energeia.com.au

Energy Consumption Forecasts – Final Report

Prepared for Power and Water Corporation

9 December 2022

ENERGEIA

Executive Summary

Power and Water Corporation (PWC) primarily uses grid energy consumption forecasts to develop National Electricity Rules as in force in the Northern Territory (NT NER) compliant network tariffs, to develop revenue forecasts for business purposes, and to fulfil any additional regulatory reporting requirements to its shareholders, as well as local and federal regulatory bodies.

PWC is obligated under the NT NER to design tariffs to be included in its Tariff Structure Statement (TSS) that allow for the recovery of its approved[1] revenues, and comply with all requirements, including side-constraints[2]. Accurate energy forecasts minimise annual revenue volatility dye to overs and unders[3] and ensure customer impacts are accurately predicted and managed.[4] The National Electricity Law (NEL) requires PWC to provide energy forecasts in response to the Australian Energy Regulator's (AER's) Regulatory Information Notices (RINs)[5].

In developing accurate connection forecasts, PWC faces challenges which are unique amongst Distribution Network Service Providers (DNSPs).

- PWC operates three standalone grids; Darwin-Katherine Interconnected System (DKIS), Tennant Creek, and Alice Springs.
- PWC's networks are geographically diverse, resulting in significant variation in climate between northern and southern networks.
- The Northern Territory has a small population, resulting in PWC's networks servicing low customer numbers over a large area.

The NT NER requires the AER to accept forecasts in a pricing proposal that are reasonable[6] and reflect the key principles set out in the NT NER and the AER Best Practice Forecasting Guidelines, which state:[7]

- Forecasts should be as accurate as possible, based on comprehensive information and prepared in an unbiased fashion.
- The basic inputs, assumptions and methodology that underpin forecasts should be disclosed.
- Stakeholders should have as much opportunity to engage as is practicable.

Key factors that have impacted PWC's grid energy consumption forecasts over the forecast period to 2032 include the COVID-19 global pandemics impact on population and Gross State Product (GSP), spot loads – being the greatest individual contributors to energy consumption, and the rising financial attractiveness of rooftop solar PV systems, which significantly reduce network energy consumption during daylight hours.

In order to meet its regulatory and statutory obligations, PWC requires a fit-for-purpose, best practice energy consumption forecast over the next regulatory control period.

---

[1] National Electricity Rules as In Force in the Northern Territory Version 96 Sections 6.18.5(e) and 6.18.5(g)(2)

[2] Ibid. Section 6.18.6

[3] Ibid. 6.18.7(b), 6.18.7(c)(1,2,3)

[4] Ibid. 6.18.6(h)(1,2,3)

[5] National Electricity (South Australia) Act 1996, Section 28D

[6] National Electricity Rules as In Force in the Northern Territory Version 96 Section 6.18.8(a)(3)

[7] AER, Forecasting Best Practice Guidelines, 2020, Section 1.1

Scope and Approach

PWC engaged Energeia to develop fit-for-purpose grid energy consumption forecasts that are accurate and accepted by the AER to be factored into its:

- network prices contained in its Tariff Structure Statement (TSS);
- population of the Reset Regulatory Information Notice (RIN); and
- ongoing business activities, including revenue forecasts and as an independent cross-check for the chargeable quantities forecast produced by the pricing team.[8]

The forecasts were to provide a P50 outlook to the 2031-32 financial year, from the most recent year of historical response data i.e., the 2020-21 financial year.

Energeia worked closely with PWC to develop the following approach for this project:

1. **Document Requirements** – Energeia reviewed the regulatory framework, recent regulatory determinations and engaged with stakeholders to define the key forecasting requirements.
2. **Develop Methodology** – Based on the outcomes from step 1, Energeia developed a best practice, fit-for-purpose procedure for producing energy forecasts.
3. **Gather Inputs** – Energeia gathered the most recent inputs from PWC, as well as a variety of external inputs from reputable sources, for use in the forecasting methodology.
4. **Forecast Energy** – Energeia produced forecasts to 2031-32 of energy, for PWC's regulated networks.
5. **Model Validation** – Energeia worked closely with PWC subject matter experts (SMEs) to validate the methodology, inputs, and outputs of the energy forecasting model.
6. **Documentation** – Energeia documented the process, methodology, key inputs and assumptions used to produce the energy forecasts in presentation materials and this report.

Energeia notes that the above methodology reflected the AER's Guidelines, and the resulting forecasts should therefore be considered reasonable and accepted by the AER as required by the NT NER.

Methodology

Energeia undertook the following key steps in the development of its forecast:

1. **Develop Energy Forecasting Procedure** – Energeia first developed a fit-for-purpose energy forecasting procedure that satisfied PWC's key requirements and reflected industry best practice.
2. **Data Gathering and Processing** – This step included sourcing and processing the key regression drivers, load profiles, historical spot loads and weather normalisation data inputs.
3. **Forecast Model Optimisation** – In this step, Energeia identified the optimal model parameters given fitness[9], sign and p-value, split the NT total forecast into regional networks, then post-processed spot and electric vehicle (EV) charging loads to complete the forecasts.
4. **Validate Optimised Results** – Energeia reviewed the technically-optimised forecasts against historical trends and validated them with published forecasts[10] and PWC stakeholders prior to finalising them.

A detailed discussion of the above steps and key inputs is presented in Section 3.

---

[8] See Section 1

[9] Fitness is defined as the model's 'R-squared' value, also known as its explanatory power.

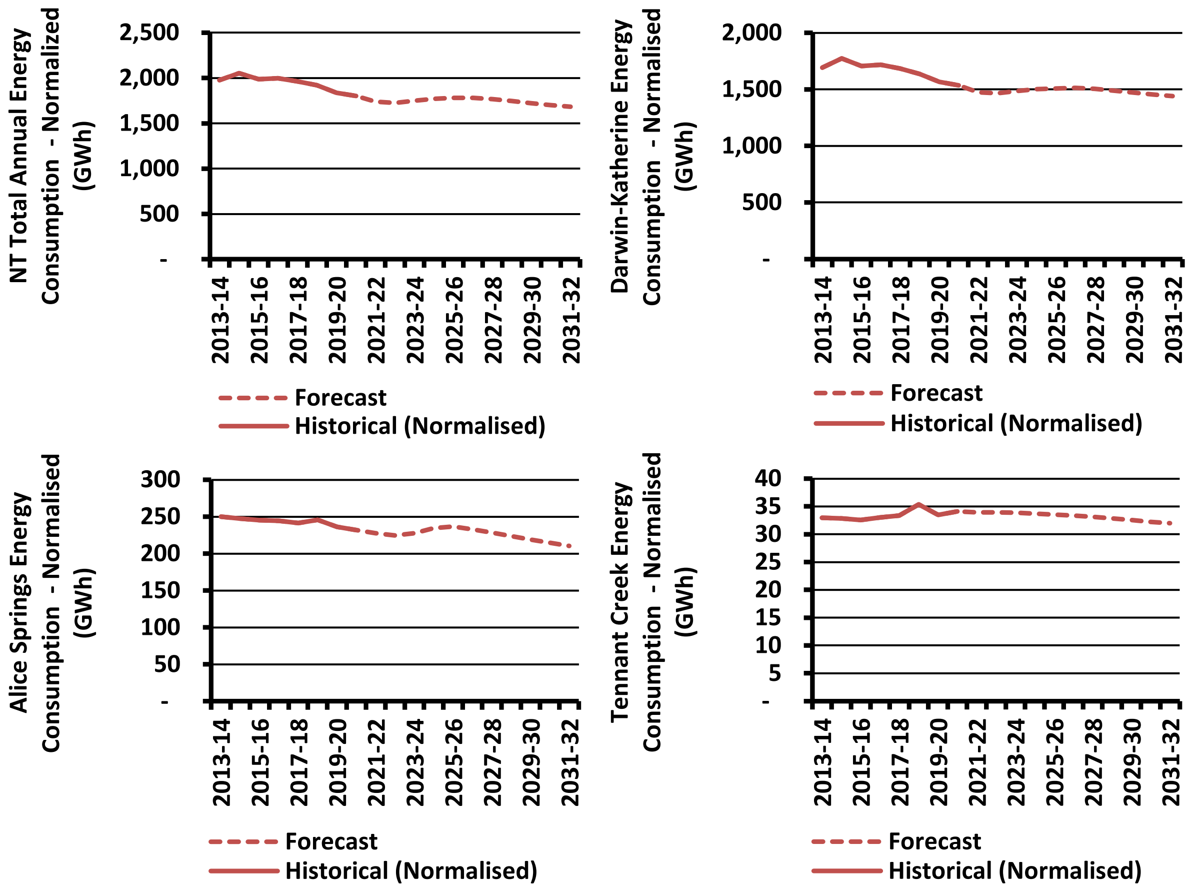
[10] AEMO for NT Utilities Commission, 2022, Northern Territory Electricity Outlook Report Data

Results

The resulting energy forecasts for the PWC's system as a whole and by regional network are given in Figure ES1. Key results include:

- Total system energy consumption is forecast to fall slightly in initial years, then begin to increase – peaking in 2026-27 – before falling again in later years.
- The underlying energy forecast falls due to the predicted increase in solar PV uptake (a key regression driver), but after the inclusion of spot loads and EVs, the forecast energy consumption initially rises – primarily due to strong growth in spot load-related energy consumption.
- Darwin-Katherine Interconnected System (DKIS), as the biggest electricity system, predominately drives the prevailing NT total trend. Energy consumption in Alice Springs also rises and falls due to the Pine Gap spot load addition in 2024-25, contributing to the NT total trend. Tennant Creek grid consumption is forecast to fall steadily over the forecast period.

Figure ES1 – Historical (Normalised) and Forecast Energy Consumption, NT Total and by Regional Network



Source: Energeia Analysis, PWC

Further detail regarding the above forecasts, can be found in Section 4.

Table of Contents

Table of Figures

Table of Tables

Disclaimer

While all due care has been taken in the preparation of this report, in reaching its conclusions Energeia has relied upon information and guidance from Power and Water Corporation, and other publicly available information. To the extent these reliances have been made, Energeia does not guarantee nor warrant the accuracy of this report. Furthermore, neither Energeia nor its Directors or employees will accept liability for any losses related to this report arising from these reliances. While this report may be made available to the public, no third party, with the exception of the Australian Energy Regulator, should use or rely on the report for any purpose.

For further information, please contact:

Energeia Pty Ltd

Level 1, 1 Sussex St
Barangaroo NSW 2000

T: +61 (0)2 8097 0070
E: info@energeia.com.au W: www.energeia.com.au

1. Background

Power and Water Corporation (PWC) primarily uses energy consumption forecasts to develop National Electricity Rules as in force in the Northern Territory (NT NER) compliant network tariffs, develop revenue forecasts for business purposes, as well as fulfil any additional regulatory reporting requirements to its shareholders and both local and federal regulatory bodies.

PWC is obligated under the NT NER to design tariffs to be included in its Tariff Structure Statement (TSS) that allow for the recovery of its approved[11] revenues, and comply with all requirements, including side-constraints[12]. Accurate tariffs minimise the impacts on annual revenues through the over and under process[13] and ensure customer impacts are accurately predicted and managed.[14] The National Electricity Law (NEL) requires PWC to provide energy forecasts in response to the Australian Energy Regulator's (AER's) Regulatory Information Notices (RINs).[15] PWC faces challenges which are unique amongst Distribution Network Service Providers (DNSPs).

- PWC operates three standalone grids; Darwin-Katherine Interconnected System (DKIS), Tennant Creek, and Alice Springs.
- PWC's networks are geographically diverse, resulting in significant variation in climate between northern and southern networks.
- The Northern Territory has a small population, resulting in PWC's networks servicing low customer numbers over a large area.
- Electricity pricing is additionally regulated under the Electricity Pricing Order[16] set by the Northern Territory Government, which prevents price signals passed through to almost all customers.

1.1. Key Regulatory Requirements

The key regulatory requirements that govern PWC's energy forecasts include the design of network tariffs, the AER's acceptance of the pricing proposal, and the provision of information in response to a Regulatory Information Notice (RIN), which are summarised in the following sections.

1.1.1. Tariff Class Revenue Recovery

Section 6.18.5 of the NT NER requires that all tariff classes recover revenue that lies between forecast standalone and avoidable cost[11]:

> *(e) For each tariff class, the revenue expected to be recovered must lie on or between:*
>
> > *(1) an upper bound representing the stand alone cost of serving the retail customers who belong to that class; and*
> >
> > *(2) a lower bound representing the avoidable cost of not serving those*

Energy consumption forecasts are a key driver of expected tariff class revenues.

