A local-community-level, physically-based model of end-use energy consumption by Australian housing stock

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Abstract
We developed a physics-based bottom-up model to estimate annual housing stock energy consumption at a local community level (Census Collection District – CCD) with an hourly resolution. Total energy consumption, including space heating and cooling, water heating, lighting and other household appliances, was simulated by considering building construction and materials, equipment and appliances, local climates and occupancy patterns (e.g., the number of occupants and occupancy time). The model was used to analyse private dwellings in more than five thousand CCDs in the state of New South Wales (NSW), Australia. The predicted results track the actual electricity consumption at CCD level with an error of 9.2% when summed to state level. For NSW and Victoria 2006, the predicted state electricity consumption is close to the published model (within 6%) and statistic data (within 10%). A key feature of the model is that it can be used to predict hourly energy consumption and peak demand at fine geographic scales, which is important for grid planning and designing local energy efficiency or demand response strategies.
1. Introduction

Global warming is widely perceived to be one of the most important environmental issues facing the world today, and it is generally accepted that global warming is very likely the result of increasing greenhouse gas concentration due to human activities such as the use of fossil fuel and deforestation [1]. Efforts to reduce energy consumption and related greenhouse carbon emissions are evident in economic sectors such as industry, commercial and residential buildings, agriculture and transportation.

According to the World Business Council for Sustainable Development, buildings account for 40% of the world's energy consumption [2]. In 2008-2009, the residential building sector was responsible for around 8% of total Australian energy consumption (5773 petajoules) [3]. The residential sector is not the largest contributor to carbon emissions in Australia, but it is one of the fastest growing sources [3]. While reducing the total energy consumption of buildings is the major challenge, peak demand management is also an important issue as it is a powerful driver of investment in networks and/or power plants. To date, minimal research attention has been given to the synergies between housing stock energy reduction and peak demand management. One obvious missing synergy is combined prediction of the total energy consumption of housing stock and peak demand. This paper details the development of a practical tool for prediction, with an hourly resolution, of total end-use energy consumption of housing stock.

2. Methodology

2.1 Review of existing modelling for housing stock energy consumption

Total residential sector energy consumption data can be obtained from published governmental sources (for example, Australia [3], Canada [4], China [5], UK [6], USA [7]) or estimated by compiling gross energy values provided by energy suppliers. These data provide useful information on residential sector energy consumption at regional and national
levels. However, the statistics do not provide details of individual end-uses, such as energy consumption for space heating, cooling and other major residential applications. These details are very important for accurate and cost-effective assessment and optimisation of energy efficiency measures, technologies and strategies (e.g., wall and ceiling insulation, energy efficient lighting, on-site renewable energy systems).

Household energy use for space heating and cooling, water heating, lighting and other appliances is highly dependent on building characteristics, climate, appliance and system characteristics, ownership type, and occupant behaviour, and may also be influenced by governmental policy, regulation and household social and economic conditions. Meanwhile, the end-uses may have complex inter-related impacts. For example, the energy consumption of some appliances (e.g., lighting, cooking, refrigerators and freezers) affects the energy consumption of space heating and cooling. Comprehensive models are required to assess social and economic impacts on energy consumption and identify key areas for reducing energy consumption and associated carbon emissions.

Various energy consumption models have been developed to quantify annual energy requirements in the residential sector. Swan and Ugursal [8] comprehensively reviewed these models, identifying two distinct modelling approaches: “top-down” and “bottom-up”. The top-down approach treats the residential sector as an energy sink and pertinent variables as contributors to the energy consumption of the entire housing sector, and is not concerned with individual end-users; the bottom-up approach, which extrapolates the estimated energy consumption of a representative set of individual houses to regional and national levels, uses two distinct methodologies: the statistical method and the building physics based method. Table 1 summarises the important attributes of the three major residential energy modelling approaches, namely the top-down, bottom-up statistical and bottom-up building physics based approaches.
Top-down models are used to determine supply requirements based on long-term projections of energy demand by accounting for historical response. Bottom-up statistical models can account for occupant behaviours and the use of major appliances. Bottom-up building physics based modelling is the only method that can be used to develop energy consumption for buildings without prior historical energy consumption information, and its functions are based on the physics of the end-uses. It has the highest degree of flexibility and capability with regard to modelling new technologies.

