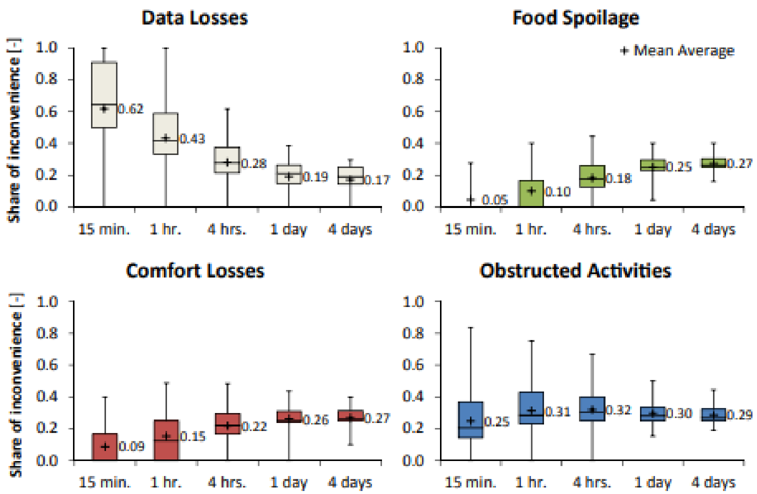


Fig. 6. Distribution of the shares of the four areas of inconveniences on interruption costs.

The diagrams above illustrate how the different impacts vary as the duration of an interruption increases.

The fact that the relative distance between WTA and WTP increases with longer interruptions suggests that the possibility to find substitutes for electricity decreases with the duration of the interruption.

The results show that the derived VOLL decreases instead of increasing with the duration of interruption. The VOLL represents a kind of average cost. With increasing interruption duration the total costs increase and the average costs decrease.

Ref.			Summary
			A household's blackout costs can be divided into a fixed and a variable component. With a change of the interruption duration Dt, the variable costs C_{var} change while the fixed costs C_{fix} remain constant. The sudden loss of data can best be regarded as mainly independent of the duration of the power cut. The average proportions of the areas of food spoilage and loss of comfort, however, increase with the duration of interruption. During a 15-minute interruption the area of food spoilage accounts for about 5 percent of the total cost. This proportion rises to 27 percent for interruption durations of 4 days. The area loss of comfort accounts for 9 percent of total costs during 15 minute interruptions and increases to around 27 percent for interruptions of 4 days. Limitations of activities due to power interruptions have a more or less constant proportion of the total interruption costs for the investigated interruption durations.
37	Johannes Reichl, Michael Schmidthaler, Friedrich Schneider, The value of supply security: The costs of power outages to Austrian households, firms and the public sector, Energy Economics 36 (2013) 256-261	Widespread outages	The economic aftereffects of electricity outages can be divided into three categories: – direct costs – indirect costs – resulting long-term costs of macroeconomic relevance. In the public eye the direct economic losses are usually at the top of the list. Of the total economic losses, they are the part that is a direct result of the failure. Direct economic losses are usually limited and subordinate to indirect economic losses. Indirect costs also arise in direct connection with the failure, yet they belong to that part of the total losses resulting from the absence of electricity supply in the aftermath of the failure, such as production outages or lost value added. Long-term economic effects of blackouts are understood to be the economically relevant changes in the behaviour of market participants as a result of a perceived long-term change in the level of supply security. Part of this category of losses is for instance the potential influence on the choice of a place as a business location, the potential price rise for production facilities due to the increased need for back-up-systems, or customer churn due to unreliability regarding delivery deadlines. Long-term economic effects cannot be assigned to individual events. The econometric modelling of willingness to pay (WTP) to avoid power cuts yielded a mean result of € 17.3 per household for a 24-hour outage. In the event of a 12-hour outage a mean WTP of € 9.9 was detected; to avoid a 4-hour power cut households were willing to pay € 3.8 on average, and willingness to pay to avoid a 1-hour power cuts was assessed at € 1.4 on average The authors' survey considered the geographical extent of an outage – it differentiated between a very limited outage which affected only one's own street/road and an outage which affected one's own home province and two neighbouring provinces. The WTP coefficient for an outage area of 3 provinces was 0.2675 (5% significance), that is, Austrian households were WTP 26.75% more to avoid an outage that extends over 3 provinces than for a local outage.

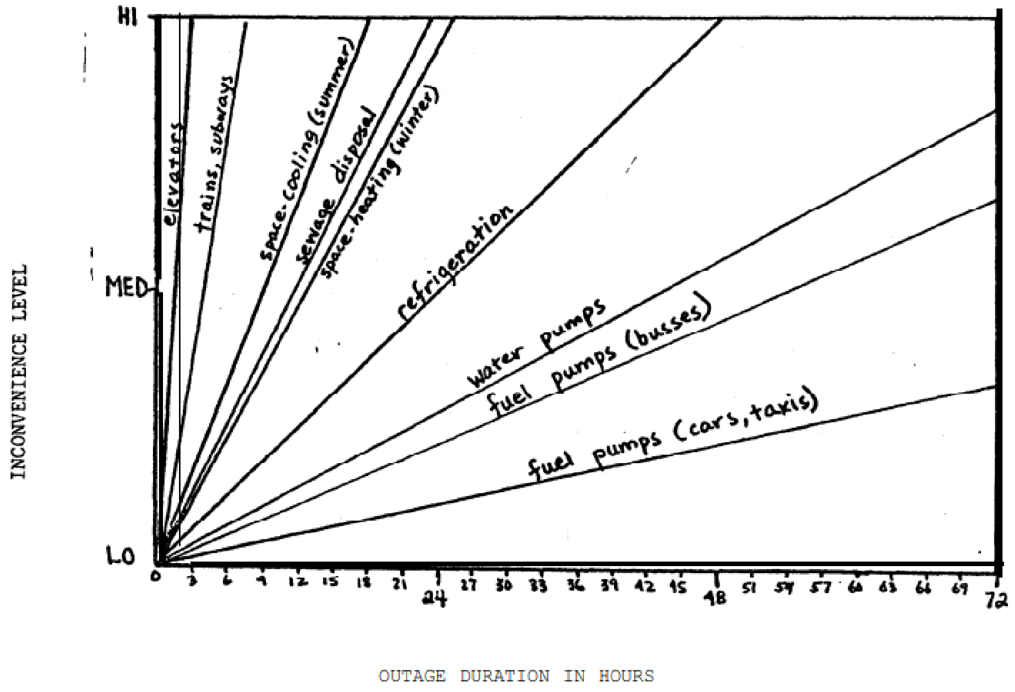
Ref.			Summary
38	Adam Rose, Shu-Yi liao, Gbadebo Oladosu, Business Interruption Impacts of a Terrorist Attack on the Electric Power System of Los Angeles: Customer Resilience to a Total Blackout, Published Articles & Papers (2007) Paper 68	Widespread outages Resilience	Darkness arising from an electricity outage can instill fear into the population, spur crime, give cover to further terrorist activity, and damage the economy. Broader considerations in assessing the impact of electricity outages include the value of any lives lost, increased crime, psychological trauma, some infrastructure costs, and property damage. The more widespread is an electricity outage, the more difficult it is for businesses to cope during the outage and when power is restored. Some examples of resilient responses for dealing with electricity disruptions include: – Conservation—utilising less electricity per unit of output – Fuel substitution—utilising some other fuel – Back-up power—utilising an alternative source of generation – Production rescheduling—making up lost production at a later date – Electricity importance—utilising the portion of a business that has no need for electricity. For the case of electricity disruptions, conservation is a limited option because of the all-or-nothing nature of the situation. Thus, a centralised electricity system can be characterized as “blacked out,” and yet some customers within its service territory are directly unaffected as a result of back-up power. On-site alternatives to centralised electricity delivery cover values ranging from 10% in most sectors to 50% in sectors with very large firms (e.g., petroleum refining), sensitive production processes (e.g., semiconductors), or where implementation is relatively easy (e.g., security brokers). Companies outside the area affected by an electricity outage need to cope with reduced supplies of goods and services from those companies whose production was curtailed by the electricity outage.
39	Alan Sanstad, Regional Economic Modeling of Electricity Supply Disruptions: A Review and Recommendations for Research, Energy Analysis & Environmental Impacts Division (2016)	Macroeconomic models	There is emerging interest among regulators and industry experts in the potential economic costs of power disruptions on larger geographic and economic scales, and of longer durations. “**Input-Output (I-O)” models** represent all inter-industry relationships or flows in an economy, i.e., how the outputs of industries are used as inputs to others, and the overall outputs of consumer goods (or “final demand”) produced by all industries, as systems of linear equations—the system of industry transactions is represented in matrix form. The key technical feature of I-O models is the assumption of fixed coefficients or proportions determining input-output relations between industries. That is, the amount of input X that is required to produce a unit of output Y by a given industry does not change according to scale, or through substitution with different inputs depending upon relative prices changes, or as a result of, for example, technological change. Essentially for this reason, the basic I-O accounting framework does not represent the actions that firms might take in order to adapt to the loss of electricity. **CGE models** represent in simplified but explicit form all supplies and demands in an economy and both their direct and indirect market interactions. Supply and demand are determined by the economic (optimising) choices of consumers and firms. CGE models are therefore based on microeconomic principles; they are complete numerical representations of economies in the form of systems of non-linear algebraic equations or related mathematical structures. By contrast to I-O models, the input-output relations among industries are non-linear and to a degree flexible, a function of technology assumptions, prices and other factors.

Ref.			Summary
			Macro-economic models are systems of statistical forecasting equations, with parameters statistically estimated on historical times series data. These have most commonly used to represent national economies and to study inflation and other monetary phenomena as well as aggregate (un)employment. However, they have also been used to analyse regional-level economies. Unlike most computational economic models (including CGE), they do not explicitly represent the decision-making behaviour of consumers or firms, nor the equilibration of supply and demand in markets. Each of the three model types has been applied to the large-scale analysis of power disruptions. Each model type has both advantages and limitations. I-O models are conceptually and computationally relatively more tractable, and pose fewer data demands, while not being well-suited for analysing resilience. CGE models are more demanding especially with regard to data requirements in addition to the necessary underlying economic transaction data akin to the input-output type; the additional data include, in particular, values for exogenous parameters of the type described above, substitution elasticities and productivity trends. However, CGE models also have the capacity to incorporate resilience and other dynamic effects. **Direct and indirect costs of disruptions** – faced with a loss of electricity, an industry will curtail its output by some amount for some duration—the associated economic losses from this are essentially its direct costs. However, every industry also uses the outputs of other industries (i.e., in addition to that of the electricity "industry") as inputs. So a disruption will also affect the availability of these other inputs. Generally speaking, the indirect costs are those resulting from these inter-industry output-to-input interruptions and how they determine the propagation of the disruption effects across an economy. In I-O models, all inter-industry flows are as noted above assumed to be in fixed proportions—i.e., firms/industries do not have the capacity to substitute among inputs **Resilience** – a key topic in this application of economy-wide models is the “resilience” of economies to power disruption—generally speaking, the capacity of consumers, firms, and markets to temporarily adjust, adapt, or otherwise compensate for the loss of electricity in ways that mitigate economic impacts.
42	Systems control, Impact assessment of the 1977 New York City blackout, Energy Systems Division	Widespread long duration outage Social costs	The cessation or interruption of a human activity whether it be conducted for leisure or occupational purposes is a social impact. The changes and adaptations made in response to these disruptions which are of a social and physical nature are also social impacts. It is difficult to assign, objectively, dollar values to these activities and adaptations. Social impacts were particularly significant in the 1977 New York City blackout due to its unique demographic and geographic characteristics. The looting and arson that accompanied the blackout set aside the NYC experience from other similar power failures. A power outage, much like a natural disaster, is associated with a sudden disruption in a community. It differs from natural disasters (e.g., an earthquake) in that little physical destruction and few physical injuries are visited on the community. The people and institutions affected are those usually more dependent upon a technological economy--living in high rise buildings, electric space heating, computerized information system, etc. The interruption of usual community activities may be accompanied by a suspension of certain social norms--particularly those relating to legitimate community leadership and authority, legitimacy of the agencies of 7-. law and order, and individual rights and private property. Part of the reason for the helpless ness of police in such situations is that they are trained to enforce generally acceptable rules and are ‘able to do so when they have at least acit community support. When these social norms and community support are in abeyance, they have to resort to force, as in a military situation, to reimpose order. The appearance of what disaster researchers call the "emergency social system”,

