LOW CARBON LIVING CRC

After-diversity electricity demand of low-energy households

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Acronyms

ADMD	after-diversity maximum demand
DNSP	distribution network service provider
kVA	kilovolt-amps
kWh	kilowatt-hour
PV	photovoltaic

Executive Summary

The capacity of electricity infrastructure required for new precincts is often based on the types of customers that will occupy the new precinct and historical electricity use for each type of customer. However, modern energy-efficient precincts with local generation can have significantly lower demand than historical precincts.

In South Australia, the SA Power Networks design standard recommends allowing 4-10 kVA per dwelling, depending on floor area. We have analysed electricicy consuption data from energy-efficient housing in Lochiel Park and from an apartment building in Bowden. The maximum demand for electricity from groups of 19–53 houses in Lochiel Park was less 3 kW per household. The maximum demand from 42 apartments was less than 1.2 kW per apartment.

This data will be useful for estimating the demand of new precincts of low-energy dwellings.

Introduction

When planning electricity network infrastructure for new precincts, distribution network service providers must estimate the maximum electrical demand that might occur and then size the distribution infrastructure, such as transformers, to meet this demand.

One way to estimate the maximum demand of a precinct is to estimate the maximum demand of a typical household and then multiply by the number of households. However, this method overestimates maximum demand because households do not all have their maximum demand at the same time.

In practice, the demand of precincts is known from historical data. Dividing the measured maximum demand of the precinct by the number of households in the precinct gives the *after-diversity maximum demand* (ADMD) per household in the precinct. ADMD can then be used to predict the maximum demand of new precincts, given the number of households in the new precinct.

In South Australia, the distribution network service provider is SA Power Networks, and the method for estimating the demand of a precinct is described in their Technical Standard TS-100. SA Power Networks uses ADMD values based on dwelling sizes:

Dwelling size	ADMD
less than 100 m^2	4 kVA
100 – 185 m^2	6 kVA
185 – 280 m^2	8 kVA
more than 280 m^2	10 kVA

The maximum demand is specified by SA Power Networks as an apparent power, measured in volt-amps (VA), whereas residenital consumers pay for real power, measured in watts (W). Apparent power is made up of the real power used by consumers, and reactive power that is delivered to consumers to support some types of loads but is not actually consumed. The difference is not important for the purpose of this report, other than apparent power demand could be up to 25% higher than real power demand but is typically only about 5% higher.

We have measured energy use from houses in Lochiel Park and from the Nexus apartment building in Bowden, to determine the actual ADMD values for each.

Lochiel Park

In 2004, the South Australian government announced that a new housing precinct to be developed at Lochiel Park would become a model “green village”, incorporating features including:

- NatHERS 7.5-star energy rated dwellings, assessed using Accurate
- photovoltaic panels generating at least 1 kW per 100 m^2 of habitable floor area
- high-efficiency appliances
- gas-boosted solar water heaters
- load limiting devices (though these are not mandated and are hence used by only a few households).

The South Australian Land Management Corporation estimated that the ADMD for the development would be 3.5 kVA, and negotiated that the design ADMD for the precinct be reduced from 8 kVA to 6 kVA.

We have used electricity data collected from households at Lochiel Park over a period of 5 years to calculate the actual ADMD of the precinct, and found that the ADMD is less than 3 kW, which is equivalent to about 3.2 kVA but could be as high as 3.75 kVA—considerably lower than the agreed 6 kVA and the 6–8 kVA specified in the technical standard for similar dwellings.

Figure 1 An aerial view of some homes at Lochiel Park

Nexus apartments

The Nexus apartment building in Bowden was built in 2015. It contains 42 apartments.

The apartment building was designed to meet 5-star Green Star requirements. The apartment floor areas range from 50–104 m^2, with a mean floor area of 68 m^2. The building has central gas water heating.

We used electricity data collected by the building management system in 2016 ancd 2017 to calculate the ADMD of the apartment building, including electricity use in common areas.

The 2016 data started on 2016-01-23. It is missing one hour of data on 2016-04-20, and six hours of data from 2016-09-28 (the day if the SA statewide blackout). The 2017 data is complete.

The ADMD of the Nexus apartments was less than 1.2 kW during 2016–2017, and was equivalent to less than 1.2 kVA. As with the Lochiel Park households, this is considerably lower than the 4–6 kVA specified in the SA Power Networks technical standard.

