NORTH PERTH

Summary of characteristics

North Perth substation has recently been converted to 132/11kV and has two transformers and operates as a NCR substation. The load type is predominantly commercial with some suburban residential. The ideal NCR capacity of the substation is 61.7MVA. The actual NCR capacity of the substation is approximately 57.8MVA due to an uneven sharing of load between the two transformers. Presently loaded at approximately 42MVA, the substation is expected to reach its capacity by 2016. A third transformer is to be installed in 2011 at an estimated cost of $10 million.

Annual profile

The July 2003 to June 2004 load profile for North Perth TX2 is shown in Figure 1. It is characterised by a fairly constant baseload around 5MW, and daily maxima about double the size of the baseload that increase in both summer and winter but show greater variability in summer. It also has a clear weekly cycle, with reduced weekend loads, especially on Sundays – see Figure 2 and Figure 3. There are a number of days of extreme demand peaks, some of which are discussed in more detail below. Figure 4 shows the 2MW simulated north-facing PV output for ACDB site 'Perth', which increases in summer as expected, particularly late Feb and early March.

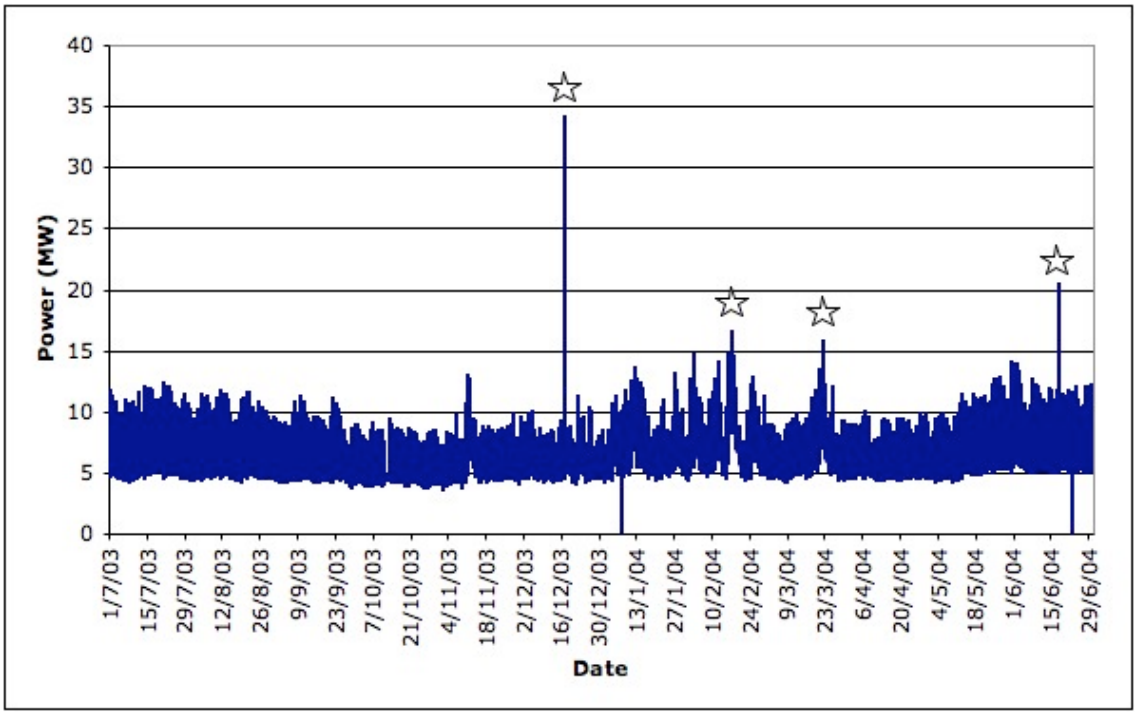

Figure 1: North Perth TX2 Load
July 2003 to June 2004
(the stars indicate the peak days analysed in detail below)