Ref.	Summary
	(the many individuals and groups who provide assistance and relief to victims), is a community's attempt to reinstitute the rules to reclaim legitimacy for its organisation. **Social impact indicators** The following are some indicators that are useful in characterising a variety of social impacts. – Movement of People and Goods. This indicator looks at changes in the flow of people and goods within and outside the blackout area. The information tells us little about the types of activities, however. – The Flow of Information. This is useful in getting an impression of public activity in and outside of the impacted area. – Economic Impacts. Indicators of economic activity, particularly market activity, are most likely to be recorded and accessible. This is useful since in some cases social events are paralled by economic events. – Impacts on Health Organizations. Information on health impacts, particularly mortality and morbidity, are available from hospital and city statistics. Health impacts on individuals due to social strains may be difficult to address if at all. – Credibility of the Electric Utility. The effects on Consolidated Edison are primarily economic but may be strongly influenced by emotional and political considerations. – Civil Disorder. Here we consider the acts of civil disorder that were carried out, the geographic, economic, racial and other variables associated with the disorders, and the response of the criminal justice system. **Levels of inconvenience** In order to arrive at some estimate of the social impacts associated with a power failure, we first identify some of the most significant end-uses of electricity in New York City. These are (in no particular order): – Elevators – Space heating – Space cooling – Ventilation – Water heating – Cooking – Lighting – Refrigeration – Water pumps – Sewage disposal – Electric tools and machines – Office appliances – Fuel pumps.

Ref.	Summary
	Figure 4.1 displays a possible approach for representing an inconvenience index for different critical uses of electricity as a function of duration of the power failure. The duration is a key variable in attempting to estimate the costs of a blackout. Presumably these inconveniences can be weighted and summed to develop a total inconvenience level for each class of customer.

INCONVENIENCE INDEX FOR CRITICAL USES
OF ELECTRICITY DURING A
PROLONGED POWER OUTAGE



High - The consumer feels great inconvenience and is forced to make adaptations.

Medium - The consumer feels inconvenience and may choose to make adaptations.

Lo - The consumer feels onlyslightinconvenience and will not make adaptations.

Ref.			Summary
43	Office of Technology Assessment, Physical vulnerability of electric systems to natural disasters and sabotage, Congress of the United States, June 1990	Widespread long duration outage	Table 1 summarises the costs of the 1977 blackout in New York City, which lasted for about 25 hours.

Table I-Cost of the New York City Blackout—1977[a]

Impact areas	Direct ($million)		Indirect ($million)	
Businesses	Food spoilage	$1.0	Small businesses	$155.4
	Wages lost	5.0	Emergency aid (private sector)	5.0
	Securities industry	15.0		
	Banking industry	13.0		
Government (Non-public services)			Federal Assistance Programs	11.5
			New York State Assistance Program	1.0
Consolidated Edison	Restoration costs	10.0	New capital equipment (program and installation)	65.0
	Overtime payments	2.0		
Insurance[b]			Federal crime insurance	3.5
			Fire insurance	19.5
			Private property insurance	10.5
Public Health Services			Public hospitals-overtime, emergency room charges	1.5
Other public services	Metropolitan Transportation Authority (MTA) revenue: Losses	2.6	MTA vandalism	0.2
	MTA overtime and unearned wages	6.5	MTA new capital equipment required	11.0
			Red Cross	0.01
			Fire Department overtime and damaged equipment	0.5
			Police Department overtime	4.4
			State Courts overtime	0.5
			Prosecution and correction	1.1
Westchester County	Food spoilage	0.25[c]		
	Public services equipment damage, overtime payments	0.19		
Totals		$55.54		$290.16

[a]Based on aggregate data collected as of May 1,1978.
[b]Overlap with business losses might occur since some are recovered by insurance.
[c]Lotting was included in this estimate but reported to be minimal.
Note: These data are derivative, and are neither comprehensive nor definitive.
SOURCE: Systems Control, Inc., Impact ofAssessrnent of the 1977 New York City Blackout (Washington, DC: US Department of Energy, July 1978), p. 3.

Blackouts have impacts that are both direct (the interruption of an activity, function, or service that requires electricity) and indirect (due to the interrupted activities or services). Examples of direct impacts include food spoilage, damage to electronic data, and the inoperability of life-support systems in hospitals and homes. Indirect impacts include property losses resulting from arson and looting, overtime payments to police and fire personnel, and potential increases in insurance rates. A more detailed list of direct and indirect costs are set out in Table 3.

Ref.	Summary

Table 3—Direct and Indirect Costs

Primary electricity user	Direct cost components (costs to household, firm, institution, etc.)	Indirect rests	Remarks
Residential	a. Inconvenience, lost leisure, stress b. Out-of-pocket costs —spoilage -property damage c. Health and safety	a. Costs on other households and firms b. Cancellation of activities c. Looting/vandalism	Indirect costs are a minimal, if not negligible, fraction of total (direct and indirect) costs of a curtailment.
Industrial, commercial, and agricultural firms	a. Opportunity costs of idle resources —labor —land -capital —profits b. Shutdown and restart costs c. Spoilage and damage d. Health and safety effects	a. Cost on other firms that are supplied by impacted firms (multiplier effect) b. Costs on consumers if impacted firm supplies a final good c. Health and safety-related externalities	Indirect effects are likely to be minimal for most capacity-related interruptions, but can be significant component of total costs for longer duration energy shortfalls.
Infrastructure and public service	a. Opportunity cost of idle resources b. Spoilage and damage	a. Costs to public users of impacted services and institutions b. Health and safety effects c. Potential for social costs stemming from Looting and vandalism	Indirect costs constitute a major portion of total costs of curtailment.

SOURCE: M. Munasinghe and A. Sanghvi, "Reliability of Electricity supply, Outage Costs and Value of Service: An Overview," *The Energy Journal*, vol. 9, 19s8, p. 5.

Social costs are difficult to quantify and have been generally neglected in estimations. For example, while losses resulting from looting and arson can be identified and assigned dollar values, the secondary or ripple effects often cannot be enumerated. These secondary effects, such as a potential increase in insurance rates, represent long-term and far-reaching economic implications

Based on the costs of the New York City blackout as set out in Table 1, the direct cost of unserved energy was $0.66/kWh and the indirect cost was $3.45/kWh. Significant impacts include losses in securities and banking, restoration costs, and capital equipment for Con Ed,8 and losses to the small business community. Levels of inconvenience appear to have been substantial. These figures should be considered as lower bounds for the total costs

Damages from looting and arson totalled around $155 million, or about 50 percent of the total economic costs associated with the blackout. The social impacts were sensitive to the unique circumstances of the event and the socioeconomic conditions.

Industrial sector impacts

Outages can spoil raw materials, work-in progress, and finished goods. Spoilage is a significant problem in chemical processes, steel manufacture, food products, and other industries. Blackouts also pose opportunity costs from idle factors of production. Human health and safety effects are another major concern in industrial outages. Not only are the workers exposed to possible injury or health hazard from the power interruption, the neighbouring population also could be exposed to risk from hazardous spills or releases due to the loss of environmental or safety equipment.

Ref.	Summary
	For example, in 1965 Dunlop Tire's Buffalo plant lost 1,700 tires (worth $50,000) when power failed during the critical curing process. The Tonawanda, New York Chevrolet plant had to junk 350 engine blocks because high-speed drills froze while boring piston holes. **Agricultural sector impacts** There can be significant hazards to livestock and produce during a blackout. Sensitive processes include incubation, milking, pumping, heating, air-conditioning, and refrigeration. **Residential sector impacts** Without electricity, air-conditioning is off, and many people do not have heat or hot water. In high-rise buildings, people must use stairwells. Senior citizens and the disabled are at an extreme disadvantage in outages. Consumers do not have lights, refrigerators and freezers, stoves and microwave ovens, toasters, dishwashers, intercoms, televisions, clocks, home computers, elevators and escalators, doorbells, hair dryers, heated blankets, can openers, food processors, carving knives, toothbrushes, razors, and garage door openers. Illness from food spoilage can be a significant problem. One of the more sociologically interesting impacts of the 1965 outage was the fact that without access to their normal forms of entertainment, people turned to each other; 9 months after the blackout, the birthrate increased from 50 to 200 percent at New York hospitals At some times of the day/year and/or for particular groups, there can be health and safety implications (e.g., lack of heat/AC, elevators, life-support systems, hot water, and refrigeration) **Transportation sector impacts** A blackout affects virtually every mode of transportation (box D). Subways, elevators, and escalators stop running, and corridor and stairwell lights usually are out. Street traffic becomes snarled without traffic lights. Gasoline pumps do not work, and the availability of taxis and buses declines over time. Parking lot gates and toll booths will not operate. Pedestrians are perhaps the least affected, although their danger increases without traffic signals and after dark with the loss of street lighting. Trains can still function, but doing so can prove hazardous without signal lights. Airports are powered by auxiliary generators that enable aircraft to land and take off in an emergency. However, considerable delays can be expected. In high-density areas where most people are dependent on public transportation, economic and other impacts are increased by the inability to get to work. Other transportation effects result from the inability to deliver goods. **Telecommunications sector impacts** The failure of a communications system can lead not only to market losses but also to the failure of the business itself. The functioning of all crucial municipal public services, such as police, fire, etc., will also depend on telecommunications. The impact of a disruption will depend on how crucial communications equipment is to a particular industry/business. Medium- and large-size businesses that use integrated information systems to link operational processes—i.e., order entry, scheduling, etc.—will experience economic damage shortly after a power failure. **Emergency services sector impacts** Emergency services include police and fire and their communications and transport, as well as hospitals. Power outages can also affect these services. All hospitals have emergency power systems to support the most critical activities, such as operating rooms, intensive-care units, emergency services, etc. Depending on the facility, auxiliary power systems may not be able to support some other activities, including

<table>
<tr><th>Ref.</th><th></th><th></th><th>Summary</th></tr>
<tr><td></td><td></td><td></td><td>x-ray, air-conditioning, refrigeration, elevators, etc. Moreover, technical problems may arise with the auxiliary generators, as evidenced in the 1977 New York blackout.

Fire-fighting and police communications could be severely disrupted by the loss of power. Fire alarm systems may be inoperable and fire-fighting maybe hampered in those areas where some power is required for pumping water. Moreover, the indirect impacts of a blackout, such as looting and arson, can severely strain fire-fighting and police services.

More than 80 injuries were reported due to the abnormal fire activity. Exhaustion was common due to the high heat and humidity and the lack of food supplies and rest areas.

Public utilities and services sector impacts

Public utilities include electric, water, gas, sewage, garbage, and related services (e.g., public health inspection).

Some power may be required at pumping stations and reservoirs. Loss of pressure in mains hampers fire-fighting and hospitals, and may permit contaminants to seep into the water supply.

Electric pumps in high-rise buildings do not work, residents would have to go without water or get it from neighbours below.

