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What is the Relation between Energy Consumption Savings and Peak Load Savings and How Can These Affect Future Energy Conservation Requirements?

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Abstract

Many of the green rating systems and standards in North America include requirements to maximize energy efficiency and reduce building energy consumption. Recently, they have included some new requirements to maximize efficiency in electricity production and distribution and increase the reliability of the power grid through requirements for peak load reduction. This paper is part of an ongoing initiative to set energy conservation requirements that are achievable, reliable, and promote resiliency in new developments. It addresses a number of questions: What is the relationship between energy consumption savings and peak load savings? Can energy consumption savings contradict peak load savings? How far can peak load savings be achieved for different building types and what type of energy end-uses contribute most to peak load? To answer these questions, this paper analyzes available data collected from the energy model reports of mid- to high-rise buildings that were submitted to the City of Toronto. A total of 60 buildings (1,782,263.6 m^2 gross floor area) were assessed, and a number of observations were made from analyzing this data. The paper concludes with a number of recommendations that need to be considered in future energy conservation targets and performance requirements.

Keywords: *Energy conservation; Peak Load; Energy End Use; Green Rating Systems*

1. Introduction

Peak electrical demand trends and pressures associated with new growth in many large cities around the world have increased concerns about electric system reliability combined with concerns about the cost of new generation and transmission and distribution. These factors lead to increased interest in and need for reducing peak loads as well as energy consumption.

Despite the fact that electricity demand in Ontario has decreased by 10% since 2005, Ontario continues to use 27% more electricity per person than its neighbours in New York State (Ontario Clean Air Alliance, 2012). This indicates that there is plenty of potential to further reduce electric demands through more robust energy conservation efforts.

Energy conservation produces a number of additional benefits that load management alone does not. It looks at energy conservation as a first priority resource to address both peak demand and energy needs (Dan, Marten and Patti, 2007).

Many green rating systems, conservation incentive programs, and green standards in North America include requirements to maximize energy efficiency and reduce building energy consumption. Buildings are required to improve their energy performance by showing a percentage of improvement above code. Recently, many of the green

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rating systems and standards have included some new requirements to maximize efficiency in electricity production and distribution and increase the reliability of the power grid through requiring reduction in peak loads.

Few studies in the past have looked specifically at the relation between energy savings and peak load savings. To fill this information gap, one of the primary goals of this paper is to investigate the relationship between total energy consumption savings, electricity consumption savings, and peak load savings.

Knowing where electric energy is being used (end-use) and which end-uses contribute most to peak loads can yield important insights and help establish better future energy conservation requirements that can address electric grid stress issues. Previous studies have analyzed electric energy end-use in a limited number of buildings in the City of Toronto, but to date, there have been no studies that covered a significant sample of buildings across the city.

Consistent with the City of Toronto's desire to use energy conservation as a first priority resource to address peak demand issues, this paper aims to answer a number of important questions that can lead to setting energy conservation requirements that are achievable, reliable, promote resiliency in new developments, and yield the required peak load reduction.

2. Scope and Limitations of the Study

Peak load savings can be achieved by two principal ways, load shifting and load reduction. This paper only focuses on peak load reduction, and more specifically on critical load peak reduction, which is the highest demand for electricity in a given year. As critical peak in Toronto happens in summer (Ministry of Energy, 2013), this paper does not include any analysis or information related to winter heating loads.

This paper is based on energy model reports for new construction projects in the City of Toronto, and it does not include information about existing buildings. It includes information about how new buildings are designed to comply with the energy conservation requirements and provides insights about how new buildings are designed and expected to perform with respect to energy use.

Residential buildings refer to low-, mid-, and high-rise, multi-unit residential buildings (MURBs) with a minimum of 5 residential units. MURBs represent the most significant component of the Toronto residential building inventory. Over half (55%) of the residential buildings in the City of Toronto consist of MURBs. Most of Toronto residential buildings (39%) are mid-rise or high-rise apartment buildings of five or more storeys. Low-rise apartments of four or fewer storeys represent 16% of the residential buildings in Toronto (City of Toronto, 2012). Commercial buildings refer to offices, shopping centers, recreational facilities, schools, and hotels.

3. Methodology and Data Acquisition

This paper is based on the available data in the energy model reports of buildings that were submitted to the City of Toronto between 2011 and 2014.

The data sample composition of the new building project analyzed in this study was predominately MURBs with a minority of commercial buildings for a total of 60 buildings (1,782,263m^2 gross floor area) comprised of:

– 43 MURBs (1,685,626 m^2 gross floor area)

– 17 commercial buildings (96,637 m^2 gross floor area)

The data was analyzed in order to investigate the relationship between total energy consumption savings, electric consumption savings, and peak load savings in relation to the Model National Energy Code for Buildings (MNECB)[1].