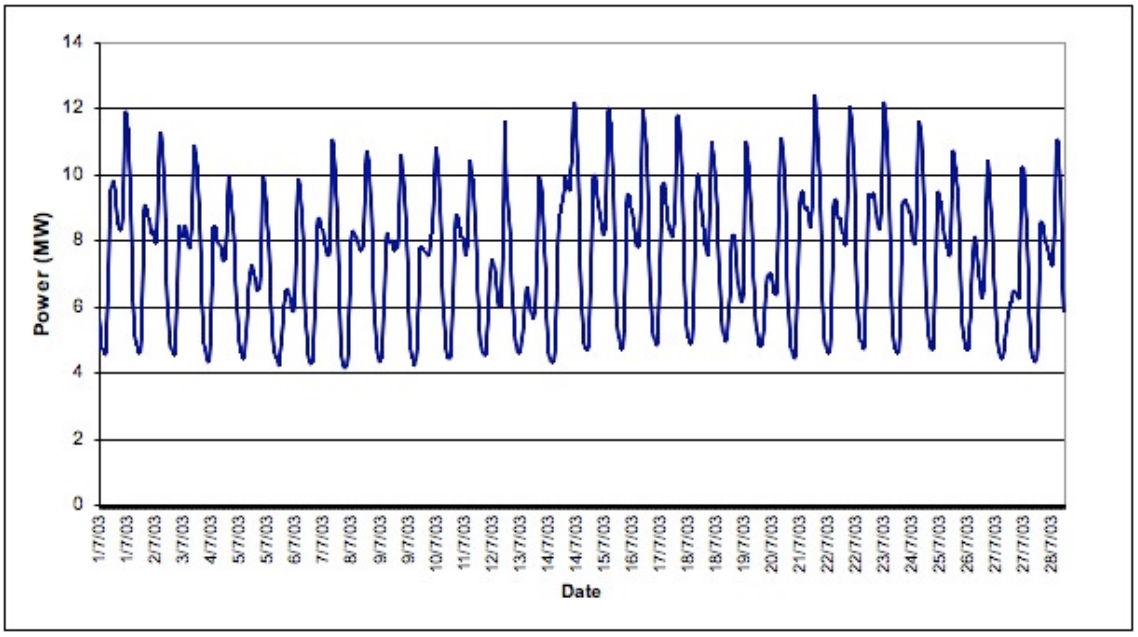

Figure 2: North Perth TX2 Load - July
The first 28 days of July 2003

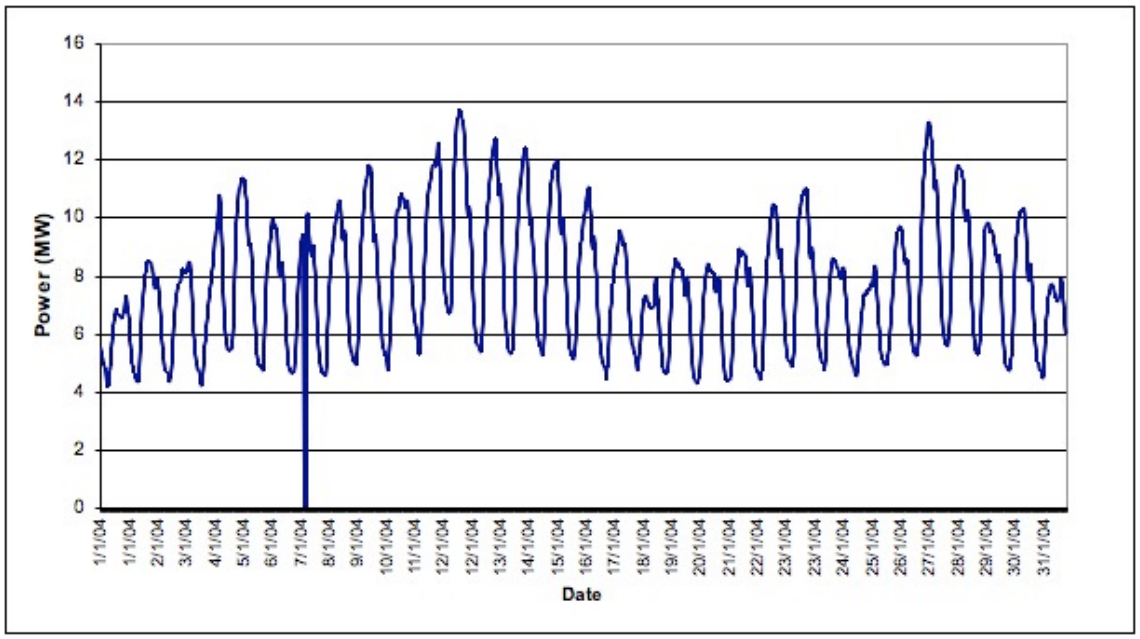

Figure 3: North Perth TX2 Load - Jan
The first 28 days of Jan 2004

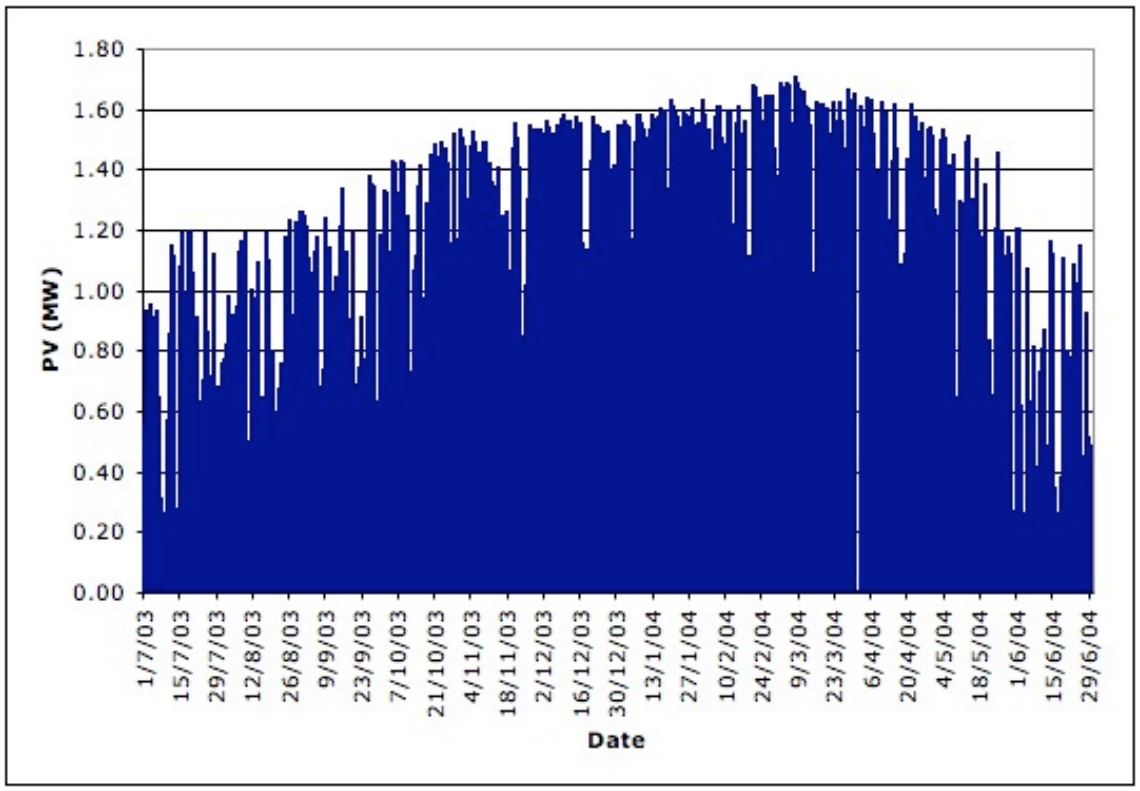

Figure 4: North Perth Simulated North-facing PV Output (2MW)
July 2003 to June 2004

Daily profiles

Figure 5 shows the daily annual average load for North Perth TX2, the simulated north-facing 2MW PV output, and the net load assuming it is reduced by PV. The annual average load peaks at 7:30pm, while the simulated north-facing PV peaks at about 12:30pm. As can be seen from Figure 6 to Figure 9, winter has the highest seasonal peak, at 7:30 to 8:30pm, most likely reflecting residential heating loads. Spring and autumn have a similar load profile, peaking in the evening, while only summer has a day time peak, at around 5pm, and so is the only seasonal peak that correlates with the simulated PV.

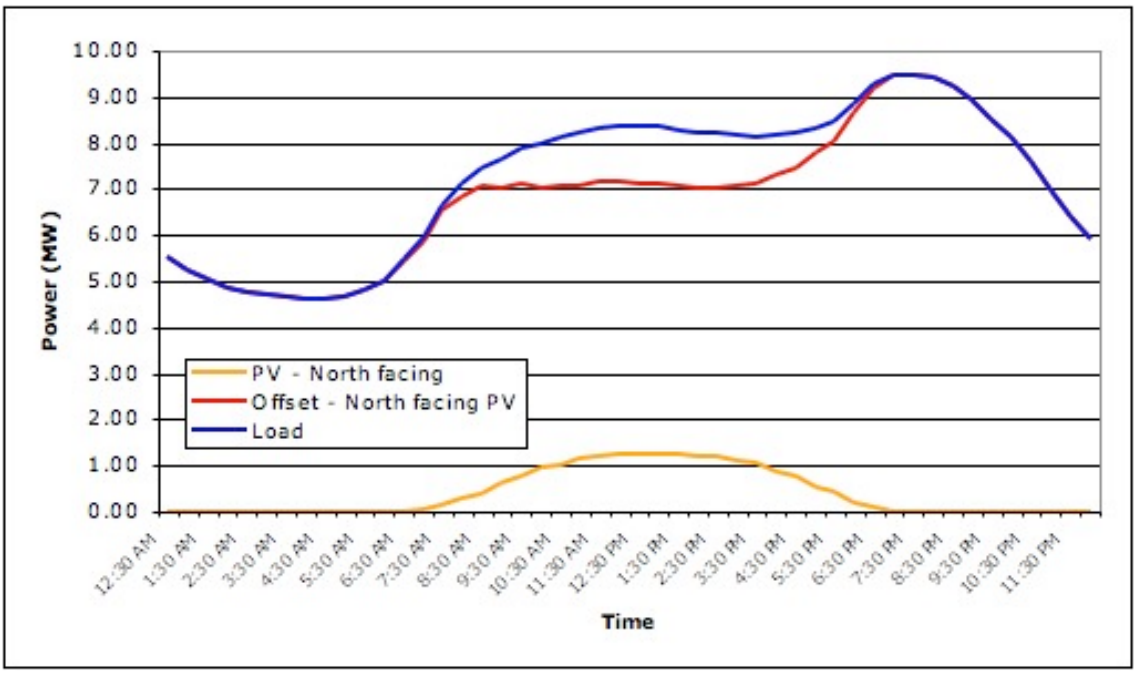

Figure 5: Daily Annual Average
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset
July 2003 to June 2004

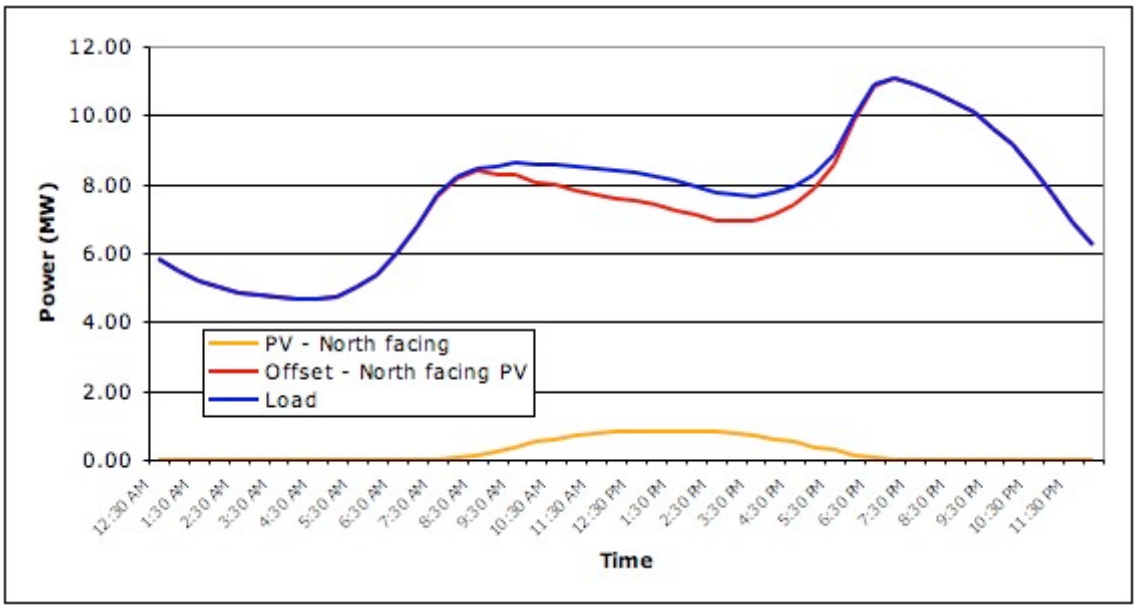

Figure 6: Daily Winter Average
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset
June 2004 and July/Aug 2003

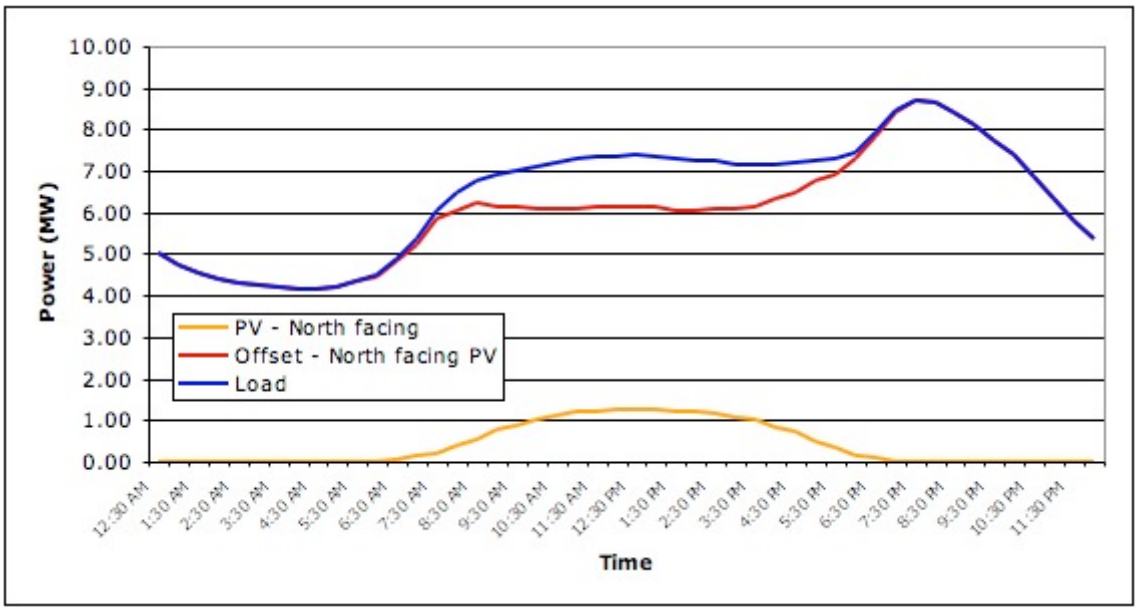

Figure 7: Daily Spring Average
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset
Sept 2003 to Nov 2003