Electricity is needed in treatment and pumping of sewage. An outage at a treatment plant causes raw sewage to bypass the treatment process and flow into the waterways. Lack of pumping station power prevents sewage flow and ultimately causes a back-up at the lowest points of input (usually basements in low-lying areas). Many of the sewage treatment plants and pumping stations had standby power supplies, but only for short durations.</td></tr>
<tr><td>44</td><td>Johannes Reichl, Michael Schmidthaler, Methodology, Assumptions, and an Application of blackout-simulator.com, Energie Institut</td><td>Link between energy and economic output

Widespread outages</td><td>Economic activity is in most cases very closely connected to electricity supply. Using load profiles, the authors broke down the annual gross value added per economic sector and per region from the aggregate figures into an approximated hourly value for the years. The underlying assumption was that electricity is an essential input for value added, and that hours without electricity supply deal damage even when happening during non-productive hours. Such damages stem from e.g. inoperable cooling appliances or safety facilities.

Households typically show higher WTP to prevent (geographically) larger interruptions compared to ones that only affect their neighbourhood. WTP to prevent a five hour power outage increases from €4.4 to €5.9 on average across all 27 member states in the European Union (2012). This is equivalent to an increase of 32.7 percent and is supported by a comparison of international studies on the valuation of electricity supply security, which can be found in Reichl et al.

<table>
<tr><th>Variable</th><th>Increase in WTP compared to the mean of the entire sample</th></tr>
<tr><td>Belonging to the country’s highest 20% income group</td><td>8.6%</td></tr>
<tr><td>Children below 14 in household</td><td>4.4%</td></tr>
<tr><td>Spare time is affected</td><td>14.6%</td></tr>
<tr><td>Whole country is affected (instead of residential street only)</td><td>32.7%</td></tr>
</table></td></tr>
<tr><td>52</td><td>Hugh Byrd, Steve Matthewman, Exergy and the City: the Technology</td><td></td><td>Irrespective of cause, patterns emerge whenever blackouts result. These include measurable economic losses and social costs that are far harder to quantify. The authors focus on economic damage, food safety, crime, transport and the problems caused by the diesel generator.</td></tr>
</table>

Ref.	Summary
and Sociology of Power (Failure), Journal of Urban Technology	Insurance industry experts suggest that indirect costs are typically in the order of up to five times higher than direct ones. The three largest gold mines and two biggest Platinum mines in South Africa were forced to shut down due to a blackout. Within minutes, the world price of these commodities rose by 5 per cent On 15 August 2003 parts of Canada and the US were hit by a blackout. Trading on the stock exchange was described as "light," people struggled to get to work and ATM machines stopped functioning. Car manufacturing was hit hard with 12 General Motors and 24 Ford plants closing. Five US and two Canadian airports were closed resulting in about 500 flight cancellations and an estimated "tens of millions of dollars" in losses. The loss of food sales amounted to €50 million with the loss of frozen food adding a further €70 million Euros. Blackouts severely impact upon foodstuffs. The need to keep food fresh through the use of fridges and freezers is a priority. The inability to safely store food has a number of consequences. Economic loss is perhaps the most immediate and obvious. In Kenya, restaurant owners noted the frustration of serving a restricted number of offerings to their customers and the fear of potentially poisoning them. In Hebei Province China, milk curdled and vegetables rotted as the domestic penalty for industries that exceeded targets for energy consumption. A more tragic consequence of a lack of refrigeration was felt in Pakistan in June 2010. Load-shedding during a heat wave resulted in 12 hours a day without electricity. Hundreds died of food poisoning as the poor ate bad food from their freezers When the lights go out, crime rates increase. Without electricity security systems fail. Blackouts provide opportunities for fraud, theft and exploitation. One of the most immediate and prevalent problems with blackouts is the loss of traffic lights and consequent dangers. Traffic jams and accidents were a recurring theme in the enforced blackouts in China in 2010. Public transport is another victim with the loss of subway trains below ground and rail systems above In September 2003, underground trains in Italy stopped in the blackout trapping passengers inside for hours. 110 trains were halted, some for 12 hours with an estimated 30 000 passengers affected (BBC, 2003b). One month earlier, in New York, the subway stopped, trapping commuters inside. The Mayor urged non-essential workers not to travel. Electric buses and underground railways also came to a halt in the Iranian blackout of 2001 (BBC, 2001b). Air travel is also sensitive to these failures due to a loss of communication systems and lack of runway lighting. Parking also becomes problematic. Security gates cease to operate causing problems to those stuck inside, and outside, secure parking areas. Given the problems detailed above, diesel-fuelled generators may appear as a lifeline to householders, hospitals and businesses. They can offset the deleterious effects of accidental power outages. However, complaints about noise and air pollution caused by this equipment are a common theme in blackout events. Such is our dependency that our comfort, security, communication systems, transport, health, food supply, businesses and social equity systems collapse when electricity supplies are interrupted. The continuing sophistication and prevalence of electrical appliances only serves to increase our dependence.

Ref.			Summary
55	Finn Landgren, Jonas Johansson, Olof Samuelsson, Quality of supply regulations versus societal priorities regarding electricity outage consequences: Case study in a Swedish context, International Journal of Critical infrastructure Protection 26 (2019)	Social costs	The costs of outages include the social costs (costs related to e.g. loss of leisure time and risk to health and safety). In outage cost studies using stated preference, revealed preference or proxy methods, it is unclear to what extent that societal costs are captured. The stated preference and revealed preference approaches are, however, more likely to, to some extent, capture societal costs than proxy methods. For studies using the case study approach, there is a problem concerning the possibility to generalise results.
56	Thomas Schroder, Wilhelm Kuckshinrichs, Value of Lost Load: An Efficient Economic Indicator for Power Supply Security? A Literature Review, Frontiers in Energy Research (2015)	Social costs	The factors influencing the blackout are divided into the subcategories of “technical factors,” “load-side factors,” and “social factors”. The social factors describe the influences that affect the consequences of the blackouts but which are difficult to assess objectively.
57	Mao Shaui, et al, Review on Economic Loss Assessment of Power Outages, Procedia Computer Science 130 (2018) 1158-1163	Social costs Macroeconomic models	There is no unified understanding of the indirect economic impact of the blackout. Some researchers refer to the economic loss caused by psychological panic, some to the invisible loss (such as inconveniences, etc.) and others to the industrial related economic loss caused by the blackout. **Assessment methods of indirect economic loss of power outages** IO (Input-output Model) is widely used in the assessment of power outages indirect economic loss. The IO method is simple and easy to use in the assessment of industrial related economic loss caused by power outages. It is suitable for indirect economic loss assessment during the power outage emergency disposal stage caused by disasters. The evaluation results can be used to optimize the allocation of resources and improve the emergency response capacity. However, this method does not consider the substitution of intermediate input, the relative price effect, and the recovery ability of the economic system, which makes the result of outage power loss assessment deviate from the actual situation. CGE (Computable General Equilibrium) is also a common method to assess the indirect economic loss of power outages. The CGE model regards the whole economy as an inseparable organic whole, and it can reflect the interdependence and interaction between different sectors and different markets, namely the optimal decision of the utility function or profit function of each economic subject. The main body of the economy this model considers is limited. And it is difficult to measure the impact of policy changes on the economic system. Therefore, it is a more conservative model, so the CGE model can be further perfected. Furthermore, when the CGE model is used to evaluate the economic loss of power outages, the load loss model of industrial, commercial and residential users is relatively simple, so further research work can be carried out. In conclusion, IO model and CGE model can comprehensively analyse the internal relations between the various sectors of the economy and effectively evaluate the loss of industrial related economy in the case of the blackout. But because it mainly uses the static analysis, it does not consider the dynamic impact of power outage costs, the users’ demand for power, the changes in policy and so on, it has some

Ref.			Summary
			limitations. Therefore, if these methods are combined with the methods that can reflect the changing characteristics of the situations, we should get better results for the assessment of the indirect economic loss in the future.
59	Michael de Nooij, et al, Optimal blackouts: Empirical results on reducing the social cost of electricity outages through efficient regional rationing, Energy Economics 31 (3) (2009) 342-347	General	Blackouts may lead to damaged machinery or equipment, which was not taken into consideration in the modelling. The electricity intensity in a sector in a municipality is assumed to equal the electricity intensity of that sector in the Netherlands as a whole.
60	Valeria Costantini, Francesco Gracceva, Social Costs of Energy Disruptions, INDES Working Papers	Social costs	Generally speaking, the social costs of supply disruptions can be classified under the category of economic externalities. The social costs of security are those costs that accrue to others in the economy, generating a need for governments to step in and take protective measures A possible list of social costs that could occur after an energy disruption is below. 1. Expenditure for military, police and emergence actions (excluding health) – Costs of activating a counter-terrorism response, because of the lack of an immediate warning about the black-out – Costs of emergency requests to police and public order forces (arrests, riots) – Costs of emergencies for fire workers (i.e. fires, elevators, closing doors, subway, etc.) 2. Expenditures for public transport – Costs to public railways owing to interruption include reduced revenues, increased emergencies, delays (affecting both the public transport system and consumers) and increased risks of accidents (i.e. computer interruptions in the traffic planning-system) – Costs of subway interruptions include reduced revenues, increased emergencies, increased risk of accidents, delays (affecting both the public transport system and consumers) – Costs of flights, increased emergencies, delays (effects on consumers) increased risk of accidents 3. Health care expenditures – Immediate costs to the health care infrastructure (hospitals, emergencies, laboratories) such as emergency surgery, emergency medical-service calls, loss of medicines, organs, blood and analysis (and experiments) owing to reduced refrigerating capacity (prolonged shortage) – Post black-out health expenditures (relating to violence, injuries as a result of fires, food poisoning, panic attacks and uncomfortable temperatures) 4. Sanitation and waste disposals – Immediate costs for the interruption in sanitation services and waste disposal, as well as recycling systems or composting/incinerator disposals – Further costs owing to excessive waste accumulation – Possible sanitary costs relating to the reduced capacity of wastewater treatment facilities 5. Other public services – Costs relating to the interruption of classes in public schools and universities – Food losses (reduced refrigeration capacity) throughout public facilities

Ref.			Summary
			– Social costs for illness (reduced work capacity) – Costs pertaining to the interruption of other public administrative services (councils, assistance, etc.) – Loss of museum revenues – Political 'fallout' 6. Human life values – Costs relating to mortalities – Costs as a result of illness – Losses of leisure time, personal injury, fear and panic Additionally, all of the sectors described above could face further high costs, which are linked to: – idle but paid-for resources such as labour and capital – equipment damage – process-restart costs – spoilage of resources – utility restoration costs. Following studies from the US National Council of Farmer Cooperatives (NCFC) and the US Agriculture Department, agriculture and the rest of the rural sector are typically at the end of the energy distribution chain, with fewer alternative supply options and greater vulnerability to disruptions. An initial (direct) effect could be the shortage of energy-dependent services (i.e. irrigation or milking cows) and a consequent loss of crops. Another (indirect) effect depends on energy price increases. In the event of energy price spikes, farmers, as price-takers for their commodity, are unable to pass price increases for energy or fertilizer on to the consumer, and therefore receive an even lower return for their products. The US Department of Agriculture recently estimated that the price increases for energy inputs and fertilizer owing to energy disruptions during the past few months in California – if projected into the year – could result in a 1-2% increase in total costs of production. This may not seem significant, but it becomes a serious matter when considering that this cost increase would translate into a one-third decrease in net farm cash-income.
64	Roland Andersson, Lewis Taylor, The social cost of unsupplied electricity, Energy Economics (1986) 139-146	Long duration outages	It is often the case that the cost per kilowatt hour decreases as the interruption continues, since there is then more time to make adaptive changes.

Ref.			Summary
65	Rahmatallah Poudineh, Tooraj Jamasb, Electricity supply interruptions: Sectoral interdependencies and the cost of energy not served for the Scottish economy, The Energy Journal 38 (1) (2017) 51-76	Social costs	A sector becomes inoperable in a power outage shock if electricity is an important input in its production process. Similarly, a sector can become inoperable if it supplies the inputs (such as gas or coal) of the electricity industry. This is because interruption in electricity services damages the business of sectors that supply its inputs. Therefore, inoperability is not limited to the unidirectional effects of interrupted power as an input to other industries; it also affects the sectors on which the electricity industry relies. The greater the interdependency between the affected infrastructures and the initially perturbed sector, the higher will be their inoperability over the period of recovery. Operational responsiveness depends on occurrence of indirect effects, the importance of power as input in production, and flexibility of the production processes.

