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# CSIRO INTELLIGENT GRID CLUSTER

## PROGRESS REPORT

**Project P6: The Intelligent Grid in a New Housing Development**

**Period: July – December 2010**

**Third Progress Report Covering:**

Analysis of the Second 6 Monthly Data
Milestone M8


**Authors**

Prof. Wasim Saman
Dr. David Whaley
Dr. Edward Halawa
Mr. Lachlan Mudge


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Institute for Sustainable Systems and Technologies

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# Acknowledgements

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# EXECUTIVE SUMMARY


Under the CSIRO Energy Transformed Flagship, a three year collaborative research project was established between five Australian universities: University of Technology, Sydney, University of Queensland, University of South Australia, Queensland University of Technology and Curtin University. University of South Australia is working on the P6 project titled: The Intelligent Grid in a New Housing Development. This project started in July 2008 and is due for completion in June 2011.

This report summarises the project progress for the period July - December 2010 which covers the 8th project milestone: analysis of the second 6 monthly monitoring data (M8).

As of the end of November 2010, 39 houses (30 occupied homes and 9 unoccupied homes, including the Sustainability Centre + Mews) have been completed. Of the 30 occupied homes, 9 homes have detailed monitoring systems, whilst the remaining 23 homes having general monitoring system. Ten homes are currently being built with 3 having EcoVision systems installed but not yet commissioned.

As in the previous report, a selected set of the data collected has been processed, analysed and presented in this report. In order to present a broader picture of the thermal performance of the houses being monitored the results presented cover the whole period of data availability which spans from January to November 2010, although the milestone statement limits the scope of this report to "second six monthly data". Where necessary the data for a specific period is presented to highlight specific or interesting findings.

The results demonstrate that net zero energy has been realised for the period covered in the analysis, i.e. February 2009 – November 2010 for some houses which use electricity as the main source of energy and which also generate electricity through the solar photovoltaic panel. Overall – based on the limited data analysed so far - the average monthly fraction of solar PV panel contribution to provide electricity needs for the Green Village houses has provided 52.5% of the total electrical energy requirements.

A comparison has also been made between some thermal performance aspects of Green Village houses with those figures extracted from 6 houses in Mawson Lakes, which were monitored by the Sustainable Energy Centre during the period from 2001-2003 (Saman et al., 2003). The results show that on average, the Lochiel Park houses perform substantially better than Mawson Lakes houses in terms of net energy consumption and greenhouse emissions due to their higher star rating, energy efficient appliances, smart features and their local solar electricity generation. The results never the less need to be considered as initial findings and will be more reliable after a full 12 month analysis has been completed.

# Abbreviations

AuSES – Australia Solar Energy Society
DAS – Data Acquisition System
ETSA - The Electricity Trust of South Australia
GHG – greenhouse gases
LMC – Land Management Corporation
ONT – Optical Network Terminal
ONU - Optical Network Unit
PEB – Pro-environmental behaviour
PLC – Programmable Logic Controller
VPN – Virtual Private Network
WREC – World Renewable Energy Congress

# Key Words

Green village, energy rating, star rating, thermal comfort, smart metering, distributed generation, distributed energy resources, solar panel, peak load, water use; behavioural responses, house energy use, greenhouse gas emission, sustainable housing.

# 1 INTRODUCTION

This report outlines the work undertaken during the period July 2010 on the UniSA's iGrid Project P6: The Intelligent Grid in a New Housing Development.

The accomplished component of work is the following single milestone: (1) Analysis of the second six months data. However, for completeness, the analysis presented in this report covers the whole period of data availability, i.e. from January – November 2010.

To date, 36 homes have been completed which includes 29 occupied and 5 unoccupied homes, and the Sustainability Centre and its Mews. The 29 occupied homes have been handed over and occupied with 9 homes undergoing detailed monitoring and 20 homes with general monitoring. The monitoring systems of each home, regardless of general or detailed level of monitoring, has been commissioned, tested and appear to operating satisfactorily. However, a small number of houses has some minor outstanding issues, which are currently being addressed. The current status of the monitoring and these related issues are discussed in Section 2.

Regular recording and processing of the monitoring data has been carried out since early January 2010 with the length and quality of data being recorded varying from house to house. As a result of considerable effort by the research team, the recording and processing of monitoring data is now progressing relatively smoothly. Substantial valuable data is now being gathered and analysed, although until recently, the network settings of optical network terminals have restricted access to some house data. This is further discussed in Section 3 and has largely been resolved.

For the purpose of presentation of this report, the data available for 9 houses with detailed monitoring (identified as houses L1TS, L20Z, L3TS, L4FO, L5SZ, L6FS, L22SS, L23SS and L26ST) and general monitoring (identified as houses L30OO, L35OT, L7OF, L8OS, L9OE, L10ON, L34TT, L11TE, L14TO, L24TT, L15TT, L16TN, L17FF, L18FT, L19FF, L20FF, L21FE, L29FN, L25SS and L36SS) has been analysed and presented in Section 4. The data analysed covers the period January – November 2010. The analysis deals with the various aspects of the data being monitored which include: instantaneous peak power demand, thermal comfort and greenhouse gas emissions in addition to electrical and gas consumption.

To get an idea about the thermal performance improvement brought about by the integrated approach of passive design, energy efficient appliances, local renewable energy generation and the introduction of a number of 'smart' features in the Green Village homes, comparisons are made with the figures extracted from 6 houses in Mawson Lakes houses built in the early 2000's (Saman et al., 2003). This can be found in Section 5.

# 2 CURRENT STATUS OF THE HOUSE MONITORING

Full description of the monitoring and data logging system has been presented at a previous report (Saman et al., 2010). In this report, current status of house monitoring is briefly described.

## 2.1 DATA LOGGING AT DETAILED MONITORED HOMES

To date, 9 fully monitored homes have been occupied and their data is being collected and checked; all 9 houses appear to be collecting valid data. All homes have a minimum star rating of 7.5 (6 homes) and a maximum of 7.6 (4 homes). All have 3 bedrooms, expect one with 4 bedrooms. All have 2 bathrooms and the majority with 3 toilets with the exception of 2 with 2 toilets. All houses use gas boosted solar hot water systems.

Table 1 summarises the specifications and appliances used in detailed monitored houses. At the time of writing this report some data was not available.

## Table 1 – Detailed Monitored Houses – Specification and Appliances

| | | | | | No. Rooms | | | Cooling | | | Hot Water | | | PV Panel | | Lighting | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Dwelling Type | AccuRate Rating | HFA (sqm) | CFA (sqm) | Bed | Bath | Toilet | Type | Input Power (kVA) | Heating Type | Hot Water Size (L) | Hot Water Energy (MJ/hr) | HW Collector Area (sqm) | Min cap (kW) | Provided (kW) | No. of lights | Total wattage |
| L3TS | T | 7.5 | 178.4 | 142.9 | 3 | 2 | 3 | Actron | 4 | RC | 260 | 26 | 4.4 | 1.78 | 2.11 | 27 | 405 |
| L1TS | T | 7.6 | 173.8 | 137 | 3 | 2 | 3 | R/C & Underfloo r | 3 | RC - Gas | 250 | 199 | 4 | 1.74 | 2 | 25 | 324 |
| L4FO | T | 7.5 | 194.5 | 150.3 | 3 | 2 | 3 | Actron | 4 | RC | 260 | 26 | 4.4 | 1.95 | 2 | 66 | |
| L6FS | D | 7.7 | 174.2 | 127.8 | 3 | 2 | 3 | N/A | N/A | N/A | 250 | 199 | 4 | 1.74 | 1.89 | 24 | 285 |
| L5SZ | D | 7.6 | 142.0 | 88.8 | 3 | 2 | 2 | N/A | N/A | N/A | 250 | 199 | 4 | 1.42 | 1.89 | 19 | 168 |
| L26ST | D | 7.6 | 208.6 | 168.4 | 3 | 2 | 3 | | | | | | | 2.09 | | 25 | |
| L22SS | D | 7.5 | 240.8 | 168.9 | 4 | 2 | 2 | EC | | Hydronic/Spli t | 260 | 26 | 4.4 | 2.41 | 2.67 | 81 | 1215 |
| L23SS | D | 7.5 | 219.3 | 162.6 | 3 | 2 | 3 | N/A | | N/A | 200 | 200 | 4.142 | 2.19 | 2.4 | | |

Dwelling type codes: A = Apartment, D = Detached, M = Mews, T = Terraced, TH = Townhouse, HFA = Habitable Floor Area, CFA = Conditioned Floor Area, Cooling / Heating Type codes: EC = evaporative Cooler, RC = Reverse cycle, HY = hydronic

Table 2 shows the current status of the measuring devices installed in each home. As shown, most sensors have worked well whilst some (main and recycled water, rain level sensors) need to be rectified. Although some data logging has started since January 2009 (Saman et al., 2009), reliable data has not been available until January 2010 when the firmware and software of the EcoVision systems were upgraded and all previously collected data was found to be invalid.

Table 3 shows a summary of the status of the individual appliance / power circuit metering and gas sensors installed in the detailed monitored houses. It is seen that some individual appliance / power meters are not connected as expected and that only one house of the nine has a second gas meter and sensor installed adjacent to the hot water system. Note that one house also currently has an issue with the mains gas meter / sensor and hence its total gas readings are invalid. The UniSA team is planning on auditing the detailed houses early in the new year to identify any wiring issues that can be corrected without the aid of an electrician, i.e. that will start giving actual data instead of zero all the time.

