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ELECTRICITY DEMAND PROFILE OF HEATING AND COOLING APPLIANCES IN AUSTRALIAN LOW ENERGY RESIDENTIAL BUILDINGS

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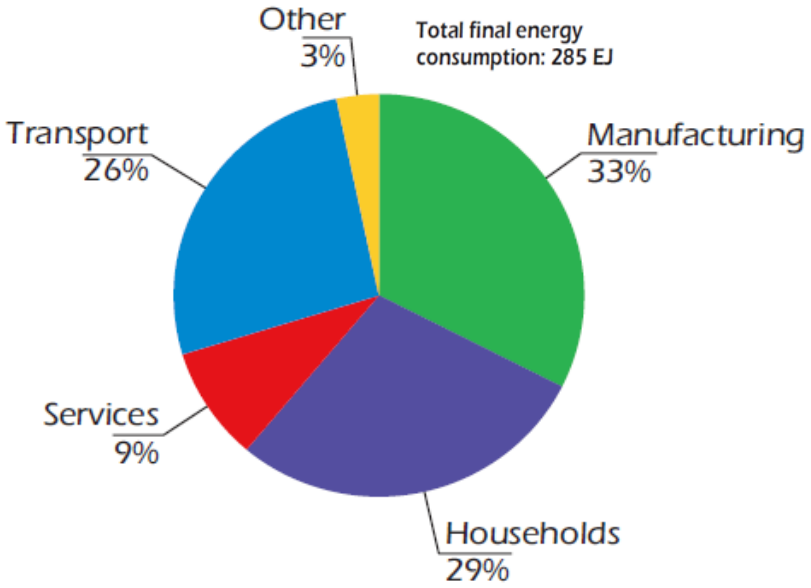
Energy use by residential buildings

The energy consumption by residential building accounts for large portion of total energy consumed in national-wide.



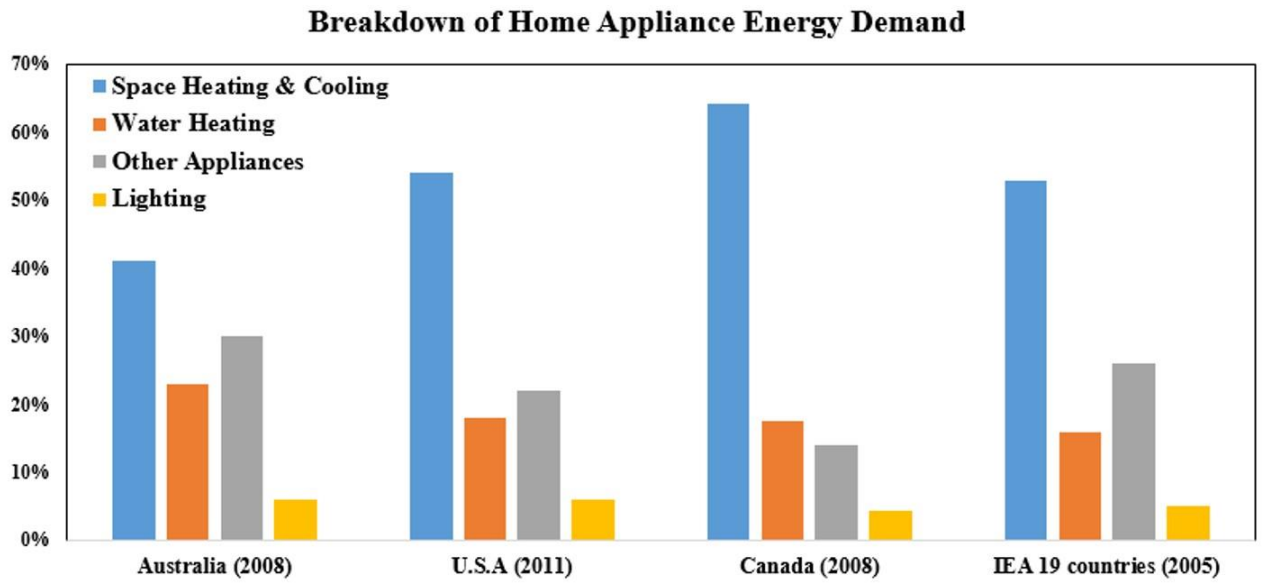
<Energy consumption by households (IEA 2007)>

Nation	%	Nation	%
World	31%	USA	25%
Saudi Arabia	50%	Canada	24%
Turkey	31%	Mexico	23%
UK	31%	Norway	21%
Jordan	29%	Sweden	19%
Malaysia	29%	Italy	17%
Brazil	26%	Finland	16%
Japan	26%		

<Secondary energy consumption by residential houses (Swan & Ugursal 2009) >

Energy use by residential buildings (Contribution on Total Energy Demand)

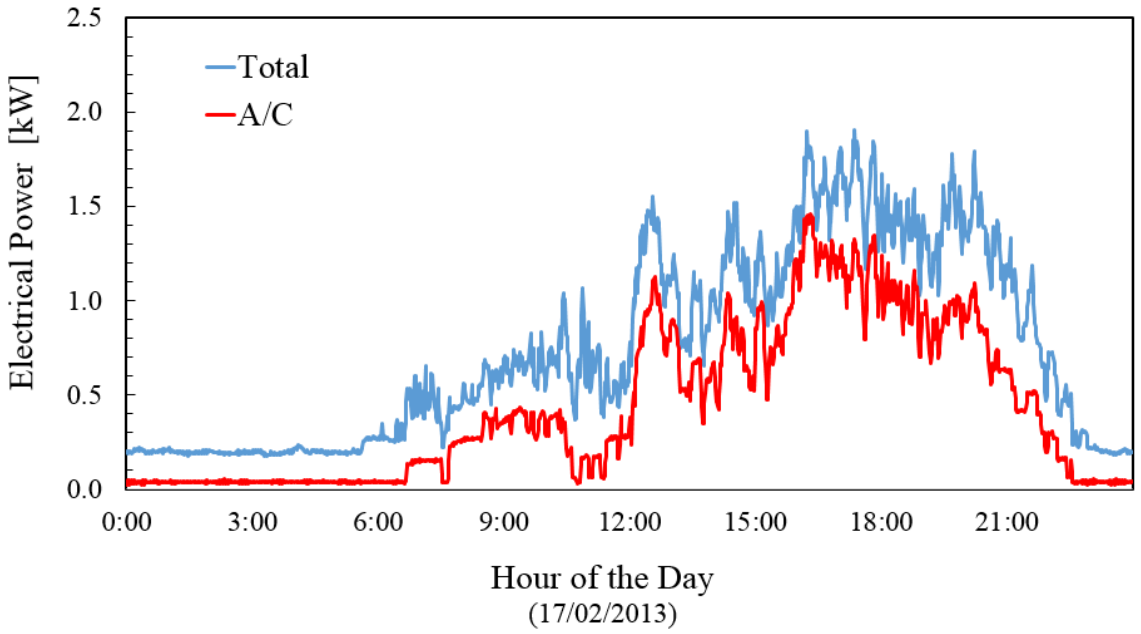
More than 40% of energy used for indoor heating and cooling in conventional buildings.