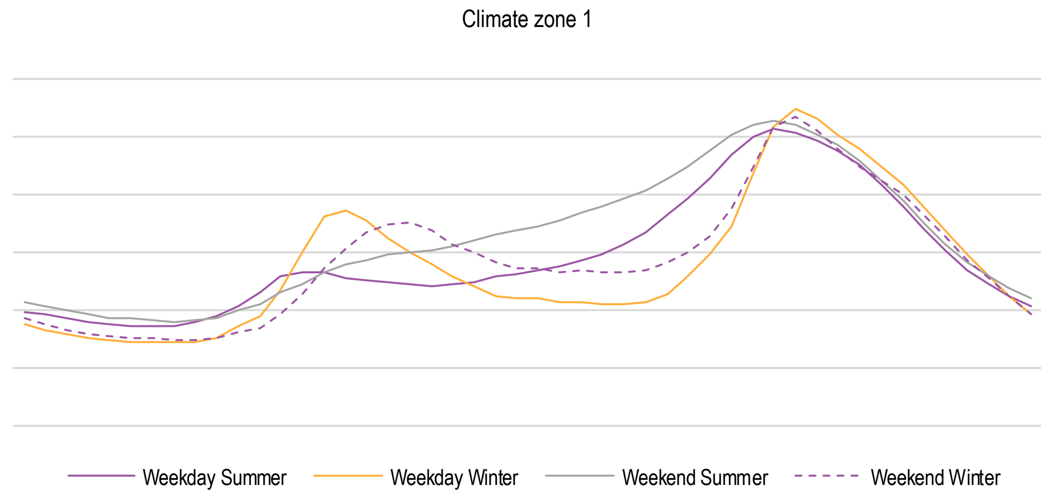
SOURCES: AS PER TABLE

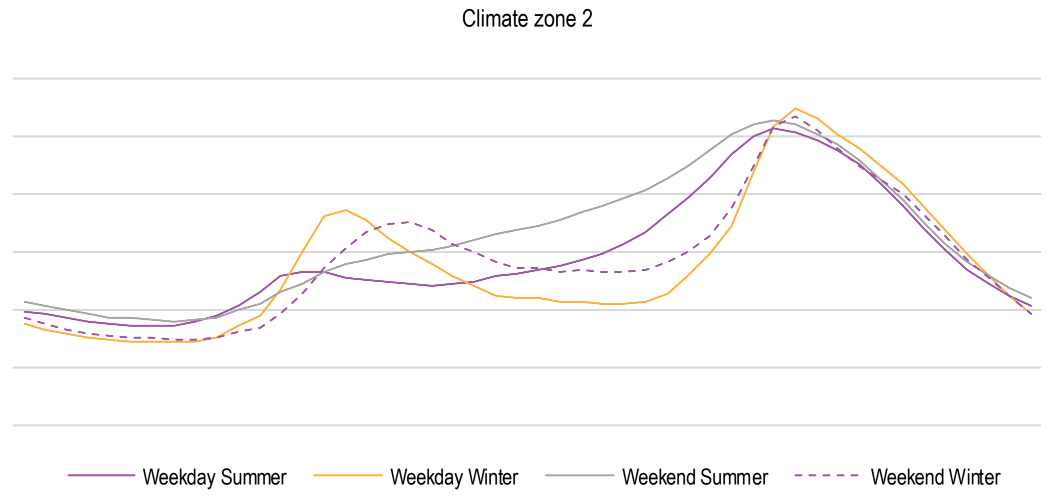
B

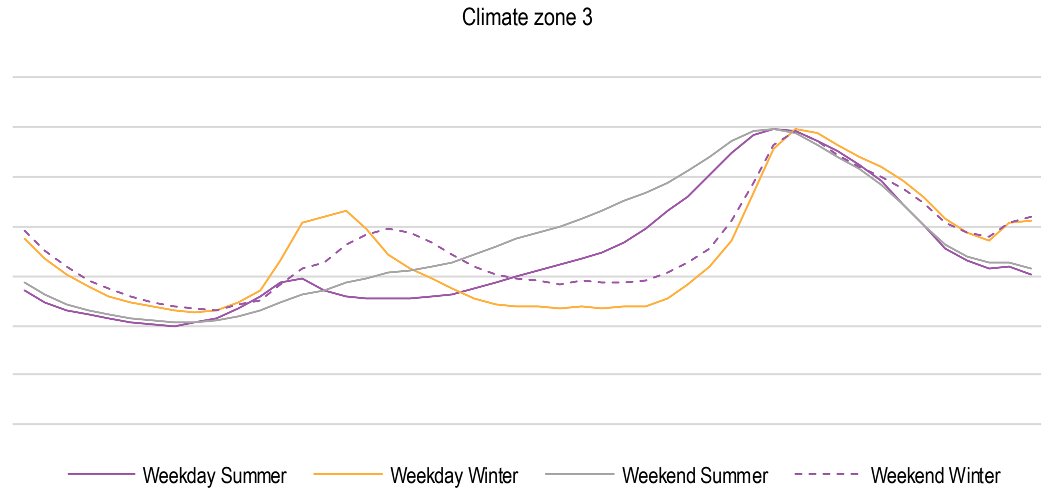
RESIDENTIAL LOAD PROFILES

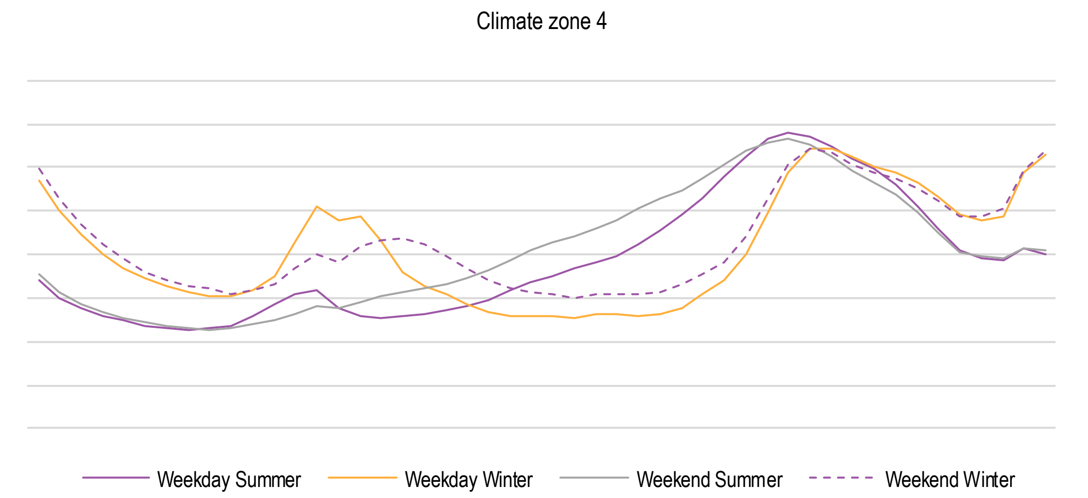
The residential load profiles, by climate zone, by season and by weekday/weekend, are provided as Figure B.1. The load profiles have been derived from consumption data for the AER's energy bill benchmarks.

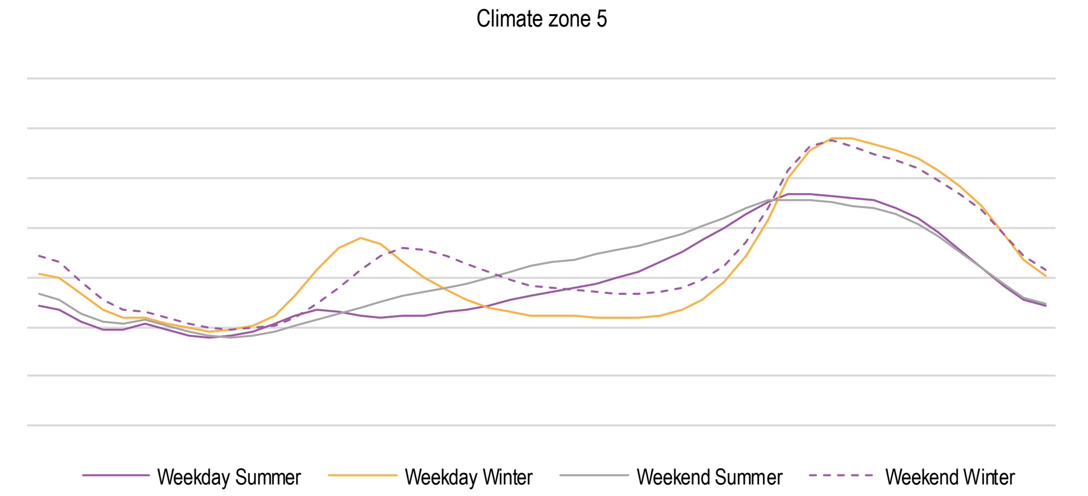
FIGURE B.1 RESIDENTIAL LOAD PROFILES, BY CLIMATE ZONE, BY SEASON, AND BY WEEKDAY AND WEEKEND

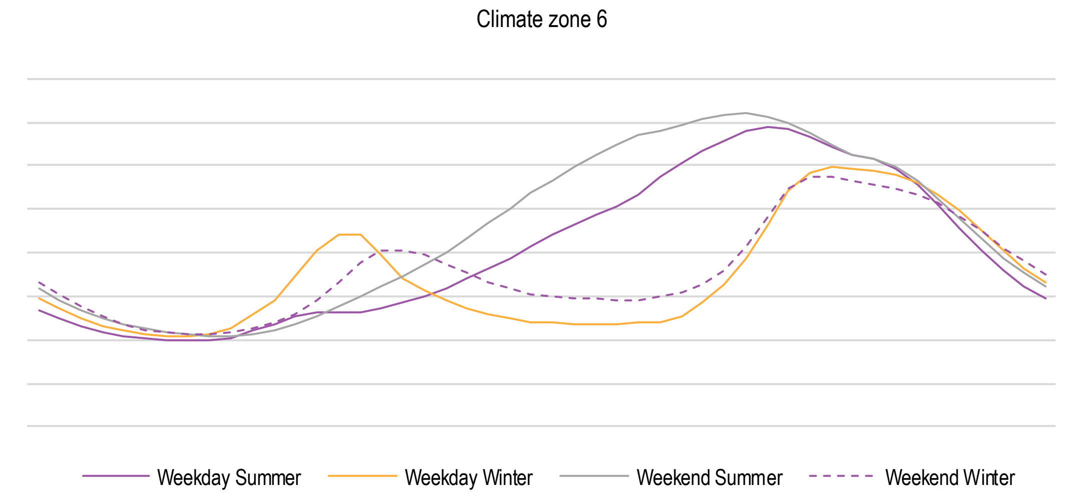




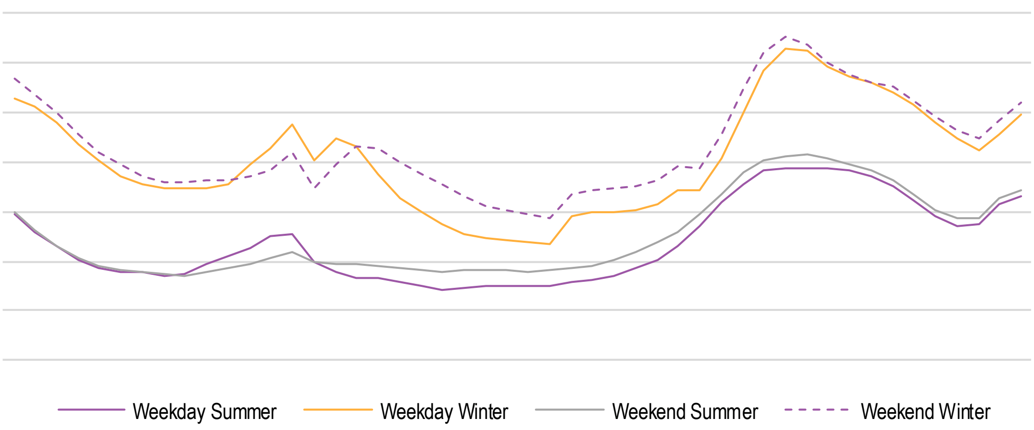



Climate zone 4
Weekday Summer
Weekday Winter
Weekend Summer
Weekend Winter


Climate zone 5
Weekday Summer
Weekday Winter
Weekend Summer
Weekend Winter


Climate zone 6
Weekday Summer
Weekday Winter
Weekend Summer
Weekend Winter

Climate zone 7



SOURCE: ACIL ALLEN ANALYSIS

C ‘STANDARD’ VCRs

The ‘standard’ VCRs, as provided to us by the AER, are set out in Table C.1 for residential customers and in Table C.2 for business customers.