**Table 2 - Status of Sensors at Detailed Monitored Homes**

| House ID | Date Sensors Checked | Commissioned | | Digital Sensors | | | | | | | | Analogue sensors | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System | Load Mangt | Water Meters | | | | Gas | Electricity | | | Rain level | Temp. / RH | | |
| | | | | Mains | Recyc. | Hot Use | Sup | | Solar | Imp | Exp | | 1 | 2 | 3 |
| L2OZ | 16/03/2010 | 03/02/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | × | ✓ |
| L3TS | 16/03/2010 | 16/02/2010 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ |
| L1TS | 16/03/2010 | 12/01/2010 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L4FO | 16/03/2010 | 19/01/2010 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L6FS | 16/03/2010 | 11/02/2010 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ |
| L5SZ | 30/04/2010 | 19/01/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ |
| L26ST | 02/08/2010 | 02/07/2010 | ✓ | ✓ | × | × | × | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ |
| L22SS | 09/06/2010 | 09/06/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | × | × | × |
| L23SS | 04/06/2010 | 04/06/2010 | ✓ | ✓ | ✓ × | ✓ | ✓ | × | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ |

**Table 3 - Status of Individual Appliance / Power meters and Gas Sensors at Detailed Monitoring Homes**

| House ID | Energy (kWh) | | | | | | | | | | | | | Gas | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Light 1 | Light 2 | Total Lighting | AC | Pool / Spa | Laundry | Oven | DW | Kitchen | Fridge | Living | General | Total Gen | Hot Water | Total |
| L2OZ | ✓ | ✓ | ✓ | ✓ | × | × | ✓ | ✓ | × | × | ✓ | × | ✓ | × | ✓ |
| L3TS | ✓ | ✓ | ✓ | ✓ | × | × | ✓ | ✓ | × | × | ✓ | ✓ | ✓ | × | ✓ |
| L1TS | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | × | ✓ |
| L4FO | ✓ | ✓ | ✓ | ✓ | × | × | ✓ | ✓ | × | × | ✓ | × | ✓ | ✓ | ✓ |
| L6FS | ✓ | ✓ | ✓ | ✓ | × | × | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | × | ✓ |
| L5SZ | ✓ | × | ✓ | × | × | × | × | × | ✓ | × | ✓ | × | ✓ | × | ✓ |
| L26ST | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | × | ✓ | × | ✓ | ✓ | × | ✓ |
| L22SS | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ |
| L23SS | ✓ | × | ✓ | ✓ | × | ✓ | ✓ | × | × | ✓ | × | ✓ | ✓ | × | × |

DW = Dishwasher

## 2.2 DATA LOGGING AT GENERAL MONITORING HOMES

Of the 106 homes to be monitored, 96 will have general monitoring systems installed. To date, 27 homes have the monitoring systems installed, 7 of which are not occupied. In addition, the data for 2 of the latter houses cannot yet be accessed. Of the 96 general monitoring homes being or to be built, 26 are terraced, 16 are apartments, 3 are townhouses and the remaining 43 are detached homes. Currently 10 houses are being built and are at different construction stages. Three have recently been completed, one of which is occupied, however it is not being monitored yet. Due to varying stages of construction or construction planning, the complete information regarding the star rating, number of bedrooms, bath rooms and toilets of these houses is not available at the time of completion of this report. All homes, however, are expected to have a minimum star rating of 7.5, the minimum requirement stipulated by the design guidelines and to adhere to other requirements stipulated in the guidelines.

Table 4 shows the latest status of the measuring devices installed in each home. As shown, most sensors have worked well whilst some, e.g. main and recycled water, import and export and gas sensors, need to be rectified. Although data logging has started since January 2009 (Saman et al., 2009), reliable data has not been available until January 2010 when the firmware and software of the EcoVision systems were upgraded and all previously collected data was found to be invalid.

**Table 4 - Status of Sensors at General Monitoring Homes**

| House ID | Date Sensors Checked | Commissioned | | Digital Sensors | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System | Load Manag't | Water Meters | | | | Gas Meter | Electricity | | |
| | | | | Mains | Recyc. | Hot Use | Suppl | | SOLAR | Imp | Exp |
| L30OO | 30/08/2010 | 26/08/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L35OT | 12/10/2010 | 12/10/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | × | × |
| L7OF | 30/04/2010 | 18/02/2010 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L8OS | 16/04/2010 | 04/03/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L9OE | 14/04/2010 | 18/02/2010 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L10ON | 12/04/2010 | 03/03/2010 | ✓ | ✓ | ✓× | × | × | N/A | ✓ | ✓ | ✓ |
| L34TT | 30/09/2010 | N/A | ×××× | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L11TE | 16/03/2010 | 27/01/2010 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L13TN | 16/03/2010 | 10/09/2009 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L12TN | 16/03/2010 | 03/11/2009 | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ |
| L14TO | 14/04/2010 | 04/02/2010 | ✓ | × | ✓ | × | ✓ | × | ✓ | ✓ | ✓ |
| L24TT | 27/10/2010 | N/A | ×××× | ✓ | ✓ | ✓ | ✓× | ✓ | ✓ | ✓ | ✓ |
| L15TT | 17/03/2010 | 11/03/2010 | ✓ | ✓ | ✓ | ✓ | × | × ✓ | ✓ | ✓ | ✓ |
| L16TN | 06/05/2010 | 06/05/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L17FF | 26/05/2010 | 26/05/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ |
| L18FT | 06/10/2010 | N/A | ×××× | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L19FF | 17/03/2010 | 17/02/2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L20FF | 17/03/2010 | 11/02/2010 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L21FE | 17/03/2010 | 18/12/2009 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L29FN | 26/08/2010 | 26/08/2010 | ✓ | ✓ | ✓× | ✓ | ✓ | ✓ | × | × | × |
| L27SF | 20/07/2010 | 20/07/2010 | ✓ | ✓ | ✓× | ✓ | ✓ | N/A | ✓ | ✓ | ✓ |
| L25SS | 02/06/2010 | 02/06/2010 | ✓ | ✓ | ✓× | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L33ST | 07/09/2010 | 26/08/2010 | ✓ | ✓ | ✓× | ✓ | ✓ | ✓× | ✓ | ✓ | ✓ |
| L31ST | 31/08/2010 | 31/08/2010 | ✓ | ✓ | ✓× | ✓ | ✓ | N/A | ? | ✓ | ? |
| L36SS | 28/10/2010 | 28/10/2010 | ✓ | ✓ | ✓× | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| L32SN | **31/08/2010** | 31/08/2010 | ✓ | ✓ | ✓× | ✓ | ✓ | ✓× | ✓ | ✓ | ✓ |
| L28EO | 18/08/2010 | 18/08/2010 | ✓ | ✓ | ✓× | ✓ | ✓ | ✓× | ✓ | ✓ | ✓ |

All houses uses gas boosted solar hot water systems. Table 5 shows the specifications and appliances in detailed monitored houses.

## Table 5 – General Monitoring House – Specification and Appliances

| | | | | | No. Rooms | | | Cooling | | | Hot Water System | | | PV Panel | | Lighting | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Dwelling Type | RATING | HFA (sqm) | CFA (sqm) | BED | BATHH | TOILET | Type | Input POWER(kVA) | Heating Type | Hot Water Size (L) | Hot Water Energy (MJ/hr) | HW Collector Area (sqm) | Solar Cell Capacity min required (kW) | Solar Cell Capacity provided (kW) | No. | Total wattage |
| L300O | D | 7.5 | 204.3 | 133.1 | 4 | 2 | 3 | RCM | 4 | RC | 250 | 199 / 17 | 4 | 2.043 | 2.4 | 23 | 280 |
| L350T | D | | 202.7 | | | | | | | | | | | 2.027 | | | |
| L70F | D | 7.5 | 233.7 | 149.8 | 4 | 3 | 3 | Actron | 4 | RC | 260 | 26 | 4.4 | 2.337 | 2.33 | 62 | 930 |
| L80S | D | 7.5 | 235.5 | 153.4 | 3 | 2 | 2 | RCM | 4 | RC | 250 | 199 / 17 | 4 | 2.355 | 2.4 | 27 | 386 |
| | D | | 175.3 | | | | | | | | | | | 1.753 | | | |
| L90E | D | 7.5 | 184.4 | 114.9 | 3 | 1 | 2 | Actron | 4 | RC | 260 | 26 | 4.4 | 1.844 | 2 | 53 | 795 |
| L100N | D | 7.9 | 235.6 | 165.1 | 3 | 3 | 3 | RC | 4 | RC | 250 | | 2.8 | 2.356 | 4.2 | 25 | 280 |
| L34TT | D | 7.5 | 247.0 | 200.5 | 3 | 2 | 3 | MH ducted & Mini-SMMS | 4 & 8 | RC | 260 | 26 | ? | 2.470 | 2.67 | 60 | |
| L11TE | T | 8.4 | 175.6 | 106.4 | 3 | 2 | 3 | RCM | 3 | RC | 250 | 199 / 17 | 4 | 1.756 | 1.89 | 30 | 264 |
| L14TO | T | 7.5 | 174.2 | 134.7 | 3 | 2 | 3 | RCM | | RC | 250 | 199 / 17 | 4 | 1.742 | 1.89 | 23 | |
| L24TT | T | 7.5 | 194.5 | 150.3 | 3 | 2 | 3 | Actron | 4 | RC | 260 | 26 | 4.4 | 1.945 | 2 | 39 | 585 |
| L15TT | D | 7.6 | 197.1 | 111.8 | 4 | 3 | 4 | EC | ???? | None | 300 | ???? | 3.96 | 1.971 | 2.4 | ???? | ???? |
| L16TN | T | 7.6 | 172.6 | 111.9 | 3 | 2 | 3 | Actron | 4 | RC | 260 | 26 | 4.4 | 1.726 | 2 | 33 | 495 |
| L17FF | T | 7.5 | 182.7 | 144.3 | 3 | 2 | 3 | Actron R/C | max 4kVA | | 260 | 26 | 4.4 | 1.827 | 2 | | |
| L18FT | T | 7.7 | 182.6 | 136.9 | 3 | 2 | 2 | Actron R/C | 3.98 | RC | 260 | | | 1.826 | 2000 | 32 | |
| L19FF | T | 7.5 | 224.4 | 171.8 | 4 | 2 | 3 | Actron | max 4kVA | RC | 260 | 26 | 4.4 | 2.244 | 2.33 | 27 | 405 |
| L20FF | T | 7.5 | 203.7 | 163.1 | 4 | 2 | 3 | Actron | 4 | RC | 260 | 26 | 4.4 | 2.037 | 2.4 | 49 | 735 |
| L21FE | D | 7.5 | 174.2 | 127.8 | 3 | 2 | 3 | RC | max 4kVA | RC | 250 | 199 / 17 | 4 | 1.742 | 1.89 | 30 | 320 |
| L29FN | D | 7.5 | 173.0 | 130.3 | 3 | 2 | 3 | | | | 250 | 199 / 17 | 4 | 1.730 | 2 | 24 | 256 |
| L25SS | D | 7.7 | 182.0 | 147.1 | 3 | 2 | 3 | | | | | | | 1.820 | | 30 | |
| L36SS | D | 7.5 | 186.6 | 145.3 | 3 | 3 | 4 | none | 0 | none | 200 | 200 | 4.142 | 1.866 | 2.4 | | |