A wide range of bottom-up building physics based housing stock models has been developed for policymakers to establish the long-term targets of residential sector energy consumption and related carbon emissions [9] (for instance, Canada [10], Finland [11], UK [12], USA [13]). In Europe, bottom-up building physics based models are seen as useful tools for estimation of the effectiveness of policies and identification of effective technologies [9]. All the models mentioned above focus on the annual energy consumption of the housing sector.

In Australia, the former Department of the Environment, Water, Heritage and the Arts (DEWHA) published a comprehensive report – *Energy Use in the Australian Residential Sector 1986-2020* [14], which tracked annual energy consumption at state level from 1986 to 2005 with projections to 2020 using a bottom-up model developed by consultants. This end-use model includes complex stock models of each major end-use, covering ownership, technical attributes and usage patterns. However, the hourly energy consumption and peak demand were not explicitly described.
2.2 Model design and structure

The study described in this article adopted building physics based techniques to develop a bottom-up engineering model to provide a quick and reliable annual end-use energy evaluation of housing stock with an hourly resolution at different levels (CCD, Statistical Local Area (SLA), city, state, nation) by aggregating hourly energy consumption for individual representative households. Figure 1 illustrates the structure of the model, which includes three key components. It:

- Identifies a limited set of “prototype” dwellings that represent classes of houses found in the housing stock in terms of available data (section 2.3);
- Develops a database for individual prototype house energy consumption using the AusZEH (Australian Zero Emission House) energy model (section 2.4); and
- Is ‘bottom up’ from individual houses to housing stock at different levels (section 2.5).

2.3 Development of prototype dwellings

Physics based modelling calculates energy consumption of end-uses of dwellings or groups of dwellings and then extrapolates the results to represent the housing stock. This method can be applied to a limited set of prototype dwellings that represent classes of houses found in the housing stock [8], in which housing stock is broadly classified according to dwelling type, vintage, size, etc.

The main source of historical data for housing and households was the Australian Bureau of Statistics (ABS) Census of Population and Housing, which has been held at five-yearly intervals since 1961; the 2006 Census is the last from which data are currently available. The data were extracted for both SLA and CCD geographical areas using the ABS TableBuilder© tool [15]. TableBuilder© provides flexibility in selecting and combining any variables...
contained in the census output record file and does not limit data selection to predefined table structures.

**Dwelling type**

Using the census tables listed in Table 2, it was possible to estimate the number of private dwellings in each profile:

1. Dwelling structure by family composition and number of persons resident was used to calculate the *occupancy type* (e.g., one couple with children, a couple, single parent with children, and other);
2. Dwelling structure by labour force was used to estimate the *occupancy time* (e.g., occupied full day, half day and evening only); and
3. Time Series data were used to estimate the age of dwellings.

{Table 2 near here}

The Australian housing stock can be classified into four dwelling structures:

- Detached (separate house);
- Semi-detached (semi-detached house);
- Low-rise apartment/unit (two storey or less);
- High-rise apartment/unit (three storey or more).

**Dwelling vintage**

Three dwelling age categories were used: 1991 or earlier, 1992 to 2006, 2006 or later. Categorisation into these differing age groups was important for two reasons:

- Each of the categories generally represents a different thermal performance of dwelling in terms of minimum energy requirements of Building Code of Australia
(BCA) or building regulations. For example, there were no Building Provisions for minimum energy requirements in the state of Victoria before 1991. On 18 March 1991, regulations for the insulation of new dwellings came into force in Victoria, which requires that buildings must either comply with specified minimum R values of insulation for roof/ceiling, external walls and ground floor, or achieve a house energy rating of at least 3-star using a nominated software tool [16]. A comprehensive study of Victorian housing showed that without regulations, houses had an average energy performance equivalent to less than 1-star, and with current regulations, the housing stock built after 1992 had an average energy rating of 2.2 stars [16]. In the 1990s, individual Australian states developed their own schemes. The Victorian scheme, based on a nominated tool, was eventually accepted as the most effective and adopted by the development of a nationwide House Energy Rating Scheme (NatHERS) [17]. In 2003, the first minimum energy efficiency standards for housing were incorporated into the BCA. Subsequent updates increased NatHERS to five stars in 2006 and then to six in 2011 [18];

- The housing stock model was developed using 2006 ABS census data [15], which allowed an estimate of number of dwellings, dwelling structure by family composition, and so on (see Table 2) for the periods of 1991 or earlier, 1992-2006, and 2006 or later.