To investigate how new buildings in Toronto can expect to use electric energy and to categorize summer peak load end-use and electric energy end-use, our study began with aggregating detailed end-use peak load and electric energy end-use data

[1] The MNECB features two types of requirements: mandatory, mostly qualitative requirements that must be met by all proposed designs, and prescriptive, quantitative requirements for which the MNECB provides three optional paths to show compliance (1. prescriptive compliance, 2. trade-off compliance, and 3. performance compliance).

for the various end-use purposes of lighting, space cooling, domestic hot water, ventilation fans, pumps, and other miscellaneous equipment. The data was analyzed and the proportion of electric energy end-use and summer peak load end-use was determined. Finally, existing energy codes and standards for new buildings in the City of Toronto are discussed to identify how future energy conservation requirements can provide relief for electric grid stresses and improve infrastructure resiliency.

4. The Relationship between Total Energy Savings, Electric Energy Savings, and Summer Peak Load Savings

The energy model report data for all the building types was analyzed in order to determine the relationship of summer peak load savings, the total energy savings, and electric energy savings. The data revealed that out of the 60 buildings analyzed, 21 buildings could achieve 25% above MNECB for electric energy savings, and only 17 buildings could achieve the same percentage for summer peak load savings. See Table 1.

Table 1

Total Number of Buildings that Achieved Peak Load Savings and Electricity Savings above MNECB (All Buildings)

	No. of buildings achieved savings ≥ 25%	% of buildings achieved savings ≥ 25%	No. of buildings achieved savings ≥ 36.25%	% of buildings achieved savings ≥ 36.25%
Summer Peak load Savings	17	28%	10	17%
Electric energy savings	21	35%	10	17%

Out of the 60 buildings analyzed, 30 buildings could achieve the total energy savings targets set by the current Toronto Green Standards (TGS)[2], which is 36.25 % above MNECB, 10 buildings could achieve the same percentage for electric energy savings, and 10 buildings could achieve the same percentage for summer peak load savings. See Table 1.

Summer peak savings ranged between -36% and 46%, electric energy savings ranged between -20% and 54%, while total energy savings ranged between 25% and 55% above MNECB (Figure 1).

The data suggests that the average and median summer peak savings are 16% and 19%, respectively. The average and median electric energy savings is 19% and 20%, respectively. This indicates that currently, there is limited feasible potential for requesting more peak savings above the current OBC requirements.

Figure 2 shows that there is a positive weak correlation between total energy savings above MNECB and peak demand reduction among the buildings analyzed, while Figure 3 shows that there is a strong positive correlation between electric energy savings and peak demand savings. The most obvious explanation is that most of the electric energy efficiency technologies yield some peak reduction (Dan, Marten and Patti, 2007).

It is worth noting here that when the total electric energy savings was compared with the total natural gas savings in the sample of buildings that were looked at, it was found that 21% of the total energy savings was electric energy, while 79% was natural gas energy.

4.1 The Relationship between Total Energy Savings, Electric Energy Savings, and Summer Peak Load Savings for Residential Buildings

When the data was broken down further, it was found that 14 of the total 43 residential buildings could achieve 25% above MNECB for electric energy savings and only 10 buildings could achieve the same percentage for summer peak load savings, while only 8 buildings could achieve 36.25% above MNECB for electric energy savings and only 7 buildings could achieve the same percentage for summer peak load savings. See Table 2.

[2] The Toronto Green Standard is a two-tier set of performance measures and supporting guidelines that promotes sustainable site and building design in the City of Toronto. The TGS requires design strategies that improve energy efficiency (City of Toronto, (2009).