Method

Lochiel Park

Each household at Lochiel Park is instrumented to record, amongst other things, the total electrial load of each household and the electricity imported from the grid. These are measured at 1-minute intervals.

We use the following terminology:

- *load* is the total power being drawn by electrical appliances in a household
- *generation* is the total power being generated, for example by a rooftop photovoltaic system
- *demand* is the power imported from the electricity distribution network.

Load, generation and demand are related by:

demand = load – generation.

If load exceeds generation then electricty is imported from the grid and demand is positive; if generation exceeds load then power is exported to the grid and demand is negative.

For each year in the period 2011–2015 we examined the load and demand profiles of each occupied household for which we had complete data for the entire year. The number of households in the precinct increased during the period. Occasional logger failures meant that households included in one year were not necessarily included in all subsequent years. There were 11 households included every year, and 46 households that were included in both 2013 and 2014.

For each minute of each year we did two calculations:

- the after-diversity load was found by summing the load values across all households then dividing by the number of households
- the after-diversity demand was found by summing the demand values across all households then dividing by the number of households.

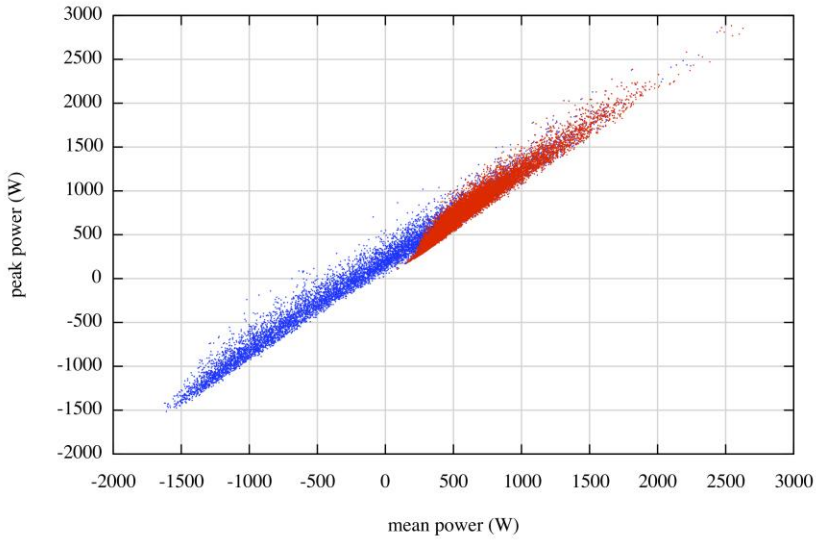
There were a few instances where some load or demand values were missing; in these cases we calculated after-diversity load and demand based on the values that we had.

These calculations gave $365 \times 24 \times 60 = 525600$ values of after-diversity load and after-diversity demand for each year. From these values we constructed a cumulative distribution that shows the proportion of time that the after-diversity load or demand was less than a specified value. The cumulative distributions also give the after-diversity maximum demand and the after-diversity maximum load.

Similar analysis could be done using 30-minute power data from interval meters rather than the 1-minute data collected at Lochiel Park. However, peak power averaged over 30-minute intervals will in general be lower than peak power averaged over 1-minute intervals. This is illustrated in Figure 2, using 1-minute data from 2011. Each dot represents a 30-minute interval; the horizontal position is the mean power during the interval, and vertical position is the peak (1-minute) power during the interval. Red dots represent load and blue dots represent demand. The after-diversity maximum demand is 2882 W using 1-minute powers, and 2543 W using 30-minute powers. Most dots are above the diagonal because maximum 1-minute demand in each 30-minute interval exceeds the mean demand for the 30-minute interval

The analysis for Lochiel Park households uses 1-minute power data.

Figure 2 Mean power and peak power for 30-minute intervals.



Nexus apartments

The Nexus apartment building is equipped with a building measurement system that records the electrical energy use of each of the 42 apartments, a laundry room, the carpark, and other common areas. The finest resolution available is hourly energy records.

We collected hourly energy use for the entire building from 2016-01-23 until 2017-12-31. We used these values to calculate the daily after-diversity demand and the cumulative distributions of energy use. Hourly values will underestimate the half-hour peak demand values, but not by much. To give an indication of the error, the 1-hour maximum demand is 2% higher than the 2-hour maximum demand. The difference between the 1-hour maximum demand and the 30-minute maximum demand will be similar—the 30-minute maximum demand will be about 2% higher than the 1-hour maximum demand.