Dwelling type codes: A = Apartment, D = Detached, M = Mews, T = Terraced, TH = Townhouse, HFA = Habitable Floor Area, CFA = Conditioned Floor Area, Cooling / Heating Type codes: EC = evaporative Cooler, RC = Reverse cycle, RCM = Reverse Cycle Multihead, HY = hydronic

# 3 COMMISSIONING ISSUES AND SOLUTIONS

The issues reported in the previous report (Saman et al., 2010) have largely been resolved which makes it possible to collect, process and analyse data more smoothly. This has been assisted by the completion of the training of one of the UniSA personnel on database handling. The main hurdle to the data monitoring is the slow pace of construction and handover of houses to the occupants. As reported in the introduction section, up to now, the number of houses that have been handed over to the occupants is 30 of the total number of houses. Based on the current pace of construction, the total number of houses which will have the monitoring systems installed at the end of June 2011 will likely be 45 houses. The 23 low income apartments are currently being built and these should be completed within 6 months.

To get a rather comprehensive analysis of the overall performance, the length of data analysis should be no less than 12 months to get at least the seasonal picture of the performance. Based on this, the number of houses involved in the analysis to be reported in the final report due in June 2011 will be around 40 – 50 with data length varying between 3 – 18 months.

Although the majority of issues that cause delays in valid data collection (as discussed above) have been addressed, one issue has surfaced since the release of the previous report. This issue, discussed below, has delayed the collection of (and the subsequent processing and analysing of) the data.

## 3.1 DATA ACCESS ISSUES

As discussed in the previous report (Saman et al., 2010), some of the optical network terminals (ONT) installed at houses have not been correctly configured. In particular, port 4 of the ONT is required to be provisioned by OptiComm staff, to allow the EcoVision system to join the virtual private network (VPN).

In the past where ONTs have been suspected of being incorrectly configured, a phone call to the OptiComm Network Operations Centre (NOC) has been made, where consultants were usually able to configure the port and correct the situation within 15 minutes. This method, however, sometimes proved to be unsuccessful, as helpdesk personnel had stated that the property (where the phone call was made from), did not match their property database. In such instances, the NOC staff were convinced that their database was correct and as such the ONT installed at the property was not properly configured, and the EcoVision was still unable to join the VPN.

In August 2010, OptiComm announced that they were moving away from a telephone logging system, to an online portal. The portal was to be used as it was claimed that technical issues could be processed and addressed in a timely manner. However, this process caused significant delays for UniSA's monitoring program, for the following reasons:

- a UniSA account was required. This took about 2 week to create as the retail service provider (RSP) relationship manager, the NOC staff and UniSA personnel discussed the issue of provisioning port 4, and how that could be logged in the OptiComm Portal and how NOC staff could address this.
- The OptiComm database was found to contain several errors, including:
    - Duplicate property (and or lot) entries,
    - Missing entries,

    - Incorrect entries (suburb, lot number, street name, street type, house number, estate name, state and postcode).

  The database entries were corrected by the RSP relationship manager, which took about 4 weeks. There were disagreements between UniSA staff and the RSP relationship manger regarding 3 database entries, which took an additional week to correct.

- Logging ONT port 4 provision requests. This took half a day as requests were made for all 36 properties. These requests were processed the following day.

Since moving to the online portal, correcting several incorrect database entries, and logging ONT port 4 provisioning requests, 5 more properties have been able to join the VPN. In one case, a detailed monitored house, which was commissioned in July, was only made accessible in November.

## 4 ANALYSIS OF THE MONITORING DATA

The results presented cover the period from January 2010 through to November 2010. The varying starting dates of availability of data makes it difficult to present a comprehensive analysis of the effect of the integrated approach of passive design, energy efficient appliances, local renewable energy generation and the introduction of a number of smart features in the Green Village homes on the overall performance of each of the houses being monitored. Despite this limitation, some significant trends and findings are emerging and are presented and discussed in this report.

### 4.1 Peak Power Profiles

Table 6 shows monthly maximum instantaneous power demand for three house (lots L1TS, L4FO and L5SZ). As seen, for lot L1TS the peak demand occurred both in February and July (Summer and winter peaks), whilst for lot L4FO there was only a significant summer peak which occurred in February. On the other hand, instantaneous power demands for lot L5SZ are relatively flat throughout the year. These are the only houses that have reliable data from February 2010 onwards.

**Table 6 – Peak Instantaneous Power Demand (kW)**

| | lot L1TS | lot L4FO | lot L5SZ |
|---|---|---|---|
| Jan | - | - | - |
| Feb | 7.020 | 9.105 | 5.580 |
| Mar | 5.985 | 5.085 | 5.445 |
| Apr | 6.975 | 5.400 | 5.220 |
| May | 4.890 | 4.800 | 4.800 |
| Jun | 5.760 | 4.935 | 5.130 |
| Jul | 7.275 | 7.020 | 5.310 |
| Aug | 6.360 | 7.230 | 5.250 |
| Sep | 4.815 | 5.340 | 5.040 |
| Oct | 5.220 | 4.725 | 4.650 |
| Nov | 5.970 | 6.120 | 4.515 |
| Dec | | | |

Figure 1 shows the daily power demand profiles at the dates of occurrence of the peak demands, i.e. on 19 July, 26 February and 3 February 2010. For lot L1TS the winter peak demand occurs both early in the morning and in the late afternoon while for lots L4FO and for lot L5SZ the summer peak occurred in the afternoon/evening. Note that lot L5SZ uses evaporative cooling.

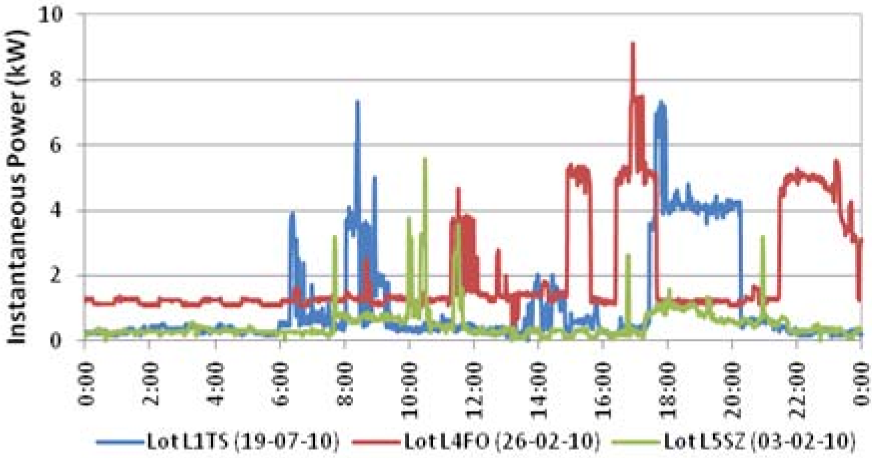


**Figure 1 - Peak Instantaneous Power Profiles for Three Houses (Lot L1T1S, L4FO and L5SZ)**

The sources of these peak demands are shown in Figures Figure 2, Figure 3, and Figure 4, respectively. For lot L1TS the morning peak demand was caused by the simultaneous operation of the oven and laundry whilst the afternoon peak demand was caused by the general power and oven. For Lot L4FO, the summer peak demand was caused by the AC unit, dishwasher and oven. The peak demand profile for Lot L5SZ constitutes the demand from the living room which most probably came from television, computer, home theatre units etc. It should be noted that this house was rarely occupied during the day and the fact the it uses an evaporative cooler explains the reason why its peak, which occurred in February was lower as it was not exacerbated by the air conditioner.

