Climate Change Induced Residential Cooling Demand in the Greater Toronto Area

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Introduction

Since 2000 the Toronto medical officer of health has issued 178 summertime heat alerts. Extreme heat alerts are used to trigger the opening of public “cooling centres” to ameliorate the health effects of extreme heat on those who find air conditioning unaffordable[2]. It is expected that demand for residential cooling during the summer season will increase as a result of climate change as temperatures climb[3]. This will have the potential consequence of increasing the pool of residents dependent on cooling centres as electricity costs assume an ever increasing proportion of income. Current long-term utility projections of electrical demand do not typically include future impacts of climate change[4].

Our objective in this study is to examine how residential cooling loads will increase in a portion of the Greater Toronto Area over the next eight decades and the corresponding implications for electrical costs.

Methods

We examine the increased cooling load on single detached and multi-unit residential dwellings by calculating hourly heat gains to 2095 with median hourly temperatures from a five member ensemble from the PRECIS regional climate model[1] driven by the Hadley Center, HADCM3 using the A1B SRES scenario, for a 25 x 25 km portion of Toronto (Fig.1). Component cooling loads (Fig.2) incorporate conduction, infiltration, solar gains and appliance and body heat contributions from a survey[5] of prototypical dwellings adjacent to the Great Lakes based on 1960-90 climate normals. Hourly conduction and infiltration heat gains are computed from modeled outdoor temperatures. Hourly appliance and body heat gains per cooling day are fixed while solar gains are scaled to sunlight intensity over the cooling season. Hourly electrical consumption assumes an air conditioner COP = 2.64 which is de-rated as outdoor temperatures increase[6]. Model runs allow for a programmable thermostat to regulate interior temperatures at different times of the day. Electrical costs utilize present-day Toronto Hydro *time-of-use* demand rates which are allowed to increase at 2% annually above the assumed inflation rate of 2%. Monthly charges for electricity include delivery and supplemental fees pro-rated to electrical usage.

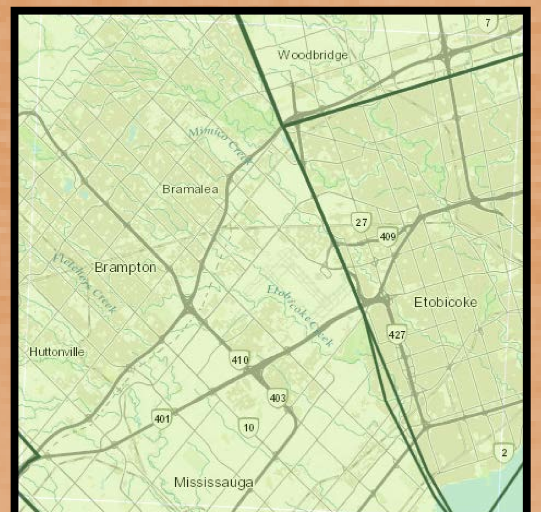

Figure 1. Study area (25 km) within the GTA.[1]

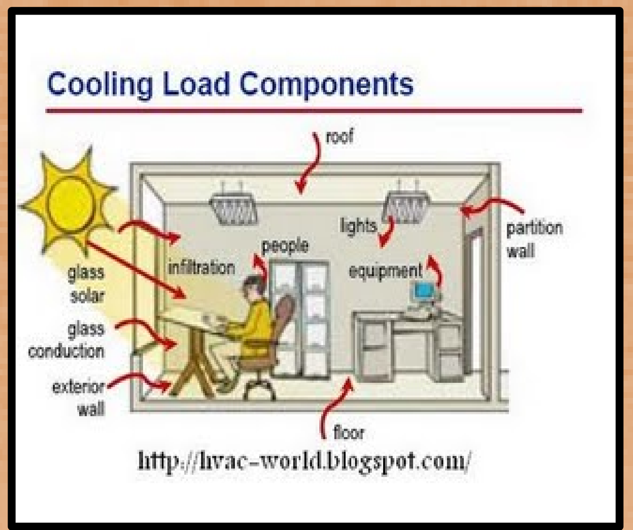

Figure 2. Residential cooling load components.