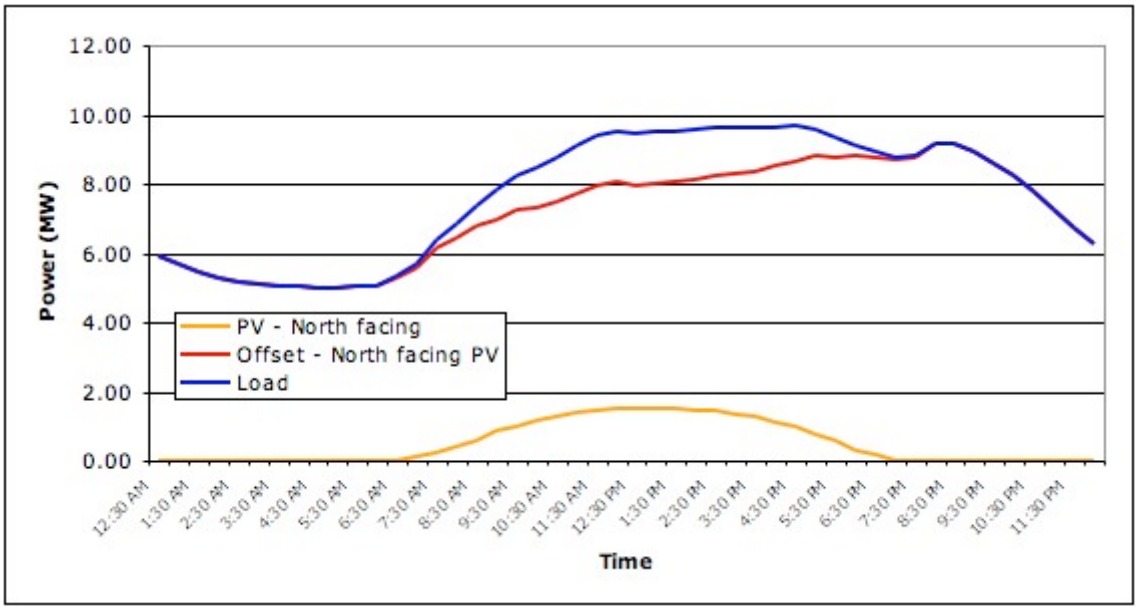

Figure 8: Daily Summer Average
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset
Dec 2003 to Feb 2004

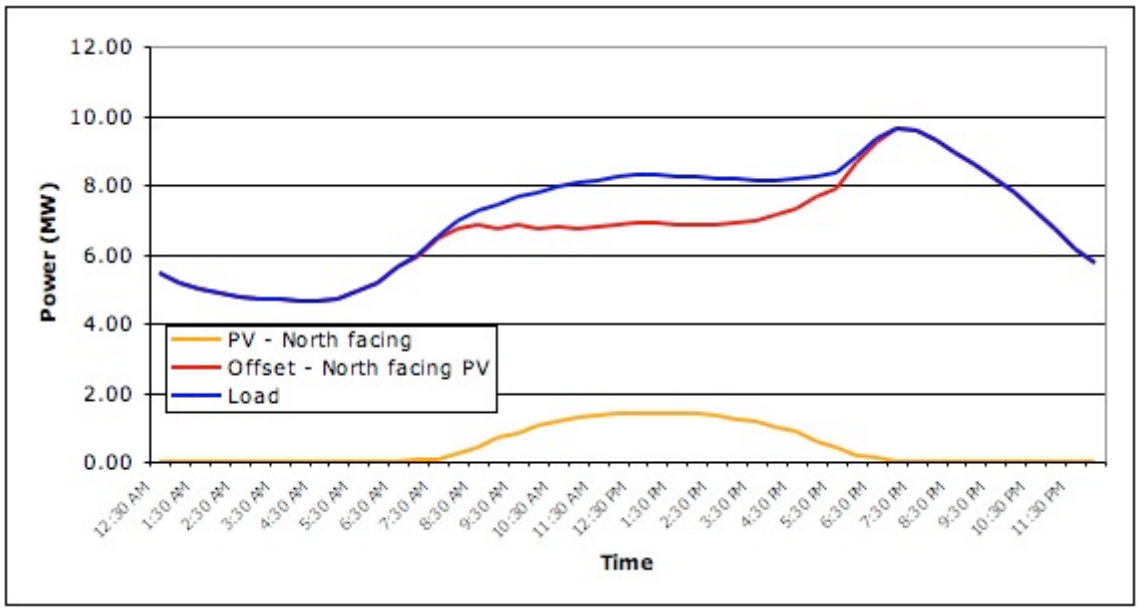

Figure 9: Daily Autumn Average
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset
March 2004 to May 2004

The impact of simulated west-facing PV is illustrated in Figure 10 to Figure 14 and Table 1. Use of simulated west-facing PV with a tilt of 25 degrees shifts the peak PV output by about 1.5 hours later in the day, and a tilt of 45 degrees brings the shift to a total of about 3 hours. Even simulated west-facing-45 PV has no significant impact on the winter, spring and autumn peaks, while all three PV simulations reduce the 5pm summer peak to below the summer evening peak.

Table 1: Annual Energy Output from Simulated 960W PV at North Perth[1]

Orientation	Tilt (degrees)	2003 (kWh/yr)	2004 (kWh/yr)
North	25	1,528	1,695
North west	25	1,585	1,757
West	25	1,476	1,614
West	45	1,409	1,546
West	90	1,015	1,116

[1] Note that these are identical to those for Forrest Ave as they are based on the same ACDB site.

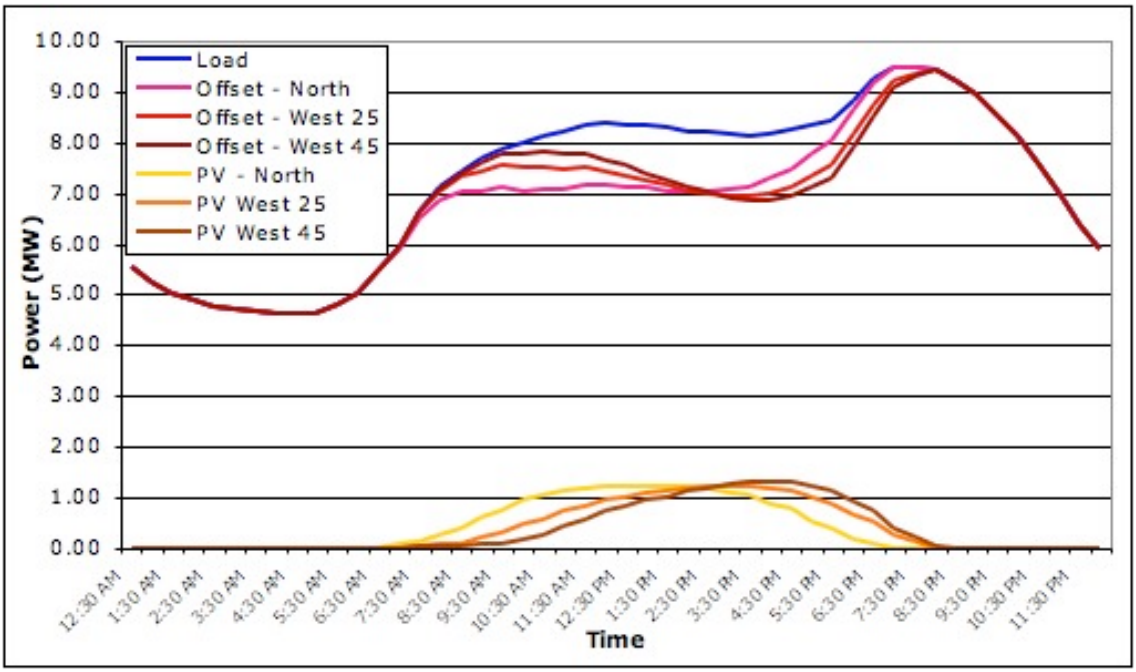

Figure 10: Daily Annual Average
North, and West (25° and 45° inclinations)
North Perth TX2 Load, North Perth PV (2MW) and Net Load after PV Offset
July 2003 to June 2004