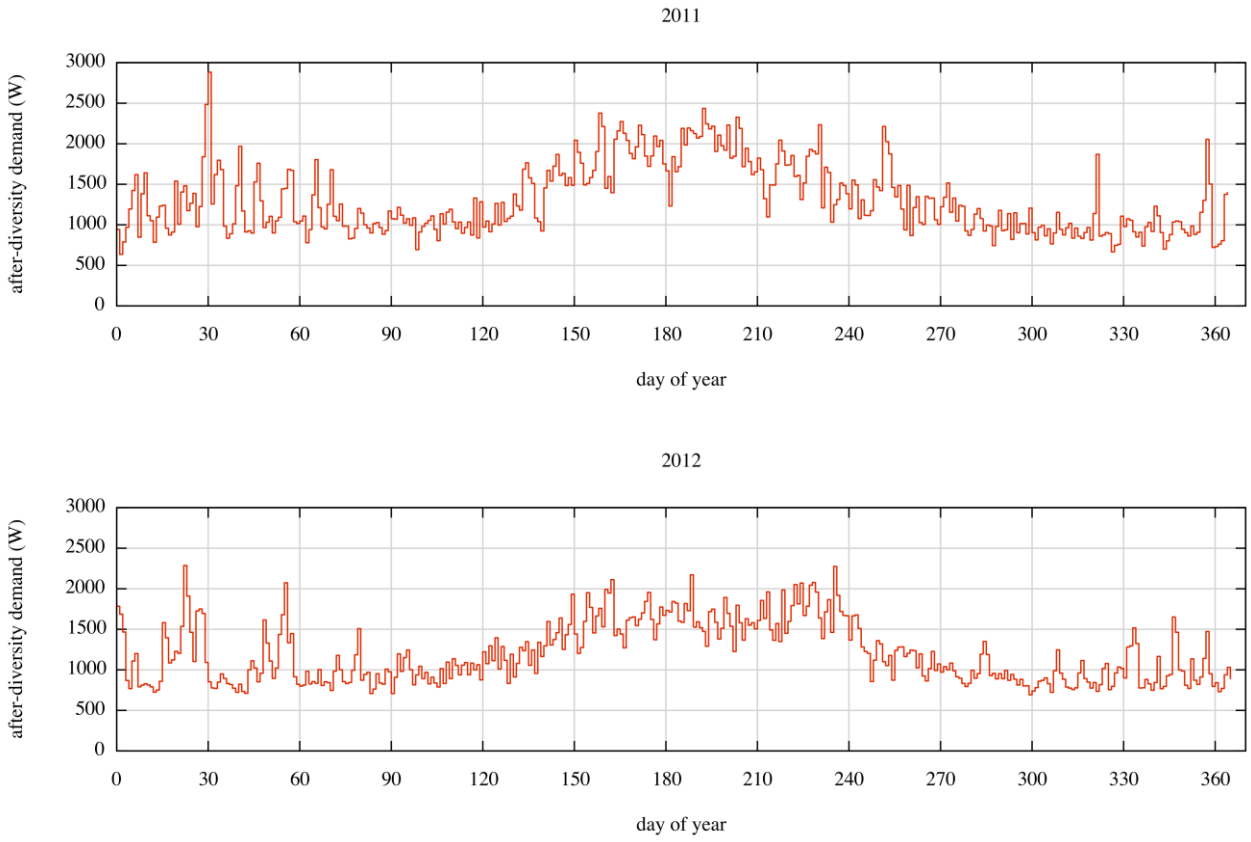
Lochiel Park results

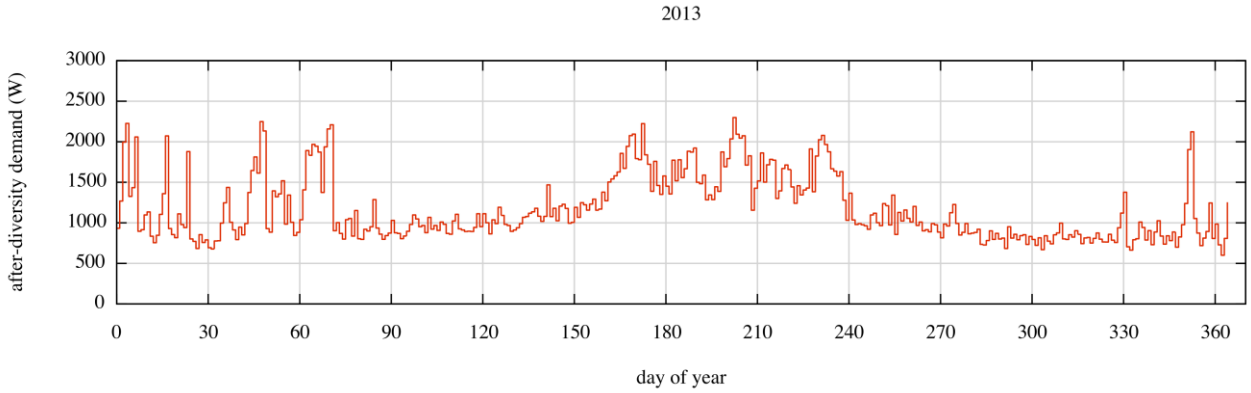
The after-diversity maximum demand for each year is summarised in the following table:

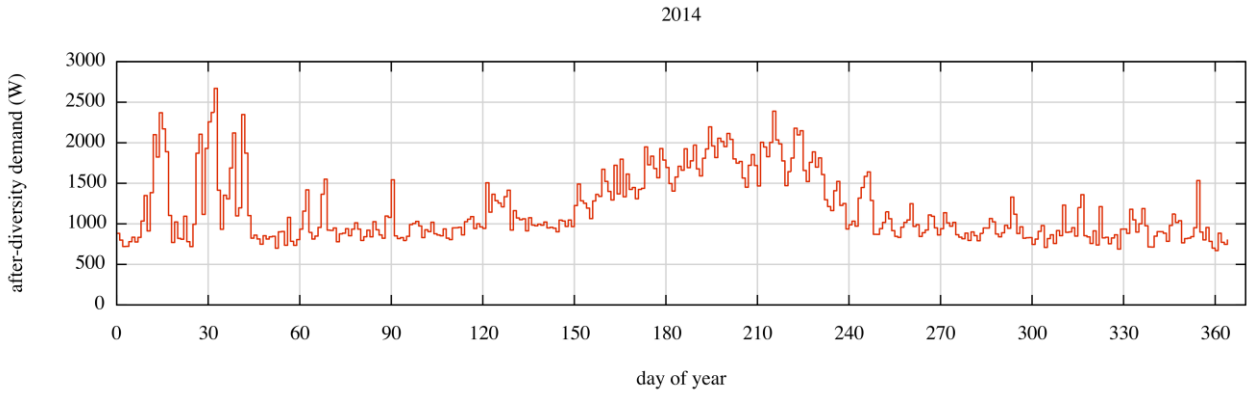
Year	Households	ADMD (W)
2011	19	2882
2012	38	2287