1.1.2. Recover Allowed Revenues

Section 6.18.5 of the NT NER also require that tariffs recover the expected revenue for the relevant services[17]:

---

[11] National Electricity Rules as In Force in the Northern Territory Version 96 Sections 6.18.5(e)(1,2) and 6.18.5(g)(1,2)

[12] Ibid. 6.18.6(b)

[13] Ibid. 6.18.7(b), 6.18.7(c)(1,2,3)

[14] Ibid. 6.18.6(h)(1,2,3)

[15] National Electricity (South Australia) Act 1996, Section 28D

[16] Electricity Reform Act 2000 As in Force at 19 November 2021 Section 44.1

[17] National Electricity Rules As in force in the Northern Territory Version 96 Section 6.18.5(g)(1,2),

(g) The revenue expected to be recovered from each tariff must:

> *(1) reflect the Distribution Network Service Provider's total efficient costs of serving the retail customers that are assigned to that tariff;*
>
> *(2) when summed with the revenue expected to be received from all other tariffs, permit the Distribution Network Service Provider to recover the expected revenue for the relevant services in accordance with the applicable distribution determination for the Distribution Network Service Provider;*

Energy consumption forecasts are again a key driver of expected tariff revenues referenced by this rule.

1.1.3. Manage Customer Impacts

Section 6.18.5 of the NT NER requires consideration of customer impacts from tariffs[18]:

(h) A Distribution Network Service Provider must consider the impact on retail customers of changes in tariffs from the previous regulatory year and may vary tariffs from those that comply with paragraphs (e) to (g) to the extent the Distribution Network Service Provider considers reasonably necessary having regard to:

> *(1) the desirability for tariffs to comply with the pricing principles referred to in paragraphs (f) and (g), albeit after a reasonable period of transition (which may extend over more than one regulatory control period);*
>
> *(2) the extent to which retail customers can choose the tariff to which they are assigned; and*
>
> *(3) the extent to which retail customers are able to mitigate the impact of changes in tariffs through their decisions about usage of services.*

Accurate foundational inputs, including energy forecasts, ensures customer bill impacts from tariffs can be accurately predicted and therefore confidently managed.

1.1.4. Minimise Over and Under Recovery Impacts

The NT NER Section 6.18.7 further outlines the pricing principles of recovering revenue. The regulation requires that networks aim to accurately meet the actual revenue received to the target[19]:

(b) The amount to be passed on to retail customers for a particular regulatory year must not exceed the estimated amount of the designated pricing proposal charges adjusted for over or under recovery

(c) The over and under recovery amount must be calculated in a way that:

> *(1) subject to subparagraphs (2) and (3) below, is consistent with the method determined by the AER in the relevant distribution determination for the Distribution Network Service Provider;*
>
> *(2) ensures a Distribution Network Service Provider is able to recover from retail customers no more and no less than the designated pricing proposal charges it incurs; and*
>
> *(3) adjusts for an appropriate cost of capital that is consistent with the allowed rate of return used in the relevant distribution determination for the relevant regulatory year.*

Accurate energy forecasts are required to collect the correct revenue in each year. This meets the aims of the NT NER by minimising the impacts on annual revenues recovered through the over and under recovery process.

---

[18] Ibid. 6.18.5(h)(1,2,3)

[19] Ibid. 6.18.7(b), 6.18.7(c)(1,2,3)

1.1.5. Comply with Side Constraints

Section 6.18.6 of the NT NER require that the expected weighted average revenue to be raised from a tariff class for a given year not breach specified side constraints[20]:

> *(b) The expected weighted average revenue to be raised from a tariff class for a particular regulatory year of a regulatory control period must not exceed the corresponding expected weighted average revenue for the preceding regulatory year in that regulatory control period by more than the permissible percentage.*

Energy consumption forecasts are again a key driver of expected year-on-year tariff revenues referenced by this rule.

1.1.6. Be Reasonable

The NT NER requires the AER to accept forecasts in a pricing proposal that are reasonable[21]. A reasonable forecast will reflect the key principles set out in the NT NER and the AER Best Practice Forecasting Guidelines[22], which state:

- Forecasts should be as accurate as possible, based on comprehensive information and prepared in an unbiased fashion.
- The basic inputs, assumptions and methodology that underpin forecasts should be disclosed.
- Stakeholders should have as much opportunity to engage as is practicable.

Energy consumption forecasts that reflect the AER's Guidelines should therefore be considered reasonable and accepted by the AER as required by the NT NER.

1.2. Reset RIN

The AER collects information from DNSPs through Regulatory Information Notices (RINs) during regulatory determinations and for performance reporting. Section 28D of the NEL[23] states:

> *A regulatory information notice is a notice prepared and served by the AER in accordance with this Division that requires the regulated network service provider, or a related provider, named in the notice to do either or both of the following:*
>
> > *(a) provide to the AER the information specified in the notice;*
> >
> > *(b) prepare, maintain or keep information specified in the notice in a manner and form specified in the notice.*

Section 3.4.1 of the Reset RIN requires the provision of energy delivery and embedded energy consumption forecasts over the regulatory period.

[20] National Electricity Rules as In Force in the Northern Territory Version 96 Section 6.18.6(b)

[21] Ibid. 6.18.8(a)(3)

[22] AER, Forecasting Best Practice Guidelines, 2020, Section 1.1

[23] National Electricity (South Australia) Act 1996, Section 28D

1.3. *Business Requirements*

Energeia worked with PWC to identify the key business requirements for a range of forecasts, including the energy forecasts. Table 1 shows the forecasts needed by business function and highlights that energy (expressed as Sales (MWhs)) are one of the key forecasts that underpin PWC's finance and pricing functions.

Table 1 – PWC Business Requirements by Forecast Type

Function	New Conns	Total Conns	Spatial Max Demand	Spatial Min Demand	System Max Demand	System Min Demand	Sales (MWhs)	Solar PV	Batteries	EV Charging Impacts
Regulation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pricing	✓	✓	✓	✓	✓	✓	✓			
Finance	✓	✓			✓	✓	✓			
Network Planning	✓	✓	✓	✓				✓	✓	✓
Metering	✓							✓	✓	
Demand Management	✓	✓	✓	✓				✓	✓	✓
Supply Chain	✓	✓	✓	✓				✓	✓	✓
System Planning	✓	✓			✓	✓		✓	✓	✓

Source: Energeia, PWC
Note: Purple indicates the energy forecast covered in this report

Specifically, PWC required energy forecasts to be fit-for-purpose, compliant, unbiased, P50[24], evidence-based, accurate, and relatable to the tariff components. PWC also plans to use these energy forecasts as an independent cross-check for the chargeable quantities forecast produced by the pricing team.

1.4. *Key Trends and Issues*

Energy consumption across PWC's three regulated networks is being increasingly impacted by a number of key factors, which have an effect on both current and future energy consumption trends, including:

- **Behind-the-Meter Solar PV –** Rooftop PV installations have grown significantly and will continue to grow in future[25]. This is contributing to a significant decrease in energy consumption during daylight hours, and the emergence of grid exports.
- **Building and Transport Electrification –** Transport and building electrification is being driven by climate policy (e.g. 50% renewables by 2030[26]), investor benefits, health and safety benefits, risk reduction, and consumer preferences[27]. They are causing vehicles, as well as industrial and household appliances to shift from fossil fuels to electrified power sources and adding major new load types to the grid.

[24] Probability of exceedances outline the percentage likelihood that demand will exceed the forecast due to temperature variances. See Appendix C – Weather Normalisation

[25] AEMO, 2022 Integrated System Plan Inputs and Assumptions, 2021

[26] NT Government, Territory Renewable Energy, 2022, from: https://territoryrenewableenergy.nt.gov.au/

[27] Green Building Council Australia, A Practical Guide to Electrification: For New Buildings, 2022

- **COVID-19 Pandemic** – The global pandemic has impacted international and domestic economies and societal behaviours significantly[28], specifically electricity consumption[29]. Uncertainty remains surrounding how long behavioural shifts will last, and the extent to which energy consumption will return to pre-pandemic dynamics. This adds an additional challenge to long-term energy forecasting.
- **New Connections** – The impacts of new connections on energy consumption are evolving for both large and small connections. Large connections (i.e., spot loads) and their load factors have changed over time and could continue to change in future[30]. Additionally, energy efficiency regulations are reducing consumption per connection (particularly residential and commercial loads).

A reasonable forecast therefore needs to consider the above evolving energy consumption drivers by explicitly including solar PV, electric vehicle (EV) charging,COVID-19, and connections as key inputs, as well as addressing the additional difficulties in developing a forecast which accounts for the variable trends and conditions occurring on the three regulated grids of PWC.

[28] ABS, Effects of COVID-19 strains on Australian Economy, 2022

[29] AER, State of The Energy Market 2021

[30] See Section 3.4.2

2. Scope and Approach

PWC engaged Energeia to develop fit-for-purpose energy consumption forecasts that are accurate and accepted by the AER to be factored into its:

- network prices contained in its Tariff Structure Statement (TSS);
- population of the Reset RIN; and
- ongoing business activities, including revenue forecasts and as an independent cross-check for the chargeable quantities forecast produced by the pricing team[31].

The forecasts were to provide a P50 outlook to the 2031-32 financial year, from the most recent year of historical response data i.e., the 2020-21 financial year.

Energeia worked closely with PWC to develop the following scope and approach for this report:

1. **Document Requirements** – Energeia reviewed the regulatory framework, recent regulatory determinations and engaged with stakeholders to define the key forecasting requirements.
2. **Develop Methodology** – Based on the outcomes from step 1, Energeia developed a best practice, fit-for-purpose procedure for producing energy forecasts.
3. **Gather Inputs** – Energeia gathered the most recent inputs from PWC, as well as a variety of external inputs from reputable sources, for use in the forecasting methodology.
4. **Forecast Energy** – Energeia produced forecasts to 2031-32 of energy, for PWC's regulated networks.
5. **Model Validation** – Energeia worked closely with PWC subject matter experts (SMEs) to validate the methodology, inputs, and outputs of the energy forecasting model.
6. **Documentation** – Energeia documented the process, methodology, key inputs and assumptions used to produce the energy forecasts in presentation materials and this report.

Energeia notes that the above methodology reflects the AER's Guidelines, and the resulting forecasts should therefore be considered reasonable and accepted by the AER as required by the NT NER.

[31] See Section 1

3. Methodology

This section describes the forecasting methodology Energeia used to develop PWC's energy forecasts at the system regional level, which can be summarised into the following key stages:

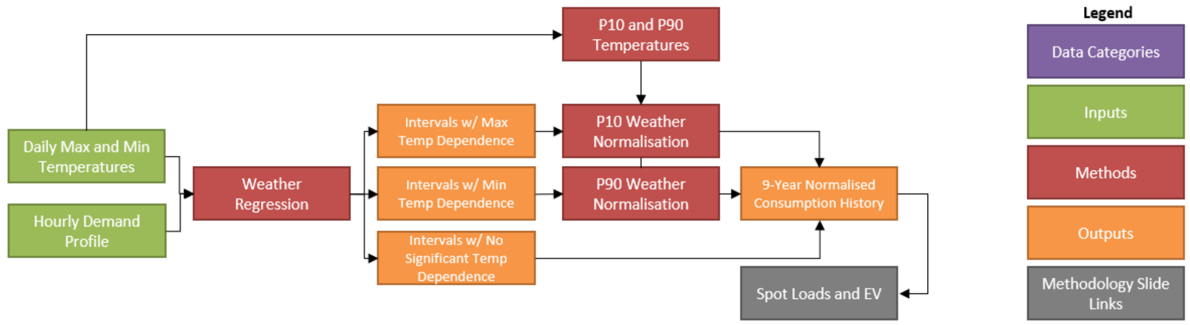
1. **Develop Demand Forecasting Procedure** – Energeia first developed a fit-for-purpose energy forecasting procedure that satisfied PWC's key requirements and reflected industry best practice.
2. **Data Gathering and Processing** – This step included sourcing the key regression drivers, processing load profiles provided by PWC for outages, historical spot loads and weather normalisation.
3. **Forecast Model Optimisation** – In this step, Energeia identified the optimal model parameters given fitness[32], sign and p-value, split the NT total forecast into regional network forecasts, and then post-processed spot and EV loads to complete the forecasts.
4. **Validate Optimised Results** – Energeia reviewed the technically optimised forecasts against historical trends and validated them with published forecasts[33] and PWC stakeholders prior to finalising them.