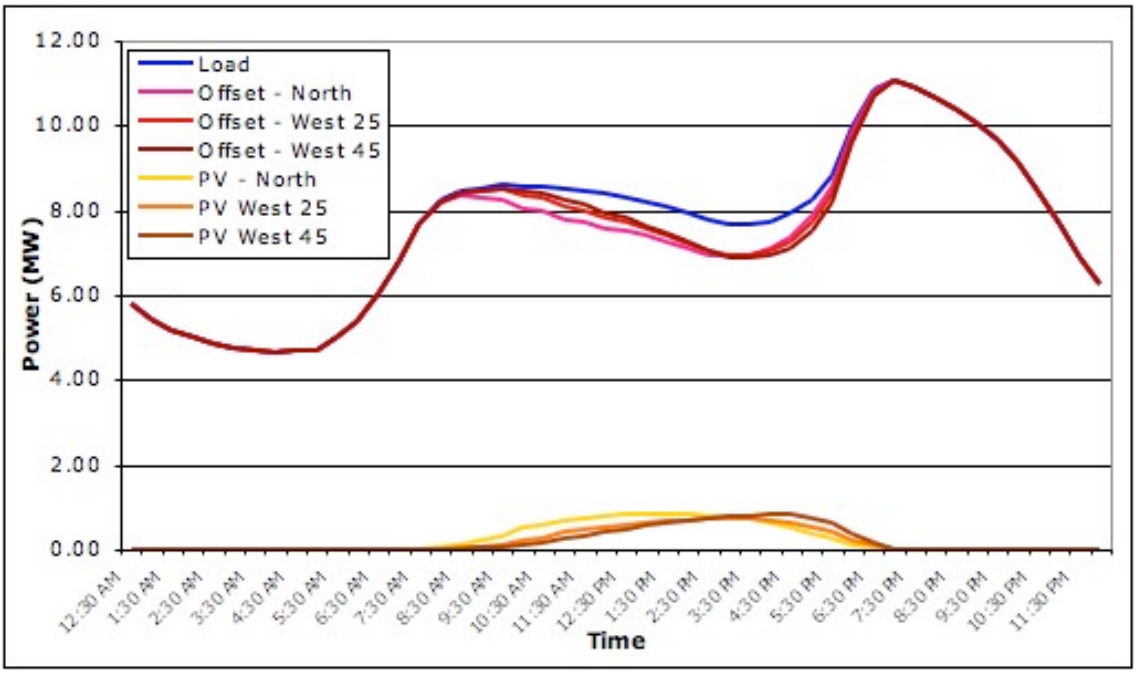

Figure 11: Daily Winter Average
North, and West (25° and 45° inclinations)
North Perth TX2 Load, North Perth PV (2MW) and Net Load after PV Offset
June 2004 and July/Aug 2003

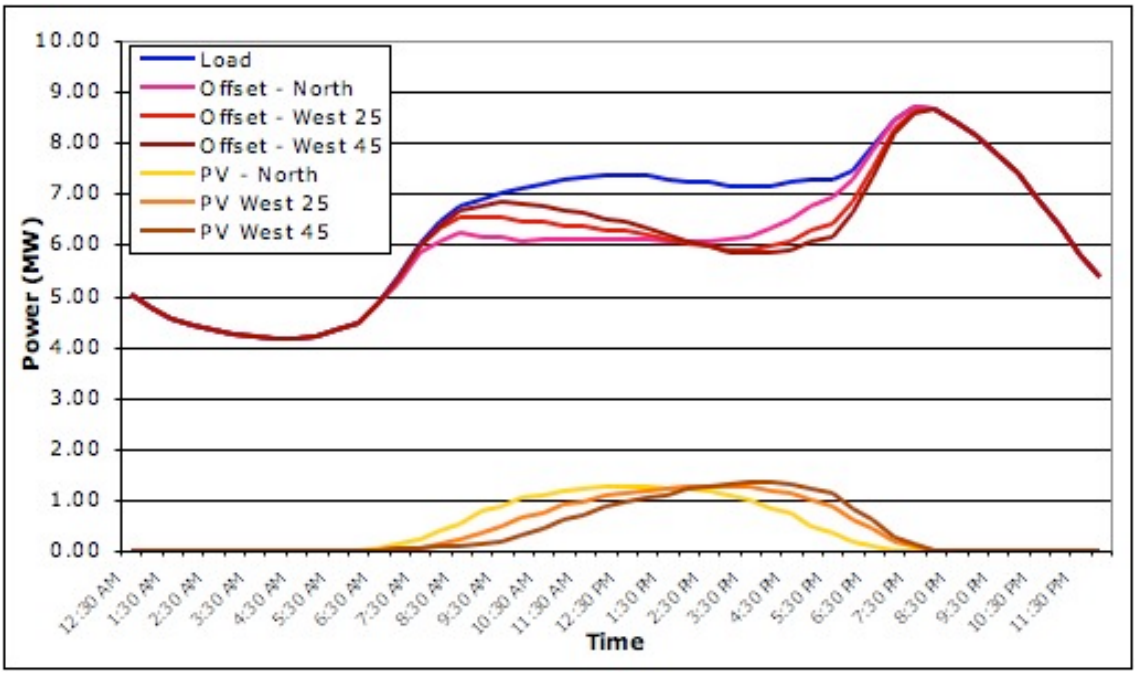

Figure 12: Daily Spring Average
North, and West (25° and 45° inclinations)
North Perth TX2 Load, North Perth PV (2MW) and Net Load after PV Offset
Sept 2003 to Nov 2003

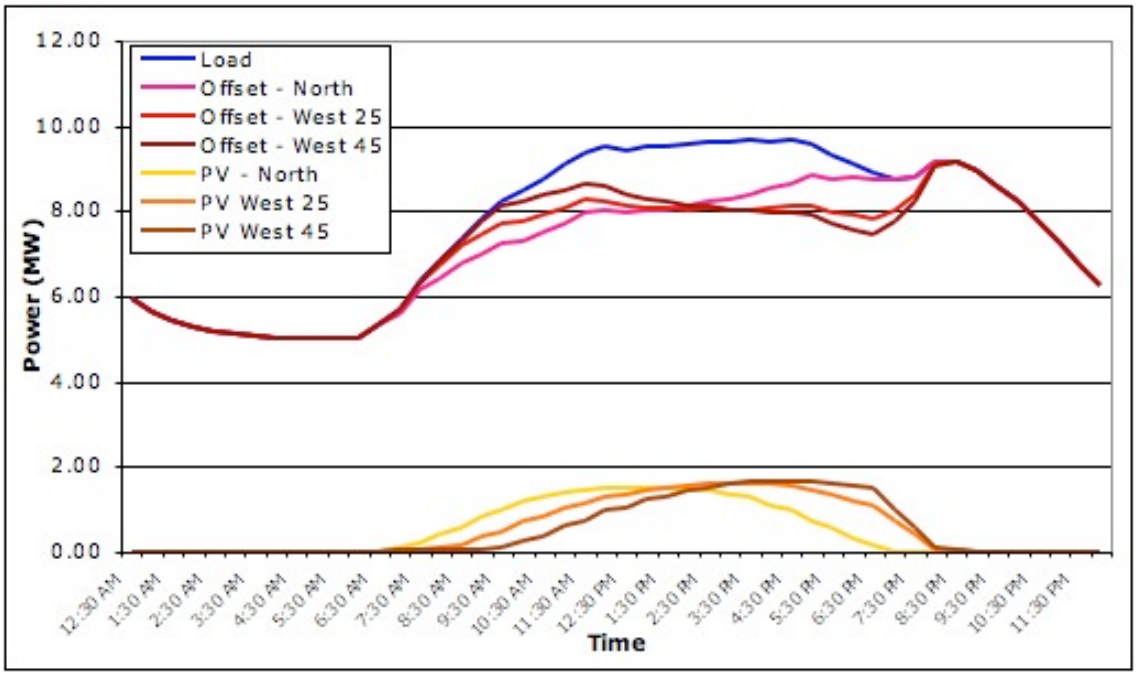

Figure 13: Daily Summer Average
North, and West (25° and 45° inclinations)
North Perth TX2 Load, North Perth PV (2MW) and Net Load after PV Offset
Dec 2003 to Feb 2004

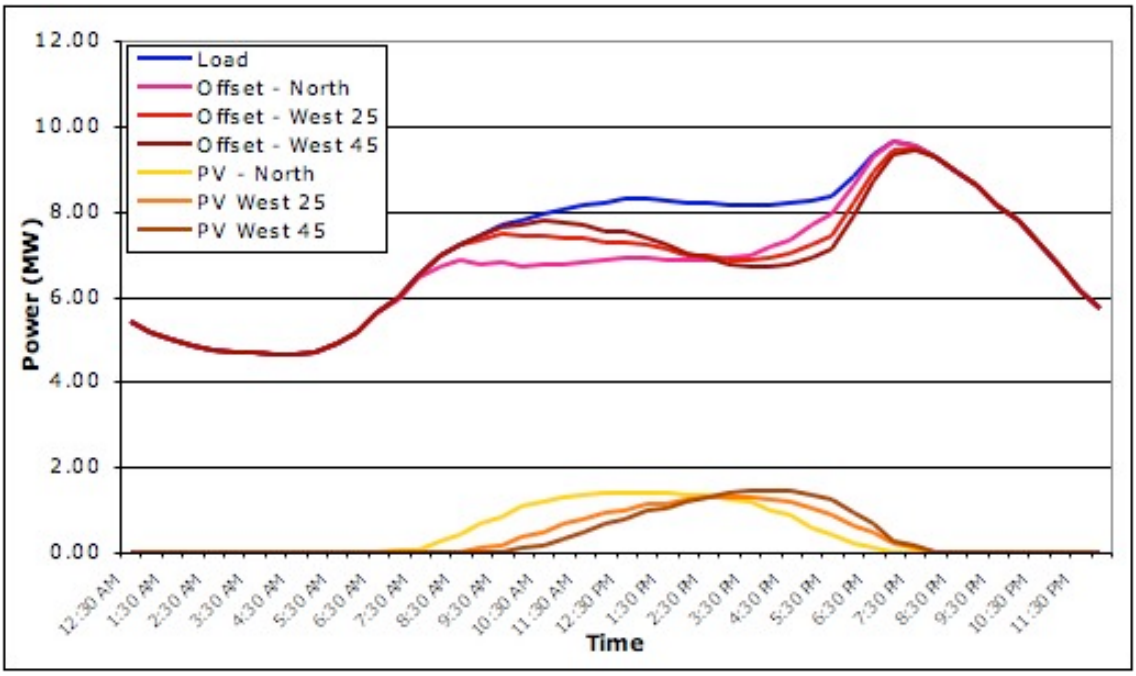

Figure 14: Daily Autumn Average
North, and West (25° and 45° inclinations)
North Perth TX2 Load, North Perth PV (2MW) and Net Load after PV Offset
March 2004 to May 2004

Times of peak demand

The ten top half-hour demand periods at North Perth TX2 are shown in Table 2. The three highest occur in summer on the 17th Dec 2003 (Figure 15), and the next 7 occurred in winter on the 18th June 2004 (Figure 20). These are also the ten highest points in the load duration curves in Figure 22 to Figure 24.