TABLE C.1 'STANDARD' VCRs FOR RESIDENTIAL CUSTOMERS

Location		Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
Remoteness	**Climate zone**				**0 – 1 hours**	**1 – 3 hours**	**3 – 6 hours**	**6 – 12 hours**
Regional Australia	1	Winter	Weekday	Off-peak	27.60	31.88	19.50	12.48
Regional Australia	1	Winter	Weekday	Peak	39.35	31.48	18.63	11.52
Regional Australia	1	Winter	Weekend	Off-peak	23.97	27.68	16.93	10.84
Regional Australia	1	Winter	Weekend	Peak	34.99	27.99	16.56	10.25
Regional Australia	1	Summer	Weekday	Off-peak	40.15	30.74	18.10	11.14
Regional Australia	1	Summer	Weekday	Peak	41.48	26.64	15.33	9.21
Regional Australia	1	Summer	Weekend	Off-peak	32.67	25.02	14.73	9.06
Regional Australia	1	Summer	Weekend	Peak	34.78	22.33	12.85	7.72
CBD Brisbane	2	Winter	Weekday	Off-peak	38.22	36.78	25.14	15.41
CBD Brisbane	2	Winter	Weekday	Peak	43.78	27.90	17.69	10.41
CBD Brisbane	2	Winter	Weekend	Off-peak	36.53	35.15	24.03	14.73
CBD Brisbane	2	Winter	Weekend	Peak	46.30	29.50	18.70	11.01
CBD Brisbane	2	Summer	Weekday	Off-peak	33.28	32.02	21.89	13.41
CBD Brisbane	2	Summer	Weekday	Peak	48.89	31.15	19.75	11.63
CBD Brisbane	2	Summer	Weekend	Off-peak	30.63	29.48	20.15	12.35
CBD Brisbane	2	Summer	Weekend	Peak	46.88	29.87	18.94	11.15
Suburban Australia	2	Winter	Weekday	Off-peak	38.22	36.78	25.14	15.41
Suburban Australia	2	Winter	Weekday	Peak	43.78	27.90	17.69	10.41
Suburban Australia	2	Winter	Weekend	Off-peak	36.53	35.15	24.03	14.73
Suburban Australia	2	Winter	Weekend	Peak	46.30	29.50	18.70	11.01
Suburban Australia	2	Summer	Weekday	Off-peak	33.28	32.02	21.89	13.41
Suburban Australia	2	Summer	Weekday	Peak	48.89	31.15	19.75	11.63
Suburban Australia	2	Summer	Weekend	Off-peak	30.63	29.48	20.15	12.35
Suburban Australia	2	Summer	Weekend	Peak	46.88	29.87	18.94	11.15

Location		Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
Remoteness	Climate zone				0 – 1 hours	1 – 3 hours	3 – 6 hours	6 – 12 hours
Regional Australia	2	Winter	Weekday	Off-peak	32.81	31.70	25.30	17.01
Regional Australia	2	Winter	Weekday	Peak	44.86	26.70	18.70	11.82
Regional Australia	2	Winter	Weekend	Off-peak	30.19	29.17	23.28	15.65
Regional Australia	2	Winter	Weekend	Peak	44.72	26.62	18.64	11.78
Regional Australia	2	Summer	Weekday	Off-peak	30.62	29.58	23.61	15.87
Regional Australia	2	Summer	Weekday	Peak	54.59	32.49	22.76	14.38
Regional Australia	2	Summer	Weekend	Off-peak	27.50	26.57	21.21	14.25
Regional Australia	2	Summer	Weekend	Peak	50.50	30.06	21.05	13.30
Inner regional Australia	3 & 4	Winter	Weekday	Off-peak	29.49	24.25	18.20	12.30
Inner regional Australia	3 & 4	Winter	Weekday	Peak	35.57	21.30	14.63	9.41
Inner regional Australia	3 & 4	Winter	Weekend	Off-peak	25.95	21.33	16.01	10.82
Inner regional Australia	3 & 4	Winter	Weekend	Peak	33.57	20.10	13.80	8.88
Inner regional Australia	3 & 4	Summer	Weekday	Off-peak	61.12	34.82	23.50	14.96
Inner regional Australia	3 & 4	Summer	Weekday	Peak	64.31	32.24	20.67	12.74
Inner regional Australia	3 & 4	Summer	Weekend	Off-peak	51.15	29.14	19.67	12.52
Inner regional Australia	3 & 4	Summer	Weekend	Peak	55.43	27.79	17.82	10.98
Outer regional Australia	3 & 4	Winter	Weekday	Off-peak	29.49	24.25	18.20	12.30
Outer regional Australia	3 & 4	Winter	Weekday	Peak	35.57	21.30	14.63	9.41
Outer regional Australia	3 & 4	Winter	Weekend	Off-peak	25.95	21.33	16.01	10.82
Outer regional Australia	3 & 4	Winter	Weekend	Peak	33.57	20.10	13.80	8.88
Outer regional Australia	3 & 4	Summer	Weekday	Off-peak	61.12	34.82	23.50	14.96
Outer regional Australia	3 & 4	Summer	Weekday	Peak	64.31	32.24	20.67	12.74
Outer regional Australia	3 & 4	Summer	Weekend	Off-peak	51.15	29.14	19.67	12.52
Outer regional Australia	3 & 4	Summer	Weekend	Peak	55.43	27.79	17.82	10.98
CBD Sydney	5	Winter	Weekday	Off-peak	37.79	33.99	24.88	15.42

Location		Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
Remoteness	Climate zone				0 – 1 hours	1 – 3 hours	3 – 6 hours	6 – 12 hours
CBD Sydney	5	Winter	Weekday	Peak	48.41	29.87	20.00	11.91
CBD Sydney	5	Winter	Weekend	Off-peak	35.54	31.96	23.39	14.5
CBD Sydney	5	Winter	Weekend	Peak	48.56	29.97	20.06	11.95
CBD Sydney	5	Summer	Weekday	Off-peak	29.02	30.29	22.74	14.24
CBD Sydney	5	Summer	Weekday	Peak	52.33	33.98	23.08	13.84
CBD Sydney	5	Summer	Weekend	Off-peak	26.13	27.27	20.47	12.82
CBD Sydney	5	Summer	Weekend	Peak	49.23	31.97	21.71	13.02
Suburban New South Wales	5	Winter	Weekday	Off-peak	37.79	33.99	24.88	15.42
Suburban New South Wales	5	Winter	Weekday	Peak	48.41	29.87	20.00	11.91
Suburban New South Wales	5	Winter	Weekend	Off-peak	35.54	31.96	23.39	14.50
Suburban New South Wales	5	Winter	Weekend	Peak	48.56	29.97	20.06	11.95
Suburban New South Wales	5	Summer	Weekday	Off-peak	29.02	30.29	22.74	14.24
Suburban New South Wales	5	Summer	Weekday	Peak	52.33	33.98	23.08	13.84
Suburban New South Wales	5	Summer	Weekend	Off-peak	26.13	27.27	20.47	12.82
Suburban New South Wales	5	Summer	Weekend	Peak	49.23	31.97	21.71	13.02
CBD Adelaide	5	Winter	Weekday	Off-peak	29.69	31.52	26.95	16.35
CBD Adelaide	5	Winter	Weekday	Peak	35.03	26.79	21.21	12.62
CBD Adelaide	5	Winter	Weekend	Off-peak	27.48	29.17	24.94	15.13
CBD Adelaide	5	Winter	Weekend	Peak	35.28	26.98	21.36	12.71
CBD Adelaide	5	Summer	Weekday	Off-peak	54.63	40.83	32.12	19.07
CBD Adelaide	5	Summer	Weekday	Peak	61.47	38.79	28.86	16.87
CBD Adelaide	5	Summer	Weekend	Off-peak	52.71	39.40	30.99	18.40
CBD Adelaide	5	Summer	Weekend	Peak	61.89	39.05	29.06	16.98
Suburban South Australia	5	Winter	Weekday	Off-peak	29.69	31.52	26.95	16.35
Suburban South Australia	5	Winter	Weekday	Peak	35.03	26.79	21.21	12.62

Location		Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
Remoteness	Climate zone				0 – 1 hours	1 – 3 hours	3 – 6 hours	6 – 12 hours
Suburban South Australia	5	Winter	Weekend	Off-peak	27.48	29.17	24.94	15.13
Suburban South Australia	5	Winter	Weekend	Peak	35.28	26.98	21.36	12.71
Suburban South Australia	5	Summer	Weekday	Off-peak	54.63	40.83	32.12	19.07
Suburban South Australia	5	Summer	Weekday	Peak	61.47	38.79	28.86	16.87
Suburban South Australia	5	Summer	Weekend	Off-peak	52.71	39.40	30.99	18.40
Suburban South Australia	5	Summer	Weekend	Peak	61.89	39.05	29.06	16.98
Regional Australia	5	Winter	Weekday	Off-peak	27.47	26.49	21.58	12.51
Regional Australia	5	Winter	Weekday	Peak	42.38	24.64	17.38	9.74
Regional Australia	5	Winter	Weekend	Off-peak	25.40	24.49	19.95	11.57
Regional Australia	5	Winter	Weekend	Peak	43.19	25.11	17.71	9.92
Regional Australia	5	Summer	Weekday	Off-peak	29.00	27.96	22.78	13.21
Regional Australia	5	Summer	Weekday	Peak	55.77	32.43	22.87	12.81
Regional Australia	5	Summer	Weekend	Off-peak	26.74	25.78	21.00	12.18
Regional Australia	5	Summer	Weekend	Peak	52.96	30.79	21.72	12.17
CBD Melbourne	6	Winter	Weekday	Off-peak	33.97	25.24	20.79	12.28
CBD Melbourne	6	Winter	Weekday	Peak	39.13	21.96	16.21	9.31
CBD Melbourne	6	Winter	Weekend	Off-peak	32.24	23.95	19.73	11.65
CBD Melbourne	6	Winter	Weekend	Peak	39.52	22.18	16.37	9.40
CBD Melbourne	6	Summer	Weekday	Off-peak	26.61	19.77	16.28	9.61
CBD Melbourne	6	Summer	Weekday	Peak	38.77	21.76	16.07	9.23
CBD Melbourne	6	Summer	Weekend	Off-peak	23.25	17.27	14.23	8.40
CBD Melbourne	6	Summer	Weekend	Peak	36.29	20.36	15.04	8.63
Suburban Victoria	6	Winter	Weekday	Off-peak	33.97	25.24	20.79	12.28
Suburban Victoria	6	Winter	Weekday	Peak	39.13	21.96	16.21	9.31
Suburban Victoria	6	Winter	Weekend	Off-peak	32.24	23.95	19.73	11.65

