15B.5 GREENHOUSE CLIMATIC IMPACTS ON RESIDENTIAL ENERGY CONSUMPTION

Melissa Hart* and Richard de Dear
Department of Physical Geography, Macquarie University, NSW, Australia

1. INTRODUCTION

The data collected during a Residential Energy Study (RES) during 1993/94 in the Sydney region was analysed in conjunction with weather data from the same study period. During the RES up to seven electrical appliances (of which only room air-conditioners will be discussed in this paper) in 136 households were logged in half-hourly increments over 18 months (Camilleri, Isaacs et al. 2000). Statistical relationships between outdoor weather and individual appliance energy consumption for the 18-month sample defined the quantitative climate sensitivity of appliance energy consumption. To project future appliance energy end-use these empirically derived weather sensitivity factors have been applied to long-term climatological observations (1961-1990) and future greenhouse climate scenario predictions (2031-2060). These analyses provide the basis for discussion of the potential impacts of climate change on household appliance energy end-use in the Sydney region.

The residential sector contributes 17% of Australia's greenhouse gas emissions (AGO 2001). Emissions in Australia are projected to rise by 1.8% per year, under a "business as usual scenario", largely driven by high emissions growth in the electricity sector, which in Australia is highly dependant on coal, the most emissions-intensive fuel (Pascoe 2001). The energy sector has shown that it is capable of effectively responding to climate change policies, as evidenced by the introduction of Minimum Energy Performance Standards (MEPS) in Australia. MEPS have been successful in eliminating less efficient models from the market, for appliances such as refrigerators, freezers and domestic electric hot water storage units.

For changes in technology and policy to occur, the impact of climate change on energy consumption under a "business as usual scenario" needs to be fully appreciated. The statistical relationship between energy consumption and outdoor weather to be deduced in this study can be used to predict the impact of climate change on appliance energy consumption. These projections can then provide the necessary impetus for implementing changes in policy and technology to further reduce the levels of greenhouse gas emission attributable to household appliances. Energy efficient appliances have the potential to significantly reduce energy-related greenhouse gas emissions in Australia (AGO 2001).

* *Corresponding author address:* Melissa Hart, Department of Physical Geography, Macquarie Univ., 2109, Australia. +61 (0)2 9850 9466, e-mail: mhart@penman.es.mq.edu.au

Previous studies on climate change and appliance energy consumption have shown the impacts to be location specific, depending on the relative heating and cooling loads. Space heating and cooling of buildings has generally assumed to be one of the most climate sensitive end-uses of energy (Skea 1997; Scott, Gupta et al. 2001) and will therefore be the focus of the present paper. Rosenthal, Gruenspecht et al. (1995) estimated the impact of global warming on US energy expenditures for space heating and cooling in residential and commercial buildings. Average results from six General Circulation Models (GCMs) of the global climate system were used to estimate change in heating and cooling degree-days in five US climate zones after a 1°C global warming. Change in energy consumption was estimated by assuming that degree-days are approximately proportional to space conditioning energy requirements. Results indicated a nationwide increase of cooling season energy consumption of 20%, a decrease of heating season energy consumption of 6%, with an overall net decrease in annual energy consumption of 11% across the USA. The study also took into account regional differences in population, baseline space conditioning intensity levels and market penetration rates across regions.

2. METHODS

Long-term meteorological records, for the years 1961-1990, were obtained from the Australian Bureau of Meteorology's Sydney Airport and Bankstown Airport Automatic Weather Stations (AWS) for use as a baseline (current climate), against which the effects of a greenhouse climate scenario on household appliance energy consumption could be compared. The baseline chosen in this study is the 30-year "normal" period as defined by the World Meteorological Organization (WMO 2001).