**Dwelling size**

Floor area data for new housing entering the population after 1992 for each state is available from ABS new housing approvals data for each type of housing (e.g., detached, semi-detached, and apartments). For dwellings built in 1991 or earlier, floor area data for each state is not available, so the average values of the entire stock of dwellings were adopted as follows [14]:
Detached dwellings = 119.3 m²
Semi-detached dwellings = 55.7 m²
Apartments (all types) = 52.5 m²

Attributes and usage patterns of household appliances and equipment were based on the DEWHA report [14]. Simulation of their energy consumption is summarised in the following section.

### 2.4 Modelling energy consumption of prototype dwellings

As shown in Figure 1, the housing stock model includes a combination of input data and the core simulation engine of AusZEH energy model. The AusZEH design tool recently developed during the AusZEH project [19] can be used to predict the annual hourly energy consumption of households considering the houses’ thermal characteristics, equipment and appliances, local climates and occupancy patterns [20, 21]. The total energy consumption of individual houses includes five parts: space heating and cooling, lighting, water heating, and other appliances.

**Prediction of energy consumption for space heating and cooling**

The heating and cooling energy requirements were projected using AccuRate – an Australian house energy rating tool [22, 23]. The AccuRate software was developed by coupling a frequency response building thermal model [24] and a multi-zone ventilation model [23] for calculating the energy requirements residential buildings. Taking into account the local climate and building fabrics, AccuRate’s simulation engine automatically switches between mechanical air conditioning and natural ventilation operation when natural ventilation satisfies thermal comfort and calculates hourly heating and cooling (H/C) energy requirements over a period of one year. To achieve thermal comfort, the heating and cooling
thermostat settings used in AccuRate for house energy rating are based on the Protocol for House Energy Rating Software published by the Australian Building Codes Board [25, 26]. The AccuRate engine was tested satisfactorily against BESTEST [27].

Based on the annual total H/C energy requirement, AccuRate assigns a star rating between 0 and 10 to the residential building for the specified climate zone, which is defined by NatHERS. The higher the star rating, the more energy efficient the building. AccuRate contains 69 Typical Meteorological Year (TMY) weather files linked to climate zones that cover all Australian states and territories. These can be used for general energy consumption analysis. For a specified year, hourly weather data should be used to estimate energy consumption for space heating and cooling, and water heating.

**Projection of energy consumption for lighting, water heating and other household appliances**

The energy consumption for hot water was calculated using the same approach as the water heating assessment developed by BRANZ Ltd for DEWHA [28]. It calculates the energy consumption for an individual household with up to three separate water heating systems under current climate, including solar hot water systems. Cold water temperatures varying with climate zones are also considered.

The energy consumption for lighting was estimated using Equation 2.1 [29]:

\[
E = \left( \frac{I_{\text{mean}}}{L_{\text{eff}}} \right) \times h \times A_{\text{floor}} \times \left( \frac{N_p}{N_r} \right) / 1000
\]  

(2.1)

where \( E \) is the daily electric lighting energy consumption (kWh/day); \( I_{\text{mean}} \) the average luminance level required; \( h \) the hours of artificial lighting per day; \( L_{\text{eff}} \) the luminance efficacy (lum/W); \( A_{\text{floor}} \) the house floor area (m\(^2\)); \( N_p \) the number of occupants; \( N_r \) the number of rooms in the house.
The average energy consumptions of other household appliances were based on the DEWHA report [14]. In general, the annual energy consumption of an appliance can be estimated as:

$$E = (h_a \times W_a + h_{sby} \times W_{sby} + h_{off} \times W_{off})/1000$$  \hspace{1cm} (2.2)$$

where $E$ is the annual electric appliance energy consumption (kWh/year); $W_a$, $W_{sby}$ and $W_{off}$ are the power (Watts) in active, standby and off modes, respectively, which can be referenced to the appliance information given by the manufacturers; $h_a$, $h_{sby}$ and $h_{off}$ are the time (hours) spent in active, standby and off modes, respectively. These are important parameters for calculations of energy consumption; the DEWHA report contains typical data [14].