Location		Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
Remoteness	Climate zone				0 – 1 hours	1 – 3 hours	3 – 6 hours	6 – 12 hours
Suburban Victoria	6	Winter	Weekend	Peak	39.52	22.18	16.37	9.40
Suburban Victoria	6	Summer	Weekday	Off-peak	26.61	19.77	16.28	9.61
Suburban Victoria	6	Summer	Weekday	Peak	38.77	21.76	16.07	9.23
Suburban Victoria	6	Summer	Weekend	Off-peak	23.25	17.27	14.23	8.40
Suburban Victoria	6	Summer	Weekend	Peak	36.29	20.36	15.04	8.63
Suburban New South Wales	6	Winter	Weekday	Off-peak	33.97	25.24	20.79	12.28
Suburban New South Wales	6	Winter	Weekday	Peak	39.13	21.96	16.21	9.31
Suburban New South Wales	6	Winter	Weekend	Off-peak	32.24	23.95	19.73	11.65
Suburban New South Wales	6	Winter	Weekend	Peak	39.52	22.18	16.37	9.40
Suburban New South Wales	6	Summer	Weekday	Off-peak	26.61	19.77	16.28	9.61
Suburban New South Wales	6	Summer	Weekday	Peak	38.77	21.76	16.07	9.23
Suburban New South Wales	6	Summer	Weekend	Off-peak	23.25	17.27	14.23	8.40
Suburban New South Wales	6	Summer	Weekend	Peak	36.29	20.36	15.04	8.63
Regional Australia	6	Winter	Weekday	Off-peak	20.37	19.16	14.29	10.32
Regional Australia	6	Winter	Weekday	Peak	32.19	20.05	13.57	9.17
Regional Australia	6	Winter	Weekend	Off-peak	19.01	17.88	13.33	9.63
Regional Australia	6	Winter	Weekend	Peak	31.93	19.89	13.46	9.10
Regional Australia	6	Summer	Weekday	Off-peak	29.64	27.87	20.78	15.01
Regional Australia	6	Summer	Weekday	Peak	50.35	31.36	21.23	14.35
Regional Australia	6	Summer	Weekend	Off-peak	27.52	25.88	19.30	13.94
Regional Australia	6	Summer	Weekend	Peak	47.88	29.82	20.18	13.64
CBD Canberra	7	Winter	Weekday	Off-peak	31.11	28.29	18.79	13.63
CBD Canberra	7	Winter	Weekday	Peak	39.02	24.34	15.11	10.23
CBD Canberra	7	Winter	Weekend	Off-peak	26.02	23.66	15.72	11.40
CBD Canberra	7	Winter	Weekend	Peak	35.38	22.07	13.70	9.28

Location		Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
Remoteness	Climate zone				0 – 1 hours	1 – 3 hours	3 – 6 hours	6 – 12 hours
CBD Canberra	7	Summer	Weekday	Off-peak	16.00	24.57	17.28	13.18
CBD Canberra	7	Summer	Weekday	Peak	37.35	27.17	17.41	12.18
CBD Canberra	7	Summer	Weekend	Off-peak	14.30	21.97	15.45	11.79
CBD Canberra	7	Summer	Weekend	Peak	33.79	24.58	15.75	11.02
CBD Hobart	7	Winter	Weekday	Off-peak	31.11	28.29	18.79	13.63
CBD Hobart	7	Winter	Weekday	Peak	39.02	24.34	15.11	10.23
CBD Hobart	7	Winter	Weekend	Off-peak	26.02	23.66	15.72	11.40
CBD Hobart	7	Winter	Weekend	Peak	35.38	22.07	13.70	9.28
CBD Hobart	7	Summer	Weekday	Off-peak	16.00	24.57	17.28	13.18
CBD Hobart	7	Summer	Weekday	Peak	37.35	27.17	17.41	12.18
CBD Hobart	7	Summer	Weekend	Off-peak	14.30	21.97	15.45	11.79
CBD Hobart	7	Summer	Weekend	Peak	33.79	24.58	15.75	11.02
Suburban Australia	7	Winter	Weekday	Off-peak	31.11	28.29	18.79	13.63
Suburban Australia	7	Winter	Weekday	Peak	39.02	24.34	15.11	10.23
Suburban Australia	7	Winter	Weekend	Off-peak	26.02	23.66	15.72	11.40
Suburban Australia	7	Winter	Weekend	Peak	35.38	22.07	13.70	9.28
Suburban Australia	7	Summer	Weekday	Off-peak	16.00	24.57	17.28	13.18
Suburban Australia	7	Summer	Weekday	Peak	37.35	27.17	17.41	12.18
Suburban Australia	7	Summer	Weekend	Off-peak	14.30	21.97	15.45	11.79
Suburban Australia	7	Summer	Weekend	Peak	33.79	24.58	15.75	11.02
Regional Australia	7	Winter	Weekday	Off-peak	18.05	19.52	13.25	7.92
Regional Australia	7	Winter	Weekday	Peak	33.44	23.03	14.59	8.44
Regional Australia	7	Winter	Weekend	Off-peak	16.79	18.16	12.33	7.37
Regional Australia	7	Winter	Weekend	Peak	33.09	22.80	14.44	8.35
Regional Australia	7	Summer	Weekday	Off-peak	1.57	23.35	17.58	10.98

Location		Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
Remoteness	**Climate zone**				**0 – 1 hours**	**1 – 3 hours**	**3 – 6 hours**	**6 – 12 hours**
Regional Australia	7	Summer	Weekday	Peak	29.91	29.34	19.68	11.70
Regional Australia	7	Summer	Weekend	Off-peak	1.47	21.89	16.48	10.29
Regional Australia	7	Summer	Weekend	Peak	28.05	27.51	18.45	10.97

SOURCE: AUSTRALIAN ENERGY REGULATOR

TABLE C.2 'STANDARD' VCRs FOR BUSINESS CUSTOMERS

Industry sector	Size of customer	Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
					0 – 1 hours	1 – 3 hours	3 – 6 hours	6 – 12 hours
Agriculture	Small	Winter	Weekday	Off-peak	$176.30	$63.47	$34.21	$17.86
Agriculture	Small	Winter	Weekday	Peak	$176.30	$63.47	$34.21	$17.86
Agriculture	Small	Winter	Weekend	Off-peak	$176.30	$63.47	$34.21	$17.86
Agriculture	Small	Winter	Weekend	Peak	$176.30	$63.47	$34.21	$17.86
Agriculture	Small	Summer	Weekday	Off-peak	$176.30	$63.47	$34.21	$17.86
Agriculture	Small	Summer	Weekday	Peak	$176.30	$63.47	$34.21	$17.86
Agriculture	Small	Summer	Weekend	Off-peak	$176.30	$63.47	$34.21	$17.86
Agriculture	Small	Summer	Weekend	Peak	$176.30	$63.47	$34.21	$17.86
Agriculture	Large	Winter	Weekday	Off-peak	$103.06	$37.10	$20.00	$10.44
Agriculture	Large	Winter	Weekday	Peak	$103.06	$37.10	$20.00	$10.44
Agriculture	Large	Winter	Weekend	Off-peak	$103.06	$37.10	$20.00	$10.44
Agriculture	Large	Winter	Weekend	Peak	$103.06	$37.10	$20.00	$10.44
Agriculture	Large	Summer	Weekday	Off-peak	$103.06	$37.10	$20.00	$10.44
Agriculture	Large	Summer	Weekday	Peak	$103.06	$37.10	$20.00	$10.44
Agriculture	Large	Summer	Weekend	Off-peak	$103.06	$37.10	$20.00	$10.44
Agriculture	Large	Summer	Weekend	Peak	$103.06	$37.10	$20.00	$10.44
Industrial	Small	Winter	Weekday	Off-peak	$209.85	$71.98	$39.70	$19.88
Industrial	Small	Winter	Weekday	Peak	$187.75	$64.39	$35.52	$17.78
Industrial	Small	Winter	Weekend	Off-peak	$221.15	$76.04	$42.29	$21.17
Industrial	Small	Winter	Weekend	Peak	$206.12	$70.88	$39.42	$19.73
Industrial	Small	Summer	Weekday	Off-peak	$216.88	$74.39	$41.03	$20.54
Industrial	Small	Summer	Weekday	Peak	$211.35	$72.49	$39.98	$20.02
Industrial	Small	Summer	Weekend	Off-peak	$225.82	$77.65	$43.18	$21.62

Industry sector	Size of customer	Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
					0 – 1 hours	1 – 3 hours	3 – 6 hours	6 – 12 hours
Industrial	Small	Summer	Weekend	Peak	$224.39	$77.16	$42.91	$21.48
Industrial	Large	Winter	Weekday	Off-peak	$122.67	$42.07	$23.21	$11.62
Industrial	Large	Winter	Weekday	Peak	$109.75	$37.64	$20.76	$10.39
Industrial	Large	Winter	Weekend	Off-peak	$129.27	$44.45	$24.72	$12.38
Industrial	Large	Winter	Weekend	Peak	$120.49	$41.43	$23.04	$11.54
Industrial	Large	Summer	Weekday	Off-peak	$126.78	$43.48	$23.99	$12.01
Industrial	Large	Summer	Weekday	Peak	$123.55	$42.37	$23.37	$11.70
Industrial	Large	Summer	Weekend	Off-peak	$132.01	$45.39	$25.24	$12.64
Industrial	Large	Summer	Weekend	Peak	$131.17	$45.10	$25.08	$12.56
Commercial	Small	Winter	Weekday	Off-peak	$181.92	$71.20	$36.94	$18.65
Commercial	Small	Winter	Weekday	Peak	$180.21	$69.94	$36.23	$18.28
Commercial	Small	Winter	Weekend	Off-peak	$198.30	$77.61	$40.27	$20.33
Commercial	Small	Winter	Weekend	Peak	$203.20	$78.86	$40.85	$20.62
Commercial	Small	Summer	Weekday	Off-peak	$184.01	$72.02	$37.37	$18.87
Commercial	Small	Summer	Weekday	Peak	$177.65	$68.95	$35.71	$18.02
Commercial	Small	Summer	Weekend	Off-peak	$200.91	$78.63	$40.80	$20.60
Commercial	Small	Summer	Weekend	Peak	$214.08	$83.09	$43.04	$21.72
Commercial	Large	Winter	Weekday	Off-peak	$106.34	$41.62	$21.60	$10.90
Commercial	Large	Winter	Weekday	Peak	$105.34	$40.88	$21.18	$10.69
Commercial	Large	Winter	Weekend	Off-peak	$115.92	$45.37	$23.54	$11.89
Commercial	Large	Winter	Weekend	Peak	$118.78	$46.10	$23.88	$12.05
Commercial	Large	Summer	Weekday	Off-peak	$107.56	$42.10	$21.84	$11.03
Commercial	Large	Summer	Weekday	Peak	$103.85	$40.30	$20.88	$10.54
Commercial	Large	Summer	Weekend	Off-peak	$117.44	$45.96	$23.85	$12.04

Industry sector	Size of customer	Season	Day of week	Peak/Off-peak	VCR values ($/kWh)			
					0 – 1 hours	1 – 3 hours	3 – 6 hours	6 – 12 hours
Commercial	Large	Summer	Weekend	Peak	$125.14	$48.57	$25.16	$12.70
Services	Direct connect				$2.26	$1.28	$1.74	$3.97
Industrial	Direct connect				$62.50	$14.26	$3.05	$1.42
Metals	Direct connect				$12.17	$2.81	$0.63	$0.32
Mines	Direct connect				$18.09	$4.64	$1.40	$0.93

SOURCE: AUSTRALIAN ENERGY REGULATOR

D

I-O MODELLING

I-O modelling assesses the contribution a sector or sectors make to the economy to analyse the potential impacts of a change in production of a particular sector or sectors, in this case, by a WALDO.