2013	53	2299
2014	53	2673
2015	49	2237

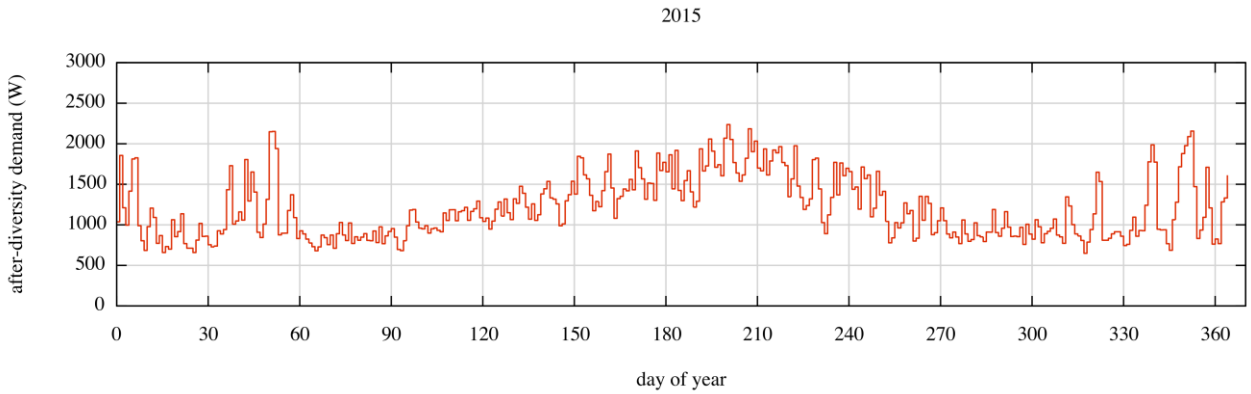
The graphs below show the after-diversity maximum demand for each day, by year. The peaks occur in both summer and winter. Demand is generally higher in winter, but there is greater variation in summer.