**Occupancy profile**

To assess energy consumption for space heating and cooling, hot water, and some other appliances, the two most critical user behaviour factors are the number of occupants and the actual hours of occupancy of the dwelling. According to the ABS Time Use Survey [30] conducted in both 1992 and 1997, seven occupancy profiles were defined in the model as follows:

- **Scenario 1**: Unoccupied period is from 09:00 to 17:00. All occupants in the house have full-time jobs.
- **Scenario 2**: The house is occupied all the time. This type of household may have a young child to look after or the occupants may be retired.
- **Scenario 3**: Unoccupied period is from 17:00 to 20:00. This profile is most prevalent on a Saturday evening.
- **Scenario 4**: Unoccupied period is from 09:00 to 13:00. One of the occupants in this type of household may have a part-time job in the morning session.
Scenario 5: Unoccupied period is from 13:00 to 17:00. One of the occupants in this type of household may have a part-time job in the afternoon session.

Scenario 6: Unoccupied period is from 09:00 to 15:30. This household may have school aged children.

Scenario 7: User defining mode. This was designed to allow the users to define their own occupancy patterns if their occupancy profiles do not fall into the above six scenarios.

Energy consumption pattern depends primarily on the occupied period. For example, when the house is not occupied, space heating/cooling systems, lighting, and most appliances are not used. In the daily appliance load profile, the house uses little power (most appliances are in standby) during sleeping hours. In the evening, houses may use relatively more energy for cooking, dishwashing, television, computers, showers, etc. Hourly energy consumption of individual households was estimated by the AusZEH energy model under these typical operations of the buildings and appliances.

The AusZEH energy model was used to assist the design of the AusZEH demonstration house located in Laurimar, north of Melbourne. Figure 2 shows simulated hourly energy consumption of the house on a summer day. The simulation predicted the two actual high energy loads: in the morning after occupants got up and in the evening, when most appliances were used. The major differences were that most of hot water was used between 10:00 and 11:00 in that day, whereas in the model most hot water was assumed to be used for showers after dinner.

{Figure 2 near here}

2.5 Extrapolation from individual prototype dwellings to the housing stock
Building physics based methods generally include the combination of building physics and empirical data from housing surveys and other data sets, and assumptions on building operations. The complexity levels of the models are determined by their core simulation engines and available data.

To calculate the energy consumption of an individual prototype dwelling, the AusZEH tool was used; it requires information on building construction (walls, ceiling, floor, roof, windows and doors), HVAC (Heating, Ventilation, and Air-Conditioning) systems, water heating systems, lighting, and other appliances, number of occupants and occupancy profiles. This information is supplied by various data sources (some of which are indicated at the top left of Figure 1); these include ABS census and survey data [15, 30] and the DEWHA report [14].

To simplify large amount of variations in housing types, construction elements, age and thermal performance, and their combinations for the simulation of housing stock, in this study housing stock was categorised into three age groups: 1991 or earlier, 1992-2006, 2006 or later (see section 2.3 for details). For the post-2006 housing, a thermal performance based model was used to estimate energy consumption for space heating and cooling of prototype houses under the assumption that they satisfy the energy requirements of BCA (e.g., five star for those built between 2006-2010, and six star built then after). For housing built between 1992-2006 or earlier than 1992, parameters, such as ceiling insulation and infiltration that have significant impact on building thermal performance, were adjusted to make prototype dwelling thermal performance equal to the average levels of the stock (e.g., around one star for those built in 1991 or earlier, and three star between 1992-2006, based on comprehensive energy surveys [14, 16, 31, 32, 33, 34]). Therefore, the thermal characteristics of the average dwelling of a particular category can be defined and fed into the AusZEH energy model.
For a prototype dwelling with typical appliances and equipment, hourly energy consumption was estimated using AusZEH tool for different occupancy profiles (e.g., occupancy types and time). There are 288 profiles for a housing stock within a climate zone (Table 3), which produce 2,522,880 (288 by 365 days by 24 hours) records in the database. For each CCD an estimate of the number of private dwellings and proportion of each profile can be calculated based on the ABS census data [15]. The hourly, daily and yearly energy consumption of a housing stock at CCD level can be estimated by aggregating individual dwelling profiles using Microsoft Access. These data at CCD level can be summed to derive the total energy consumption of the house stock at larger scale (such as SLA, city, state or nation).