The highest peak load day (17th Dec 2003) occurred in summer, is illustrated in Figure 15, and involved a sudden increase from 10 to almost 35MW, peaking at around 11:30am. Although the temperature was quite high at 34°C, the suddenness of the peak is consistent with operational changes by Western Power. The simulated north-facing PV coincides well at this time, and, as can be seen from the load duration curves in Figure 23 and Figure 24, reduced the three half hour peak periods by about 1.1MW.

The second highest peak load day assessed here (18th June 2004; Figure 16), had a broad load peak from 8am to 1:30pm, and highest at around 8:30am. The suddenness of the peak, and low temperature (16°C) mean it was probably caused by operational changes by Western Power. The simulated PV made little contribution partly because of low output and partly because the load peak occurred early in the day.

The third highest cluster of peak load days assessed here (16th-18th Feb 2004; Figure 17), peaked at 5pm, and was probably caused by high temperatures which reached over 40°C on that day and over 38°C the day before. The simulated north-facing PV made a relatively small contribution at that time, reducing the peak from 16.7MW to 16.05MW. The impact of using simulated west-facing PV at 45 degree tilt is shown in Figure 18,

shifting the peak PV output about 3 hours later reduced the load further to 15.35MW, meaning about 67% of the simulated west-facing-45 PV was contributing to peak load reduction at that time.

The fourth highest cluster of peak load days assessed here (21st-23rd March 2004, Figure 19) was quite hot, reaching over 41°C, with the peak occurring at 4pm, when the simulated north-facing PV was able to make a reasonable contribution, reducing and shifting the peak to about 7pm. Simulated west-facing-25 PV reduced the highest load points even more (Figure 20), while simulated west-facing-45 PV reduced them further still (Figure 21). Both types of simulated west-facing PV also reduced the 7pm peak and shifted it to about 8pm.

Table 2: Ten Top Half-hour Demand Peaks at North Perth TX2

Demand (MW)	Date	Day	Time
34.30	17-Dec-03	Sat	11:30
31.88	17-Dec-03	Sat	12:00
26.17	17-Dec-03	Sat	11:00
20.55	18-June-04	Sat	8:30
20.43	18-June-04	Sat	9:30
20.37	18-June-04	Sat	9:00
20.27	18-June-04	Sat	8:00
20.25	18-June-04	Sat	11:00
20.05	18-June-04	Sat	10:30
19.98	18-June-04	Sat	10:00

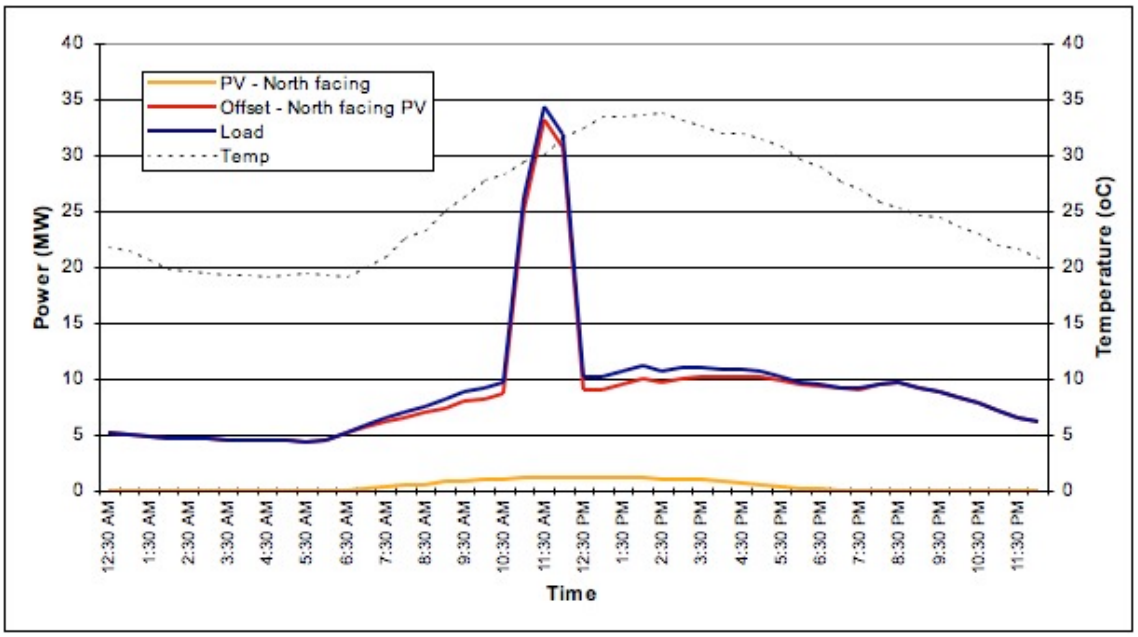

Figure 15: Summer peak day
17th Dec 2003
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset

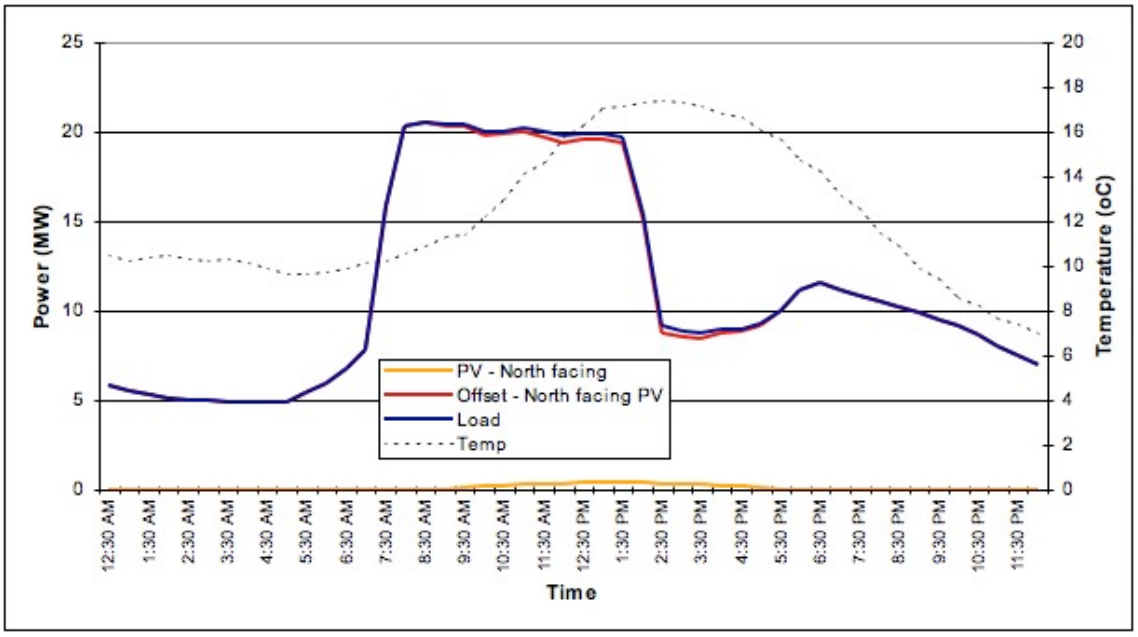

Figure 16: Winter peak day
18th June 2004
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset

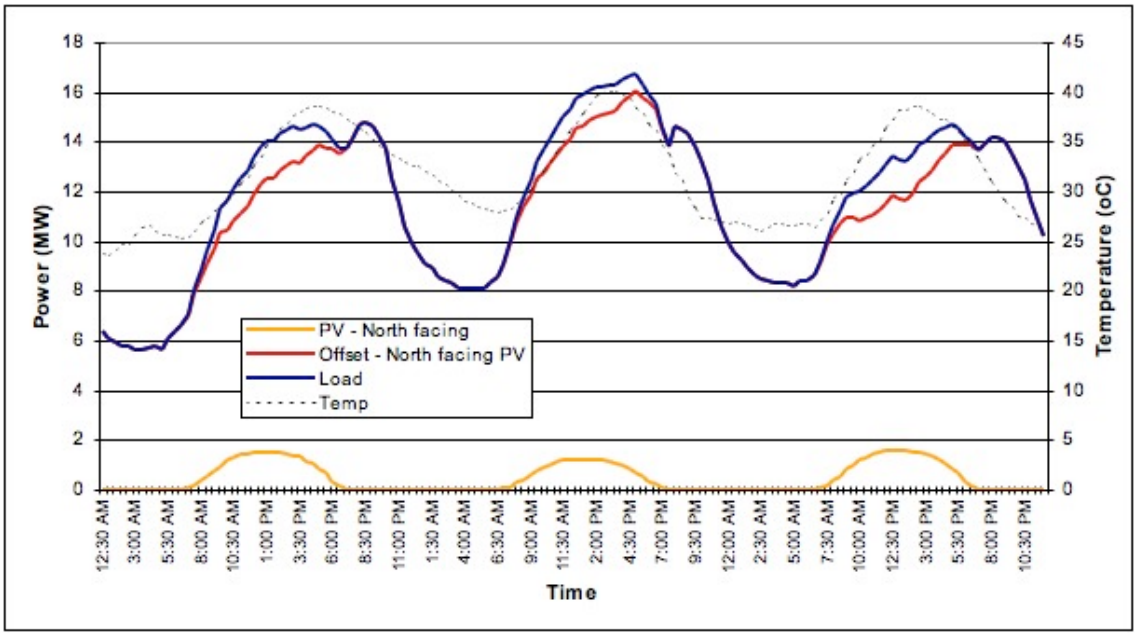

Figure 17: Summer peak day (north-facing PV)
16th-18th Feb 2004
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset

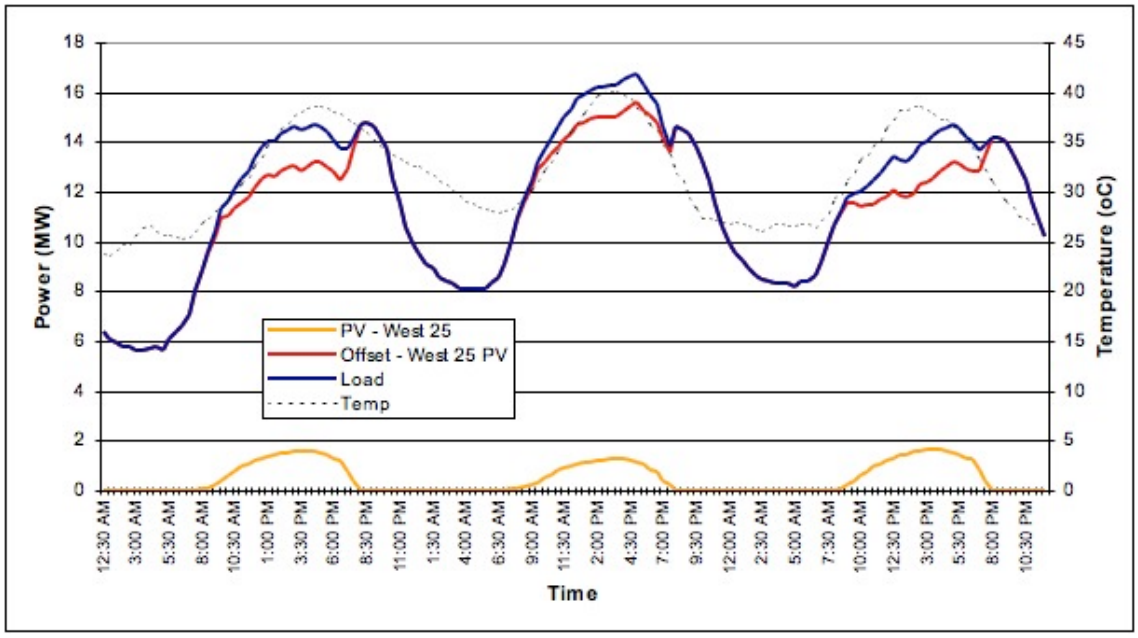

Figure 18: Summer peak day (west-facing-45 PV)
16th-18th Feb 2004
North Perth TX2 Load, North Perth Simulated West-facing-45 PV (2MW) and Net Load after PV Offset

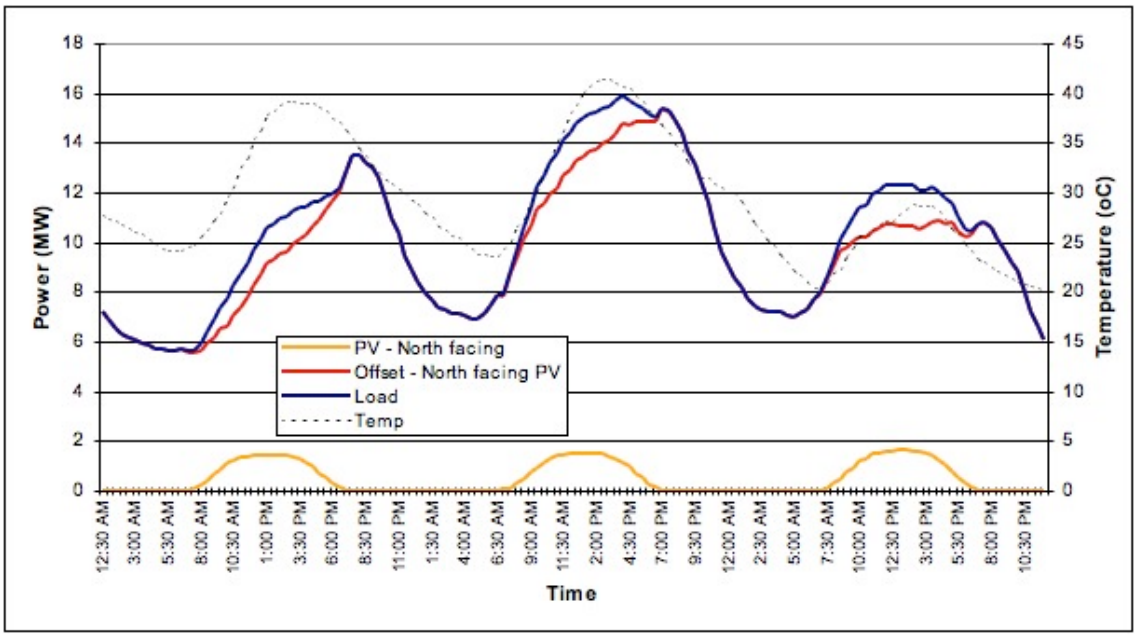

Figure 19: Autumn peak day (north-facing PV)
21st-23rd March 2004
North Perth TX2 Load, North Perth Simulated North-facing PV (2MW) and Net Load after PV Offset

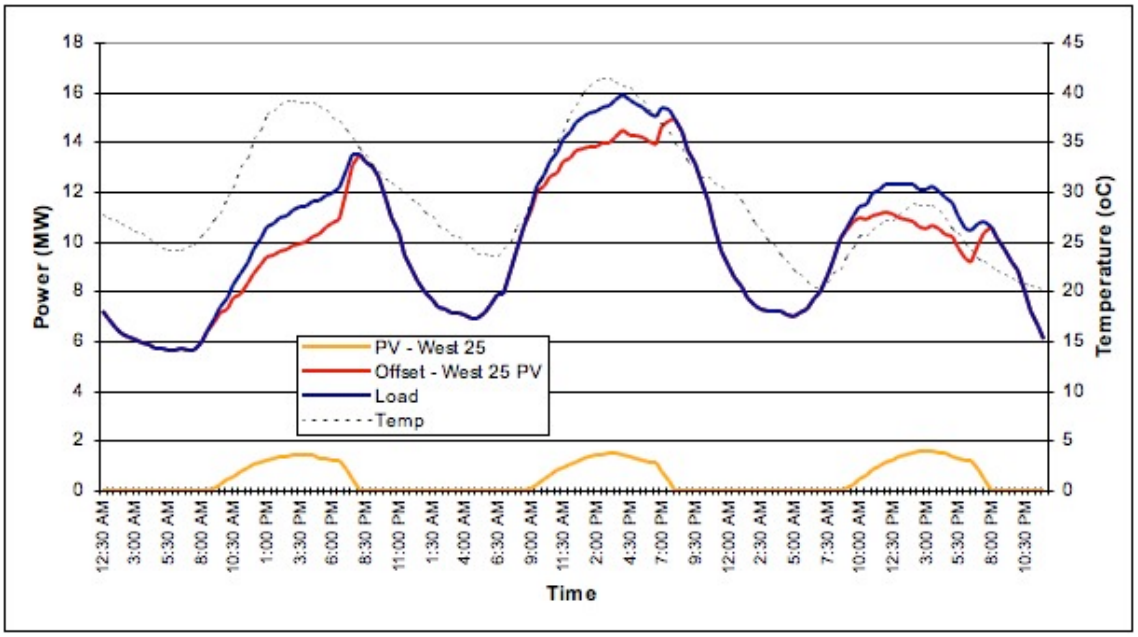

Figure 20: Autumn peak day (west-facing-25 PV)
21st-23rd March 2004
North Perth TX2 Load, North Perth Simulated West-facing-25 PV (2MW) and Net Load after PV Offset