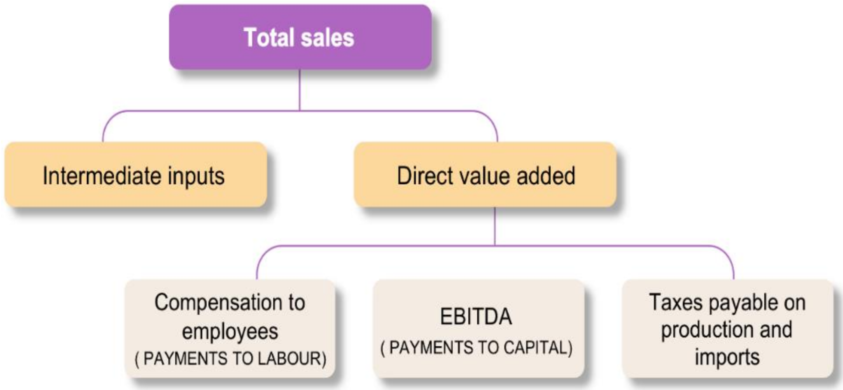
D.1 Direct economic contribution

The standard measure of economic contribution is the extent to which it increases the value of goods and services generated by the economy as a whole – in other words, the extent to which it increases economic activity as measured by gross regional, state or domestic product (GRP, GSP or GDP). An economy has a range of factors of production (including labour and capital stock) and access to various intermediate inputs. By using the factors of production appropriately industries add value to intermediate inputs by converting them into a range of goods and services more suited for use by consumers or other industries. An industry or business' contribution to GDP measures the total value added generated and is defined as the income that an industry or business generates, less the cost of the inputs that it uses to generate that income, plus certain taxes paid.

The direct contribution of an industry or a company to the Australian economy can therefore be estimated by determining their payments to the factors of production plus the taxes (less subsidies) payable on production and imports. This is shown graphically in Figure D.1.

Box D.1 provides a summary of the definitions used by the Australian Bureau of Statistics (ABS) as part of the System of National Accounts (SNA).

FIGURE D.1 CALCULATION OF DIRECT VALUE ADDED



Note: EBITDA is equivalent to the SNA93 definition of gross operating surplus

SOURCE: ACIL ALLEN CONSULTING

BOX D.1 ABS DEFINITIONS OF VALUE ADDED

An industry's direct contribution to Gross Domestic Product or Gross State Product is well defined under the standard national accounting framework used by the Australian Bureau of Statistics (ABS), which is known as the System of National Accounts (SNA). SNA recognises three different measures of value added:

a) Value added at Purchasers' Prices. This is defined as output valued at purchasers' prices, less intermediate consumption valued at producer prices. This measure is equivalent to the traditional measure of value added at market prices.
b) Value added at Basic Prices. In this measure, the output is valued at basic prices while intermediate consumption is valued at producer prices. In the case of beer production this measure excludes beer excise as they are viewed as production taxes levied on output.
c) Value added at factor Cost. This measure excludes all production taxes net of subsidies. In other words, it excludes all production taxes – such as payroll taxes, fringe benefit taxes etc – and not just those that are levied on output.

The measure of value added to be used depends on the nature of the analysis that is to be conducted. When presenting an industry view of GDP for example, the ABS uses value added at basic prices and adds an aggregate estimate of net taxes on products in question to give a total measure of GDP at purchasers' prices (ABS Cat no. 5216).

SOURCE: ACIL ALLEN CONSULTING

D.2 Indirect economic contribution

Indirect effects are a broader notion of the economic contribution. For example, when a transmission line is built, indirect effects are generated by the businesses supplying the component parts, the transporter who made deliveries to site, and the purchase of goods and services by the labour force. To fully measure the indirect effects, account should also be taken of changes in incomes which may feed through to further changes in domestic demand.

The intermediate inputs used by an industry can be sourced either from within the Australian economy or from foreign economies. If purchased from within the Australian economy, then the portion of value added embodied in the intermediate input is indirectly associated with the activity of the purchaser. The calculation of the indirect contribution quickly becomes difficult as one considers that value-added embodied in the intermediate inputs of the intermediate input.

Input-output tables and the associated 'input-output multipliers' can be used to estimate the indirect economic contributions. Input-output multipliers are summary measures generated from input-output tables that can be used for predicting the total impact on all industries in the economy of changes in demand for the output of any one industry. The tables and multipliers can also be used to measure the relative importance of the production chain linkages to different parts of the economy.

It should be noted that some of the assumptions underpinning input-output multipliers can be an impediment to credible analysis. Understanding these assumptions is necessary to prevent the inappropriate application of input-output multipliers – for example, in situations where economic constraints are present or when the profile of a business or project differs substantially from the industry average. We do not consider that these conditions apply for the purpose of this analysis and that the use of input-output multipliers to estimate the impact on economic contribution of a WALDO is appropriate.

Further information on input-output tables and the calculation of multipliers can be found in ABS Catalogue number 5246.0.

D.3 Overview of I-O tables

Input-output tables provide a snapshot of an economy at a particular time. The tables used in this analysis were for the 2016-17 financial year, escalated to 2019 dollars.

Input-output tables can be used to derive input-output multipliers. These multipliers show how changes to a given part of an economy impact on the economy as a whole.

The input-output multipliers allow rigorous and credible analysis of the economic footprint of a particular facility, industry or event for the region of interest. Although input-output multipliers may also be suitable tools for analysing the impact of various types of economic change, caution needs to be adopted in their application for this purpose. Misuse of input-output multipliers for the purpose of impact analysis has led to scepticism of their general use in favour of other tools such as computable general equilibrium (CGE) modelling. Notwithstanding this, they are still eminently suitable for understanding the economic linkages between a given facility or industry to gain an appreciation of the wider interactions of the industry beyond its direct contribution.

D.4 Multiplier types

Input-output multipliers estimate the economic impact on a region's economy from a one dollar change in the final demand for the output of one of the region's industries. Generally, four types of multipliers are used:

- output – measures the impact on the output of all industries in the economy
- income – measures the effect on the wages and salaries paid to workers within the economy
- employment – measures the jobs creation impact
- value-added – measures the impact on wages and salaries, profits and indirect taxes.

The sum of wages and salaries, profits and indirect taxes for a given industry provides a measure of its contribution to the size of the local economy – its contribution to gross regional product (GRP). The value added multiplier can therefore also be considered to be the GRP multiplier.

Input-output multipliers are a flexible tool for economic analysis. Their flexibility stems from the different forms of each multiplier type. For each region, multipliers were estimated in the following forms:

- initial effects
- first round effects
- industrial support effects
- production induced effects
- consumption induced effects
- simple multipliers
- total multipliers
- type 1A multipliers
- type 1B multipliers
- type 2A multipliers
- type 2B multipliers.

The above multiplier types are defined in full in ABS Catalogue No. 5246 for output, income, employment and value-added multipliers; however, a brief overview of the different types of output multipliers is presented below.

D.5 Multiplier effects

When additional sales to final demand are made, for example through increased exports or sales to the public, production increases to meet the increased demand, and this is the initial effect. Since production increases to exactly match the increased final demand, the increase is always equal to one (noting that the multipliers are defined in terms of a one dollar increase in final demand).

The industry producing the additional output makes purchases to enable itself to increase production, these new purchases are met by production increases in other industries and these constitute the first round effect. These first round production increases cause other industries to also increase their purchases, and these purchases cause other industries to increase their production, and so on. These 'flow-on' effects eventually diminish, but when 'added together constitute the industrial support effect.

The industrial support effect added to the first round effect is known as the production induced effect. So far this chain of events has ignored one important factor, the effect on labour and its consumption. When output increases, employment increases, and increased employment translates to increased earnings and consumption by workers, and this translates to increased output to meet the increased consumption. This is the consumption effect.

D.6 Multipliers

The simple and total multipliers are derived by summing the effects. The simple multiplier is the sum of the initial and production induced effects. The total multiplier is larger, because it also adds in the consumption effect. So far, all the effects and multipliers listed have had one thing in common, they all measure the impact on the economy of the initial increase in final demand.

The remaining multipliers take a different point of view, they are ratios of the above multiplier types to the initial effect. The type 1A multiplier is calculated as the ratio of the initial and first round effects to the initial effect, while the type 1B multiplier is the ratio of the simple multiplier to the initial effect. The type 2A multiplier is the ratio of the total multiplier to the initial effect, while the type 2B multiplier is the ratio of the total multiplier less the initial effect to the initial effect.

Given the large number of multiplier types to choose from, output, income, employment and value added multipliers, and each with numerous variations (simple, total, type 2A, etc) it is important that the analysis uses the most appropriate multipliers. Usually, the multipliers that include consumption effects (i.e. the added impact that comes from wage and salaries earners spending their income) are used. These are the total and type 2A multipliers. The total and type 2A multipliers will generally provide the biggest projected impact. Simple or type 1B (which omit the consumption effect) may be used to provide a more conservative result.

E INDUSTRIAL LOAD PROFILES

The industrial load profiles, by industrial load sector and by weekday/weekend, are provided as Figure E.1. We have assumed the same load profile in summer and in winter.

The load profiles indicate the percentage of load on a weekday and on a weekend. If a sector has a higher weekday load than weekend load, the overnight load on the weekend may be a higher percentage than the overnight load on a weekday.

Some of the industrial sectors include a wide range of load types. For example, the agriculture, forestry and fishing sector includes dairy, which has peak loads in the morning and evening and piggeries that may have a more constant load to maintain a constant temperature. The assumed load profile for the sector is effectively an aggregate of these diverse loads.

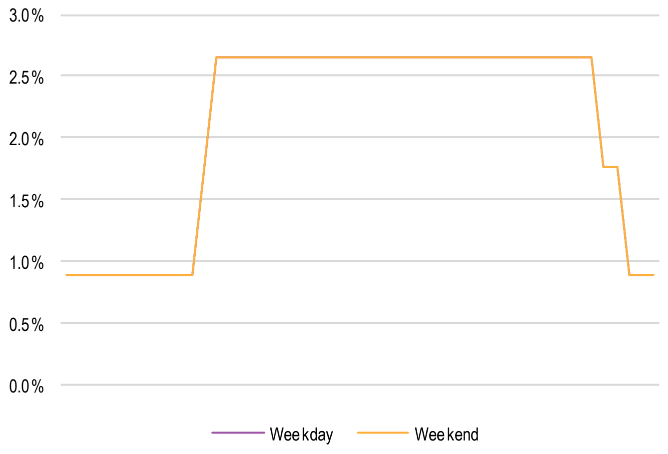
The load profile is assumed to be flat for some industries, such as metal smelting, that operate on a 24/7 basis.

The load profile is generally assumed to be higher during the day than overnight, with the start time for the ramp up at the beginning of the day and for the ramp down at the end of the day dependent on the sector. For example, the ramp up and down for the construction sector is assumed to occur earlier than in the public administration and safety sector.

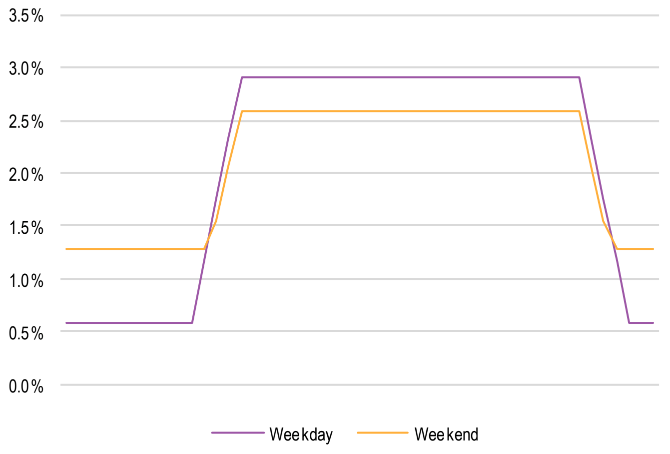
The load profile is assumed to be the same on the weekday and weekend for sectors such as agriculture, forestry and fishing, and arts and recreation services. The load profile is assumed to differ on a weekday and weekend for sectors such as education and training, and professional, scientific and technical services.