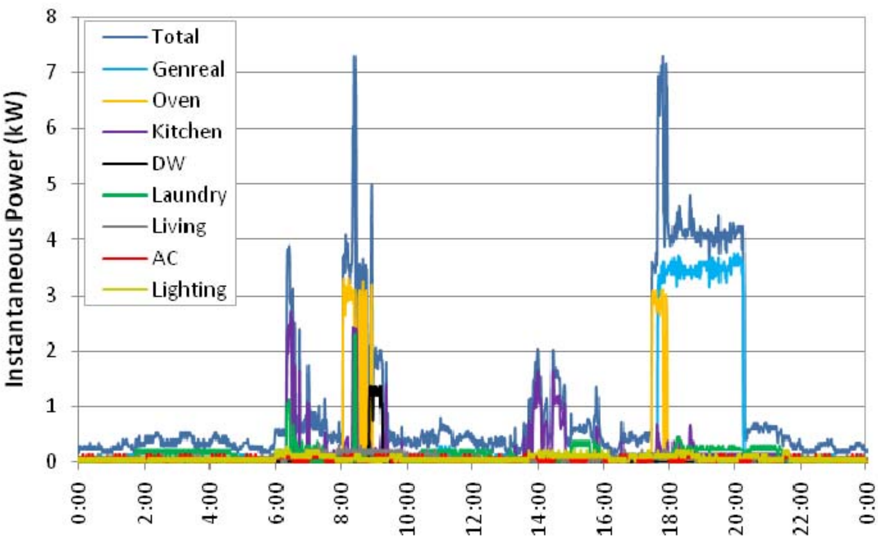


**Figure 2 - Lot L1TS Electricity Peak Demand Breakdown**

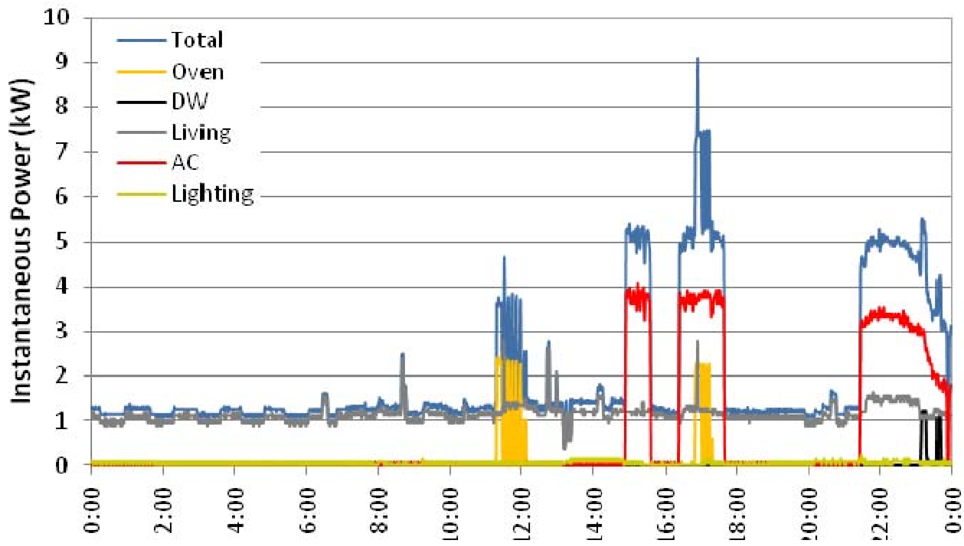


**Figure 3 - Lot L4FO Electricity Peak Demand Breakdown**

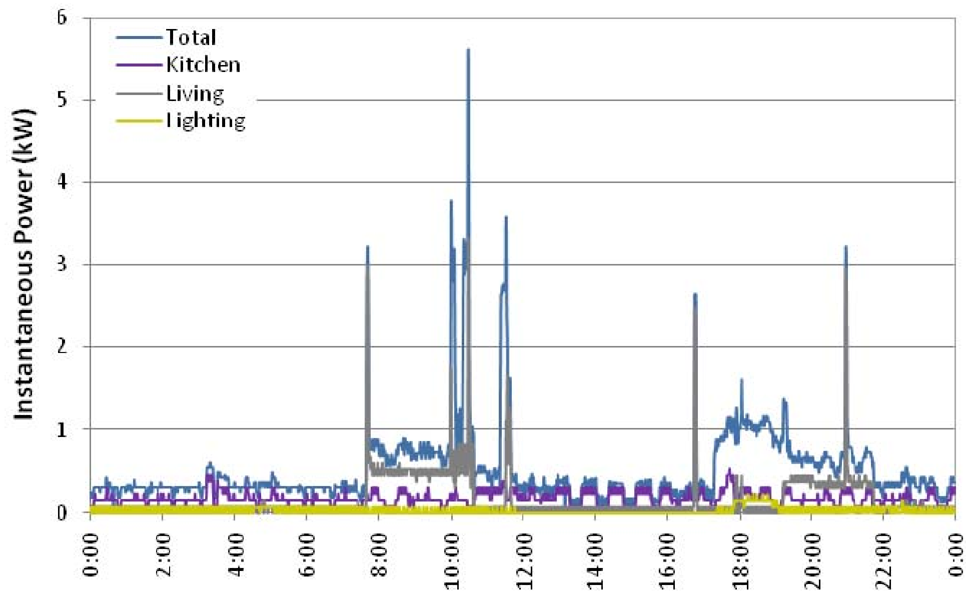


**Figure 4 - Lot L5SZ Electricity Peak Demand Breakdown**

The figures presented here have come from very small number of houses. Therefore at this stage, any general conclusions cannot be made.

## 4.2 Energy consumption/generation

Figure 5, Table 7 and Figure 6 summarise the monthly average total electrical energy consumption, electricity generated by the solar PV panels, total electricity imported from and exported to the grid and the net electricity used for the period: January – November 2010 for the houses with detailed and general monitoring with varying starting dates of data availability. The first point worthy of note is the increasing number of houses involved in the analysis from the start of the data recording in January (1 house) to the end of November (27 houses)[1].

As shown, the monthly average total electrical consumption ranges from 348.66 kWh in November to 587.6 kWh in June. In June, the PV panels generated only slightly over a quarter of the electricity required whilst in November almost 90% of the electricity requirement came from the PV panels. For the period monitored, the average net monthly electricity consumption is 214.4 kWh with 53.8% of the consumption being generated on the roofs of the houses. Further data from increased number of houses involved in the analysis is required before a more definite conclusion can be drawn as to the contribution of solar PV panels to reduction on the reliance of the houses on the conventional grid and reduction in the GHG emissions.

Figure 5 shows the total electricity consumption and solar PV electricity production for lot L10ON for the period: May – November 2010 where the PV system consistently generated more energy than the householders consume. This house has a larger PV system than most (4.2 $kW_p$) to compensate for the use of electric boosted solar hot water system.

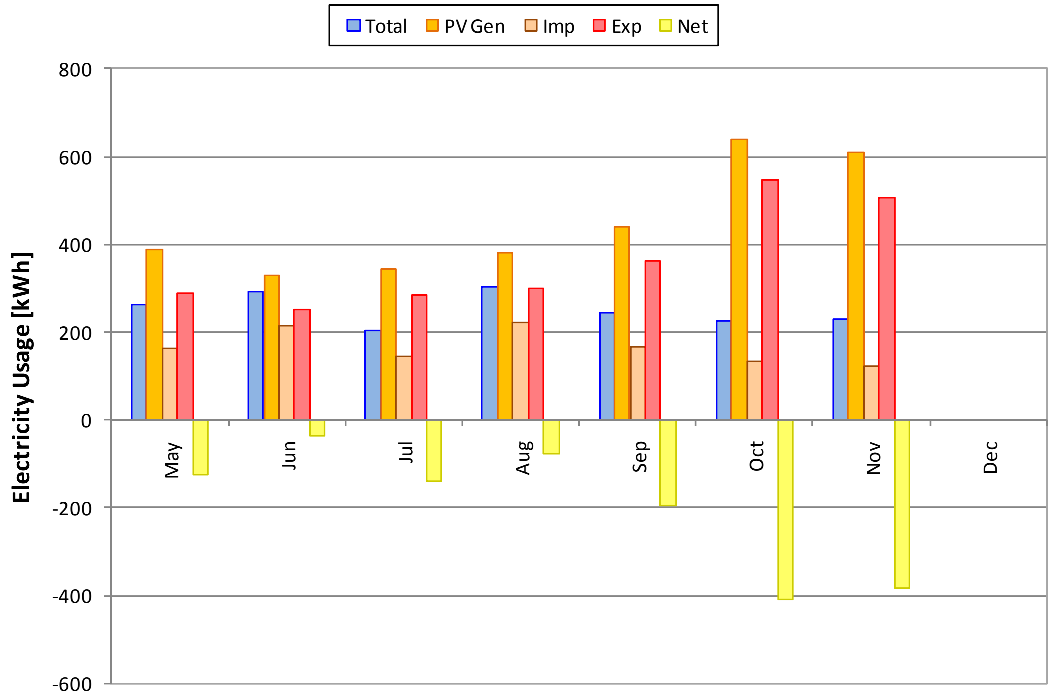


**Figure 5 – Total Electricity Consumption and Solar PV Electricity Production for lot L10ON for the Period: January – November 2010**

1 The number in the square bracket after the name of the month is the number of houses involved in the analysis

**Table 7 – Total Electricity Consumption and Solar PV Electricity Production for the period: January – November 2010**

| Month | No. of houses | Total Elec Usage [kWh] | Total PV gen'n [kWh] | Total Import from Grid [kWh] | Total Export to Grid [kWh] | Net | Percentage local Generation % |
|---|---|---|---|---|---|---|---|
| Jan [1] | 1 | 444.3 | 341.4 | 319.3 | 216.3 | 102.9 | 76.8 |
| Feb [5] | 5 | 475.2 | 297.8 | 338.7 | 161.1 | 177.5 | 62.7 |
| Mar [9] | 9 | 420.1 | 297.1 | 296.4 | 173.2 | 123.2 | 70.7 |
| Apr [10] | 10 | 387.4 | 228.1 | 283.6 | 124.1 | 159.4 | 58.9 |
| May [15] | 15 | 431.1 | 198.0 | 340.6 | 107.2 | 233.3 | 45.9 |
| Jun [16] | 16 | 587.6 | 161.8 | 507.3 | 81.1 | 426.0 | 27.5 |
| Jul [17] | 17 | 574.1 | 167.7 | 496.2 | 89.5 | 406.5 | 29.2 |
| Aug [18] | 18 | 576.2 | 191.1 | 489.0 | 103.6 | 385.2 | 33.2 |
| Sep [20] | 20 | 475.6 | 221.3 | 376.9 | 122.3 | 254.5 | 46.5 |
| Oct [22] | 22 | 385.9 | 333.2 | 258.0 | 205.0 | 52.9 | 86.3 |
| Nov [27] | 27 | 348.7 | 312.0 | 238.4 | 201.5 | 36.9 | 89.5 |
| Dec [] | | | | | | | |