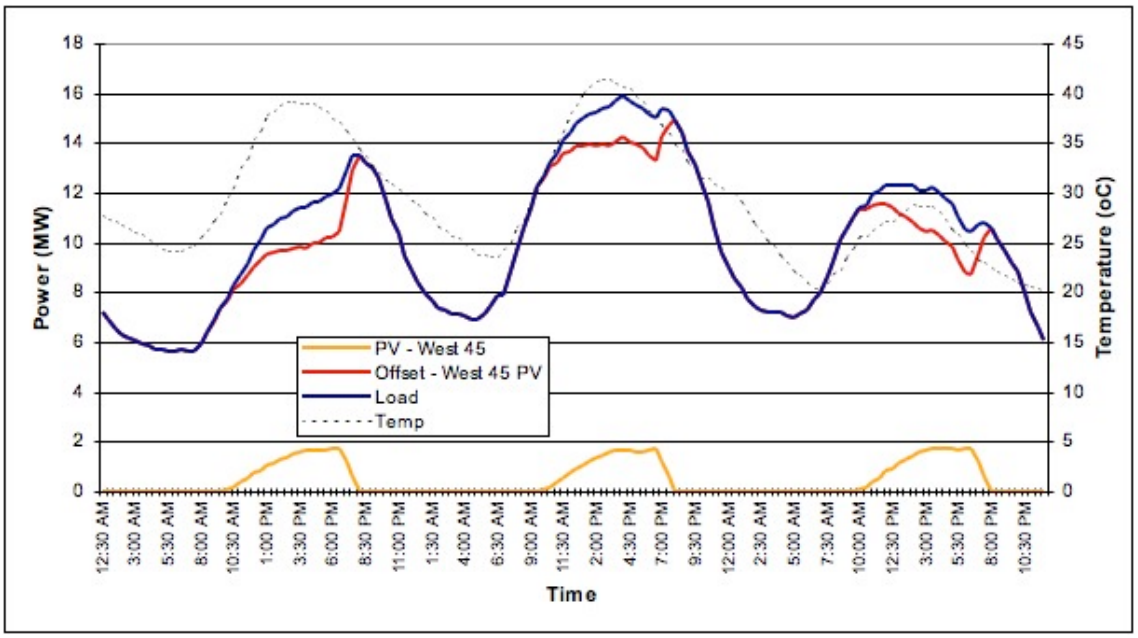

Figure 21: Autumn peak day (west-facing-45 PV)
21st-23rd March 2004
North Perth TX2 Load, North Perth Simulated West-facing-45 PV (2MW) and Net Load after PV Offset

Load duration curves

The load duration curve for North Perth TX2 is in Figure 22 and shows that the top 50% of the load occurred for less than 0.1% of the study period, while the top 10% occurred for 0.015% of this time.

Figure 23 shows the top 50 half hour load periods, together with the offset load duration curve assuming reduction by simulated north-facing PV or simulated west-facing PV at either of two tilt angles (25° and 45°). It can be seen that the simulated north-facing PV reduced the top three load periods the most, followed by west-facing-25 then west-facing-45. The rest of the top 10 load periods were reduced very little by any of the PV options because they all occurred early on a winter morning due to what appear to be operational changes by Western Power. 2MW of simulated north-facing PV changed the highest load period from 34.30MW to 33.17MW (a reduction of 1.13MW, meaning that 56.5% of the PV was contributing to load reduction at this time), the top 3 load periods were reduced by an average 1.13MW, and the top 10 load periods were reduced by an average 0.42MW.

Figure 24 shows the same load duration curves except that the offset periods now correspond to the load periods directly above them on the chart, and it can be seen that the 16 highest load periods are in the same order as in Figure 23.

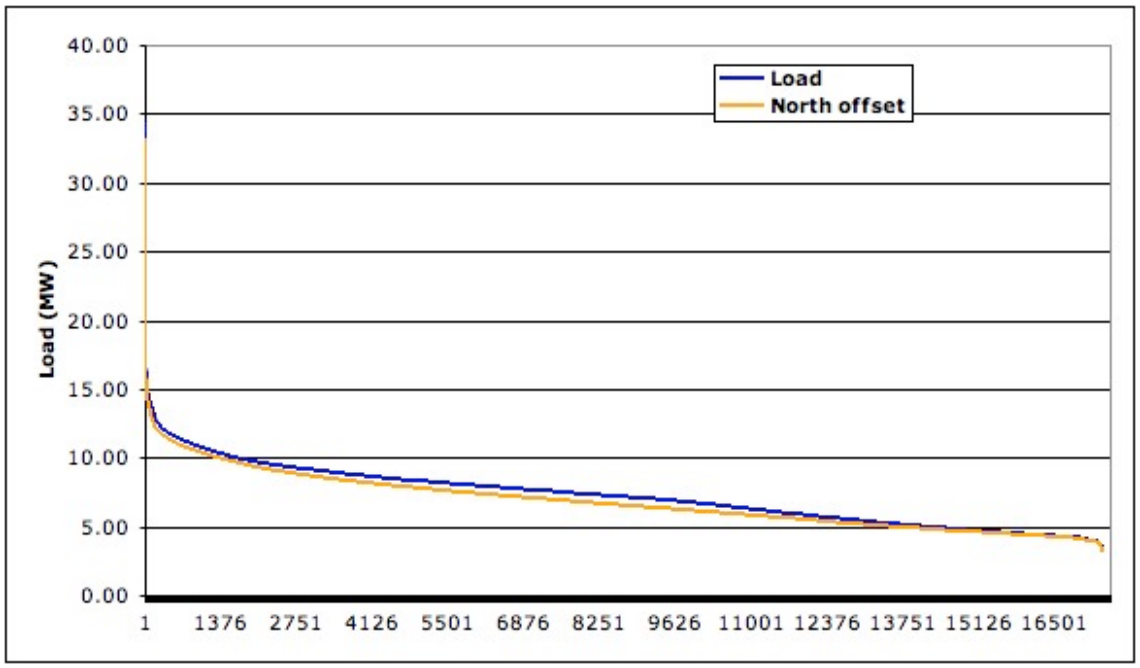

Figure 22: Load Duration Curve - July 2003 to June 2004
North Perth TX2 Load and North Perth TX2 Net Load after PV Offset (2MW)

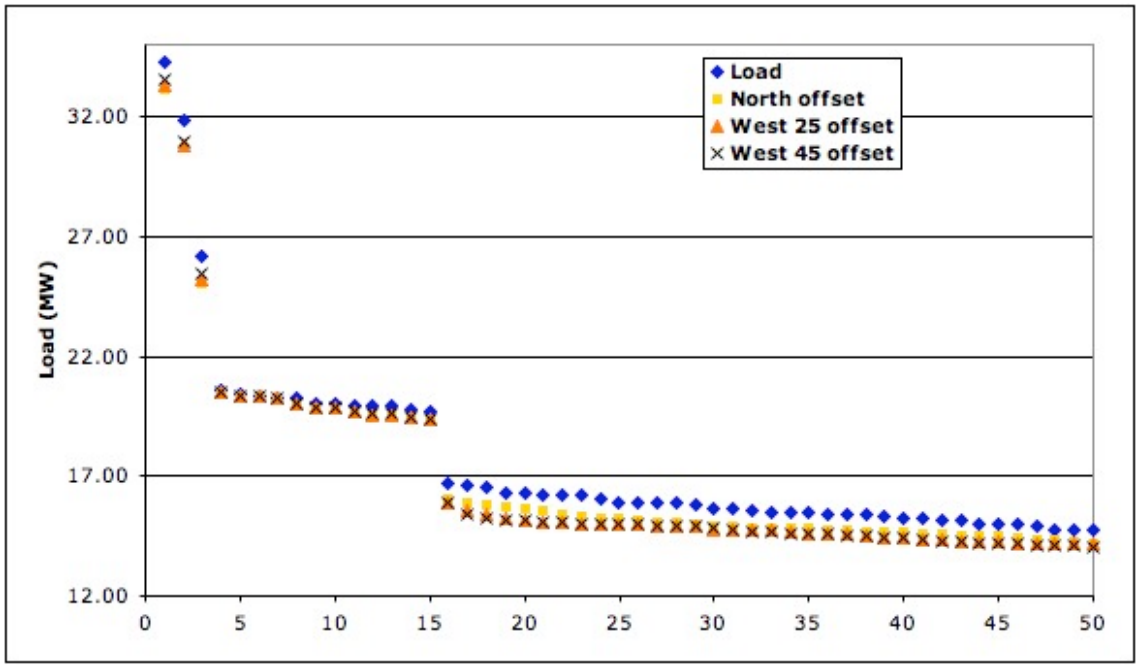

Figure 23: Load Duration Curve - top 50 load periods
North, and West (25° and 45° inclinations)
North Perth TX2 Load and North Perth TX2 Net Load after PV Offset (2MW)
July 2003 to June 2004

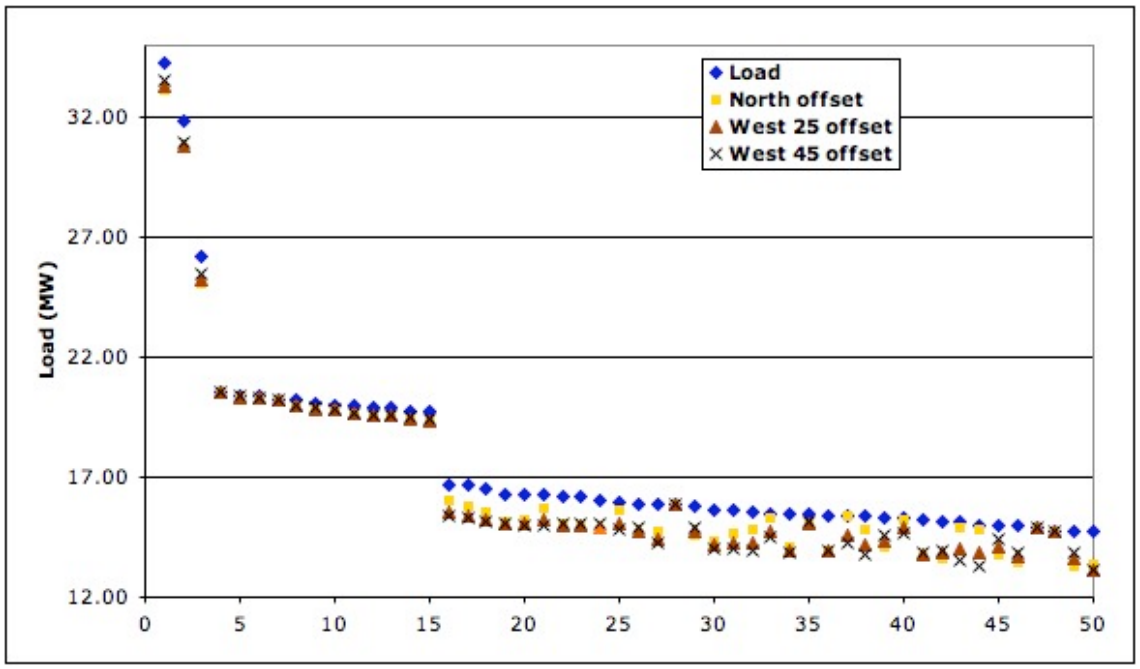

Figure 24: Load Duration Curve - top 50 load periods (linked)
North, and West (25° and 45° inclinations)
North Perth TX2 Load and North Perth TX2 Net Load after PV Offset (2MW)
July 2003 to June 2004