Results-Hourly Energy Gains

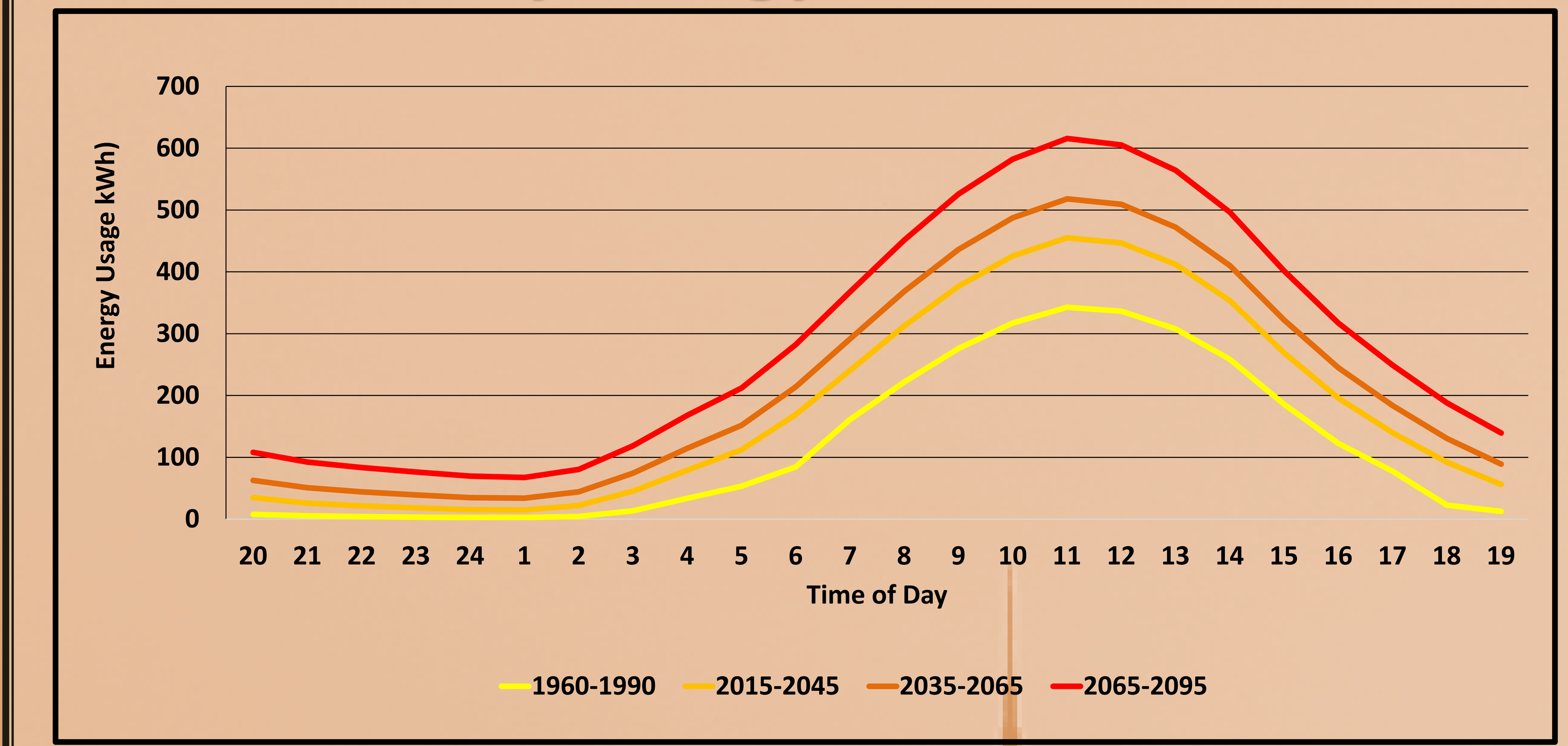

Figure 3 The diurnal patterns in modeled annual average hourly cooling loads for the time periods 1960-1990, 2015-2045, 2035-2065, and 2065-2095 for a single detached dwelling with interior temperature fixed at 20^{0}C.