<Breakdown of Home Appliance Energy Demand (ABS 2011; Behidj et al. 2008; IEA 2008; USDE 2012)>

Energy use by residential buildings (Contribution on Peak Demand)

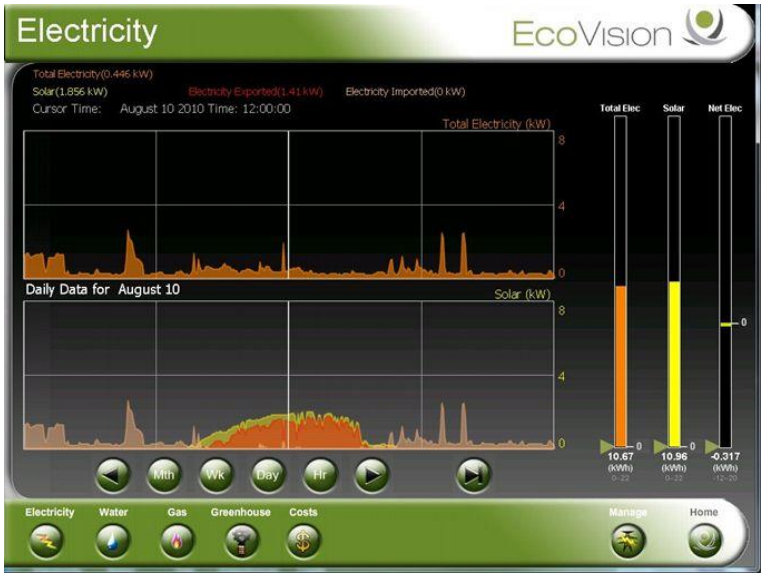
Considerable energy contribution of heating and cooling appliances on peak demand.



<The impact of space cooling on peak demand in low energy house of Australia>

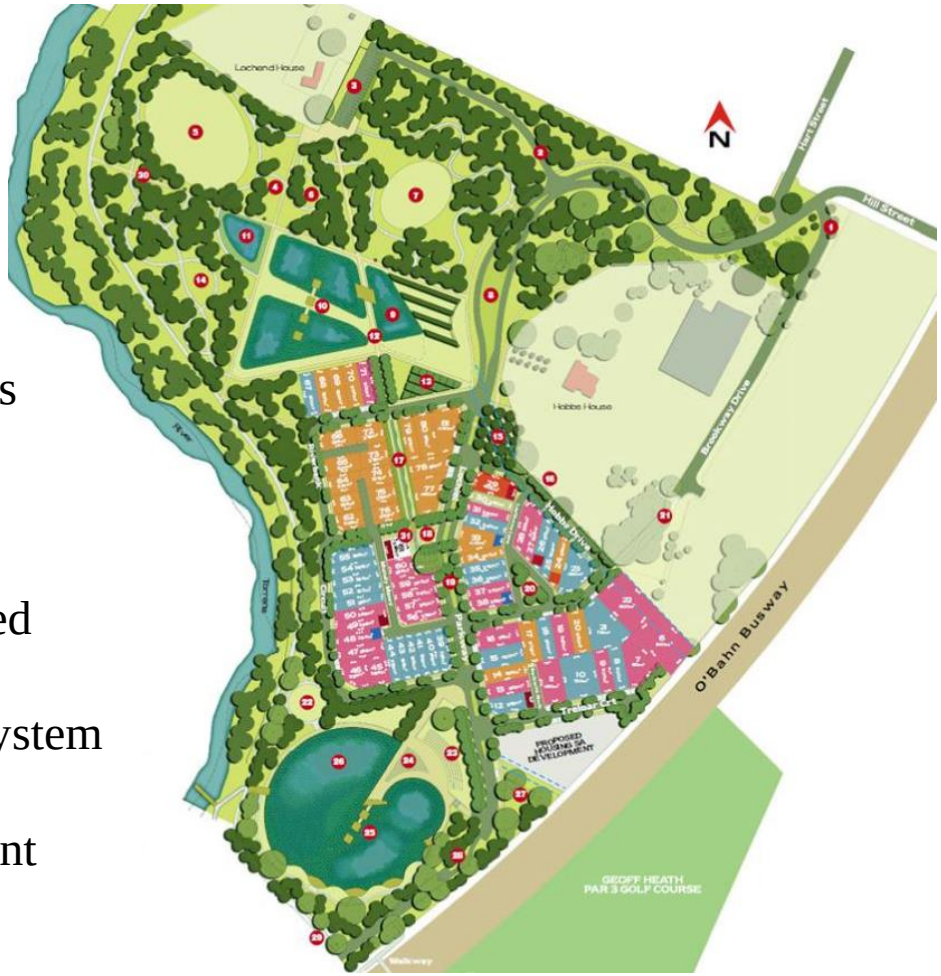
Aims of the study

- Electricity usage profile of H/C appliances in various time frames
- The contribution of H/C appliances
  - ✓ on the total electricity consumption
  - ✓ peak demand of low energy Australian dwellings
- Analysis installed H/C appliances from appliance audits



About Lochiel Park Green Village

- Monitoring 106 low-energy dwellings (83 houses and 23 apartments)
- Following strict urban design guidelines and development targets
  - ✓ Passive design of homes with minimum 58MJ/m^2
  - ✓ 66% energy demand
  - ✓ 74 % greenhouse gas emission reductions
- Technologies
  - ✓ PV system (min.1.0 kW_p per 100 m^2)
  - ✓ Solar water heating
  - ✓ High level of insulation and double glazed windows
  - ✓ High performance heating and cooling system (≤ 4kVA)
  - ✓ Daylighting, skylights and energy efficient lights
  - ✓ Smart metering and In-home monitoring system (EcoVision)



Monitoring system and data processing

LEHs in Lochiel Park Green Village

Monitoring system

Control

Digital input

Programmable Logic Controller

Serial

In-home Display

Ethernet

Optical Network Terminal

Measuring equipment

- ✓ Electricity
- ✓ Solar
- ✓ Individual appliances
- ✓ Etc.