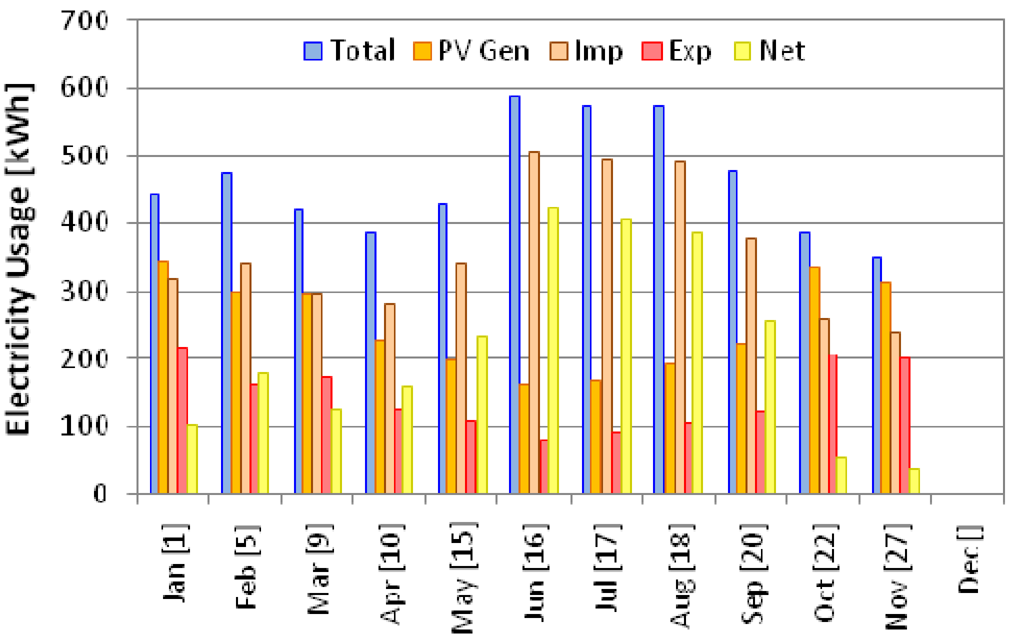


**Figure 6 - Total Electricity Consumption and Solar PV Electricity Production for the period: January – November 2010**

The contribution that photovoltaic energy generation has made to the reductions in energy and greenhouse gas emissions is highlighted below in Figure 7.

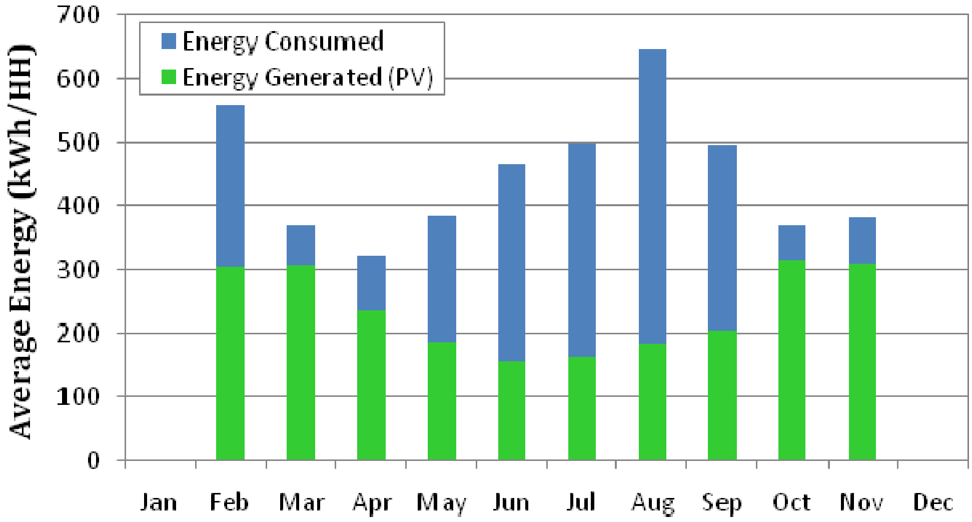


**Figure 7 – Total Electricity Consumption (Detailed Monitored Houses)**

It should be noted that the figures given above, in relation to the nine monitored Lochiel Park households, are based on a small data set. Consequently, Figure 8 compares the average monthly household electricity use for the detailed houses, versus all houses for which data has been collected. Although there are some differences, this figure justifies the use of the nine house data set in this report, based on the absence of glaring differences and the fact that, in total, the total annual difference amounts to less than four percent.

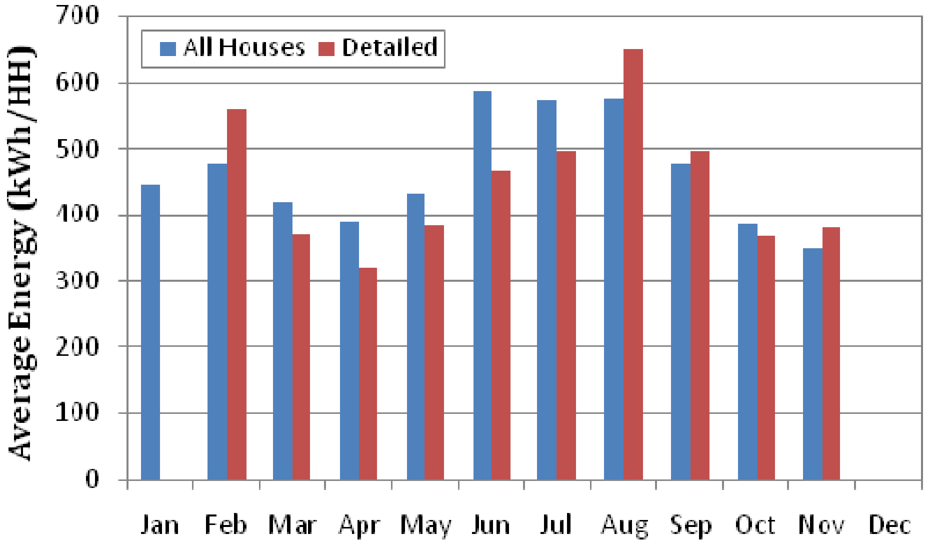


**Figure 8 – Electrical Energy Consumption at Lochiel Park**

## 4.3 ENERGY FOR COOLING/HEATING

Figure 9 shows the total monthly energy consumption for cooling and heating for each detailed monitored house[2]. As shown, energy consumption for summer months are generally lower than those for winter months, in line with the South Australia's heating and cooling trends. In absolute terms, the electrical energy requirements for cooling and heating of the Green Village houses are considerably lower than the Adelaide average (Saman, et al, 2008; see also Section 5).

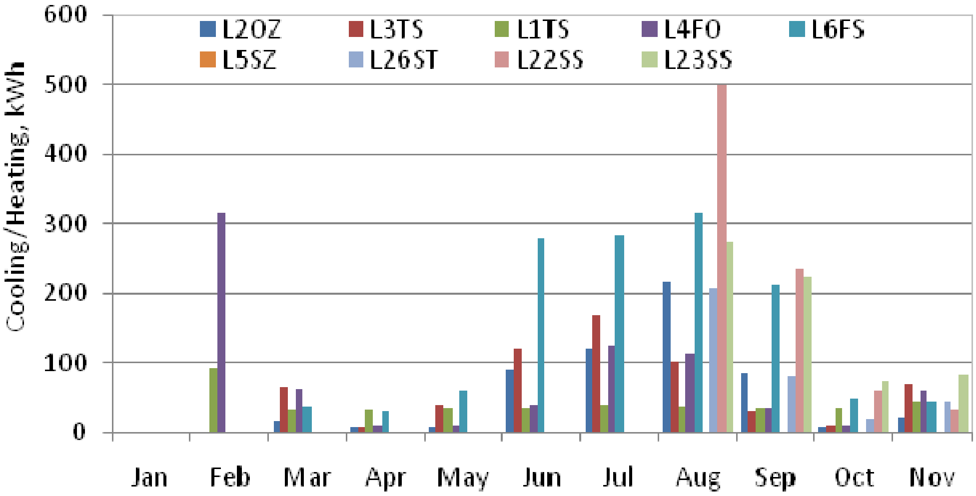


**Figure 9 - Monthly Cooling / Heating Energy Consumption for the Detailed Monitored Houses**

## 4.4 PV ENERGY GENERATION

Figure 10 shows the average amount of energy generated, together with a comparison of that generated by the smallest (1.89kW) and the largest (4.2kW) roof-mounted photovoltaic (PV) systems[3,4,5,6], for a period of 11 months, i.e. February – November 2010. As expected, the power production is mainly proportional to the PV panel capacity and is also dependent on seasonal solar insolation with summer months producing around double the electricity of winter months.

2 The data availability for each house varies due to the time of house hand over

3 The PV system sizes were obtained from a Lochiel Park database provided by LMC (LP, 2009).

4 Data for the largest system (4.2kW) was only available from May onwards whilst data for the smallest system (1.89kW) was available from February onwards. The above figures will for the average PV system sizes vary each month, as houses (with various sized PV systems) are continuously commissioned.

5 The number within the square brackets, e.g. [15], indicates the number of houses used to calculate that month's average amount of PV generated energy.

6 The information shown in the chart contains data for houses that are lived in only, i.e. it does not include data for display houses or dwellings owned by LMC.a

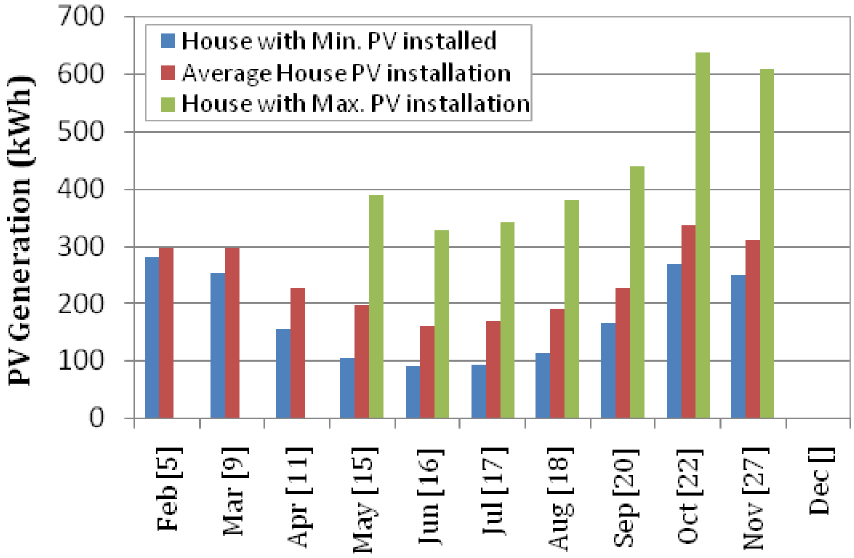


**Figure 10 - Electrical Energy Generated by the Smallest (1.89 Kw), Largest (4.2 Kw) and Average**

## 4.5 ELECTRICAL ENERGY CONSUMPTION BREAKDOWN BY APPLIANCES

Figure 11 shows – on average – the percentage of energy consumed by each appliance in the 9 houses involved in the analysis. The general power consumed almost half the energy used in the house whilst heating and cooling appliances consumed almost a quarter. This indicates that there is no direct relation between the rated power input of an appliance and the energy it consumes. The data demonstrates that for well designed houses having energy efficient appliances, the energy use for home entertainment and computers make up an increasing portion of the overall energy use. Of the remaining contributions, laundry appliances also have a disproportionally large contribution.