Results-Annual Component Loads

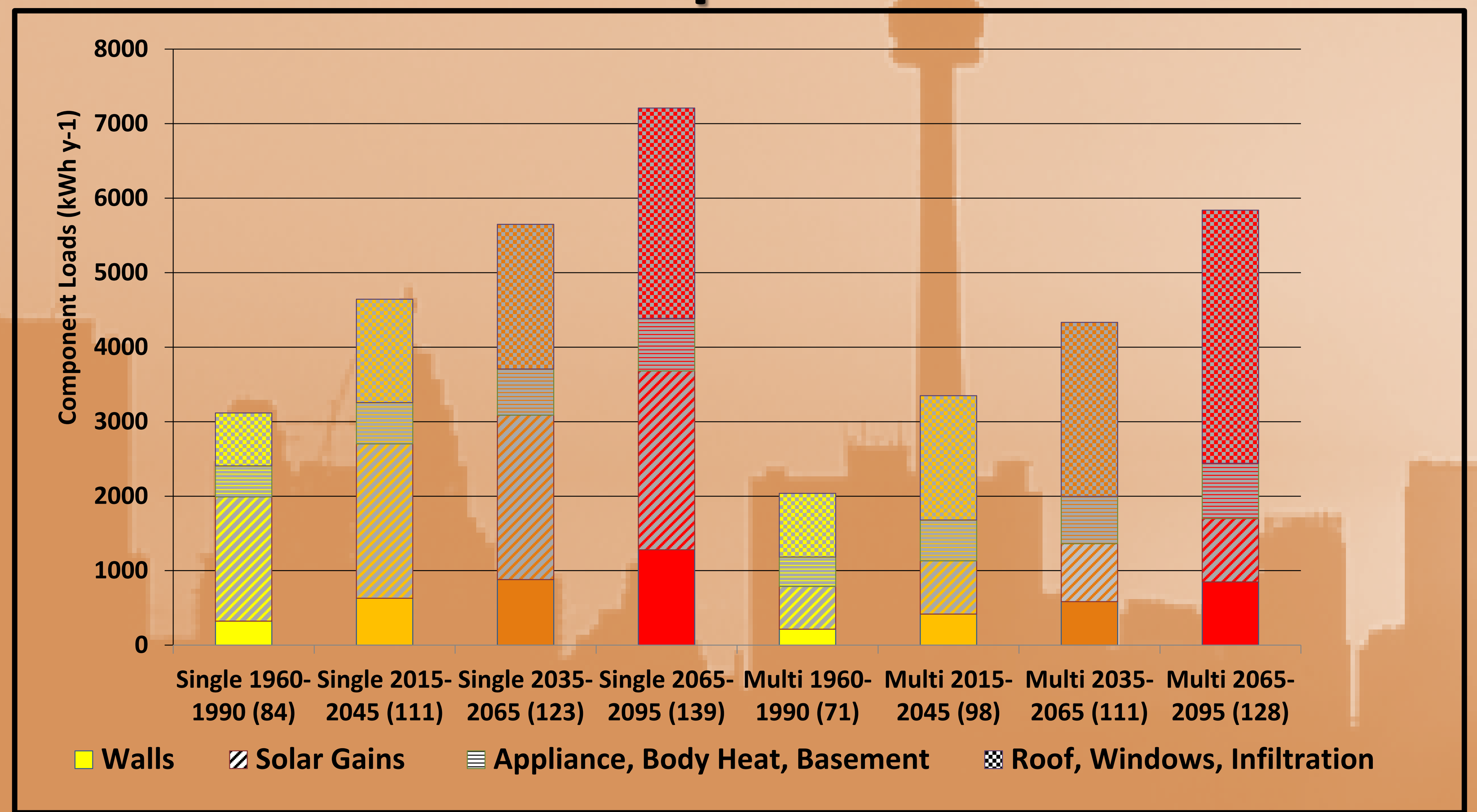

Figure 4 Comparison of component loads for a single detached dwelling and multi-unit dwelling for each time period and cooling days with interior temperature fixed at 20^{0}C.