Individual power circuit

CSV Data

Data filtering & Re-arrangement

- Find missing &duplicated data
- Change to daily & hourly base data
- Data separation by Pattern recognition

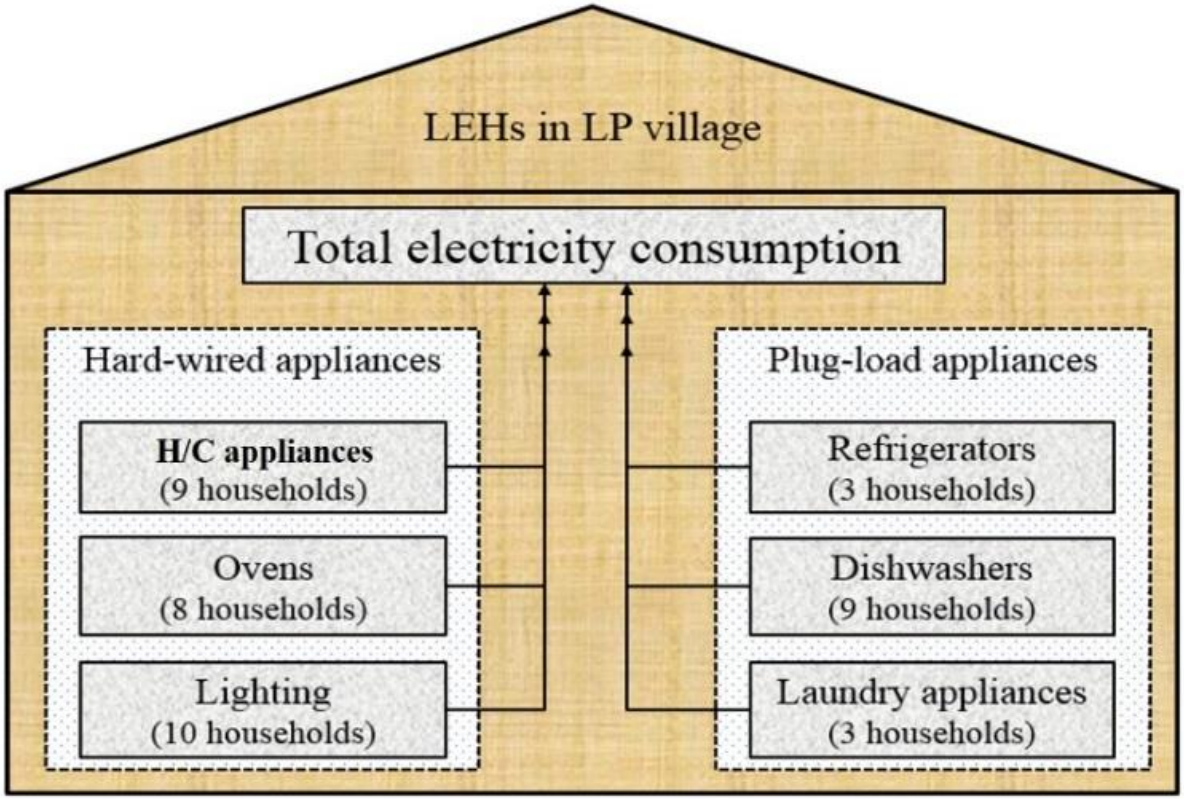
Electrical demand profile generation

- Variation(yearly, monthly)
- Usage signature
- Respective contribution
- Actual Usage
- Usage condition

Household characteristics

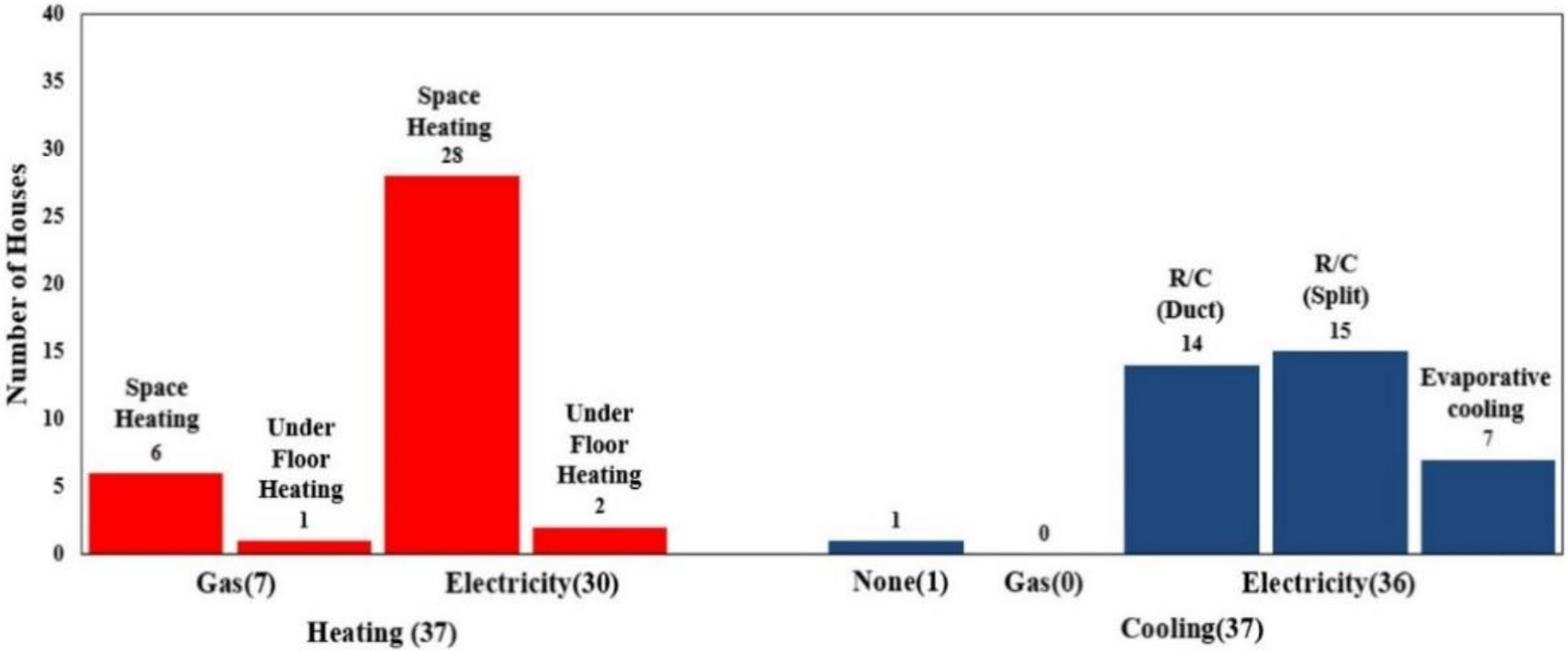
Evaluation of LEHs electricity demand

Monitoring system (Detailed houses)



Installed H/C system

- ✓ Majority of the houses prefer electricity over gas for heating.
- ✓ Most other houses use ducted/split RCAC for both heating and cooling; one house has gas space heating with no cooling device.
- ✓ Evaporative cooling A/Cs, which are suitable for the dry climate region, are installed in seven houses



Detail monitored houses

Table 1. Survey results: Household Information of Lochiel Park Green Village

House ID	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
L02OZ	2	0	2	0	0	0	3	2	3	238.3	7.5	D	-	-	R/C	R/C	Ducted
L62OF	1	1	0	0	0	0	-	-	-	173.1	-	D	12	12	R/C	R/C	Ducted
L03TS	2	0	2	0	0	0	3	2	3	178.4	7.5	T	9.8	10.6	R/C	R/C	Ducted
L01TS	2	0	2	0	0	0	3	2	3	173.8	7.6	T	8	9.4	R/C	U/F	Split
L04FO	2	0	2	0	0	0	3	2	3	194.5	7.5	T	12	13	R/C	R/C	Ducted*
L06FS	2	0	2	0	0	0	3	2	3	174.2	7.7	T	8	9	R/C	R/C	Split
L26ST	4	0	2	0	1	1	3	2	3	208.6	7.6	D	6	7	R/C	R/C	Split*
L22SS	2	0	2	0	0	0	4	2	2	240.8	7.5	T	14	11	EV	U/F	Ducted
L23SS	4	0	4	0	0	0	3	2	3	219.3	7.5	D	17	18	R/C	R/C	Split