Simulated greenhouse climate scenario data was obtained from the Australian CSIRO's Division of Atmospheric Research's (DAR) Limited Area Model DARLAM. DARLAM is a regional climate model that has produced high-resolution climate change scenarios over NSW. The DARLAM experiment uses 140 years of input data from 1961-2100 from the CSIRO coupled ocean-atmosphere GCM. The experiment involved DARLAM first being nested in the GCM using a horizontal resolution of 125km over Australasia and the south Pacific. This provided fine resolution boundary conditions for a second nesting over south-eastern Australia at 60km resolution (Hennessy, Whetton et al. 1998; Whetton, Katzfey et al. 2001). Data from the GCM provides boundary conditions for the LAM (Hennessy 1998). The finer spatial and temporal resolution of LAMs enable more detailed representation of orography and coastlines than GCMs and as a result, are widely assumed to provide a more realistic representation of climate at regional scales than GCMs. The IS92a scenario was chosen for this impacts study because it has been widely adopted as a standard reference scenario for use across a variety of impacts assessments (IPCC-TGCIA 1999). This scenario involves climate models modelling historical forcing due to greenhouse gases and extending into the future under an assumed forcing of 1% increase per year in equivalent CO_2 concentration.

To ascertain the change in climate during a greenhouse climate scenario in Sydney, average monthly degree-days were calculated from DARLAM greenhouse climate scenario output for the period 2031-2060. The change in monthly degree-days between DARLAM's current and greenhouse climates was then applied to the monthly degree-days for Sydney actually observed during years 1961-1990. A scenario for future climate was obtained by adjusting the baseline observations by the difference between period-averaged results for the model experiment and the corresponding averages for the model control simulation (the Delta-T method) (IPCC-TGCIA 1999). The change in climate equates to an overall increase in mean temperature of 1.4°C.

A base temperature of 18°C was used for the calculation of both heating and cooling degree-days, this temperature has been found to be the most appropriate degree-day base temperature for Sydney (Hart and de Dear 2002). These monthly degree-day values for the current and future climates were applied to the empirically fitted regression equations of appliance weather sensitivity (detailed in (Hart and de Dear 2002)) in order to produce current and predicted energy consumption. Seasonal differences described in this section are defined as differences in energy consumption between the heating and cooling season. Those months in which the mean degree-day fell below zero (i.e. <18^{o}C) constituted the heating season (winter) and months where average degree-day was positive (i.e. >18^{o}C) were classified into the cooling season (summer).

3. RESULTS

Weather sensitivities observed between air-conditioner energy consumption and outdoor weather were applied to monthly average degree-days from observed current and simulated future climates. The method simply consisted of inserting a value of degree-days, either current climate or greenhouse scenario, into the appliances' weather sensitivity regression equation and the output was defined as predicted energy consumption. Using this method it was possible to calculate and compare current patterns of air-conditioner energy consumption to those expected under greenhouse climate scenarios.

Figure 1 details the expected monthly room air-conditioner energy consumption under a greenhouse climate scenario, compared to patterns of energy consumption experienced under the current climatic conditions in Sydney. Under a greenhouse climate scenario air-conditioner energy consumption increases by an average 1,320 Wh/day (31%) in summer and decreases by an average 830 Wh/day (19%) in winter, leaving a net annual increase in energy consumption of an average 260 Wh/day (6%). Figure 1 also shows a shift forward in time for cooling season energy consumption under a greenhouse climate scenario, with the onset of the cooling season predicted to occur in September, compared to October under current climatic conditions.

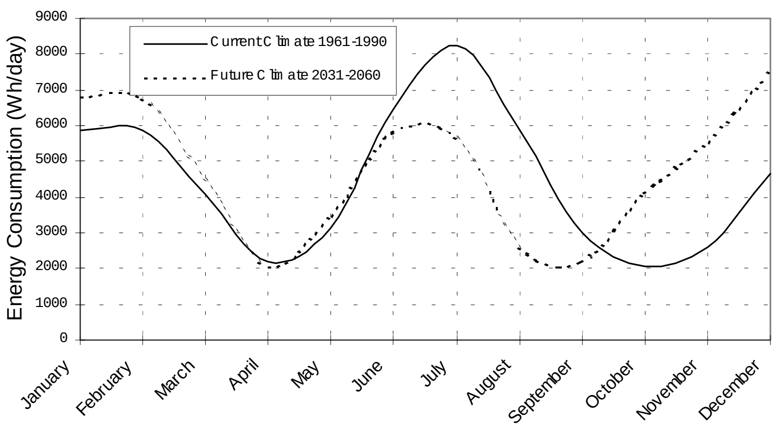

Figure 1 Comparison of room air-conditioner energy consumption for the current climate and under a future greenhouse climate scenario.