Each stage of the methodology is further explained in the following sections.

3.1. Develop Energy Forecasting Procedure

The energy forecasting procedure developed for PWC has been designed to address PWC's key requirements and to reflect industry best practice given the data available. Figure 1 shows the weather normalisation procedure used to process the historic system loads.

Figure 1 – Weather Normalisation Methodology Overview



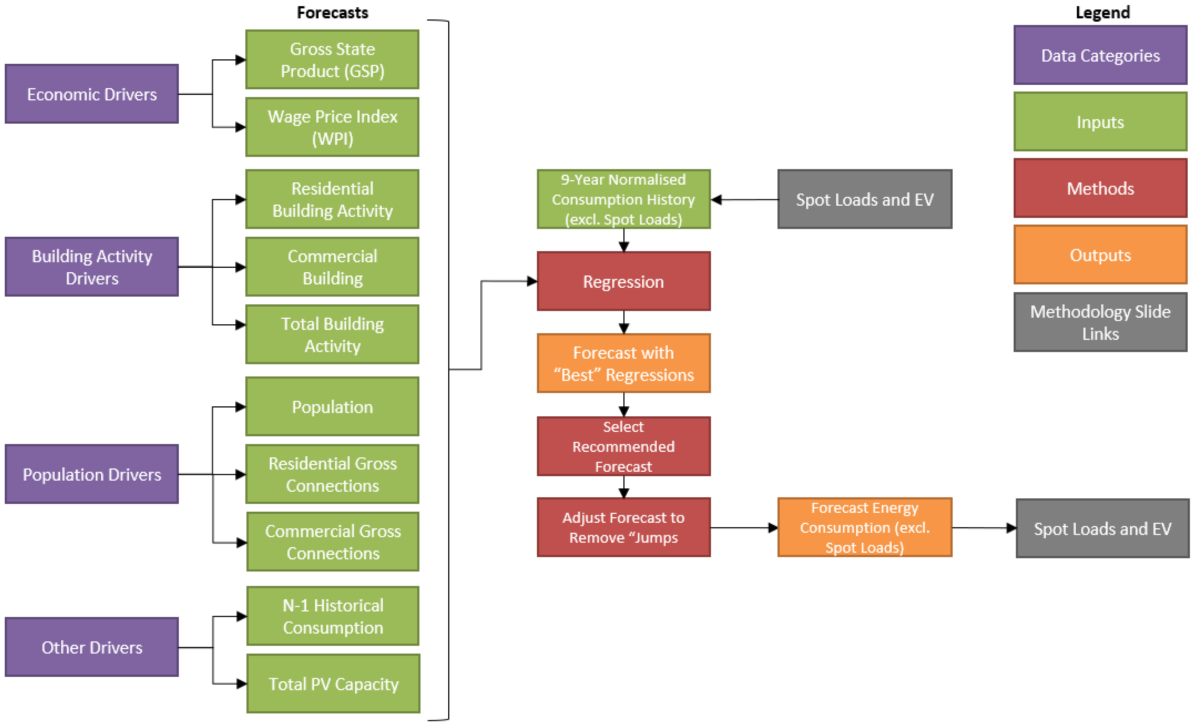
Source: Energeia

Figure 2 shows the core regression procedure used to forecast annual system energy consumption.

[32] Fitness is defined as the model's 'R-squared' value, also known as its explanatory power.

[33] AEMO for NT Utilities Commission, 2022, Northern Territory Electricity Outlook Report Data

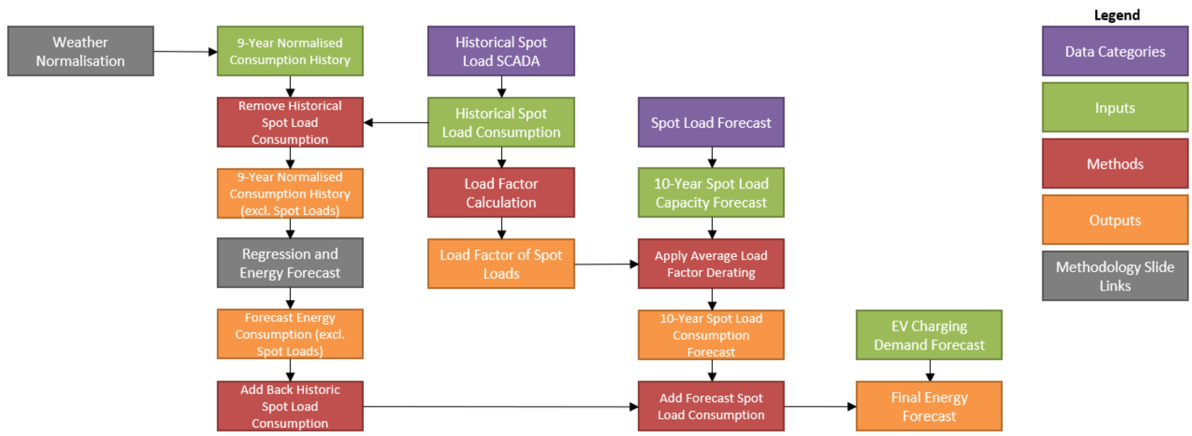
Figure 2 – Regression Methodology Overview



Source: Energeia

Figure 3 outlines the spot load and EV procedure, used to adjust the generated system energy forecasts to account for probable future consumption not considered in the regression analysis.

Figure 3 – Spot Loads and EV Methodology Overview



Source: Energeia

This procedure, and in particular the key methods, are further explained below.

3.2. Data Gathering and Processing

Processing of PWC's system level historical consumption history undertaken in this step included outage correction, treatment of spot loads and weather normalisation. Table 2 details the key data sources used in the implemented minimum and maximum demand forecasting methodology.

Table 2 – Data Sources

Data Type	Data Description	Start/End Date	Contact Provided
Historical Temperature	Daily Max and Min temperature by network	July 2014 – June 2021	Goutham Maddirala
Historical Half-Hourly Network Demand	Half-hourly demand trace by network	July 2014 – June 2021	Santos Sukumaran
Outage Records	Date and time of generator and network outages	January 2015 – May 2021	Santos Sukumaran
Historical Spot Loads	Half-hourly meter data for major historical spot loads	April 2013 – October 2021	Santos Sukumaran
Spot Load Forecast	Annual spot load additions by regional network	2023 – 2032	Santos Sukumaran

Source: Energeia, PWC

3.2.1. Outage Correction

Energeia firstly corrected the historical data for outages in the historical interval data provided by PWC, to minimise the distortion of historical energy consumption due to recording errors or system limitations.

Appendix B – Outage Correction covers the method used for interpolating outage impacted data.

3.2.2. Spot Load Correction

Spot loads are typically treated separately from the rest of the energy forecast by DNSPs, due to differences in the level of specific knowledge regarding their future timing and impact compared to other growth-related factors.

Energeia removed changes in spot loads from historical (outage corrected) interval data using data supplied by PWC. The resulting historical load time series was then carried forward into the weather normalisation step.

3.2.3. Weather Normalisation

Energeia weather normalised historical half hourly network load data in order to produce three probabilities of exceedance (POE or P): P10, P50 and P90 which indicate the extent of temperature extremities. Load interval data, grouped by hour, month, and day type (weekday or weekend), were regressed against temperatures to estimate their relationship. If statistically significant, the resulting regression was used to remove the weather sensitive load based on the actual daily temperature, and to replace it using the temperate at the given probability, e.g. the 10th percentile for P10.

For the final energy forecasts, the P50 weather normalised energy was used consistent with industry practice.

The process Energeia used to weather normalise half hourly demand over the year is described in detail in Appendix C – Weather Normalisation.

3.2.4. Source Potential Regression Drivers

Energeia gathered potential regression factors from a list that filtered out drivers that were not suitable. Suitable drivers needed to have adequate history and a forecast produced by a reputable source to develop a defensible, robust statistical relationship.

Resulting Inputs

Table 3 summarises the candidate energy forecast drivers considered, including their source, how they are forecasted, and the years of history and forecast available.

Table 3 – Summary of Potential Energy Consumption Drivers

Driver	Source	Forecasting Summary	Years of History	Years of Forecast
N-1 Energy Consumption	PWC Interval Data + Energeia Energy Forecast Model	Using best performing regression with population/economic variables	N/A	N/A
Population (#)	Australian Bureau of Statistics (ABS) (undated) https://dbr.abs.gov.au/ (historical) NT Treasury (2019) https://treasury.nt.gov.au/dtf/economic-group/population-projections (forecast)	Applying population growth rates based on NT Treasury projections	40+	25
Cumulative Residential Building Activity ($)	Australian Construction Industry Forum (ACIF) (2019) https://www.acif.com.au/documents/item/869	Applying growth rates based on ACIF NT building activity forecasts to 2028, with trend to 2030	40+	7
Cumulative Commercial Building Activity ($)	ACIF (2019) https://www.acif.com.au/documents/item/869	Applying growth rates based on ACIF NT building activity forecasts to 2028, with trend to 2030	40+	7
Total Cumulative Building Activity ($)	ACIF (2019) https://www.acif.com.au/documents/item/869	Sum of residential and commercial	40+	7
Gross State Product ($)	RDA Northern Territory (2020) https://economy.id.com.au/rda-northern-territory/gross-product?WebID=150 (historical) BIS Oxford Economics (2020) https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2020/bis-oxford-economics-macroeconomic-projections.pdf?la=en (forecast)	Applying annual GSP growth rate forecasts projected by BISOE	30+	30
Wage Price Index	ABS, Department of Treasury and Finance (undated) https://e.infogram.com/f136daf4-d710-4c22-b722-22e650873e02?src=embed	Using source for historic and forecast to 2025, applying a trend to 2030	10	4
Total Gross Residential Connections	PWC RIN responses: https://www.aer.gov.au/networks-pipelines/performance-reporting/power-and-water-corporation-rin-responses + Energeia Connections Forecast Model	Using best performing regression using population/economic variables	4	10
Total Gross Commercial Connections	PWC RIN responses: https://www.aer.gov.au/networks-pipelines/performance-reporting/power-and-water-corporation-rin-responses + Energeia Connections Forecast Model	Using best performing regression using population/economic variables	4	10
Total PV Capacity	AEMO Behind the Meter PV Data + PWC RIN: https://www.aer.gov.au/networks-pipelines/performance-reporting/power-and-water-corporation-rin-responses + Energeia PV Uptake Model	Using a regression of return-on-investment against actual PV uptake	9	10

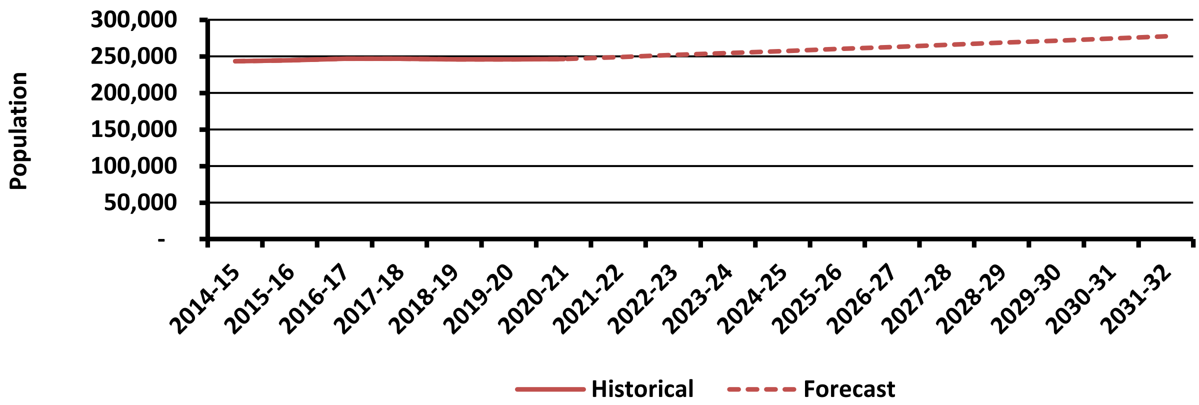
Source: Energeia

Population

Population growth tends to have a strong relationship with electricity consumption, particularly residential loads.