Figure 3 After-diversity maximum demand at Lochiel Park for each day, by year







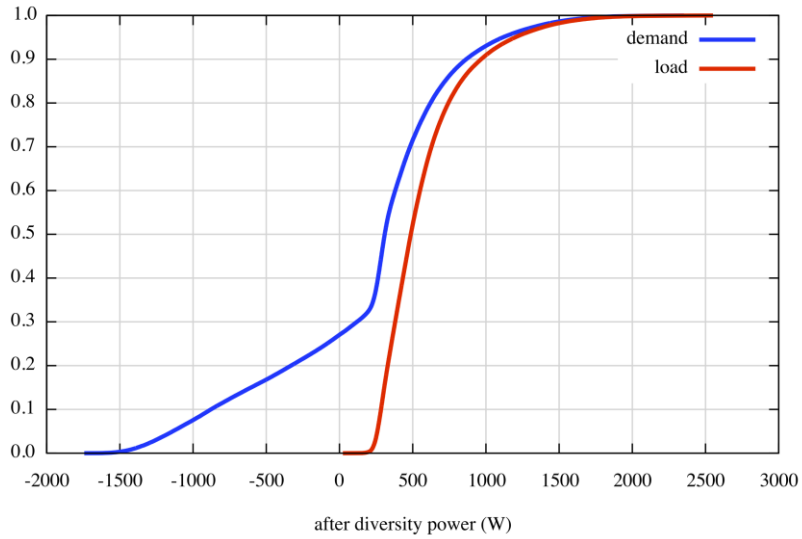


The following sections describe the distribution of after-diversity load and demand each year.

2011

During 2011 there were 19 households with almost complete data. Figure 4 shows the cumulative distribution of after-diversity demand and after-diversity load. The horizontal axis is power; the vertical axis is the proportion of time that the after-diversity power was less than the specified value.

Figure 4 After-diversity demand and load at Lochiel Park during 2011



The graph shows that:

- load and demand were each less than 2900 W for 100% of the 1-minute samples
- load was less than 1000 W for 91% of the samples; demand was less than 1000 W for 93% of the samples
- 50% of the samples had load less than 490 W; 50% of the samples had demand less than 310 W
- households were exporting power for 27% of the samples.

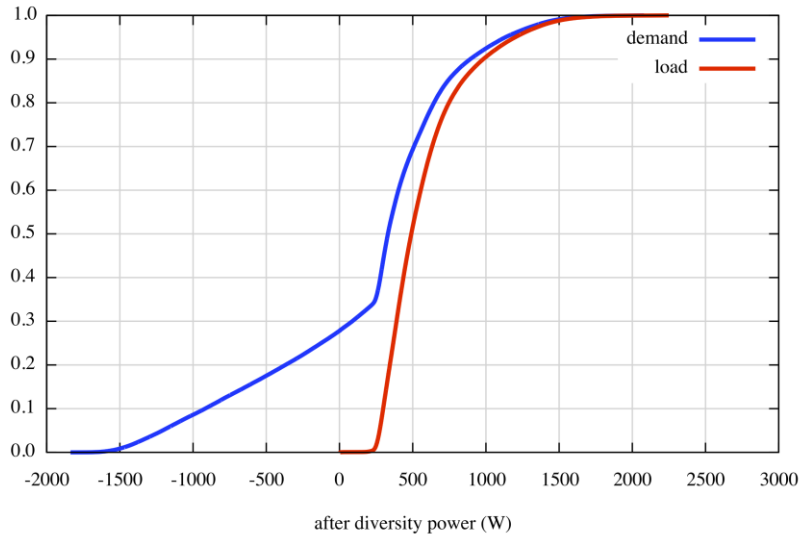
Load represents the total electricity used by each household, and is hence always positive. Demand is lower than load when there is generation from the photovoltaic panels, and is negative when households are exporting electricity to the grid.

Nineteen households is about one-fifth of the final size of the precinct. We expect the after-diversity demand, and the after-diveristy maximum demand, to decrease in the following years as the number of households increases.

2012

In 2012 there were 38 households with almost complete data. Figure 5 shows the cumulative distribution of after-diversity demand and load. Demand and load are both less than 2300 W.