A: Total number of residents
B: Number of seniors (age over 65)
C: Number of adults (age 18~64)
D: Number of young adults (high school)
E: Number of children (primary school)
F: Number of toddlers (preschool)
G: Number of bedrooms
H: Number of bathrooms
I: Number of toilets

J: Habitable floor area (m^2)
K: House energy rating (Accurate rating)
L: Dwelling type: Detached(D) / Terrace(T)
M: Rated cooling capacity (kW)
N: Rated heating capacity (kW)
O: Cooling Type: Reverse cycle (R/C) / Evaporative cooling (EV)
P: Heating Type: Reverse cycle (R/C) / Underfloor heating (U/F)
Q: Split / Ducted
-: Information not provided
*: two outdoor compressors

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Annual Consumption of H/C appliances

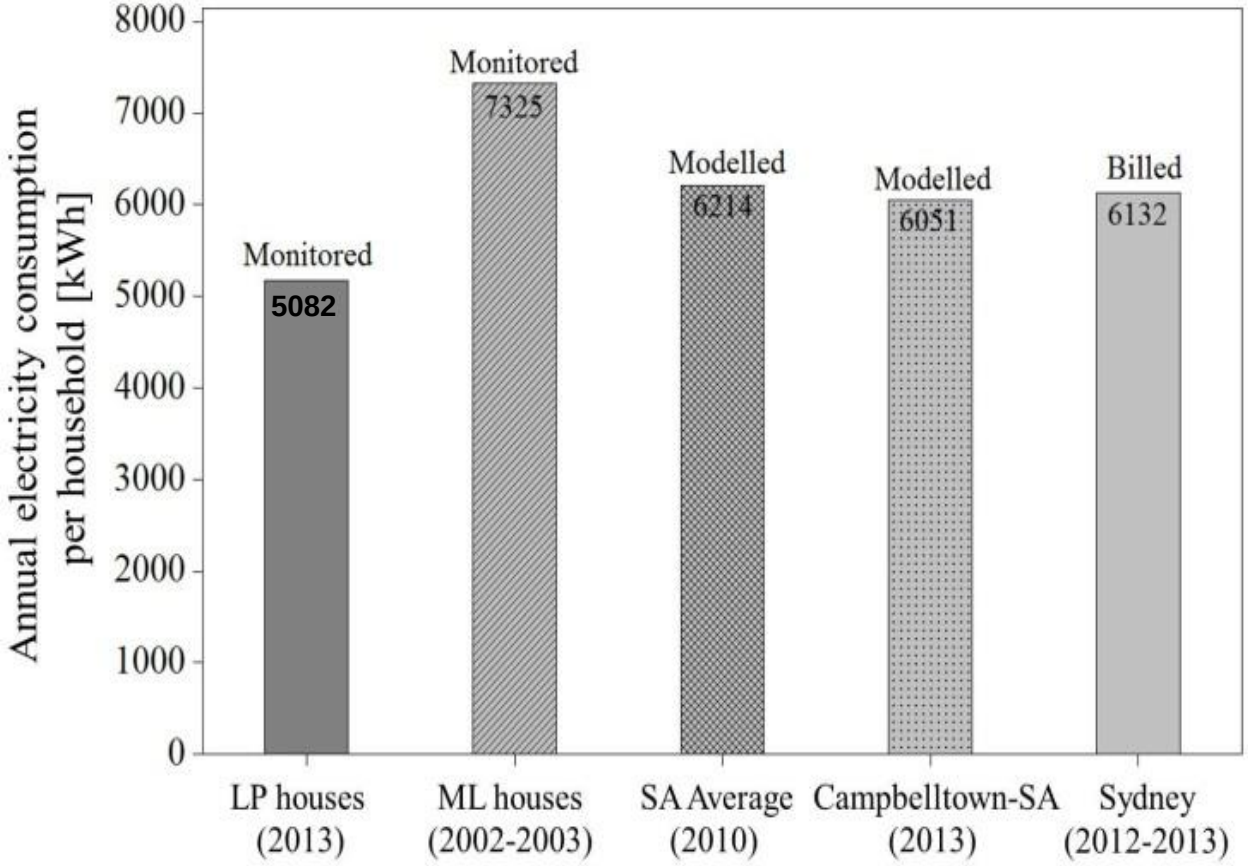
Table 2. The Contribution of H/C Appliances to Total Electricity Consumption and Peaks

House ID	Electricity Consumption (kWh)		Number of		Peak Time of demand (O'clock)		Contribution of H/C Appliance (%)	
	Total	H/C Appliance	Days H/C used	Residents	Total	H/C Appliance	Energy Consumed	Peak
L02OZ	2612.2	230.9	12	2	16~17	17~18	8.8	12.5
L62OF	4321.3	1143.0	110	1	17~18	17~18	26.4	42.3
L03TS	5217.0	1036.3	122	2	17~18	21~22	19.9	24.3
L01TS1	4144.3	542.0	34	2	17~18	17~18	13.1	11.6
L04FO	6190.0	993.5	71	2	20~21	20~21	16.0	17.4
L06FS	3104.8	582.9	54	2	20~21	20~21	18.8	23.6
L26ST	8131.6	1466.1	189	4	18~19	18~19	18.0	22.9
L22SS2	5755.0	978.8	58	2	18~19	18~19	17.0	21.1
L23SS	6264.8	1677.6	170	4	17~18	19~20	26.8	30.5
Average	5082.3	961.2	91	2.3	19~20	17~18	18.3	22.9

1) Gas under floor heating, hence the RCAC is only used for cooling
2) Heat pump for under floor heating / Evaporative cooling

Annual electrical demand by low energy houses

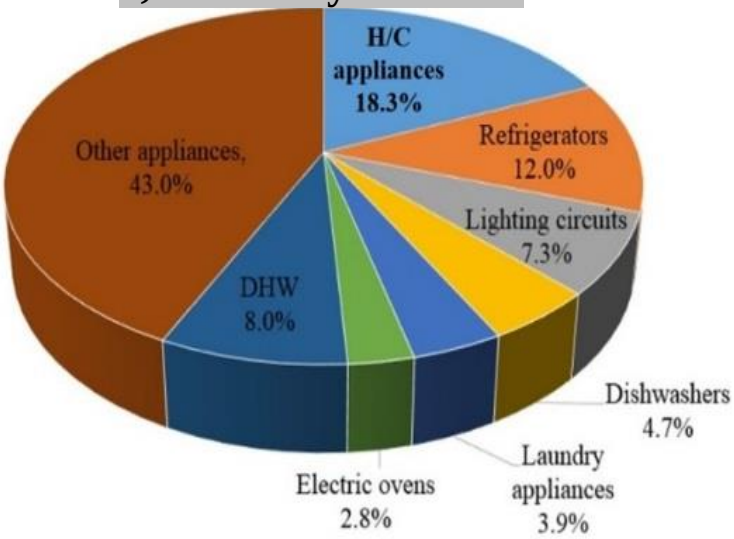
- Considerable reduction of electrical demand by low energy houses*
  (* Average 2.3 residents and 205m^2 of habitable floor area
  - ✓ 71~86 % of other housing clusters
  - ✓ Due to advanced house design and technologies (less for H/C, but more plug loads)