Figure 4 displays the historical and forecast total population for the NT. Population rose steadily in the past, peaking in 2017-18 and plateauing since. In contrast, the NT Government is predicting strong future population growth in their forecasts.

Figure 4 – NT Historical and Forecast Total Population



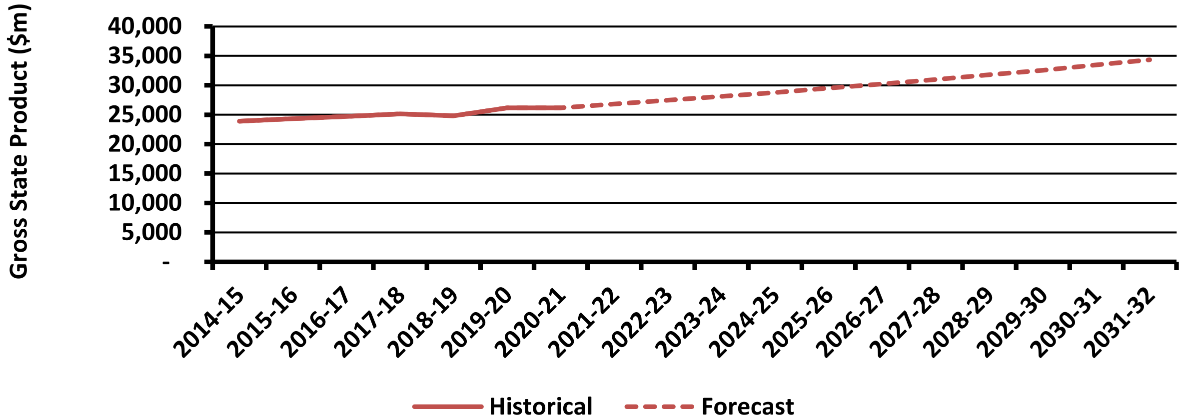
Source: Energeia Analysis, Northern Territory Government (2019)

Gross State Product

GSP reflects growth in business activity, which is also correlated with an increase in commercial customer electricity consumption.

Figure 5 displays the historical and forecast GSP for the NT. Historical GSP has risen steadily, though it has plateaued during the recent COVID pandemic. BIS Oxford Economics' (BISOE) forecast predicts a continuation of this trend.

Figure 5 – NT Historical and Forecast Gross State Product



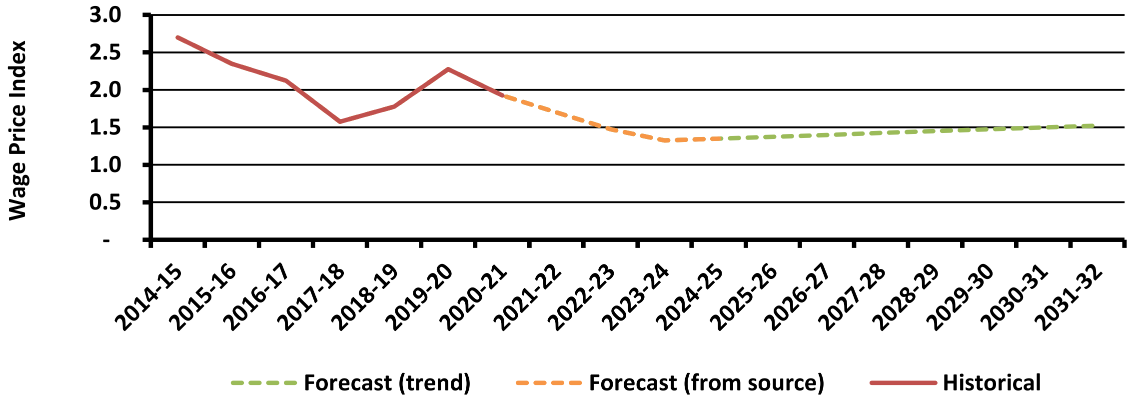
Source: ABS (2021), BIS Oxford Economics (2020)

Wage Price Index

The Wage Price Index (WPI) indicates consumer buying power and can drive shifts in energy usage due to increased investment in technology including solar PV, batteries and/or EVs.

Figure 6 displays historical and forecast WPI for the NT. WPI fell historically, reaching a low point in 2017-18. It then rose to a peak in 2019-20 but fell again after during the beginning of the COVID pandemic. The forecast from the ABS predicts this recent fall to continue until 2024-25, before recovering. Energeia has trended this rise to continue out to 2031-32, due to the lack of a publicly available forecast.

Figure 6 – NT Historical and Forecast Wage Price Index



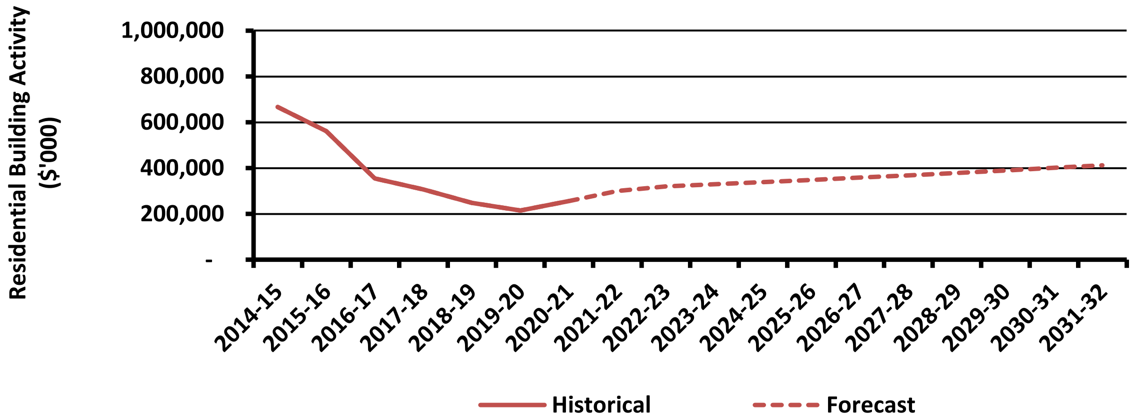
Source: ABS (2021), Energeia Analysis

Building Activity

Figure 7 and Figure 8 display historical and forecast building activity, segmented by residential and commercial building activity, respectively.

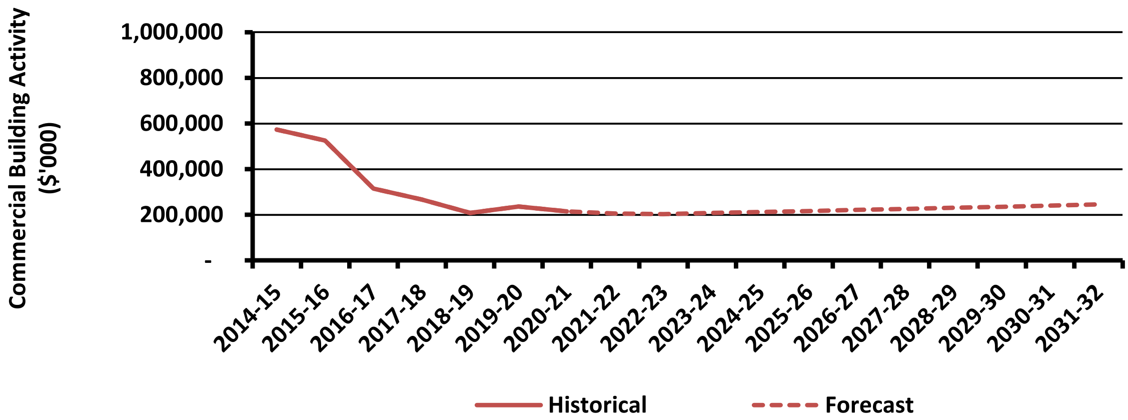
Both historical residential and commercial building activity peaked at the start of the period and fell thereafter, plateauing in recent years, with residential building activity rising again. The Australian Construction Industry Forum (ACIF) forecast predicts steady growth in residential building activity, with some continued plateauing, and slight growth in commercial building activity.

Figure 7 – NT Historical and Forecast Residential Building Activity



Source: ACIF (2019), Energeia Analysis

Figure 8 – NT Historical and Forecast Commercial Building Activity



Source: ACIF (2019), Energeia Analysis

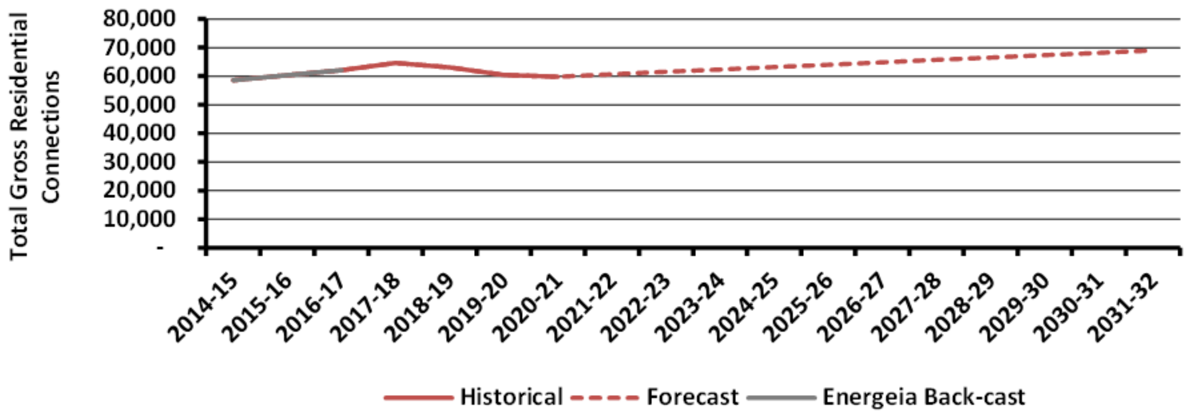
Connections

Growth in residential and commercials connections directly increases energy consumption.

Figure 9 and Figure 10 display the back-cast, historical and forecast gross connections, segmented by residential and commercial building activity, respectively. Residential gross connections rose and then fell historically and are forecasted to grow steadily. Commercial gross connections fell and plateaued historically and are also forecasted to rise steadily.

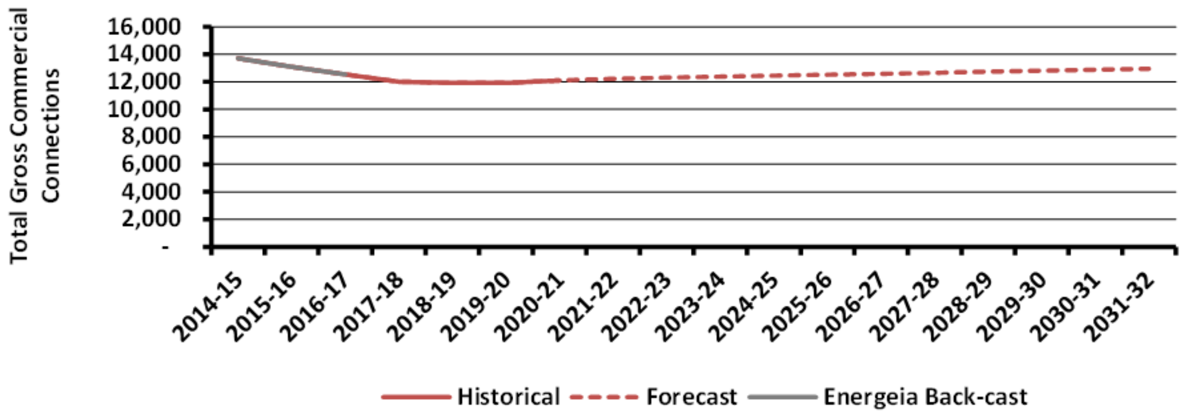
Energeia produced the reporting below as part of the RIN connection forecasting workstream for PWC – which is described in its own detailed report. The back-cast history was used to extend the limited data history (only 4 years of historical actuals) and was based on the historical relationship between gross connections and customer connections.