3. Application and validation

As mentioned above, the 2006 Census was the main data source for the modelling. The following analysis focuses on the 2006 electricity consumption in NSW and Vic.

In Australia, energy statistics are mostly reported at a national or state level. It is difficult to assess energy data at urban or smaller scales such as SLA or CCD level. New South Wales was chosen for a case study at CCD level as electricity consumption data for 2006 was available for all the 11880 CCDs. CCDs were excluded if the difference between the energy customer count and the actual number of private dwellings was larger than 5%.

There are 18 climate regions in NSW defined in NatHERS (Figure 3) for energy star rating purposes using software tools such as AccuRate. They were grouped into 10 categories to reduce the number of profiles of housing stock based on the total energy demand for space heating and cooling, especially for cooling as most cooling systems consume electricity only. In Australia, 80% of houses are detached [14]. For the purposes of grouping climate zones,
two detached prototype houses were used to evaluate housing thermal performance in different climate zones (Table 4). No CCDs are located in zones 25 and 69 as they are very small areas. For this case study, 1920 profiles of housing stock (10 climate zones by 192 for two age groups (1991 or earlier, and 1992-2006) – see Table 3) were used.

{Figure 3 near here}

{Table 4 near here}

In 2006, the total actual electricity consumption of all the considered CCDs was 10,694,109,183 kWh. Gas and other non-electric appliance penetration for the four main end-uses (ovens, cooktops, space heating and water heating) was around 35% in NSW [35, 36]. Based on this, the total electricity consumption of all considered CCDs from the model is 9,705,533,164 kWh, 9.2% lower than the actual figure. Electricity consumptions of individual CCDs are presented in Figure 4, which shows, in general, the model tracks the actual electricity consumption (the correlation coefficient R-value is 0.72, where $R = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i - \bar{x})^2(y_i - \bar{y})^2}}$, $x$ and $y$ are the actual and predicted electricity consumption, respectively, and $\bar{x}$ and $\bar{y}$ are their average value of all the CCDs ($N$ is the total number of CCDs). The divergence occurred where the gas penetration is not close to 35%. For those CCDs with gas penetration of 35±5%, the modelling estimation is closer to the actual consumption (Figure 5) (the R-value increased to 0.79).

{Figure 4 near here}

{Figure 5 near here}

The total electricity consumptions for NSW and Victoria in 2006 estimated by our model differ by less than 6% from the DEWHA model estimates [14], and by less than 10% from
Energy Supply Association of Australia (ESAA) data [37] (Table 5). This gave some confidence for further analysis.

Figures 6 and 7 show hourly electricity consumption for NSW on a summer day (January 5) and a winter day (July 5) in 2006, respectively. For both seasons, the peak demands occurred in the evenings (between 19:00 and 22:00) due to space cooling/heating and heavy operation of appliances. The daily electricity consumption of NSW 2006 is shown in Figure 8, which indicates that in NSW housing stock consumed more electricity in winter (June, July, August) than summer (December, January, February); this is contrary to patterns in many other NSW CCDs. For example, in one of the Sydney Inner CCDs (1400104 being the CCD number), more electricity is consumed in summer than in winter (see Figure 9).

4. Conclusions

Using occupant patterns (number of occupants and occupancy profiles), we developed a physics based bottom-up model to predict end-use energy consumption of Australian housing stock with an hourly resolution from individual buildings to extrapolate them to the levels of CCD, SLA, region and nation using recent Census data and other available data sources. To model a housing stock, a representative set of 288 dwellings were used, which included five key variables: building type, age, family type, occupied time, and primary energy. The method was validated using actual energy consumption at CCD level in NSW and against the
published model by DEWHA and ESAA data at state level. The model tracks actual energy consumption at CCD level and agrees well with the DEWHA model and actual consumption data at state level.

This model is a powerful tool for estimating hourly, daily and monthly energy residential energy consumption at a range of geographical scales (from CCD to nation); it provides information on peak demand and total energy consumption that will be useful for policymakers and grid management. The capability of the physics-based model engine to simulate down to individual dwellings and appliances, means this tool could also provide insight and analysis of the impacts of new technologies, building regulations and policies on housing stock energy consumption at local (CCD) or state level. In Australia, no existing tools combine building physics with explicit occupant patterns at such scales.

5. Acknowledgments

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6. References


[34] SECWA (State Energy Commission of Western Australia). Domestic energy use in Western Australia. Demand Paper No. 1, State Energy Commission of Western Australia, Perth, Australia, 1991.