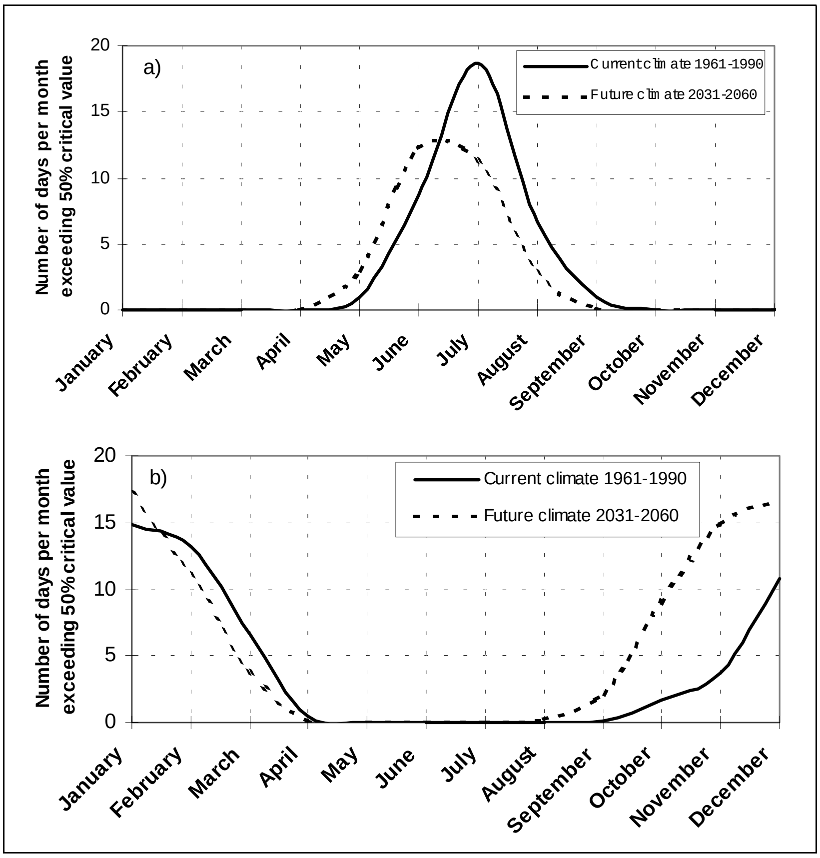

Figure 2 Number of days per month, averaged across the thirty year current and future climate datasets, exceeding the 50% threshold temperature in which half of the households had their air-conditioners switched on at sometime during the day, for a) the heating season (50% threshold = -7.2°C degree-days) and b) the cooling season (50% threshold = +5.5°C degree-days)

During the heating season (Figure 2a) there was, on average, a decrease of 6.4 days per year, under the greenhouse climate scenario, in which the majority of households would have their air-conditioners switched on to heat; this represents an 18% decrease. During the cooling season (Figure 2b) under the greenhouse scenario simulated by DARLAM there was on average an increase of 23.2 days per year (up 45%) in which the majority of households were predicted to be using their air-conditioners to cool.

The Probit regression technique was used to assess the relationship between degree-days and the probability of air-conditioners being switched on. The technique was used to fit sigmoidal response functions between the daily temperature or degree-day (stimulus) and the percentage of sample households with their air-conditioners switched on in heating or cooling mode (response). The Probit regression method returns a 50% threshold temperature which represents the temperature (or degree-day index value) at which 50% of households had their appliance switched off and 50% switched on sometime during the day. For room air-conditioners the 50% threshold temperature was calculated to be -7.2°C degree-days during the heating season (i.e. daily average temperature of 10.8°C) and +5.5°C degree-days (daily average temperature of 23.5°C) during the cooling season. The average number of days per month that this 50% threshold was exceeded was calculated for both current and future climates (presented in Figure 2), in order to assess changes in air-conditioner usage patterns under a greenhouse climate scenario.