Figure 9 – NT Back-Cast, Historical and Forecast Total Gross Residential Connections



Source: PWC Category Analysis RIN Response, Energeia Analysis

Figure 10 – NT Back-Cast, Historical and Forecast Total Gross Commercial Connections



Source: PWC Category Analysis RIN Response, Energeia Analysis

Solar PV

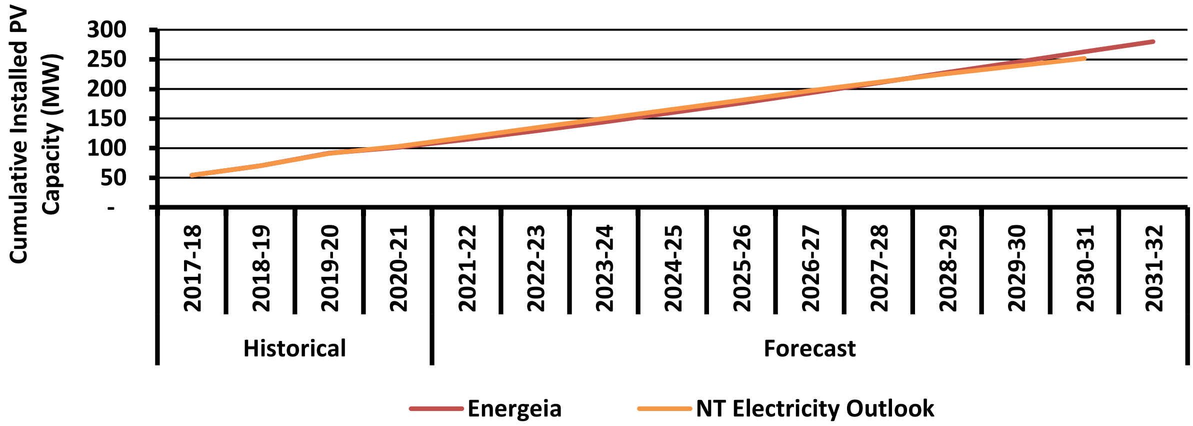
Rooftop solar PV is expected to be the key driver of energy consumption reductions, as it can significantly reduce loads during the daytime.

Energeia used its solar PV uptake model to forecast cumulative installed distribution connected solar PV capacity (MW) in the NT. The model uses an estimate of first-year return-on-investment[34] (ROI) as the primary driver in a regression-based forecast of customer uptake of solar PV.

[34] This is equivalent to a payback metric. For example, a 10% first year ROI is around a 10 year pay

Figure 11 displays a comparison of Energeia's forecast with that of the Utilities Commission. It shows that both forecasts were very similar but diverge very slightly in the early and late forecast years. This comparison provides evidence for the reasonableness of the solar PV uptake forecast used in our energy consumption forecast.

Figure 11 – Historical and Forecast Cumulative Installed Distributed PV Capacity by Source



Source: Energeia, NT Utilities Commission (2022)

3.3. Forecast Model Optimisation

The resulting outage, spot load, and weather-corrected energy consumption for each historical year was then used in a multi-factor regression model optimisation procedure to identify the optimal parameters and data history to reasonably and accurately forecast network energy consumption over the forecast period.

3.3.1. Regression Overview

All candidate regression drivers identified by desktop research were considered as potential independent variables into the multi-factor energy consumption forecasting models, as outlined in detail below. Each variable was assessed individually and in two and three-factor regressions to determine the associated regression statistics and to identify the most statistically significant regression equation with the correct signs and lowest p-values. External forecasts were used as inputs into the regression equations.

Both 5- and 9-year regressions were considered, to take the potential unique impacts of COVID pandemic into account, as well as other factors that have emerged only in the last five years including distribution solar PV generation. In addition to these regressions, simple linear trends (5- and 9-year) were also considered to cover instances where regression results were statistically insignificant or deemed unsuitable based on trend analysis and expertise.

3.3.2. Data History Length

The load profiles and historic spot load additions and subtractions provided had 9 years of complete history (Tennant Creek had 8 years of history from 2013-14 onward but was trended backward to complete the 9th year of history, 2012-13), and hence 9-year regressions and trends were produced to include these histories in their entirety. 5-year regressions and trends were also produced to provide a greater focus on the most recent years of historical data, whilst still maintaining a sufficient number of data points for a reasonable regression.

3.3.3. Number of Independent Variables (Drivers)

There were 10 total potential independent variables considered (see Table 3), with up to three variables per regression model. Energeia chose to test no more than three independent variables to avoid overfitting, based on our experience developing system minimum and maximum demand forecasts for other distribution and transmission network service providers.

3.3.4. Selection of Optimal Energy Forecast

Eight potential forecasts arose from the set of tested regressions and trends, which were as follows:

- 5-Year History, Single Variable Regression
- 5-Year History, Two Variable Regression
- 5-Year History, Three Variable Regression
- 5-Year History, Trended
- 9-Year History, Single Variable Regression
- 9-Year History, Two Variable Regression
- 9-Year History, Three Variable Regression
- 9-Year History, Trended.

Regression forecasts were preferred over trend forecasts. However, trends were used if all regression models were deemed insufficient, which occurred when:

- P-values were above >0.05, which is considered statistically insignificant
- R2 was too low (<0.8)
- Beta-coefficients were the wrong sign, e.g. negative for population or positive for solar PV
- Forecasts did not pass a sense check.

Where the forecast produced unreasonable results, which was validated with PWC stakeholders, it was not selected. An average of the last five years was considered as a last resort where trending was deemed unsuitable.

3.4. Post-Model Adjustments

Once the underlying regression forecasts were complete, post-model adjustments were made to complete the forecasts. These adjustments included splitting the NT total forecast by the regulated regional networks (DKIS, Alice Springs, and Tennant Creek), then adding forecast spot load and EV consumption.

3.4.1. Split NT Forecast by Regional Networks

The NT total energy consumption forecast was split based on trends in the historical consumption percentage breakdown by regional network. This split was done as PWC required the forecasts by regional network. The consumption percentage breakdown used is shown in Table 4.

Table 4 – NT System Consumption Percentage Breakdown by Regional Network

Year	DKIS	Alice Springs Grid	Tennant Creek Grid
2012-13	84.91%	13.44%	1.65%
2013-14	85.56%	12.75%	1.68%
2014-15	86.13%	12.25%	1.62%
2015-16	85.71%	12.62%	1.67%
2016-17	85.60%	12.68%	1.71%
2017-18	85.25%	12.96%	1.79%
2018-19	84.96%	13.15%	1.89%
2019-20	85.00%	13.14%	1.86%
2020-21	84.89%	13.17%	1.94%
2021-22	84.96%	13.09%	1.95%
2022-23	84.88%	13.13%	1.99%
2023-24	84.80%	13.16%	2.03%
2024-25	84.73%	13.20%	2.07%
2025-26	84.65%	13.24%	2.11%
2026-27	84.58%	13.28%	2.15%
2027-28	84.50%	13.31%	2.19%
2028-29	84.42%	13.35%	2.23%
2029-30	84.35%	13.39%	2.27%
2030-31	84.27%	13.42%	2.30%
2031-32	84.20%	13.46%	2.34%

Source: Energeia, PWC

3.4.2. Spot Load Additions

PWC provided a forecast of yearly additional spot load capacities added to each network by year, based on load requests by its customers. To determine how much consumption these spot loads were expected to add to the forecast, Energeia calculated the 'load factor' of historical spot loads, taken as the percentage of actual energy consumed over the maximum potential energy consumed if operating at rated capacity all year. Table 5 shows the historical load factors.

Table 5 – Historical Load Factors for Spot Loads

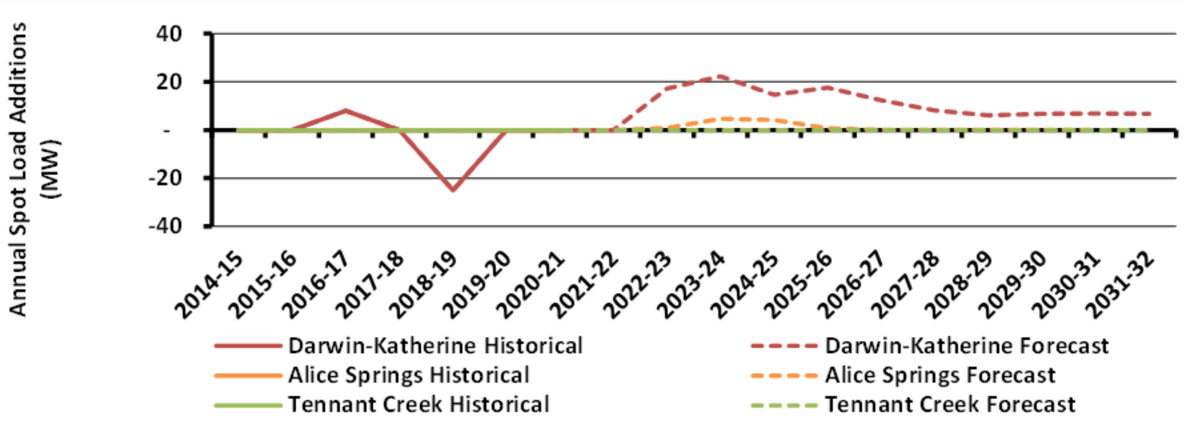
Year	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Load Factor	2%	9%	13%	17%	29%	20%	32%	31%

Source: Energeia, PWC

The selected load factor applied to the forecast spot loads was 30%, as it was the average of the most recent years of spot load history – excluding the 2017-18 outlier.

Figure 12 displays the historical and forecast annual spot load additions and removals from PWC-provided data. Some spot loads were connected in 2016-17 and some were disconnected in 2018-19 in DKIS. A large amount of spot load capacity was anticipated to be connecting annually in the near future, slowing down in later years. DKIS notably dominates in spot load additions.

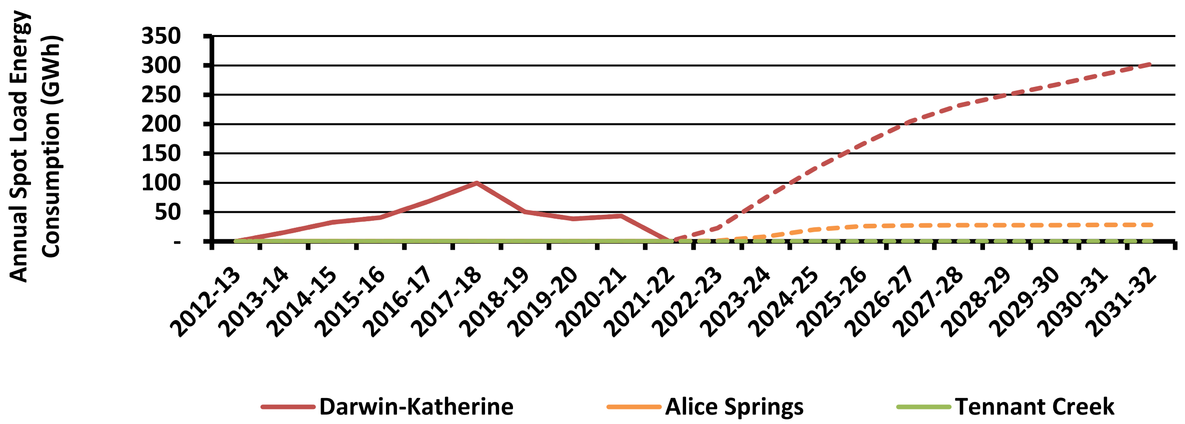
Figure 12 – NT Historical and Anticipated Annual Spot Load Additions, by Regional Network



Source: PWC

Figure 13 shows the historical and anticipated spot load energy consumption by region, after the inclusion of the 30% load factor. DKIS outweighs the other regions in spot load consumption. Tennant Creek has no historical or anticipated spot load consumption.

Figure 13 – NT Historical and Anticipated Spot Load Energy Consumption, by Regional Network



Source: PWC, Energeia Analysis

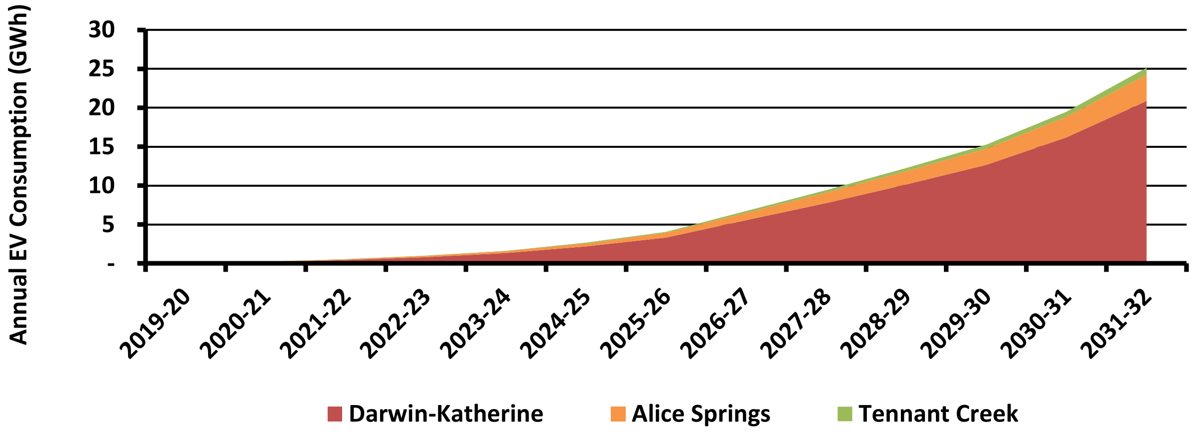
3.4.3. Electric Vehicles

Forecast EV charging consumption was added as a post modelling adjustment due to the lack of historical data on its impact on the NT system to drive the regression. As no EV forecasts for the NT are available in the public domain, these forecasts came from Energeia's 2020 EV uptake forecasts for the Department of Industry, Science, Energy and Resources[35].