FIGURE E.1 RESIDENTIAL LOAD PROFILES, BY CLIMATE ZONE, BY SEASON, AND BY WEEKDAY AND WEEKEND

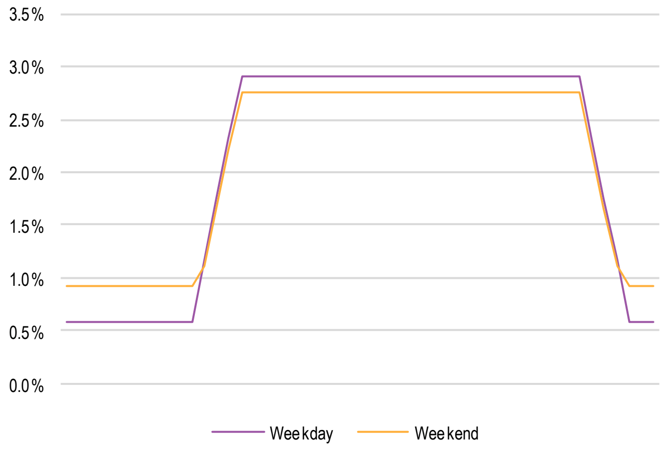
Electricity, gas, water and waste services



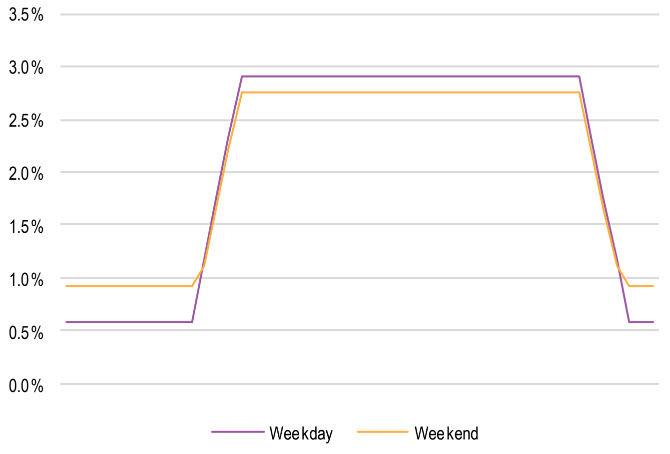
Financial and insurance services



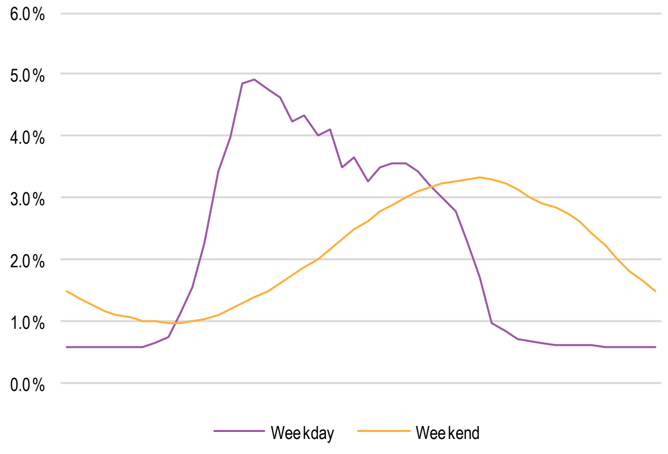
Health care and social assistance



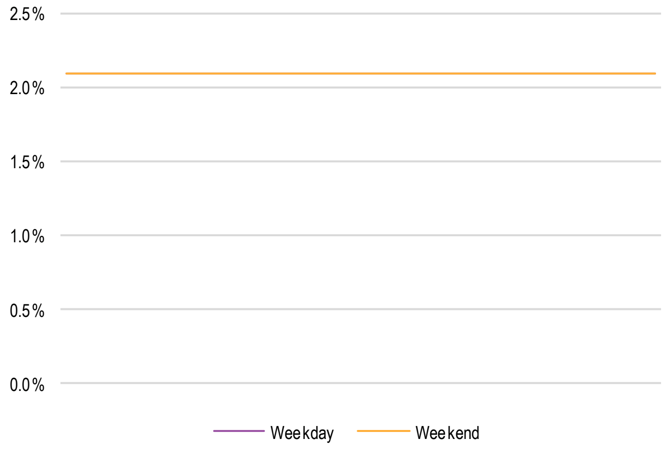
Information, media and telecommunications

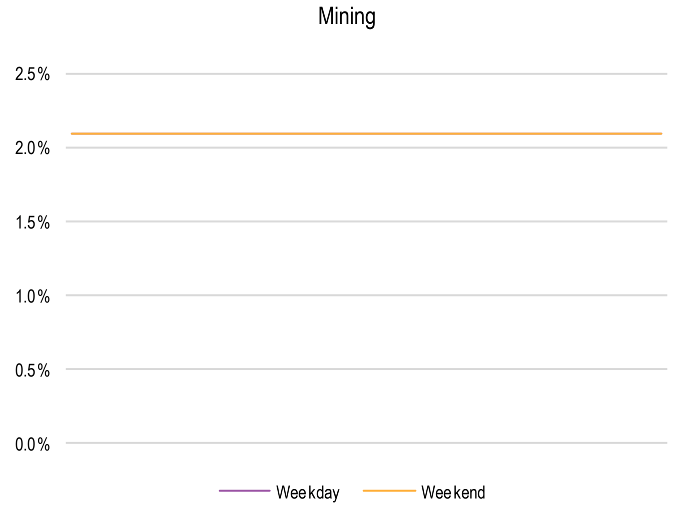


Manufacturing, excluding metal smelting

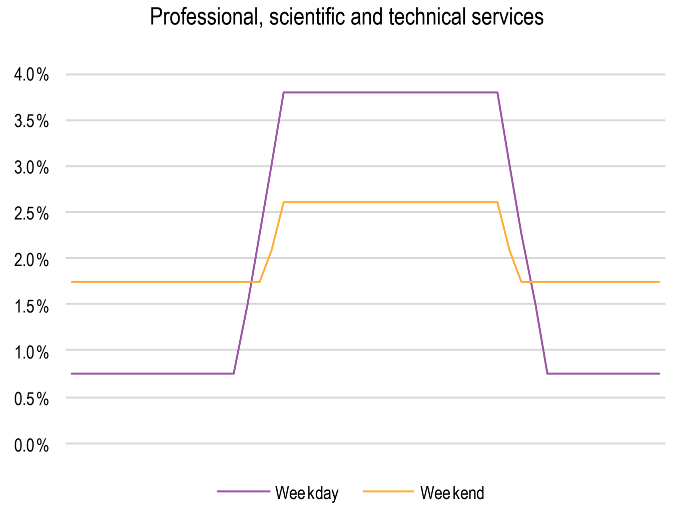


Metal smelting




Mining
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
Weekday
Weekend


Other services
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
Weekday
Weekend


Professional, scientific and technical services
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
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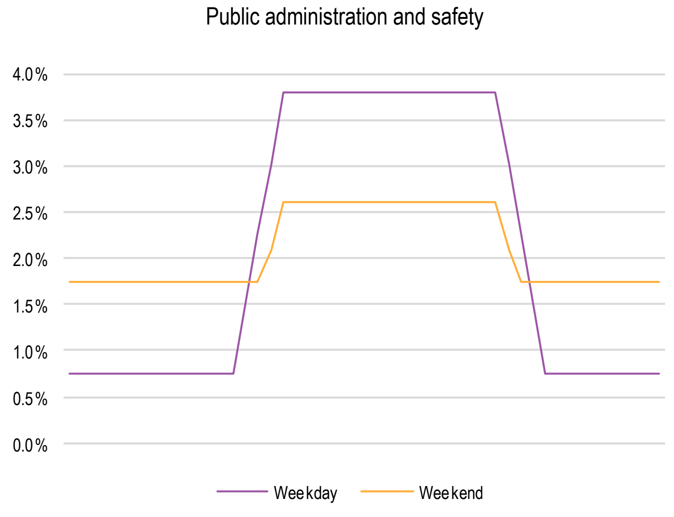
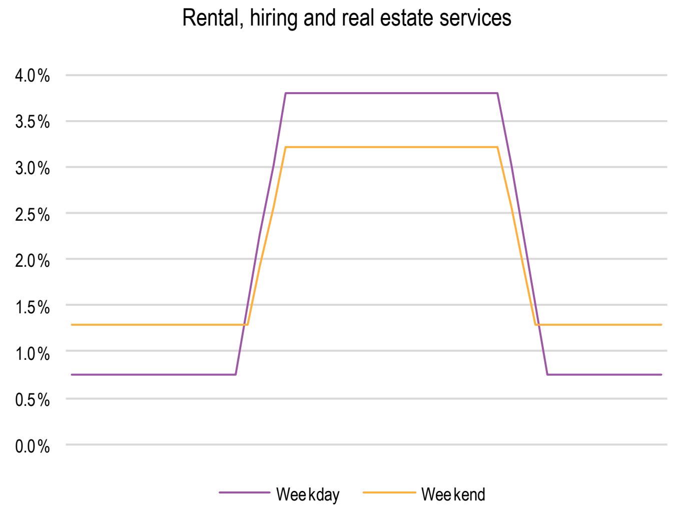
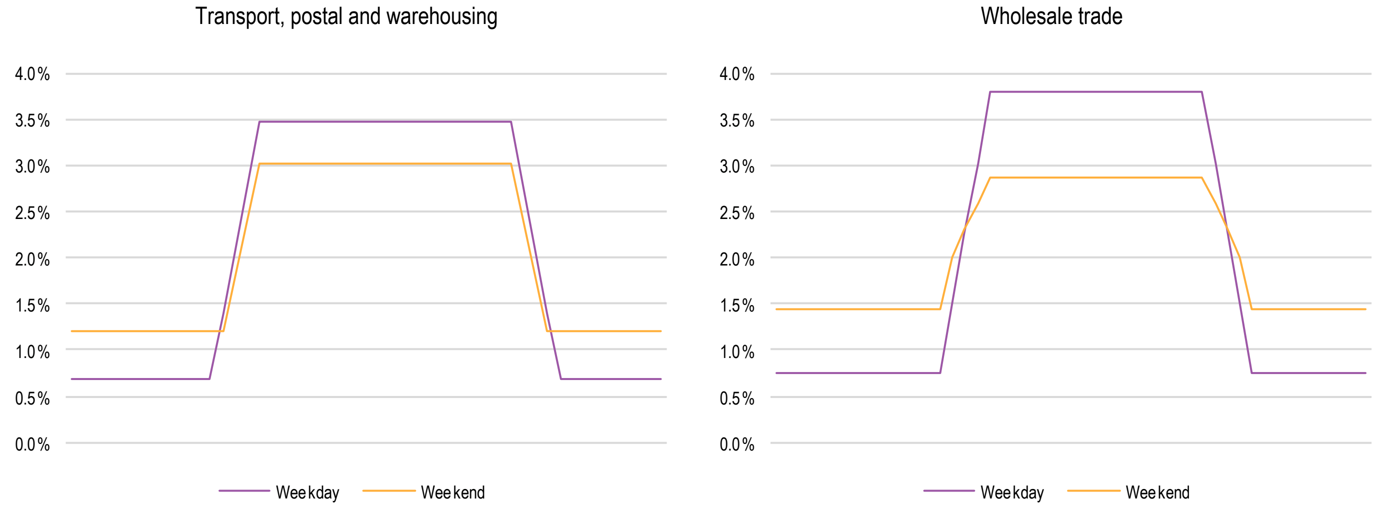
Weekday
Weekend


Public administration and safety
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
Weekday
Weekend


Rental, hiring and real estate services
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
Weekday
Weekend


Retail trade
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
Weekday
Weekend



SOURCE: ACIL ALLEN ANALYSIS AND ASSUMPTIONS

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