Figure 5 After-diversity demand and load at Lochiel Park during 2012



As expected, the after-diversity maximum demand dropped as the number of households increased.

2013 and 2014

In 2013 and 2014 there were 53 households with almost complete data; 46 of these households had complete data for both years. Figures 6 and 7 show the cumulative distributions of after-diversity demand and load.

Figure 6 After-diversity demand and load at Lochiel Park during 2013

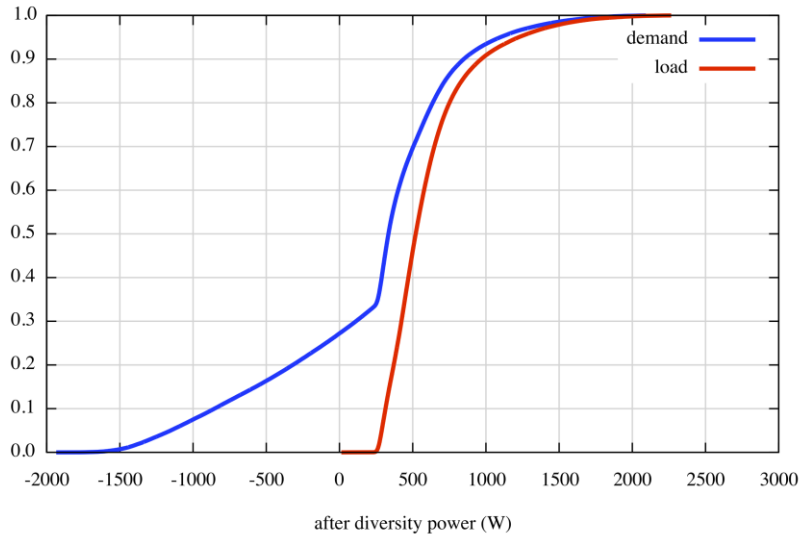
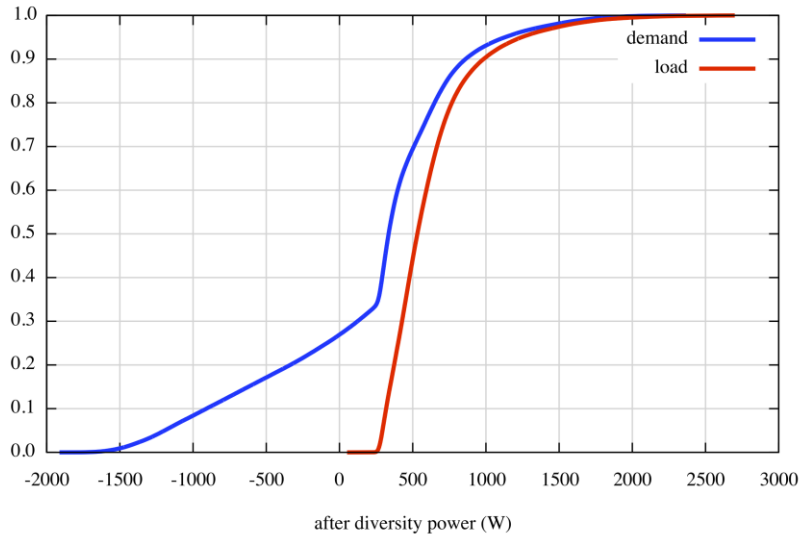