Figure 14 shows historical and forecast annual EV charging consumption in the NT. Note that EV charging loads before 2019-20 were negligible. Energeia forecasts annual charging consumption to reach 25 GWh by 2031-32.

[35] PWC has commissioned Energeia to develop a new forecast in FY23

Figure 14 – NT Historical and Forecast Annual EV Charging Consumption



Source: Energeia

3.5. Consultation and Validation

Energeia engaged PWC stakeholders throughout the forecasting process to provide an opportunity for feedback on the validity of the recommended energy consumption forecasts. Additionally, solar PV uptake – as a key driver of energy reduction – was compared to the NT Outlook Report for the Utilities Commission. This comparison was shown in Section 3.2.4.

4. Forecasting Results

This section reports the results of Energeia's P50 weather normalised forecast of energy at the system and regional levels, including the impact of spot loads and EVs.

The final system level forecast produced from Energeia's best practice and fit-for-purpose regression methodology has the characteristics presented in Table 6.

Table 6 – Recommended Forecast Characteristics

Forecast	Years of History	Trend or Regression	One, Two, or Three Variable Regression	Regression Variable
NT Energy Consumption	5	Regression	One	PV Capacity

Source: Energeia

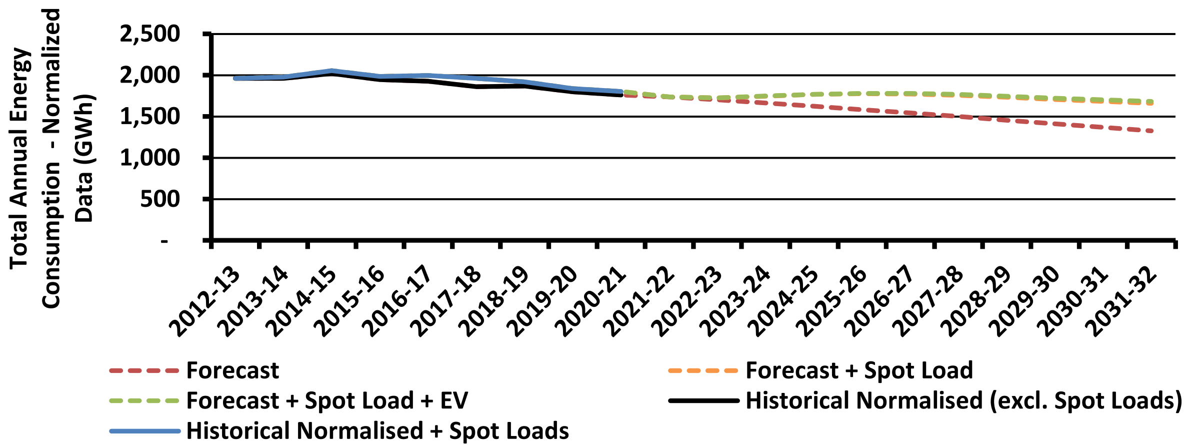
Additional detail surrounding candidate regression and trend forecast assessment is provided in Appendix A – Energy Regressions.

4.1. Energy Forecasts

4.1.1. System

Figure 15 displays the P50 energy forecast at PWC's system level and indicates how spot loads and EVs impacted trends. The final forecast is labelled 'Forecast + Spot Load + EV'.

Figure 15 – NT Total, Historical and Forecast P50 Energy Consumption, Spot Loads and EVs



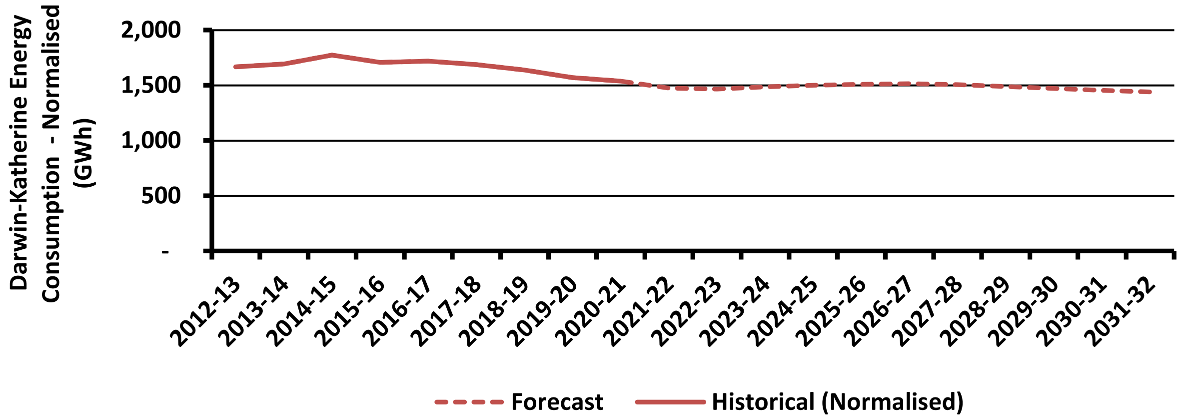
Source: Energeia Analysis

The forecast shows consumption falling slightly in the initial years, then increasing up to the peak in 2026-27, before falling again in the later years. The underlying forecast falls due to the increase in solar PV uptake reducing net load, but after the inclusion of spot loads and EVs, the forecast increases toward the middle forecast years primarily due to strong forecast growth in spot load energy consumption, before falling again in the later forecast years.

4.1.2. Darwin-Katherine Interconnected System (DKIS)

Figure 16 displays the final P50 energy forecast for DKIS.

Figure 16 – DKIS, Historical and Forecast P50 Energy Consumption



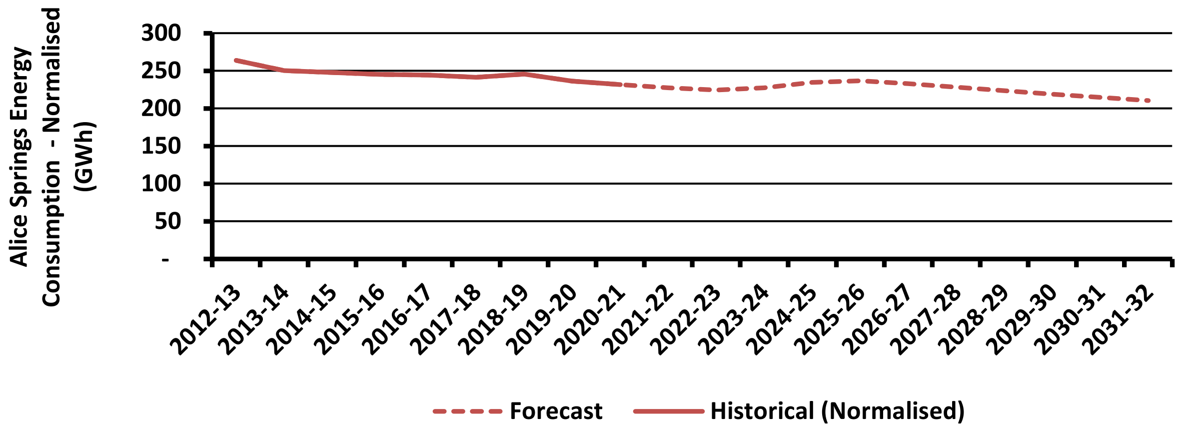
Source: Energeia Analysis

The forecast for DKIS largely mirrors the system level given it is the largest regional network and dominates the forecast. Similarly, the forecast falls for two years, rises to a peak in 2026-27, and then falls toward the end.

4.1.3. Alice Springs

Figure 17 displays the P50 energy forecast for Alice Springs.

Figure 17 – Alice Springs, Historical and Forecast P50 Energy Consumption



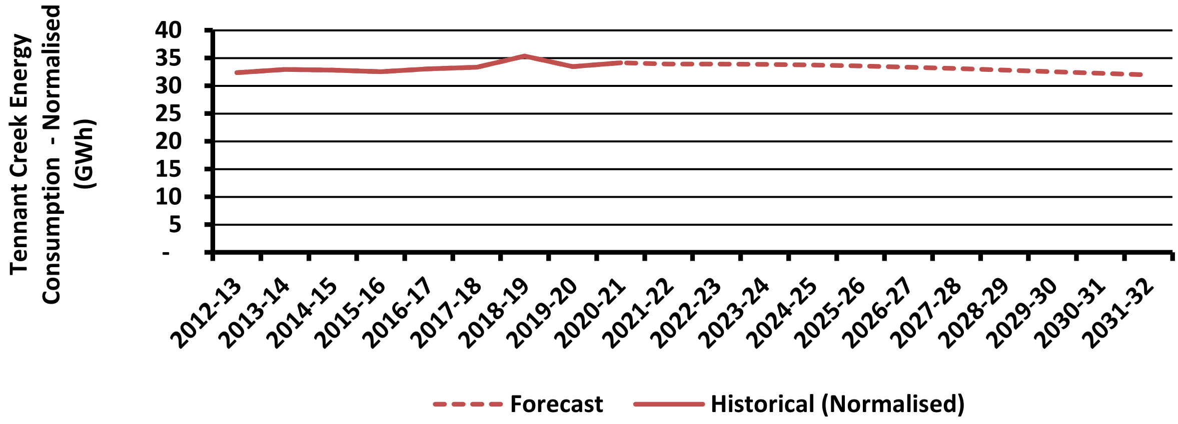
Source: Energeia Analysis

The Alice Springs forecast predicts a steady fall in energy consumption in line with historical consumption, then then a rise toward 2024-25, due largely to the Pine Gap spot load addition, before falling again steadily in the later forecast years.

4.1.4. Tennant Creek

Figure 18 displays the P50 energy forecast for Tennant Creek.

Figure 18 – Tennant Creek, Historical and Forecast P50 Energy Consumption



Source: Energeia Analysis

Tennant Creek energy consumption is predicted to decrease slowly over the forecast period. This contrasts with the slow rise in consumption historically, as forecast solar PV uptake begins to reduce consumption. Tennant Creek also has no anticipated spot load connections and too few forecast EVs to contribute to any significant increase in energy consumption.

Appendix A – Energy Regressions

This appendix provides additional detail regarding the regression/trend forecast candidates for the underlying energy forecast. It also shows their results, noting that results are before the addition of spot loads and EVs.

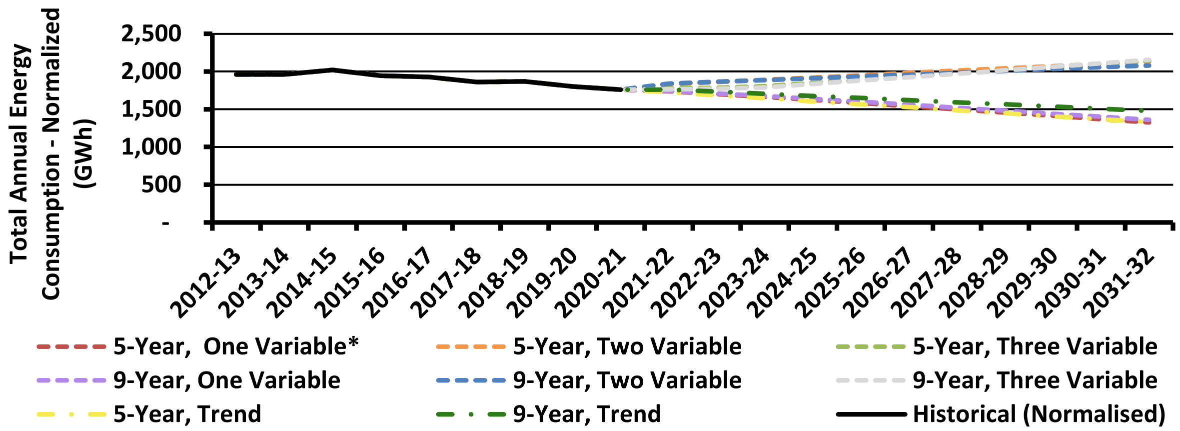
Table A1 provides a summary of the regression parameters for the 'best' (i.e., most statistically significant) regression for each regression type tested in the energy forecast model. Figure A1 shows these regression outcomes graphically, including the 5 and 9-year trends.