Results-Energy Costs

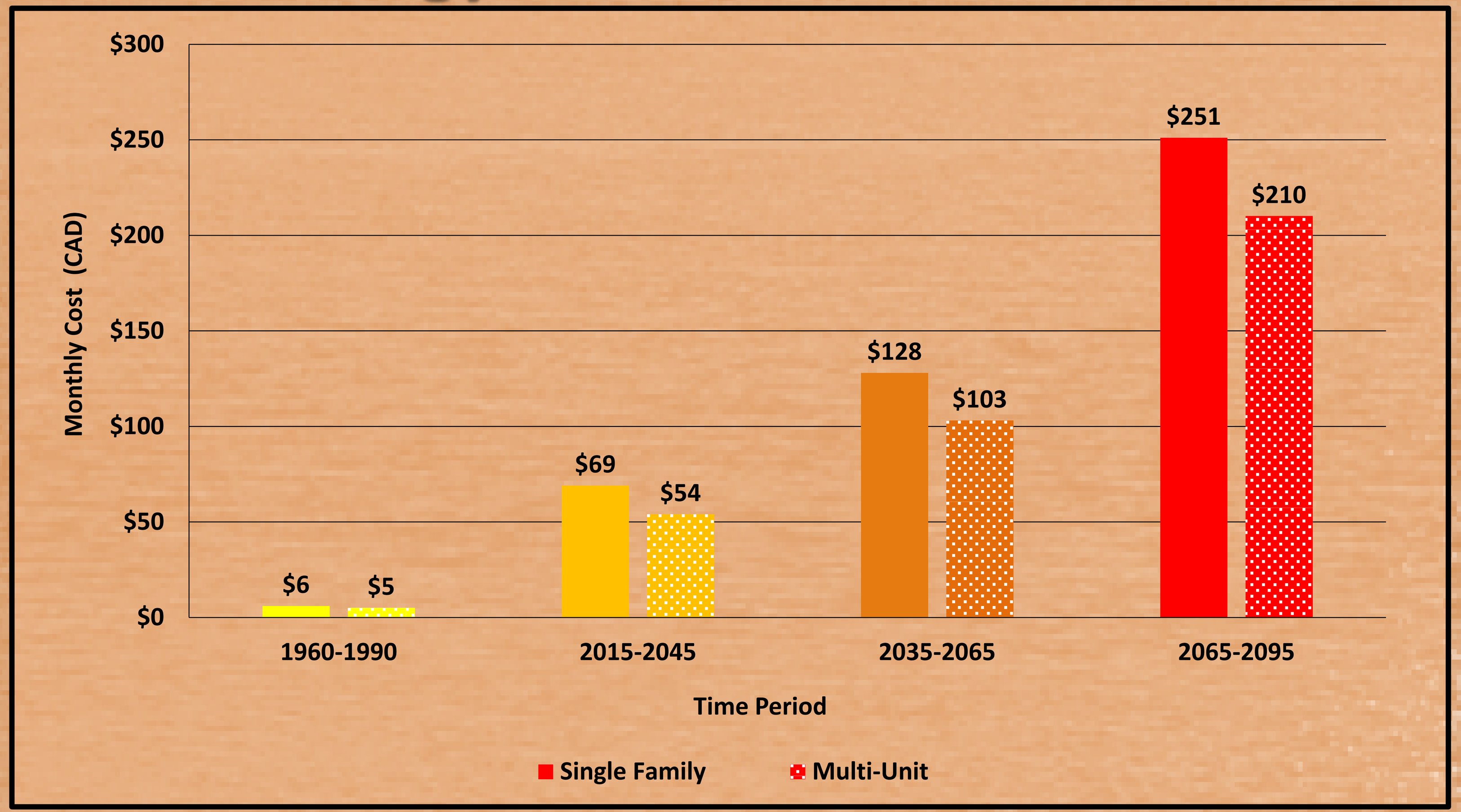

Figure 5 Average monthly electrical charges for cooling residences in Toronto including delivery, HST and debt charges for 2015-2045, 2035-2065, and 2065-2095. Interior temperature fixed at 20^{0}C.

Discussion

Figure 3 shows that average hourly residential heat gain increases unevenly over the four model periods. Peak cooling loads occur between 11:00 am and noon which correspond to maximum *time-of-use* electrical charges. Largest proportional changes occur in the evening as nocturnal temperatures rise faster due to the greenhouse effect. Over the entire period examined, cooling load increases by a factor of 2.4 for single detached residences.

Figure 4 shows that the number of cooling days and total cooling loads are smaller for apartments. This reduced heat loss of 31% for apartments in 1960-90 diminishes to 16% by 2065-95. This is because solar gains form a larger proportion of total cooling load in single detached residences at present, but sunlight intensity is not increasing. Outdoor temperature increases, which enhance wall, roof, window and infiltration gains, are more important for apartments.

The cooling loads translate into air conditioners operating for more hours per day, for more days per year and less efficiently as temperature differentials increase. Much of the increase in load is occurring during mid-day when electrical rates are at a premium. These factors combine (Fig.5) to increase the average monthly electrical bill for cooling only from a 1960-1990 average of $6 ($5) to $251 ($210) in 2065-2095 for the two housing types, respectively.

For a minimum wage earner living in an apartment, these average monthly cooling charges will increase from 2.5% (1960-90) to 3.6% (2065-95) of gross monthly income, assuming wages increase with inflation at 2% annually. For the hottest months during the 2065-95 period, cooling an apartment will consume as much as 9.9% of income.

Conclusions

Climate change will have a profound impact on Toronto residents in a warming world which will include increased cooling loads and associated cooling costs. The related issues of affordability and heat related health effects require heightened consideration by all levels of government.

References

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