Figure 7 After-diversity demand and load at Lochiel Park during 2014

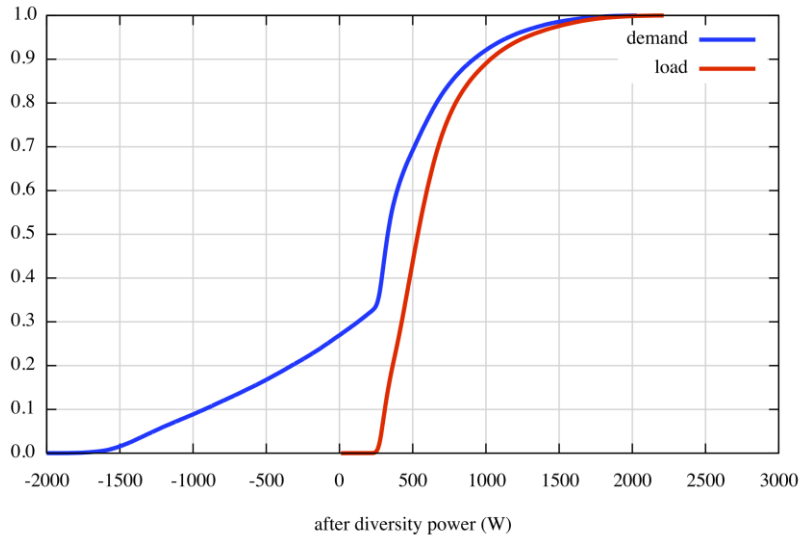


After-diversity maximum demand was 2300 W in 2013 and 2700 W in 2014. The difference is due to hot weather in 2014; almost all of the after-diversity demand exceeding 2300 W occurred on 2 February in the evening, on a day when the maximum temperature in Adelaide was 44.7°C and the maximum temperature on the previous day was 43.4°C.

2015

In 2015 there were 49 households with almost complete data. Figure 8 shows the cumulative distributions of after-diversity demand and load. After-diversity maximum demand was 2237 W.

Figure 8 After-diversity demand and load at Lochiel Park during 2015



Nexus apartments results

The after-diversity maximum demand of the Nexus apartments for each year is summarised in the following table:

Year	Households	ADMD (W)
2016	42	1044
2017	42	1111

The daily after-diversity maximum demand for each year is shown in Figure 9. Figure 10 shows the cumulative distributions of load for the Nexus apartments.

Figure 9 After-diversity maximum demand of the Nexus apartments for each day, by year

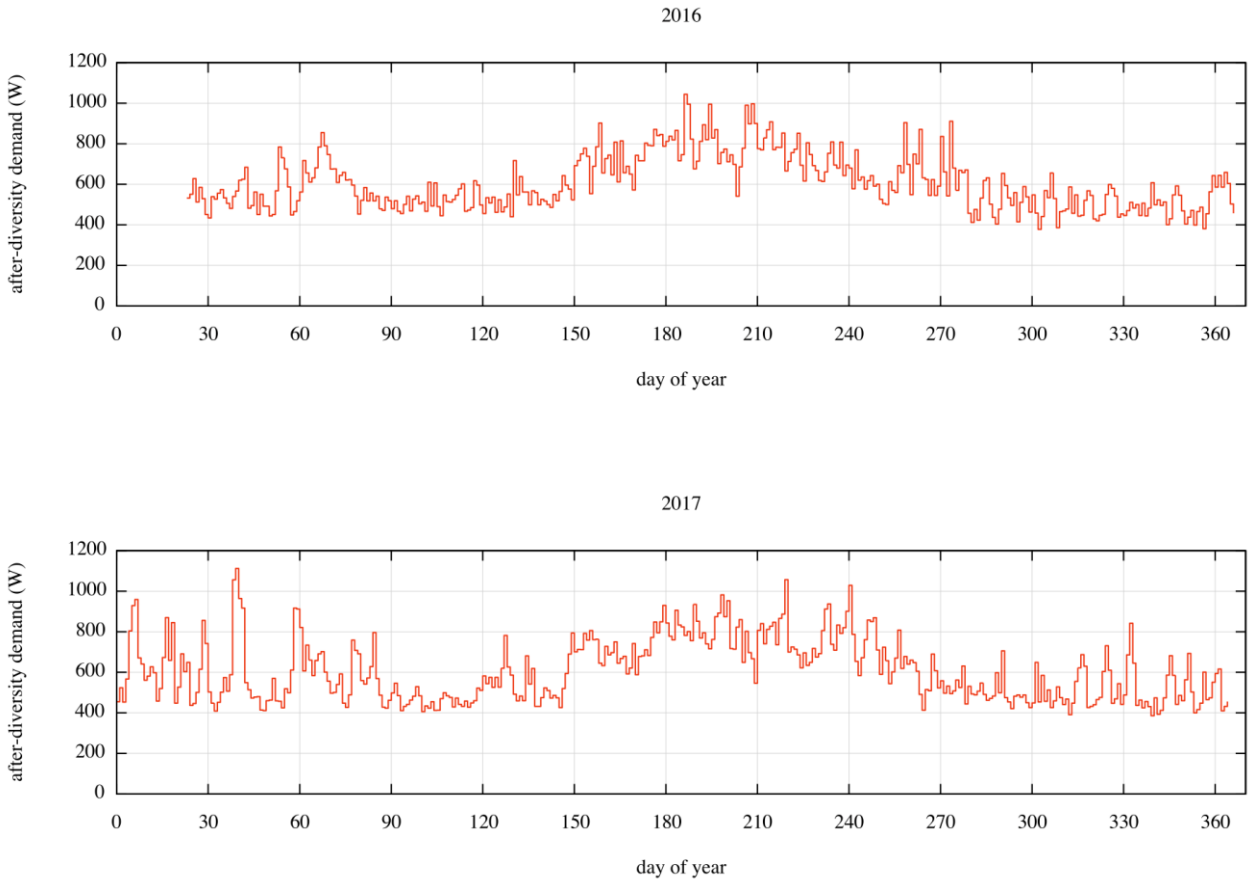
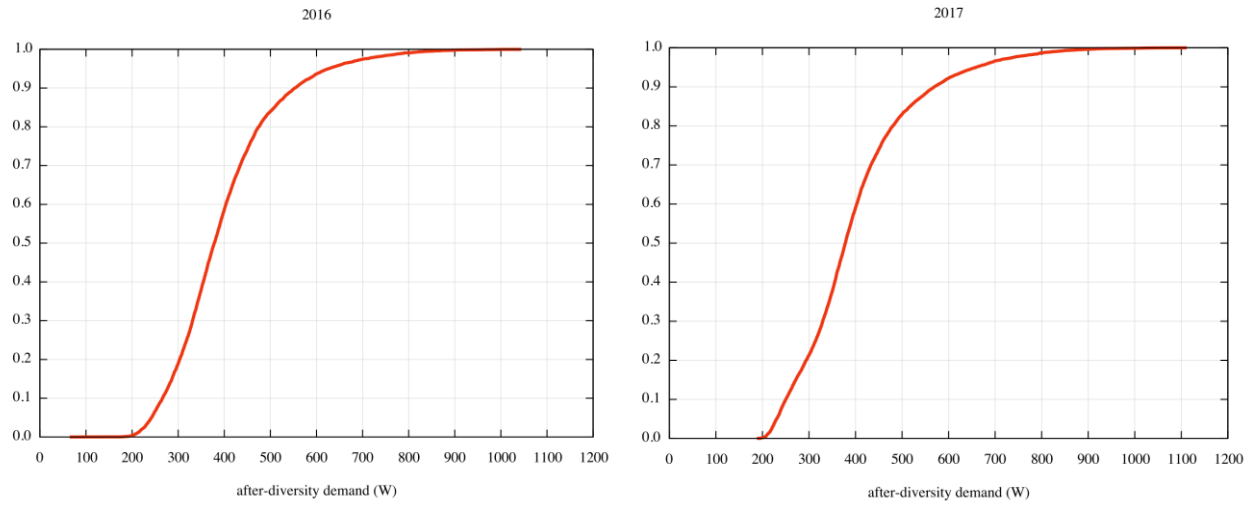