4. DISCUSSION

The Inter-Governmental Panel on Climate Change (IPCC) reports that the impacts of climate change on residential energy consumption will be perceptible but modest in relation to the impact factors such as changes in technology and patterns of economic activity (Scott, Gupta et al. 2001). Adaptability is high in the residential energy sector. However, for changes in technology and policy to occur it is necessary to appreciate the impact of “business as usual” on residential energy consumption under a greenhouse climate. In short, “business as usual” impact studies can act as an impetus for technological and operational adaptation and mitigation; consumer change will not occur unless the penalties of not changing are made abundantly clear. The present paper projects current usage patterns and appliance efficiencies (business as usual) onto future climate scenarios, *ceteris paribus*.

Other appliances included in this project's climatic impacts analysis but omitted from the current paper included: room heaters (portable), refrigerators, freezers and domestic hot water systems. These appliances constitute 53% of current household greenhouse gas emissions for Sydney residents (AGO 2001). Depending on the nature of the appliance, energy consumption either increased or decreased under a greenhouse climate. Those appliances involving refrigeration (air-conditioning, refrigerators and freezers) demonstrated an increase in energy consumption, whereas appliances involved in heating (air-conditioners in heating mode, room heaters and domestic hot water) decreased their energy consumption. The major change in energy consumption for all appliances occurred in the second half of the calendar year, particularly during spring months, coinciding with the most intense change in climate under a greenhouse scenario, as simulated by DARLAM.

5.CONCLUSION

The statistical relationships between outdoor weather and appliance energy consumption empirically established under current atmospheric conditions were used to project future energy demand under greenhouse climate scenarios. Future climate was obtained from greenhouse climate simulations from the DARLAM climate model, which were superimposed on long-term observed current climate observations from Sydney using the Delta-T method. The consequences of a net increase in mean temperature for Sydney included an increase in energy consumption for cooling devices, such as air-conditioners, refrigerators and freezers, and a decrease in energy consumption for heating devices; reverse-cycle air-conditioners in heating mode, room heaters and domestic hot water. This was the first climatic impacts assessment undertaken on household appliance energy usage in Australia, and the implications of this "business as usual" assessment should provide additional impetus for technological and policy adaptation and mitigation strategies.

6. REFERENCES

AGO (2001). National appliance and equipment energy efficiency program. Future directions 2002-2004. Canberra, Australian Greenhouse Office**:** 15.

Camilleri, M., N. Isaacs, et al. (2000). Energy used in Australian appliances- Analysis of 1993/1994 RES appliance energy use data, BRANZ**:** 59.

Hart, M. and R. J. de Dear (2002). Human biometeorological dimensions of residential energy consumption. Proceedings of the 16th International Congress of Biometeorology, Kansas City.

Hennessy, K. J. (1998). CSIRO Atmospheric Research technical paper No. 37. Melbourne, CSIRO Atmospheric Research.

Hennessy, K. J., P. H. Whetton, et al. (1998). Fine resolution climate change scenarios for New South Wales. Melbourne, CSIRO Atmospheric Research.

IPCC-TGCIA (1999). Guidelines in the use of scenario data for climate impact and adaptation assessment, Intergovernmental Panel on Climate Change, task group on scenarios for climate impact assessment**:** 69.

Pascoe, M. c. (2001). International Climate Change Policy. Outlook 2001, Sydney.

Rosenthal, D., H. Gruenspecht, et al. (1995). "Effects of global warming on energy use for space heating and cooling in the United States." Energy Journal **16**(2): 987-998.

Scott, M., S. Gupta, et al. (2001). Human settlements, energy, and industry. Climate Change, 2001, Impacts, adaptation, and vulnerability. Contribution of working group 2 to the third assessment report of the Intergovernmental Panel on Climate Change. J. McCarthy, O. Canziani, N. Leary, D. Dokken and K. White. Cambridge, Cambridge University Press**:** 381-417.

Skea, J. (1997). The Energy Sector. Applied climatology principles and practice. R. Thompson and A. Perry. London, Routledge**:** 256-269.

Whetton, P. H., J. J. Katzfey, et al. (2001). "Developing scenarios of climate change for Southeastern Australia: an example of using regional climate output." Climate Research **16**: 181-201.

WMO (2001). World Meteorological Organization. 1961-1990 WMO Global Standard Climate Normals. **2001**.