Table A1 – Best Regression Summary

	One Variable		Two Variables		Three Variables	
Parameter	**5 Year***	**9 Year**	**5 Year**	**9 Year**	**5 Year**	**9 Year**
Best R2	0.92	0.91	0.79	0.83	0.92	0.94
Variable 1	Cumulative Solar Capacity	Cumulative Solar Capacity	Commercial Gross Connections	Residential Gross Connection	Residential Gross Connection	Residential Gross Connection
Variable 2			Residential Gross Connection	Commercial Gross Connections	Commercial Gross Connections	Commercial Gross Connections
Variable 3					Wage Price Index	Wage Price Index
Slope 1	-2.48	-2.32	148.53	17.89	36.92	41.43
Slope 2			23.02	128.10	114.32	101.37
Slope 3					134,749	159,570
Intercept	2,020,572	2,008,441	-1,381,730	-813,337	-2,090,932	-2,261,116
R2	0.92	0.91	0.79	0.83	0.92	0.94
P1	0.01	0.0000592	0.21	0.07	0.42	0.01
P2			0.17	0.00	0.37	0.00
P3					0.24	0.03

Source: Energeia Analysis
* Indicates selected forecast

Figure A1 – NT Total, Historical and Forecast P50 Energy Consumption Forecast Range



Source: Energeia Analysis
* Indicates selected forecast.

The 5- and 9-year, single variable regression produce similarly statistically significant outcomes, with solar PV uptake as the key driver. The 5-year forecast was ultimately chosen as it better reflects more recent factors.

The 9-year, three variable regression was also statistically significant, but the forecast did not pass sense-checks and validation with PWC subject matter experts.

Appendix B – Outage Correction

This appendix covers the purpose, method, and outcome of Energeia's outage correction methodology.

Purpose

Energeia accounted for outages in the load profiles that occurred as a result of generation, transmission faults and meter data recording errors. This was important to ensure that the energy regressions were not distorted by outages driving changes in energy consumption. Outages occur at random and therefore should not be a factor in forecasting energy consumption in a network.

The data was provided by PWC, with a sample seen in Table B1.

Table B1 – Sample of Outage Record

Date	Power System	Time Off (HH:MM)	Time On (HH:MM)	Incident Duration (HH:MM)	Description	Indicative Cause	Year
03/01/2016	Alice Springs	14:42	15:25	00:43	Alice Springs Power System - UFLS Stage 1A - OSPS Unit 2 Loss of Power	Generation	2016
09/01/2016	Alice Springs	17:08	18:11	01:03	Alice Springs Power System - UFLS Stage 3A - BR-SD 2 Slow Clearance Fault	Networks Transmission	2016
24/01/2016	DKIS	18:46	19:05	00:19	DKIS Power System - 132kV PK-KA Line Tripped- UFLS Stage 2 in Katherine Island - Weather Lightning Strike	Networks Transmission	2016

Source: PWC

Method

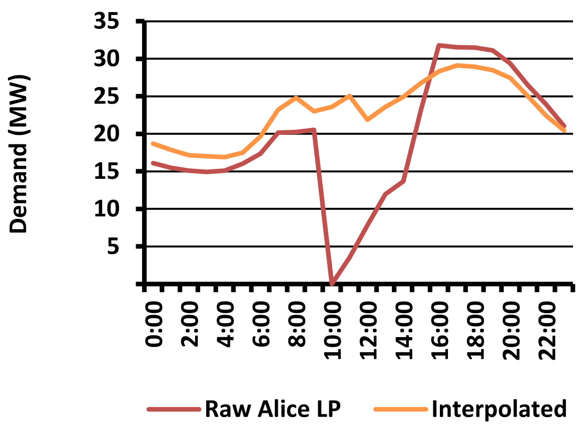
Network outages were corrected under two methods:

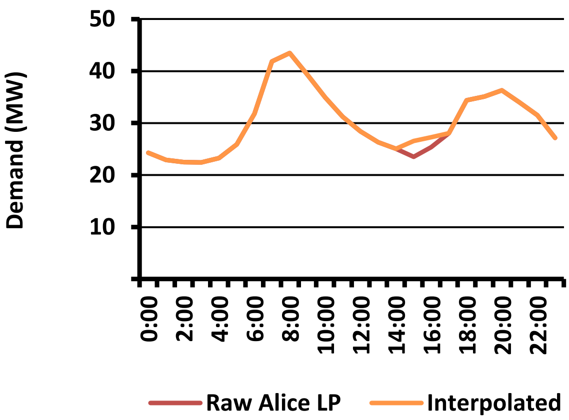
- **Short Outages** – Outages lasting less than 2 hours were corrected through linear interpolation
- **Long Outages** – Outages lasting longer than 2 hours were replaced with the comparable day-type one week either before or after, though before was preferred. Note both were considered to account for periods where outages occur more than one week in a row.

Outcome

The impacts of outage correction can be seen in Figure B1.

Figure A1 – Alice Springs Example Long (Left) and Short (Right) Outage Correction





Source: PWC
Note: Interpolation shows Alice Springs load profiles on the days 9/11/2017 and 20/07/2015 respectively

Appendix C – Weather Normalisation

This appendix covers the purpose, method, and outcome of the weather normalisation methodology.

Purpose

Energeia performed weather normalisation on the outage-corrected historical demand to adjust for the impacts of temperature conditions, such as inducing greater space conditioning loads. Exceptionally high or low temperatures in a historical year of data can shift demand, and hence energy, in a way that makes it unreasonable to compare to other historical years which may have had more 'normal' weather conditions. Thus, it was important to normalise the temperature impacts on demand to improve energy regression outcomes.

Method

Energy consumption tends to be correlated with temperature variation. Weather normalisation removes stochastic weather variation, enabling more accurate quantification underlying demand trends. It also ensures that weather sensitive load reflects a standard level of probability, which is typically 1 in 2 for an energy consumption analysis.

The above methodology was implemented in the following steps:

- **Determine Weather-Dependent Load** – Load interval data was regressed by hour, day-type (i.e. – weekday/weekend) and month against the minimum and maximum observed daily temperature[36]. The regression coefficients, when the correct sign and with p-values < 0.05, indicate the percentage of demand which is correlated with an increase or decrease in temperature.
- **Adjust Demand for Historical and Target Weather** – Energeia first estimated and removed the weather sensitive load in each hour, day-type and month using the actual temperature and the hourly regression coefficient, where it was statistically significant. Energeia then added back the weather sensitive load using the same regression coefficients and the P50 temperature. Total load for the given hour, day-type, month and year is thus the sum of the weather insensitive and the weather normalised, weather sensitive load.

Application of weather normalisation results in forecasts that account for variation in weather dependent load (such as HVAC) and non-weather dependent load (such as industrial/commercial demand trends, cooking and other non-weather sensitive household appliance loads).

Outcome

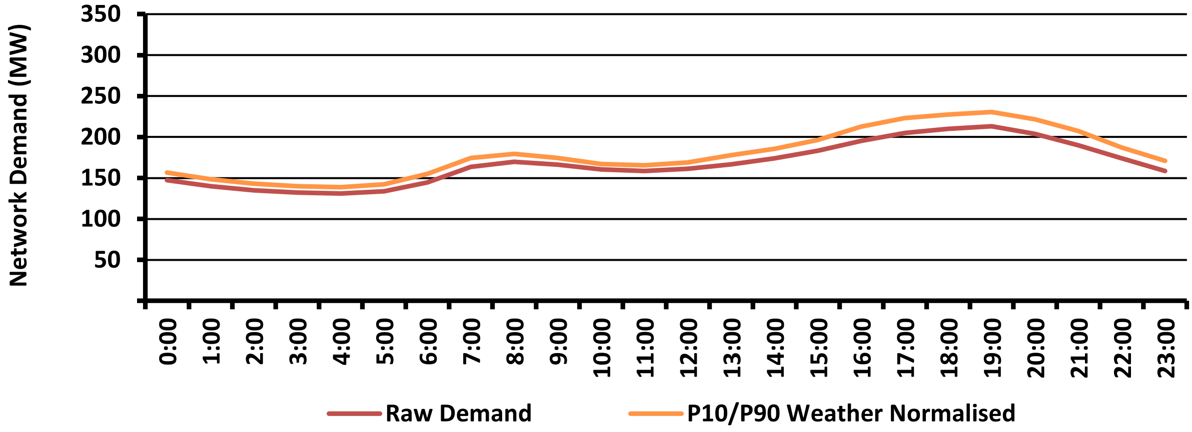
As discussed in Section 3.2.3, P50 weather normalised demand was used to generate the energy consumption history used in regression. However, P10, and P90 are shown here as they were produced in the complete weather normalisation procedure.

DKIS Load Profiles

The raw load profiles can be seen for representative average, peak and minimum demand days for the DKIS system, seen in Figure C1, Figure C2, and Figure C3 below. The charts additionally show the demand inputs weather normalised: the direct input to the peak period modelling.

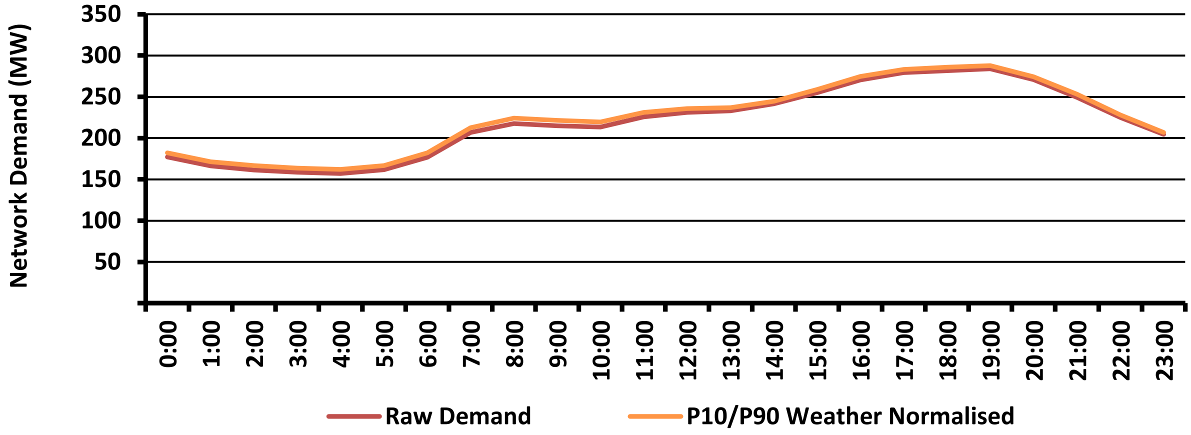
[36] Weather normalisation could account for other measurements of weather such as humidity and solar irradiance to improve accuracy. At the time of this analysis, other weather data was not available at the required granularity.