- LP : Lochiel Park
- ML : Mawson Lakes
- SA : South Australia

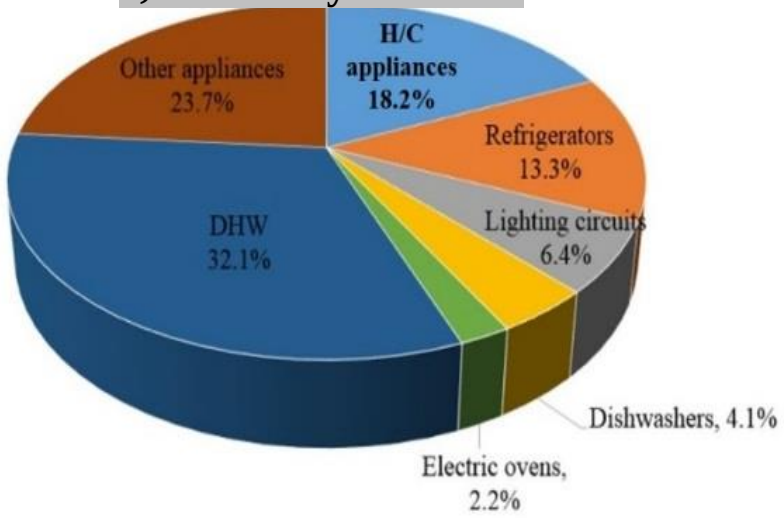
Contribution on total electricity consumption

5,082 kWh/year/house



(a) LP Green Village (2013)

7,325 kWh/year/house



(b) Mawson Lakes (2002/2003)

1. NatHERS star rating: 7.5 stars
(58 MJ/m^2 thermal comfort requirements)
2.Average No. of residents: 2.3
3. Average habitable floor area:205 m^2

1. NatHERS star rating: 4.1 stars
(160 MJ/m^2 thermal comfort requirements)
2.Average No. of residents: 3
3. Average habitable floor area:155.7 m^2

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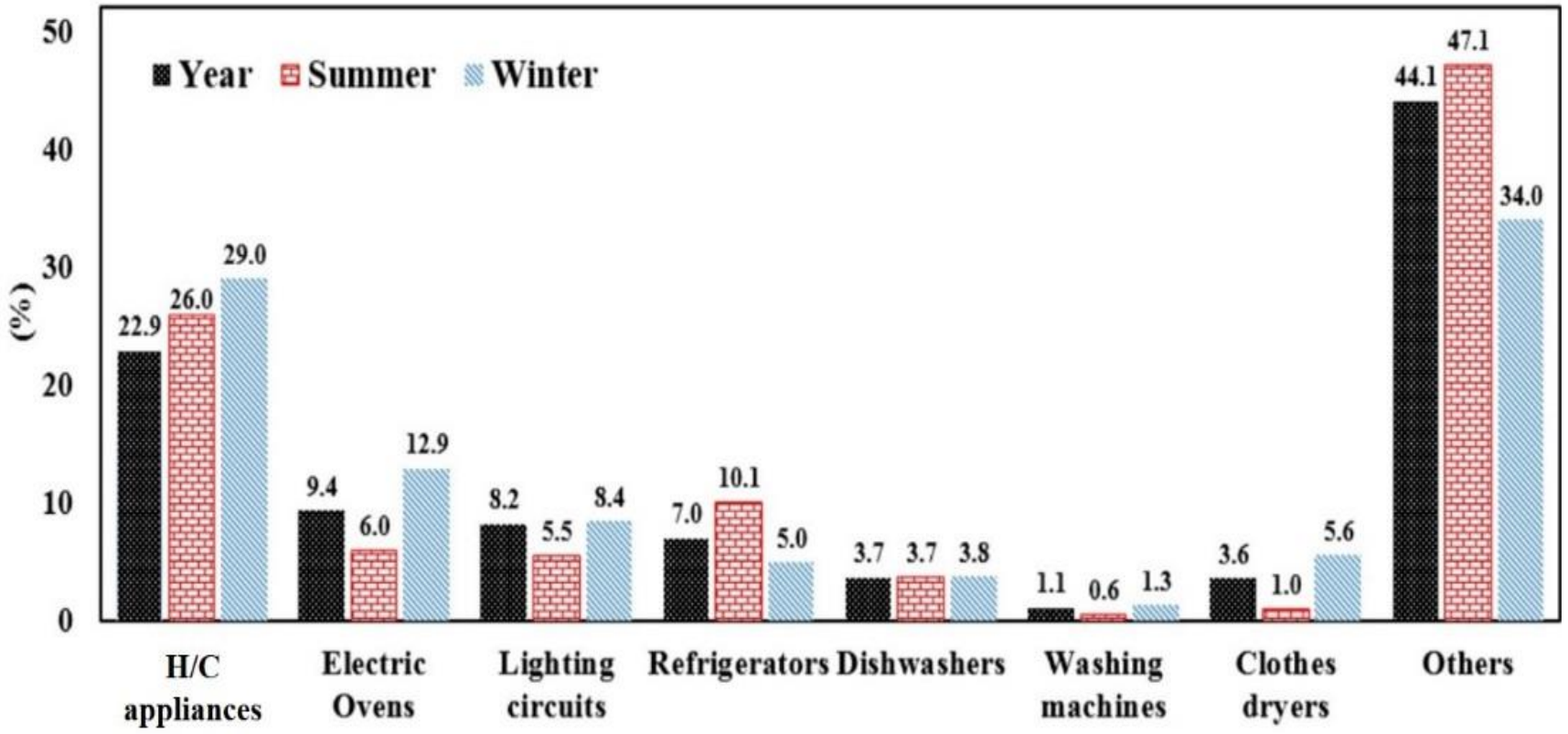
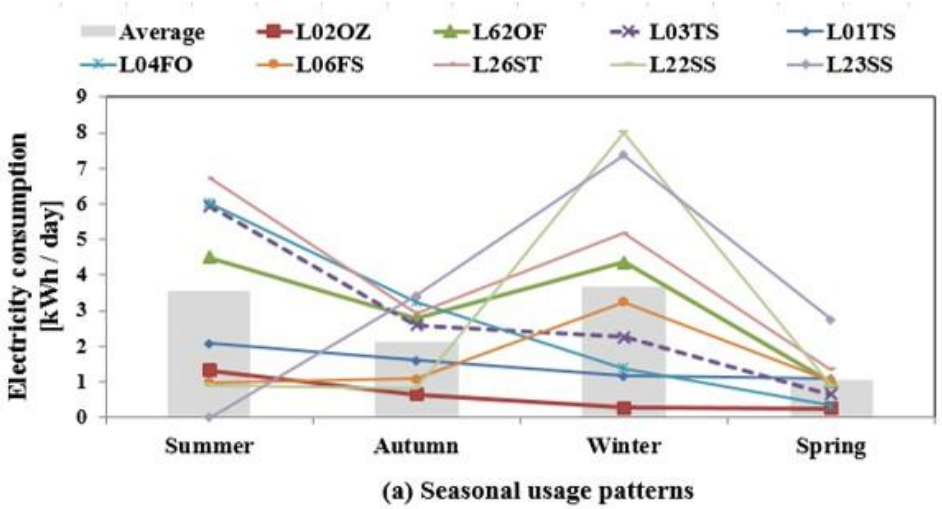
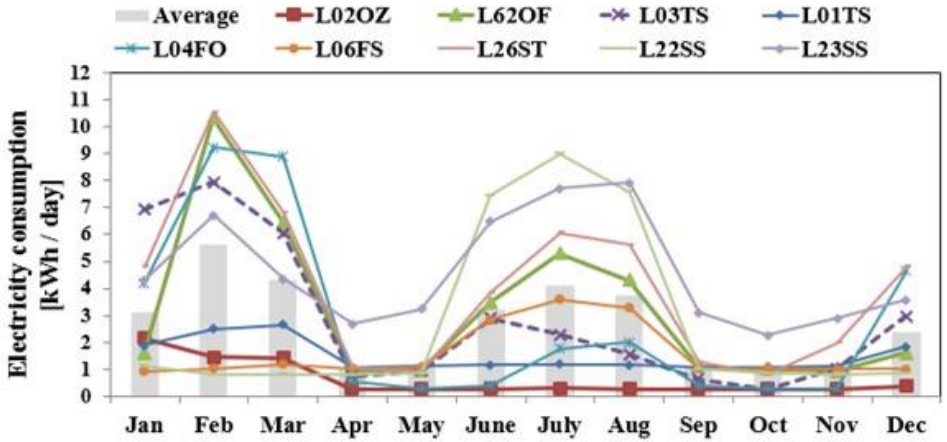
Contribution on Peak Electrical Demand