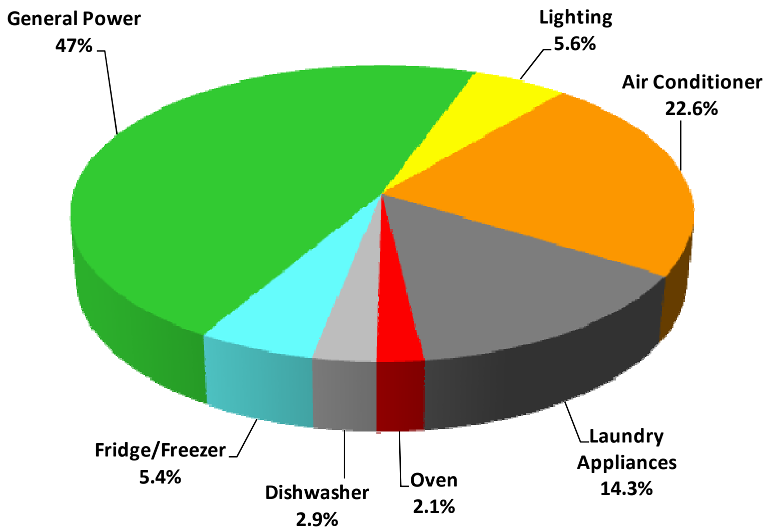


**Figure 11 – Energy Consumption Breakdown by Appliances**

## 4.6 ROOM TEMPERATURES

One of the main objectives of a good house design is to provide thermal comfort for the occupants. While this research project does not focus on this topic, the data being monitored enable an approximate evaluation of the thermal comfort conditions in the detailed monitored houses where temperature and humidity sensors were installed in the bedrooms and living areas. However, at the time of the preparation of the report, only two houses have sufficient data for the purpose of the analysis. Therefore in this Section, a detailed analysis which normally involves referencing a relevant thermal comfort standard will not be made. Instead, graphs showing the temperatures and reverse-cycle air conditioner power usage is shown for lot L1TS. Figure 12 shows the temperatures for one of the hottest days of the year (9th February 2010, maximum outdoor temperature of 39.0°C), whilst Figure 13 shows the indoor temperatures and AC usage for the one of the coldest days of the year (21st July 2010, maximum outdoor temperature of 13.7°C).

Lot L1TS has one split system reverse-cycle air conditioner with multiple outlets installed in the house. One outlet is installed in the each of the two upstairs bedrooms, one in the Master (downstairs) bedroom and one in the kitchen / living / dining area. Figure 12 shows the residents used two of these outlets to cool only the sections of the house they were occupying at the time. The residents used the Master bedroom outlet during the early hours of the morning (until 4am) and in the late evening (after 9pm), whilst between 3pm and 8:30pm, the kitchen / living room outlet was used. Note that the residents were not home between the hours of 9:30am and 3pm, and that upstairs bedrooms were not cooled, despite temperatures approaching 39°C, as these rooms were unoccupied.

Figure 13 shows that the reverse-cycle AC was used for about half an hour at 6:30am to warm the Master bedroom and kitchen / living area. Only a small amount of heating was required as the bulk of the lower floor was heated using an underfloor heating system, which is connected to the instantaneous gas-boosted solar hot water system. Note that this house has its solar water collectors optimised for winter usage, and that the gas usage during this period is not discussed in this report.

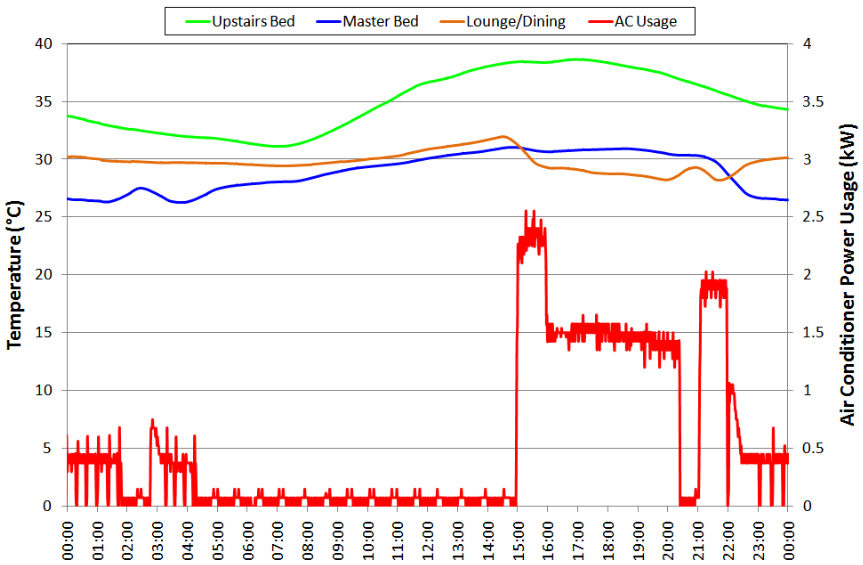


**Figure 12 – Indoor Temperatures And AC Power Usage for 9th February 2010, for lot L1TS.**

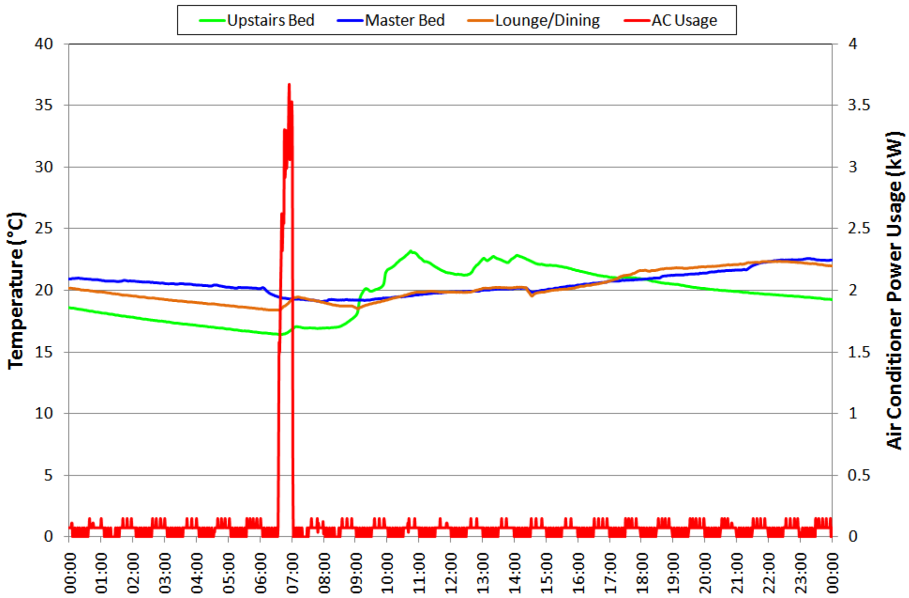


**Figure 13 - Indoor Temperatures And AC Power Usage for 21st July 2010, for lot L1TS.**

## 4.7 GREENHOUSE GAS EMISSIONS

Figure 14 shows the minimum, average and maximum amount of greenhouse gases (GHG) emitted to the environment from a number of Lochiel Park houses for a period of 10 months, i.e. February – November 2010[7,8]. The emission values are due to both electricity and natural gas consumption.

As seen, some houses consistently generate negative emissions whilst, on the other extreme, another produces emissions of up to as 1.2 tons per month. So far, the monthly average GHG emissions from all the houses ranges from 57.9 kg $CO_{2\text{-}e}$ recorded in November to about 500 kg $CO_{2\text{-}e}$ in June. These figures are well below those of similar Adelaide sized houses (see Section 5). The same house has the maximum emissions for the months of March to September, due to consistently having the maximum net imported electricity usage.

7 The information shown in the chart contains data for houses that are lived in only, i.e. it does not include data for display houses or dwellings owned by LMC.

8 In estimating the GHG emitted, the following emission factors were used: 0.85 kg CO2-e/kWh for electricity and 2.43 kg CO2-e/kWh for gas. These are the current emission factors for South Australia.