Figure C1 – DKIS Average Day Load Profile



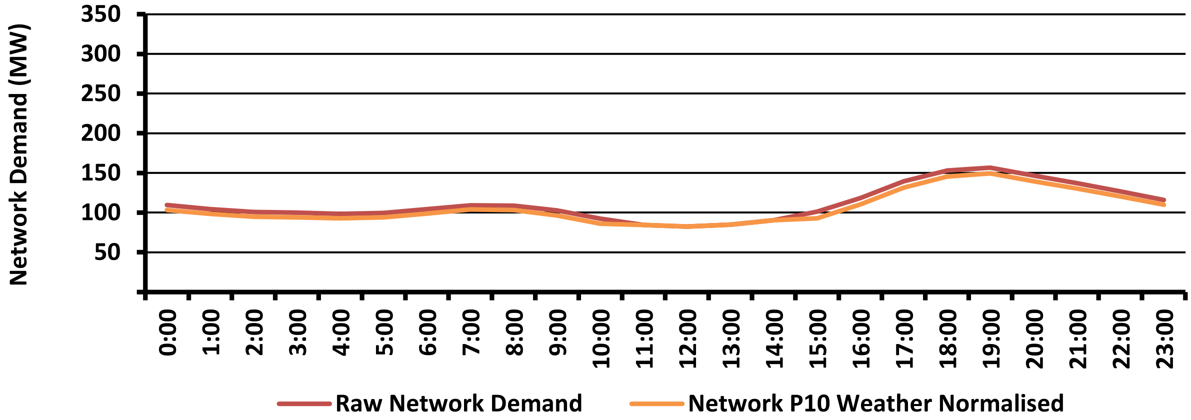
Source: PWC, Energeia Analysis

Figure C2 – DKIS Peak Day Load Profile



Source: PWC, Energeia Analysis

Figure C3 – DKIS Min Day Load Profile



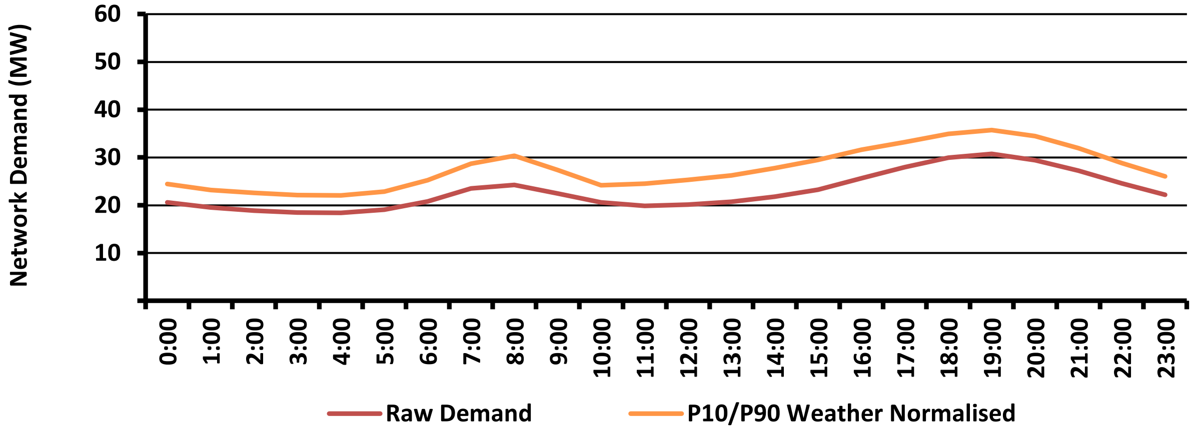
Source: PWC, Energeia Analysis

Weather normalising the demand had a larger impact on the average day than the peak and minimum days due to the dependency on temperature. The result indicates that peak day temperature is consistently close to the P90 temperature and is thus robust to weather normalisation.

Alice Springs Load Profiles

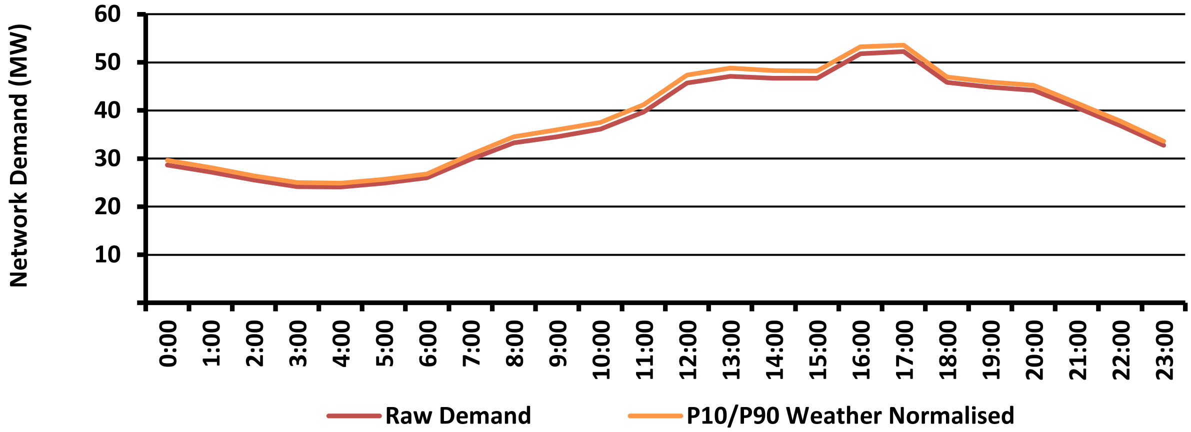
The average, peak and minimum day for Alice Springs is seen in Figure C4, Figure C5, and Figure C6 below for raw and weather normalised demand. Consistent with the pre-processing outcomes shown above, Alice Springs average demand is higher on the average day after weather normalisation. The extent of the difference before and after weather normalisation is correlated to how extreme weather varies. The temperature variation in Alice Springs results in the upwards shift of demand after weather normalisation.

Figure C4 – Alice Springs Average Day Load Profile



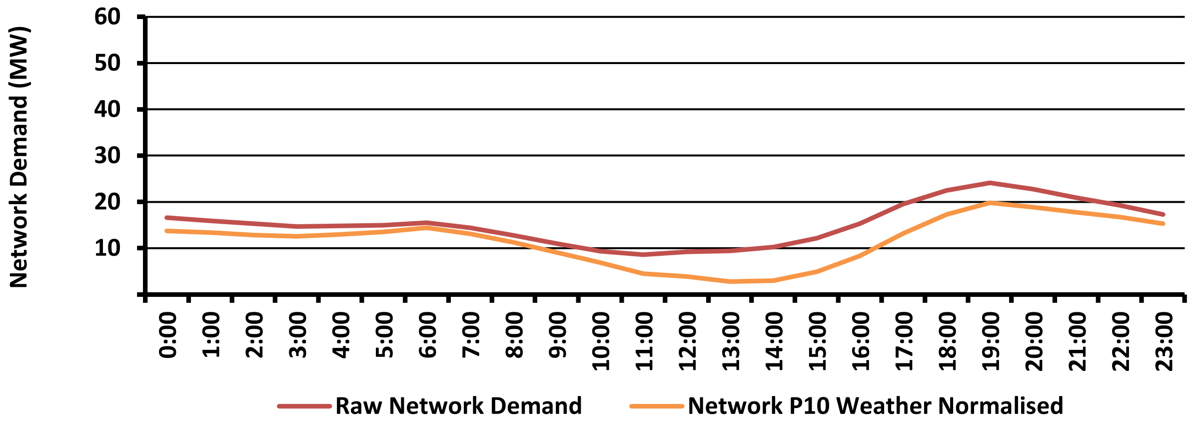
Source: PWC, Energeia Analysis

Figure C5 – Alice Springs Peak Day Load Profile



Source: PWC, Energeia Analysis

Figure C6 – Alice Springs Min Day Load Profile

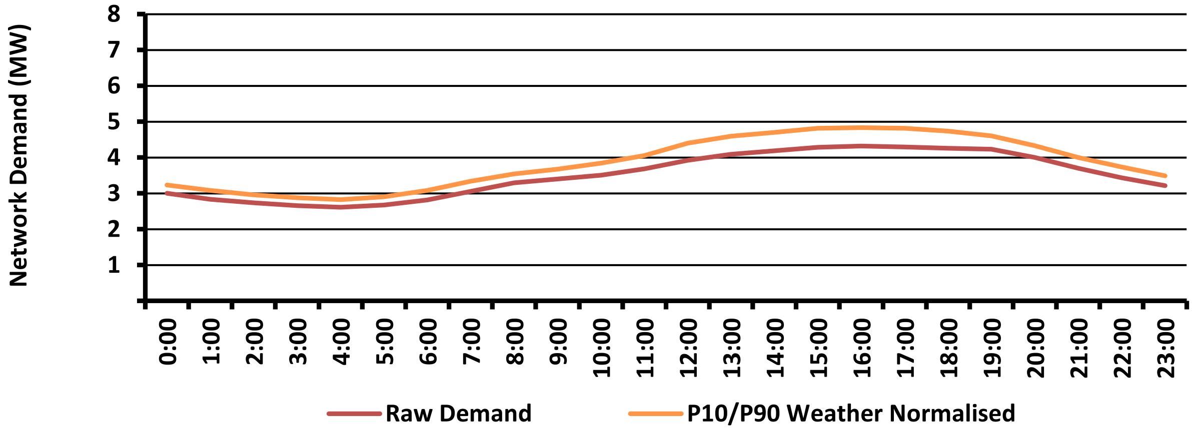


Source: PWC, Energeia Analysis

Tennant Creek Load Profiles

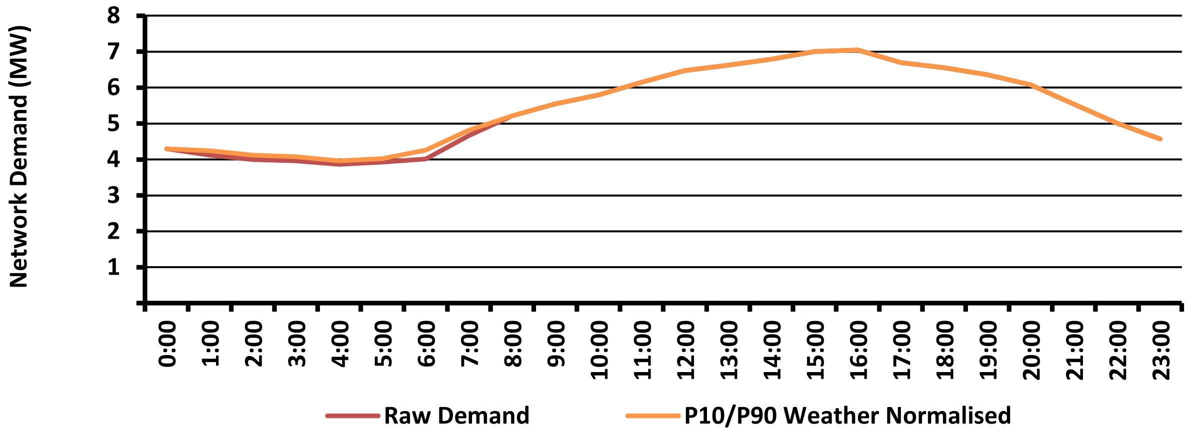
Tennant Creek load profiles before and after the weather normalisation process can be seen in Figure C7, Figure C8, and Figure C9 below for average, peak and min demand days.

Figure C7 – Tennant Creek Average Day Load Profile



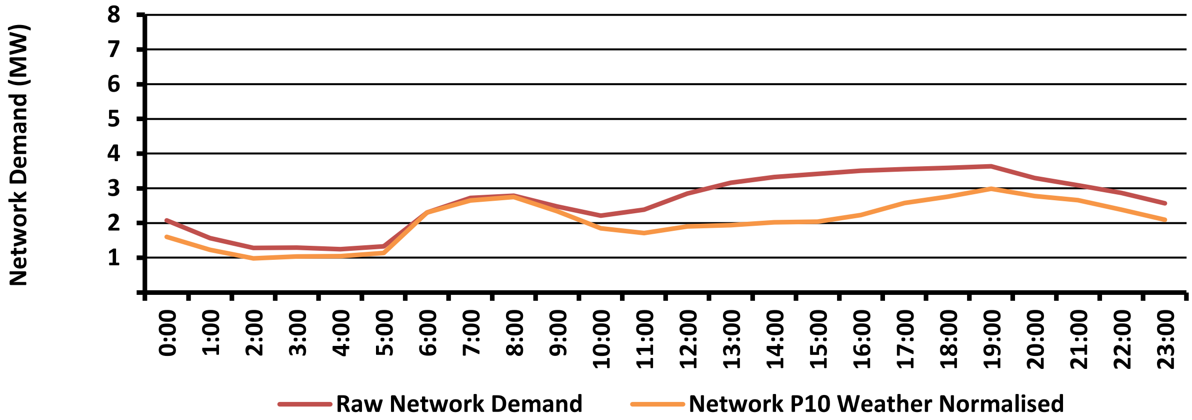
Source: PWC, Energeia Analysis

Figure C8 – Tennant Creek Peak Day Load Profile



Source: PWC, Energeia Analysis

Figure C9 – Tennant Creek Min Day Load Profile



Source: PWC, Energeia Analysis