Seasonal and Monthly Usage Patterns



(a) Seasonal usage patterns



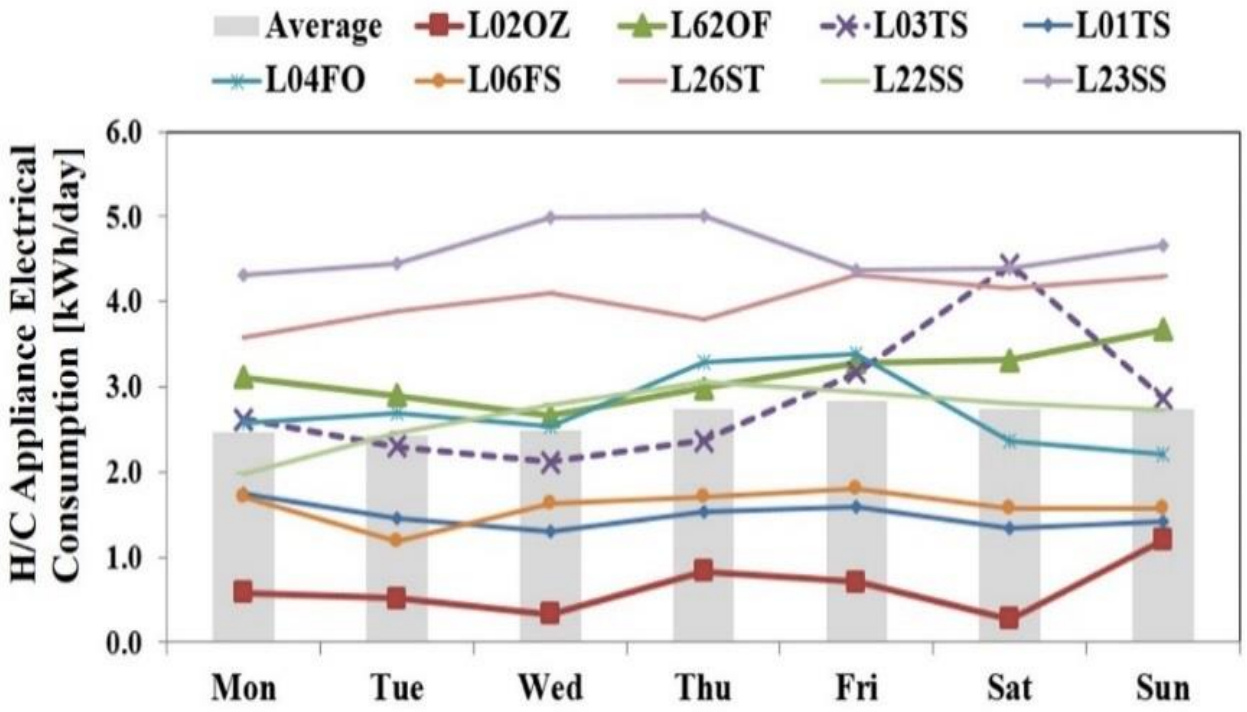
(b) Monthly usage patterns

On average, the H/C appliances consume about 3.7 kWh/day in both summer and winter, whilst they consume 2.1 and 1.0 kWh/day in autumn and spring.

L01TS: RCAC for cooling & gas-fired under floor heating.

Weekday and Weekend Usage Patterns

The H/C appliances consume slightly more electricity during the weekends (2.7 kWh/day) compared with weekdays (2.6 kWh/day)



Daily electricity consumption vs. outdoor temperature

H/C appliances are frequently used in low energy houses when the maximum outdoor air temperature is below 20ºC or above 30ºC.
The electricity consumption of H/C appliances is closely linked to outdoor air temperature