Figure 1 The structure and form of the housing stock energy consumption model

Figure 2 Monitored and simulated hourly energy consumption of the AusZEH demonstration house

Figure 3 Proposed climate zones in NSW for AccuRate

Figure 4 Comparison of actual and predicted electricity consumption of individual CCDs

Figure 5 Comparison of actual and predicted electricity consumption for CCDs with gas penetration rates of 35±5%

Figure 6 Hourly electricity consumption of NSW on a summer day (January 5, 2006)

Figure 7 Hourly electricity consumption of NSW on a winter day (July 5, 2006)

Figure 8 Daily electricity consumption of NSW in 2006

Figure 9 Daily electricity consumption of a Sydney inner CCD in 2006
Table 1 Positive and negative attributes of the three major residential energy modelling approaches (adapted from Table 3 of [8])

<table>
<thead>
<tr>
<th></th>
<th>Top-down</th>
<th>Bottom-up statistical</th>
<th>Bottom-up building physics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive attributes</strong></td>
<td>• Long term forecasting in the absence of any discontinuity</td>
<td>• Encompasses occupant behaviour</td>
<td>• Model new technologies</td>
</tr>
<tr>
<td></td>
<td>• Inclusion of macroeconomic and socioeconomic effects</td>
<td>• Determination of typical end-use energy contribution</td>
<td>• “Ground-up” energy estimation</td>
</tr>
<tr>
<td></td>
<td>• Simple input information</td>
<td>• Inclusion of macroeconomic and socioeconomic effects</td>
<td>• Determination of each end-use energy consumption by type, rating, etc.</td>
</tr>
<tr>
<td></td>
<td>• Encompasses trends</td>
<td>• Uses billing data and simple survey information</td>
<td>• Determination of end-use qualities based on simulation</td>
</tr>
<tr>
<td><strong>Negative attributes</strong></td>
<td>• Reliance on historical consumption information</td>
<td>• Multicollinearity</td>
<td>• Assumption of occupant behaviour and unspecified end-uses</td>
</tr>
<tr>
<td></td>
<td>• No explicit representation of end-uses</td>
<td>• Reliance on historical consumption information</td>
<td>• Detailed input information</td>
</tr>
<tr>
<td></td>
<td>• Coarse analysis</td>
<td>• Large survey sample to exploit variety</td>
<td>• Computationally intensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No economic factors</td>
</tr>
</tbody>
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Table 2. Census tables used to construct housing stock profiles

<table>
<thead>
<tr>
<th>2006 Census table</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRD x LFSP</td>
<td>Dwelling Structure By Labour Force</td>
<td>Occupancy time</td>
</tr>
<tr>
<td>STRD x FMCF</td>
<td>Dwelling Structure By Family Composition</td>
<td>Occupancy type - SLA only</td>
</tr>
<tr>
<td>STRD x NPRD</td>
<td>Dwelling Structure By Number of persons resident</td>
<td>Occupancy type - CCD only</td>
</tr>
</tbody>
</table>
Table 3 Housing profiles in a climate zone

<table>
<thead>
<tr>
<th>Dwelling structure</th>
<th>Dwelling age</th>
<th>Occupancy type</th>
<th>Occupancy time</th>
<th>Fuel source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detached</td>
<td>1991 or earlier</td>
<td>Couple with children</td>
<td>Half day</td>
<td>Electricity only</td>
</tr>
<tr>
<td>Semi-detached</td>
<td>1992-2006</td>
<td>A couple</td>
<td>All day</td>
<td>Electricity with gas or other</td>
</tr>
<tr>
<td>2 or less storey flat</td>
<td>2006 or later</td>
<td>Single parent with children</td>
<td>Evening only</td>
<td></td>
</tr>
<tr>
<td>3 or more storey flat</td>
<td>3</td>
<td>other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Total profiles = 4×3×4×3×2 = 288</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4 Grouping 18 climate regions into 10 zones based on the thermal performance of detached prototype houses