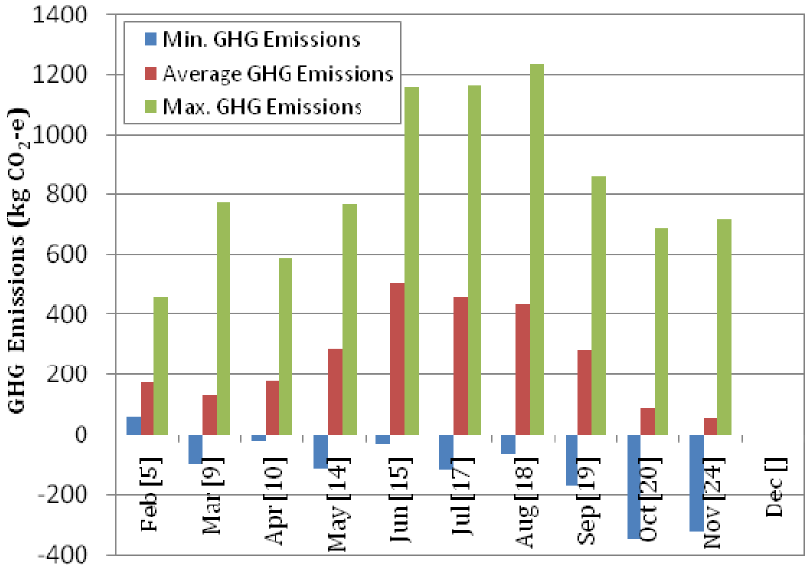


**Figure 14 – Monthly Greenhouse Gas Emitted by The Houses (kg $CO_{2\text{-}e}$)[9]**

# 5 COMPARISON WITH DATA FROM MAWSON LAKES HOUSES

To enable an appreciation of the performance improvement brought about by the integrated approach of passive design, energy efficient appliances, local renewable energy generation and the introduction of a number of 'smart' features in the Green Village homes, comparisons are made with the figures extracted from 6 houses of similar floor area and number of occupants in the Mawson Lakes Development, which were monitored during the two year period from 2001-2003 (Saman & Mudge, 2003).[10] It should be noted that these houses were newly constructed in the early 2000's utilising a number of energy efficient strategies, leading to an average reduction of 26% of total energy use per unit floor area in comparison with the Adelaide average at the time. According to the AccuRate household energy rating software, the average rating of the six monitored Mawson Lakes houses was 4.1 stars (range: 3.4 - 4.7) (Saman et al, 2008) whereas the nine Lochiel Park houses that have been monitored in detail, to date, had an average rating of 7.6 stars (range: 7.5 - 7.7).

Where comparable data exists for both the Lochiel Park and Mawson Lakes monitored houses, the average household electrical energy consumption of certain end uses and major appliances has been compared. The results of such comparisons are shown below in Figure 15 through Figure 22. The results demonstrate a noticeable reduction in energy use due to the house design, its smart features and energy efficient appliances. More detailed analysis of individual appliances is under way.

9 The number within the square brackets, e.g. [15], indicates the number of houses used to calculate that month's average amount of PV generated energy.

10 The Green Village modeled target of 66% reduction in energy and 74% in greenhouse gas emissions was based on the reference to the "against Adelaide average" of 2004 data. However, at the time of writing of this report, LMC has not supplied the UniSA team with the associated reference figures, therefore data from Mawson Lakes has been used for comparison in this report.