$$E = 0.03 \times T^2 - 1.56 \times T + 20.6$$

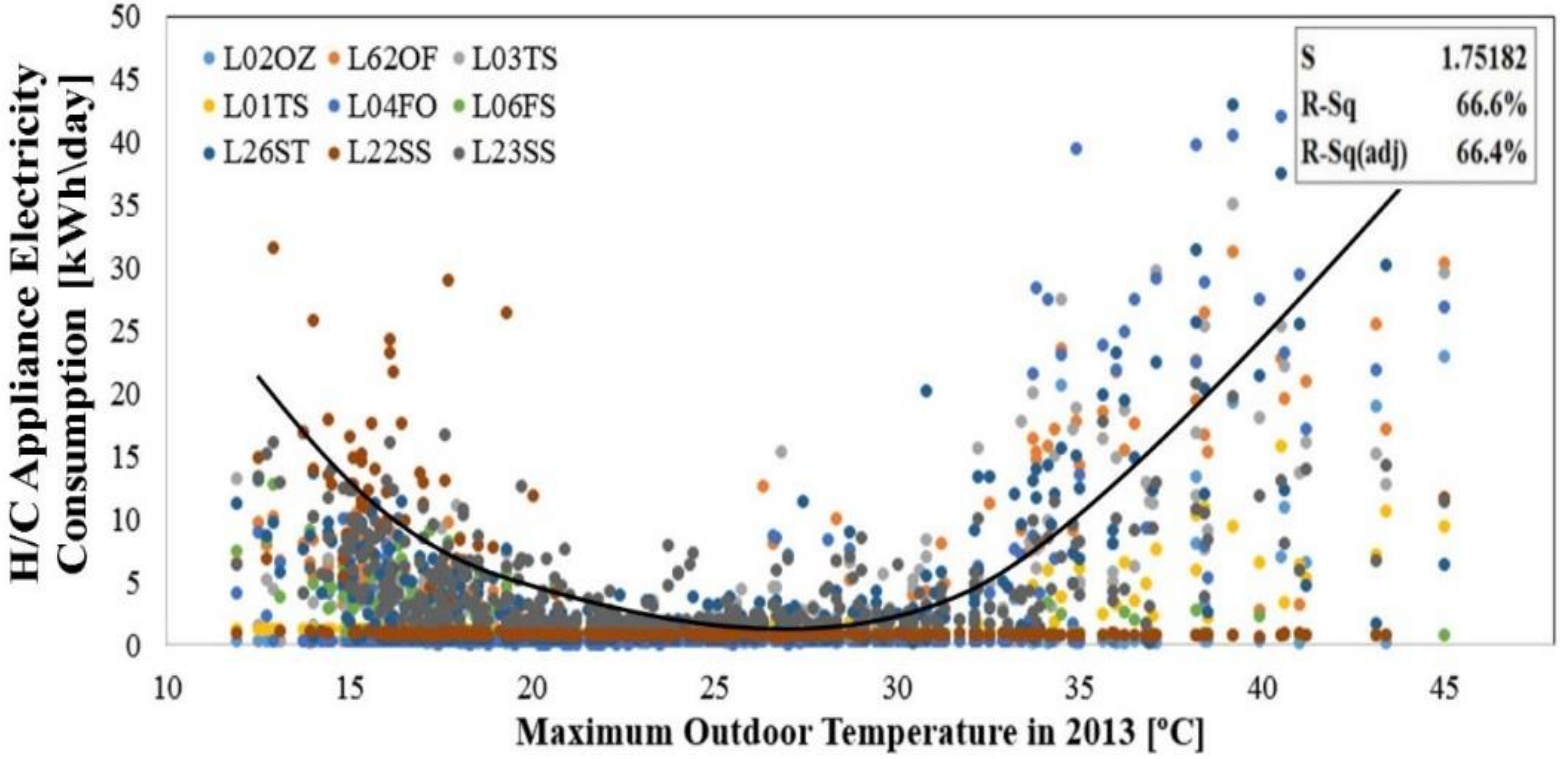
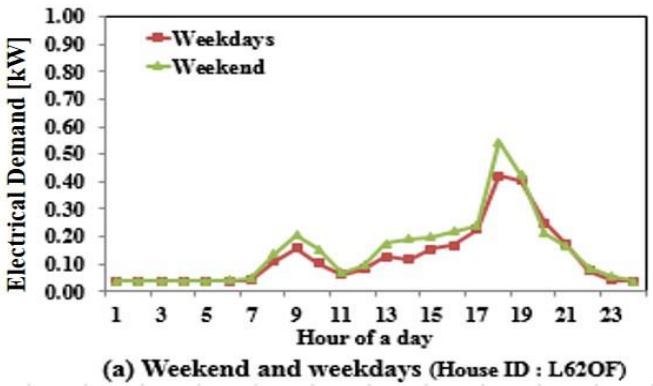
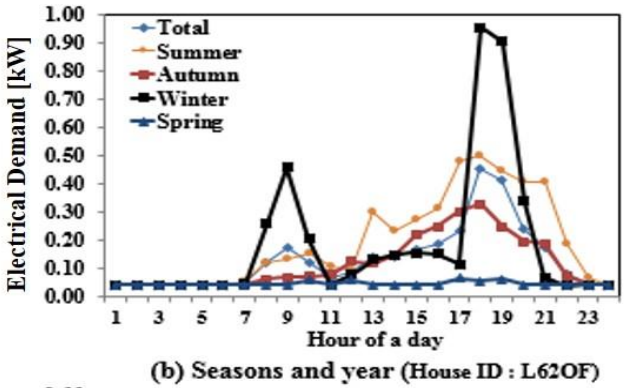


Figure 5. H/C appliances' daily electricity consumption vs. maximum outdoor air temperature

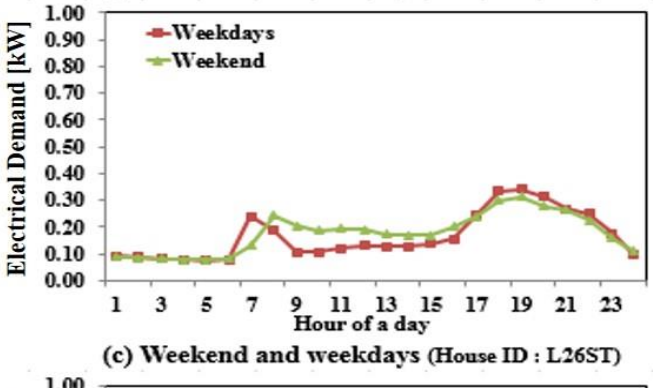
Hourly Usage Patterns



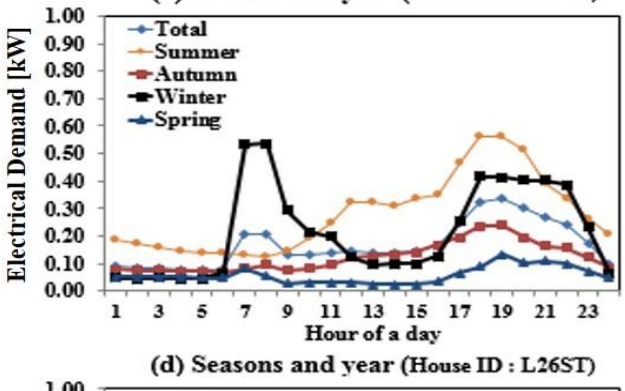
(a) Weekend and weekdays (House ID : L62OF)



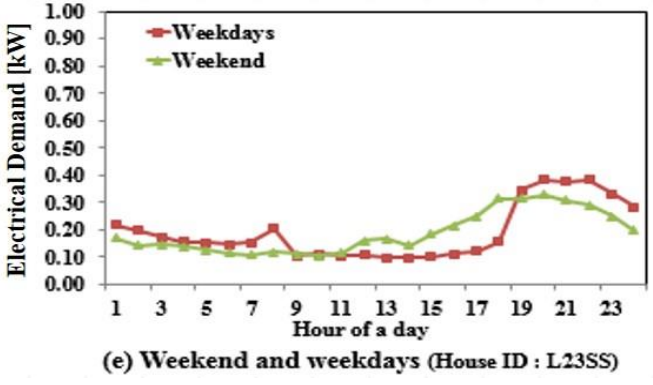
(b) Seasons and year (House ID : L62OF)