<table>
<thead>
<tr>
<th>Region</th>
<th>Climate zone in AccuRATE</th>
<th>Postcode</th>
<th>House Pre-1991</th>
<th>House 1992-2006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heating (MJ/m²)</td>
<td>Heating (MJ/m²)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cooling (MJ/m²)</td>
<td>Cooling (MJ/m²)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Star rating</td>
<td>Star rating</td>
</tr>
<tr>
<td>Moree</td>
<td>8</td>
<td>2400</td>
<td>190.5</td>
<td>72.0</td>
</tr>
<tr>
<td>Amberley</td>
<td>9</td>
<td>4306</td>
<td>115.6</td>
<td>31.7</td>
</tr>
<tr>
<td>Brisbane</td>
<td>10</td>
<td>4000</td>
<td>67</td>
<td>23.7</td>
</tr>
<tr>
<td>Coffs Harbour</td>
<td>11</td>
<td>2450</td>
<td>106.9</td>
<td>38.7</td>
</tr>
<tr>
<td>Armidale (old Tamworth)</td>
<td>14</td>
<td>2350</td>
<td>468.3</td>
<td>220.8</td>
</tr>
<tr>
<td>Williamstown</td>
<td>15</td>
<td>2300</td>
<td>189.9</td>
<td>78.4</td>
</tr>
<tr>
<td>Sydney RO (Observatory Hill)</td>
<td>17</td>
<td>2000</td>
<td>107.1</td>
<td>35.3</td>
</tr>
<tr>
<td>Nowra</td>
<td>18</td>
<td>2541</td>
<td>271.1</td>
<td>116.2</td>
</tr>
<tr>
<td>Wagga</td>
<td>20</td>
<td>2650</td>
<td>408.5</td>
<td>198.9</td>
</tr>
<tr>
<td>Canberra</td>
<td>24</td>
<td>2600</td>
<td>703</td>
<td>296.1</td>
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<tr>
<td>Cabramurra (Old Alpine)</td>
<td>25</td>
<td>2629</td>
<td>1120.</td>
<td>626.2</td>
</tr>
<tr>
<td>Mildura</td>
<td>27</td>
<td>3500</td>
<td>360.9</td>
<td>128.5</td>
</tr>
<tr>
<td>Richmond</td>
<td>28</td>
<td>2753</td>
<td>229.5</td>
<td>91.9</td>
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<tr>
<td>Cobar</td>
<td>46</td>
<td>2835</td>
<td>200.7</td>
<td>75.3</td>
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<tr>
<td>Dubbo</td>
<td>48</td>
<td>2830</td>
<td>307.6</td>
<td>140.8</td>
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<tr>
<td>Mascot (Sydney Airport)</td>
<td>56</td>
<td>2020</td>
<td>158.2</td>
<td>62.8</td>
</tr>
<tr>
<td>Orange</td>
<td>65</td>
<td>2800</td>
<td>753.7</td>
<td>383.7</td>
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<tr>
<td>Thredbo (Village)</td>
<td>69</td>
<td>2625</td>
<td>961.0</td>
<td>535.2</td>
</tr>
</tbody>
</table>

Climate zone groups: 8 (9, 27, 28, 46), 11(10, 17), 14(20), 15, 18, 24, 25(69), 48, 56, 65.
Table 5 Total residential electricity consumption NSW and VIC 2006

<table>
<thead>
<tr>
<th>State</th>
<th>This model (PJ)</th>
<th>DEWHA model (PJ)</th>
<th>EESA (PJ)</th>
<th>Difference between this model and DEWHA</th>
<th>Difference between this model and EESA</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW</td>
<td>68.81</td>
<td>70.0</td>
<td>75.0</td>
<td>-1.7%</td>
<td>-9.0%</td>
</tr>
<tr>
<td>VIC</td>
<td>43.42</td>
<td>41</td>
<td>45</td>
<td>5.6%</td>
<td>-3.6%</td>
</tr>
</tbody>
</table>
Figure 1

Data sources
ABS: Yearly statistics; Census data every five years; Survey.
DEWHA: housing features and appliances.
Other findings.

Households in category
Building type and Characteristics
Family profile
Occupancy
Appliances
Fuel usage

Climate and weather

AusZEH Energy model for hourly end-use energy consumption of individual buildings

Number of households in category

Housing stock energy consumption with an hourly resolution
Figure 2
Figure 3
Figure 4
Figure 5
Figure 6
State, July 5, with proportion predominately electricity - 0.65

Figure 7
State, with proportion predominately electricy - 0.65

Figure 8
Figure 9