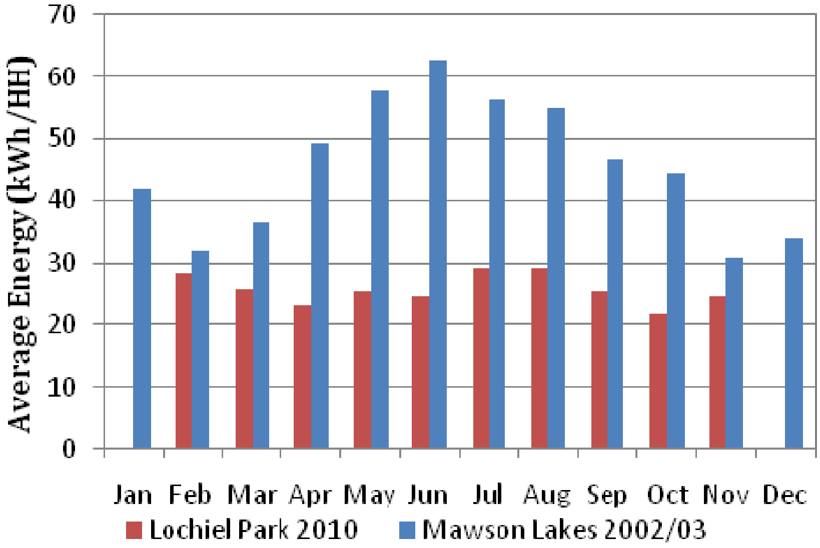


**Figure 15 – Energy Use for Lighting**

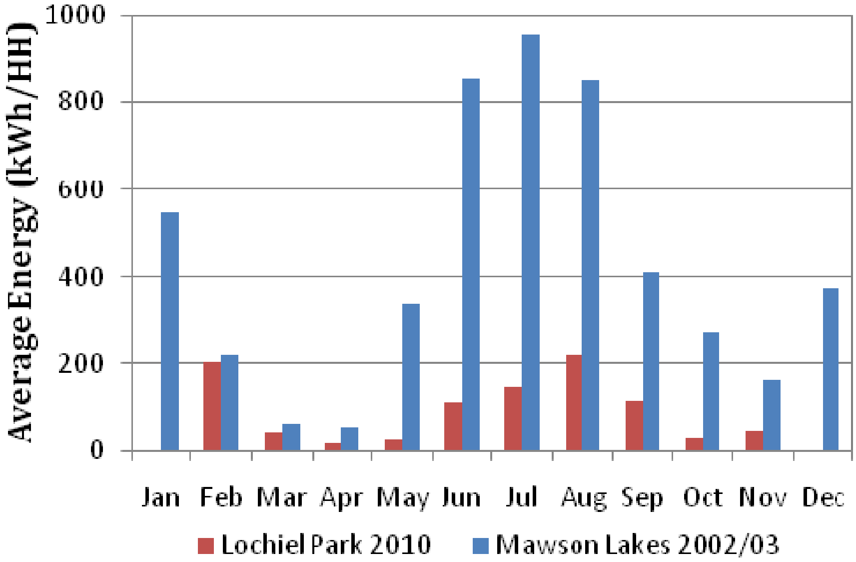


**Figure 16 – Energy Use for Space Heating & Cooling**

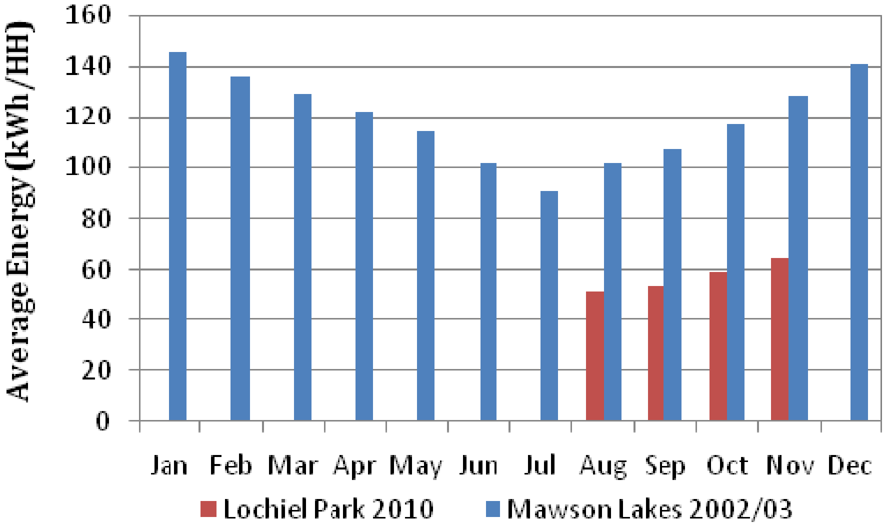


**Figure 17 – Energy Use for Fridge/Freezer**

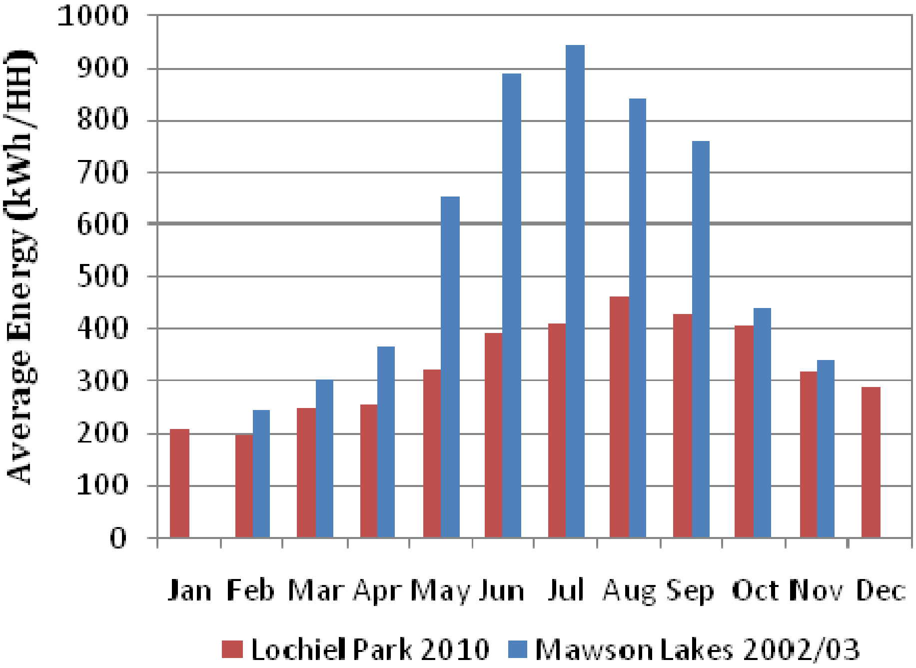


**Figure 18 – Energy Use for Water Heating**

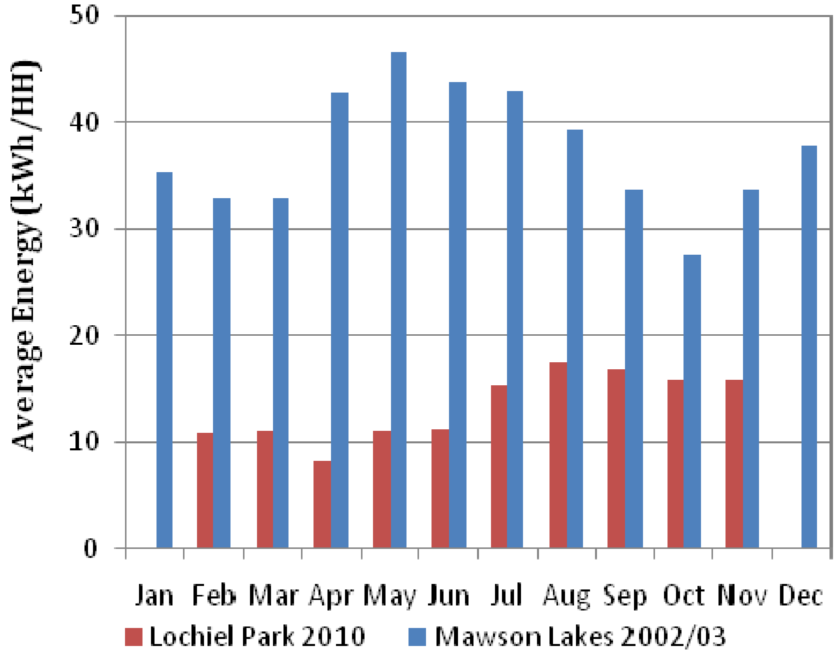


**Figure 19 – Energy Use in Dishwasher**

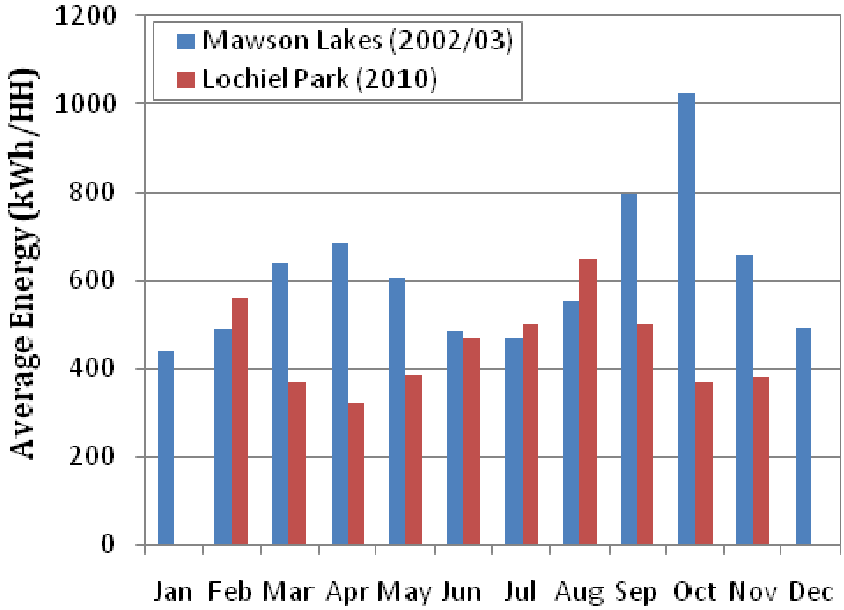


**Figure 20 – Total Electrical Energy Consumption (Detailed Monitored Houses)**

Figure 21 shows a comparison between the net energy consumption, by energy source, for Mawson Lakes and Lochiel Park detailed monitored houses. It should be noted that the Lochiel Park data has been linearly extrapolated to estimate annual figures and allow subsequent comparisons. The Lochiel Park electrical data comprises the difference between the total energy consumed in the household and that generated by the PV systems. The installation of gas boosted solar hot water has affected the natural gas consumption. In comparison to Mawson Lakes households, it can be seen that, on average, Lochiel Park households consume approximately 54% less energy.

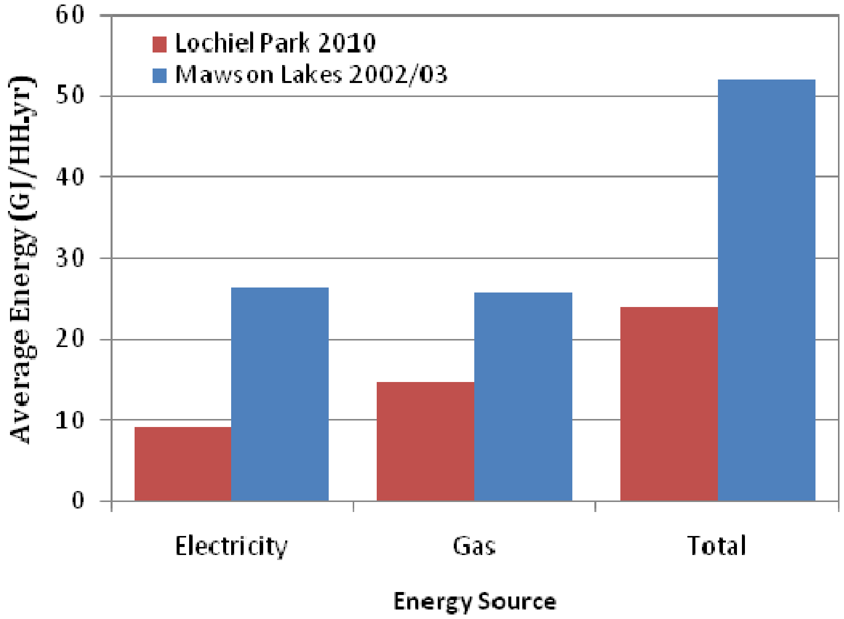


**Figure 21 – Average Net Energy Consumption**

Figure 22 below shows a comparison between the net greenhouse gas emissions, by energy source, for Mawson Lakes and Lochiel Park detailed monitored houses. It should be noted that the Lochiel Park data has been linearly extrapolated to estimate annual figures and allow subsequent comparisons. In comparison to Mawson Lakes households, it can be seen that Lochiel Park households emit approximately 65% less greenhouse gases.

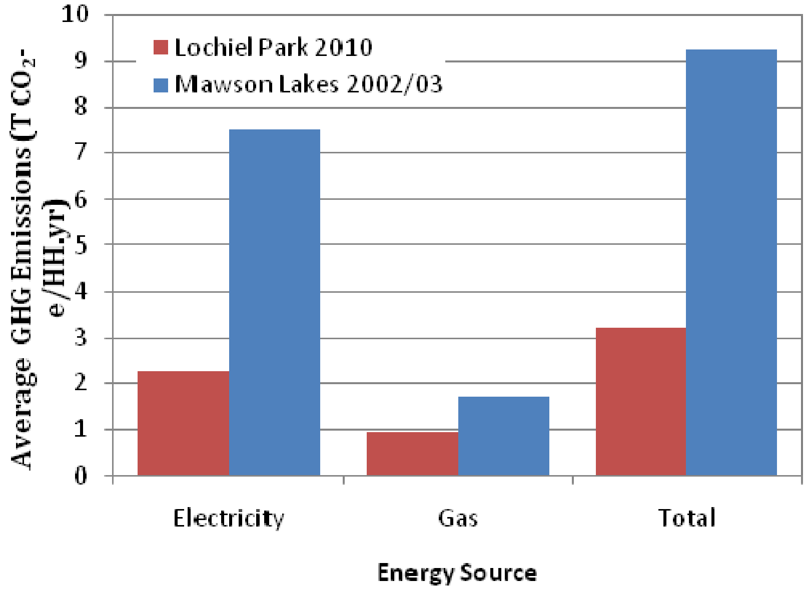


**Figure 22 – Average GHG Emission**

# 6 CONCLUSIONS

The analysis of monitoring data covering the period of February – November 2010 which constitutes milestone M8 of the P6 UniSA iGrid project has been presented. During the period, recording and processing of monitoring data of 29 houses have been carried out on a continuing basis with installation of monitoring equipment being implemented for the houses under construction. Despite the need for caution in using these results due to the number and duration of monitoring, the outcome represents the most comprehensive household energy monitoring program known to the research team. The results demonstrate the benefits of using an integrated approach to energy delivery and consumption in housing and represents the likely future trends of energy management in future Australian housing. The implications on the electricity grid will be discussed in more detail in the next report.

# 7 PUBLICATIONS

W. Saman: *Towards Zero Energy Homes Down Under*, Invited paper - Presented at the World Renewable Energy Congress IX, Abu Dhabi, UAE, 25-30 September 2010.

Whaley, D., Saman, W., Halawa, E., Mudge, L.: *Lessons learnt from implementing intelligent metering and energy monitoring devices in a new housing development* - Presented at the Australia Solar Energy Society (AuSES) Solar2010 Conference, Brisbane, 1st -3rd December 2010.

# 8 MEETINGS / CONFERENCE / TRAINING

- Lachlan Mudge attended the Database Training program for the period 20th to 30th September 2010. The custom training package was delivered by Jeff Headley from Academy IT.
- Wasim Saman was invited to and attended the Smart Grid/Smart Home Australia and New Zealand Conference which was held in Melbourne 3-5 November. Wasim made a presentation entitled "The Lochiel Park Green Village: How can smart homes reduce energy and water consumption and reduce peak demand?"
- David Whaley and Lachlan Mudge attended the project meeting held on 16 November 2010 at Lochiel Park Sustainability Centre to discuss the project progress and implementation details.
- David Whaley, Wasim Saman and Edward Halawa attended the AuSES Solar 2010 Conference held in the Australian National University, Canberra 1 – 3 December 2010 and presented a paper (see Publication Section).

# 9 REFERENCES


- LP 2009 – *Spreadsheet on Status Report of Construction of Homes at Lochiel Park Green Village* – Land Management Cooperation (LMC).
- Saman, W. & Mudge, L.T. 2003, *Development, Implementation and Promotion of a Scoresheet for Household Greenhouse Gas Reduction in South Australia: Final Report*, Sustainable Energy Centre, University of South Australia, Mawson Lakes, Adelaide.
- Saman, W., Halawa, E., Mudge, L., Edwards, J. & Whaley, D., 2009: *Progress Report of the Project P6: The Intelligent Grid in a New Housing Development, Period: July – December 2009*. Submitted to the Intelligent Grid Cluster Coordinator.
- Saman, W., Halawa, E., Whaley, D., Edwards, J. & Mudge, L., 2010: *Progress Report of the Project P6: The Intelligent Grid in a New Housing Development, Period: January – July 2010*. Submitted to the Intelligent Grid Cluster Coordinator.
- Saman, W., Oliphant, M., Mudge, L. & Halawa, E., 2008: *Study of the Effect of Temperature Settings on AccuRate Cooling Energy Requirements and Comparison with Monitored Data* - Final Report, http://www.nathers.gov.au/about/pubs/accurate-coolingsettings-0608.pdf.