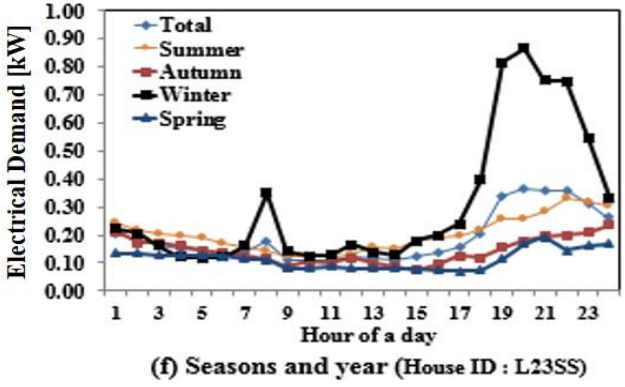
(c) Weekend and weekdays (House ID : L26ST)



(d) Seasons and year (House ID : L26ST)



(e) Weekend and weekdays (House ID : L23SS)



(f) Seasons and year (House ID : L23SS)

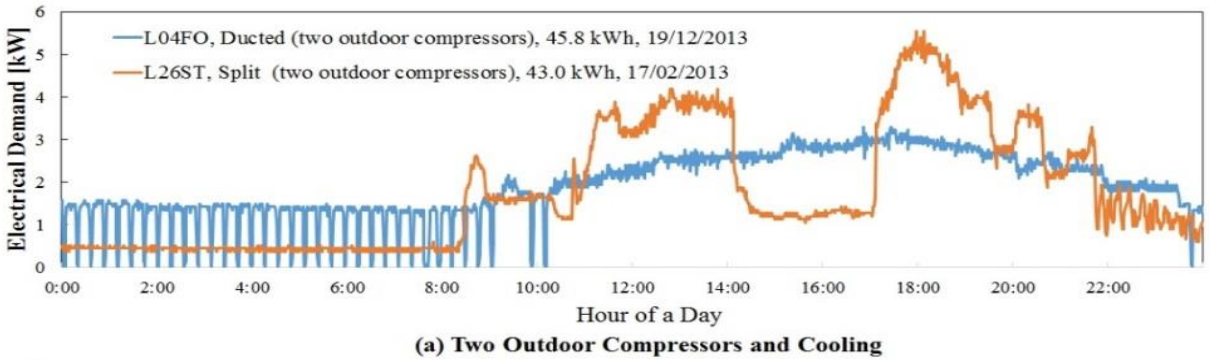
Higher hourly electrical demand in winter
higher peak electrical demand in winter

Winter: two peaks (morning, evening)
➔ high outdoor air temperature and sun radiation, no residents

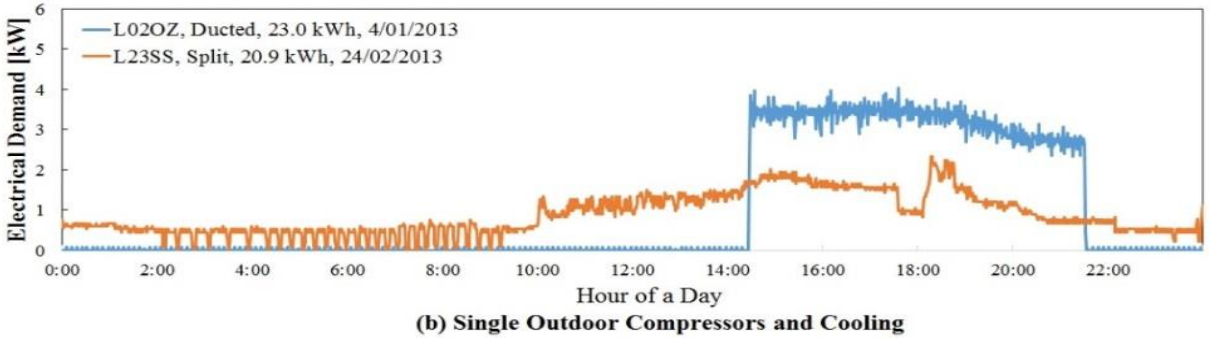
Summer: increasing trends around 11am until 7pm
➔ gradual increase of outdoor air temperature

Typical Minute by Minute Usage Signatures

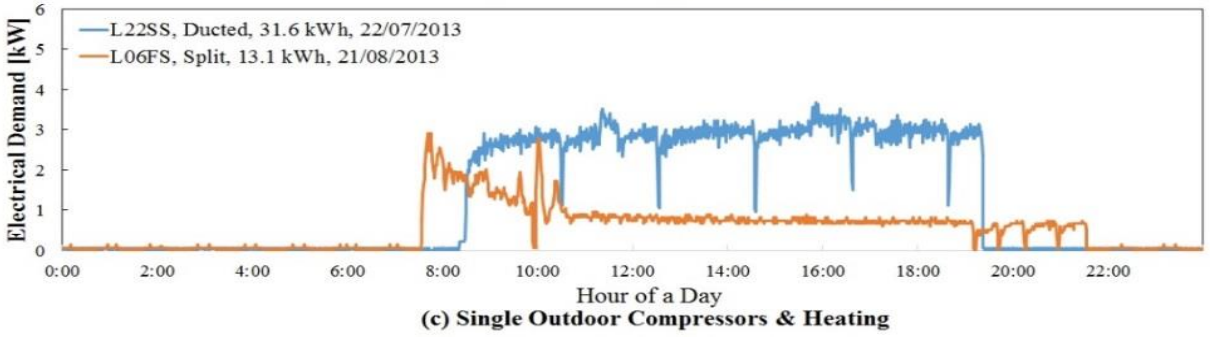
Signatures of H/C appliances on the one day of the year when each H/C appliance consumes electricity the most



(a) Two Outdoor Compressors and Cooling



(b) Single Outdoor Compressors and Cooling



(c) Single Outdoor Compressors & Heating

- ✓ 7 out of 9 have the maximum electrical demand of H/C appliance in summer for cooling when the outdoor air temperature exceeds 38ºC
- ✓ Two houses have the maximum electrical demand in winter
- ✓ Ducted system shows continuous use of electricity during its operating period while split system shows more fluctuation depending on the use of individual indoor unit

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Conclusion

- Considerable reduction in household energy consumption can be achieved in low energy residential buildings, which is attributed to the decrease of energy consumed by H/C appliances, due to high standards of thermal comfort and the requirement of highly energy efficient air conditioning systems.

- Despite the reduction in H/C energy usage, the outdoor air temperature is still the most influential parameter and their electricity consumption is predictable based on maximum outdoor air temperature.

- The results presented here are expected to be used as empirical evidence to refine end-use electricity demand modelling for new housing developments in South Australia and other Australian locations that also experience moderate to hot climate; these can then be used to assist the design of electrical infrastructure requirements in new low energy housing developments.