General correlation between PV Output and Load

Figure 25 shows the relationship between north-facing simulated PV output and the North Perth TX2 load at any one time, and shows limited correlation. The three data points between 25 and 35MW load correspond to the three highest load points on the 17th Dec 2003 (Figure 15), and the cluster of data points at 20MW load correspond to the peak load points on the 18th June 2004 (Figure 16). When the PV output is plotted against the offset load (ie. reduced load because of PV), the PV shifts the load points at the top of the chart to the left – see Figure 26.

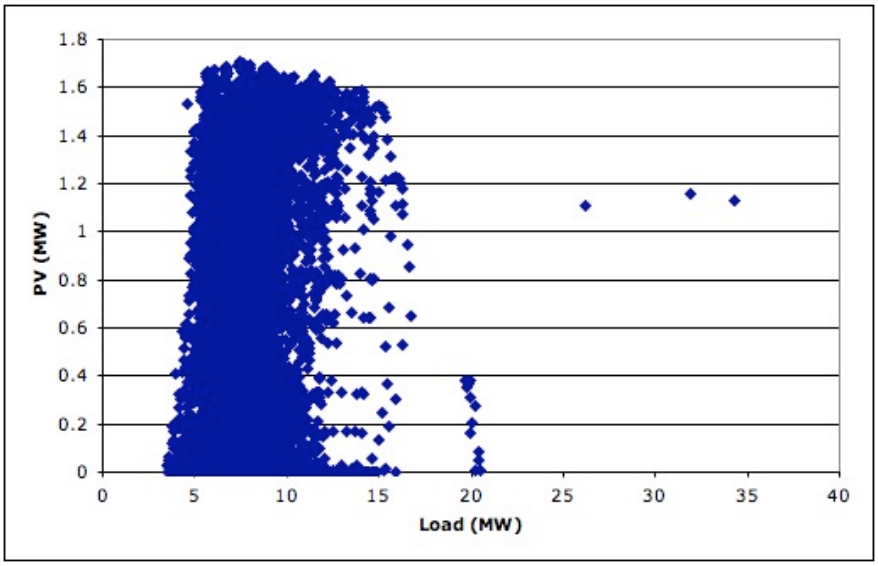

Figure 25: North Perth Simulated North-facing PV (2MW) vs North Perth TX2 Load
July 2003 to June 2004

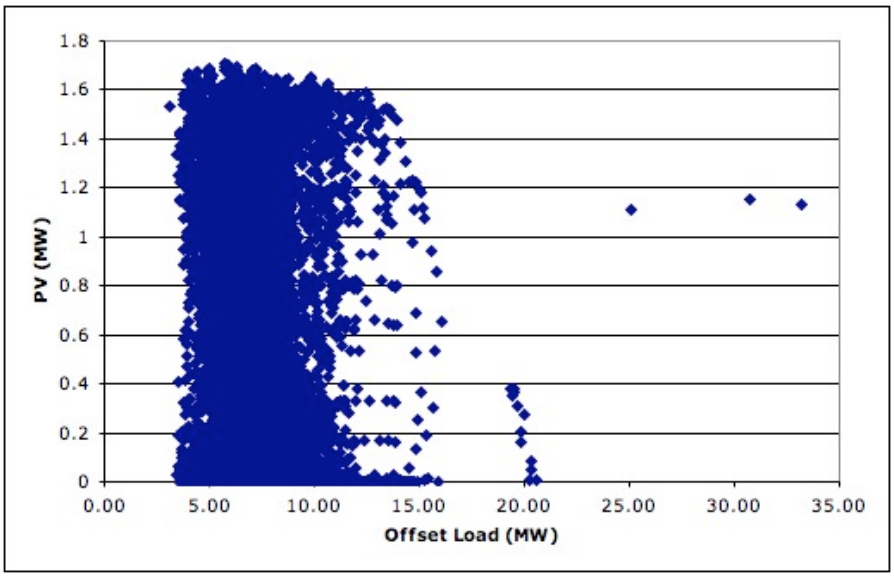

Figure 26: North Perth Simulated North-facing PV (2MW) vs North Perth TX2 Net Load after PV Offset
July 2003 to June 2004

Correlation with temperature

Figure 27 shows the relationship between the North Perth TX2 load and temperature, and shows signs of a classic residential load correlation, with load increasing at low temperatures due to winter heating needs and at high temperatures due to summer cooling needs. Figure 28 shows the relationship between simulated north-facing PV output and temperature and shows that PV tends to increase at higher temperatures, which would normally occur during the middle of the day – although note there are instances of zero PV output at high temperatures, presumably on hot summer evenings. The sudden cutoff around 1.6 to 1.7MW is likely an artefact of the PV simulation. Again the outlier data points correspond to the highest load points on the 17th Dec 2003 (Figure 15) and the 18th June 2004 (Figure 16).

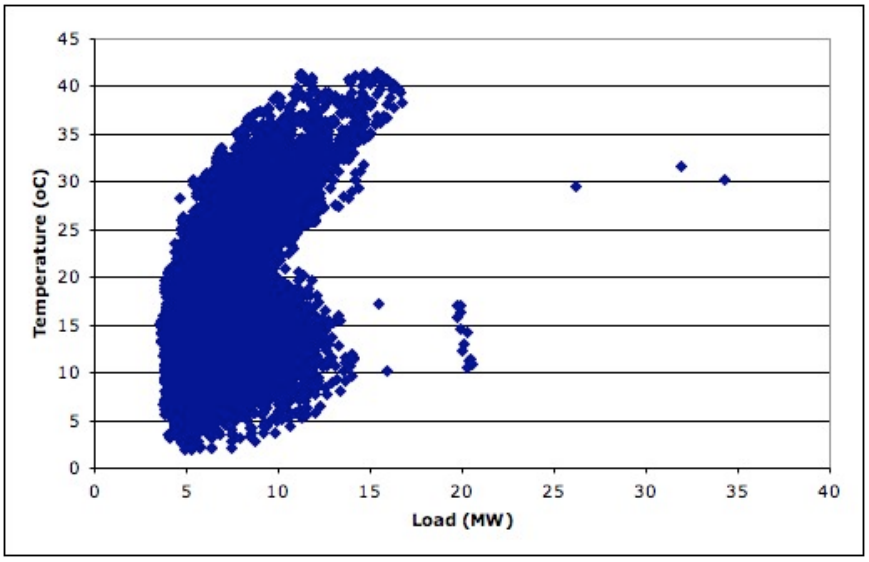

Figure 27: North Perth TX2 Load vs Temperature
July 2003 to June 2004

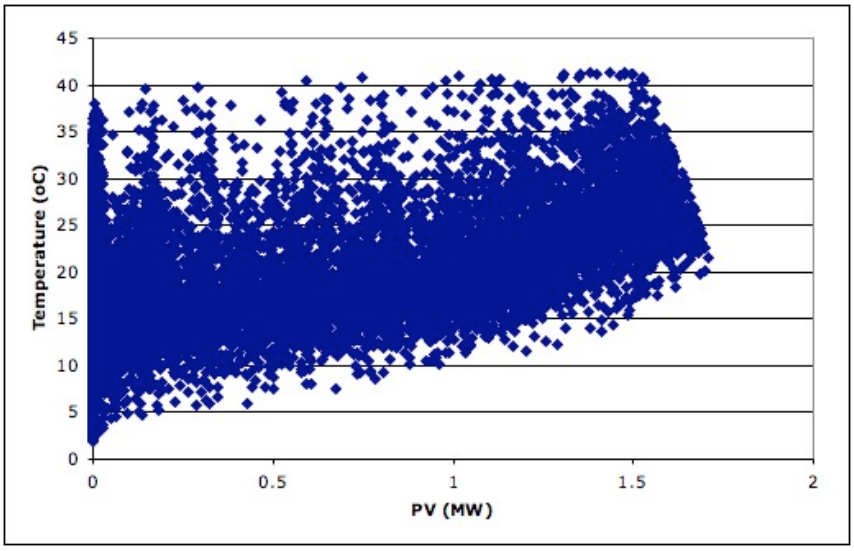

Figure 28: North Perth Simulated North-facing PV (2MW) vs Temperature
July 2003 to June 2004