Figure 10 Cumulative distribution of demand of the Nexus apartments, by year



Conclusion

The after-diversity maximum demand (ADMD) measured in low energy households at Lochiel Park and in the Nexus apartments at Bowden are 20–50% of the values specified in the SA Power Networks technical standards used to determine electrical infrastructure requirents.

At Lochiel Park, during the period 2011–2015, the after-diversity maximum demand did not exceed 2882 W, which was recorded in 2011 with diversity from only 19 households. The next highest annual after-diversity maximum demand was 2673 W, which occurred on a day when the maximum temperature was 44.7°C. The after-diversity maximum demand measured at Lochiel Park is substantially lower than the values of 6-8 kVA specified by the SA Power Networks technical standard, and lower than the 3.5 kVA predicted for the development.

The Nexus apartment building, with 42 apartments, has an after-diversity maximum demand of 1111 W during 2016–2017, which is considerably less than the 4 kVA allowed for dwelling with less than 100 m^2 floor area.

Developers, and ultimately consumers, pay for electricity infrastructure. There is no national standard method for determining how much capacity should be provided for a new precinct; each distribution network service provider has their own methods for determining the likely demand, but is required to meet the demand efficiently (that is, without excessive infrastructure).

The data from Lochiel Park and from the Nexus apartments provides useful information on after-diversity load and after-diversity demand for low-energy housing, and should be used to inform the design of electricity infrastructure for future low-energy precincts.

The data from the Nexus apartments may also be used to inform the design of embedded networks for future apartment developments with, a view to optimising tariffs and reducing costs for end users.