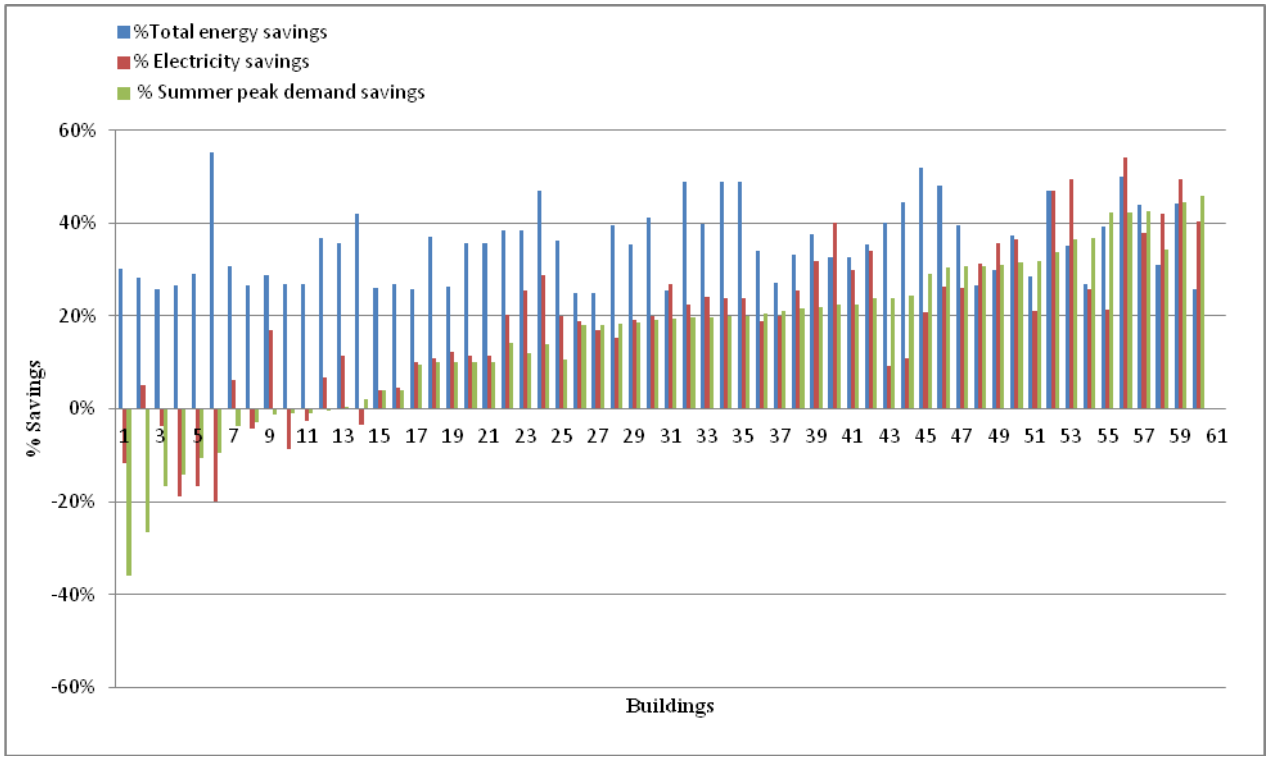


Figure 1: Summer Peak Demand Savings, Total Energy Savings, and Electric Energy Savings (All Buildings)

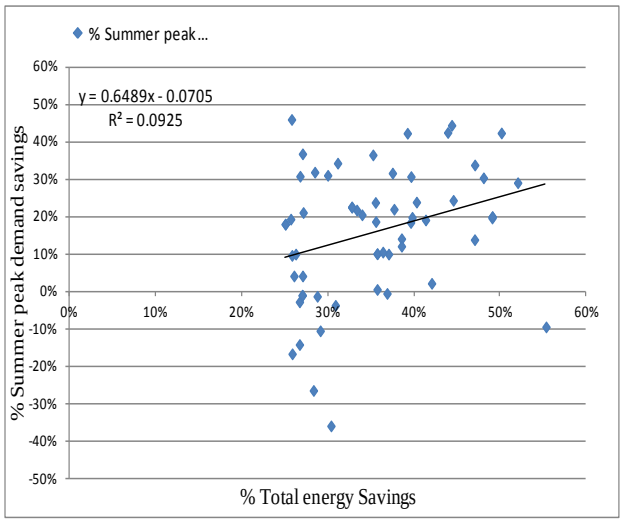


Figure 2: Summer Peak Demand Savings Relative to Total Energy Savings (All Buildings)

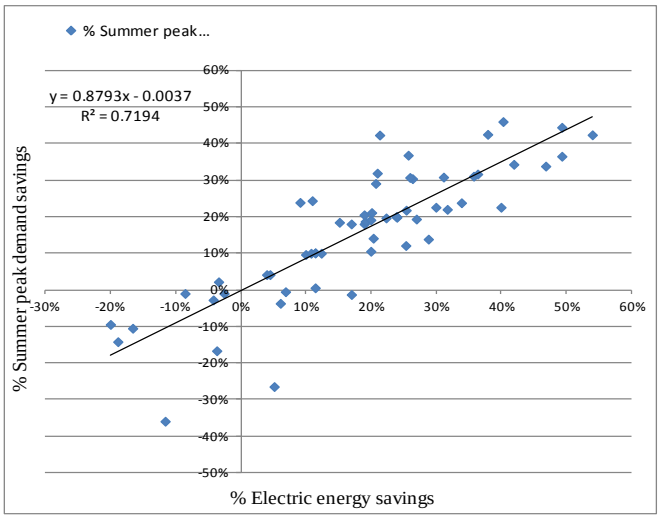


Figure 3: Summer Peak Demand Savings Relative to Electric Energy Savings (All Buildings)

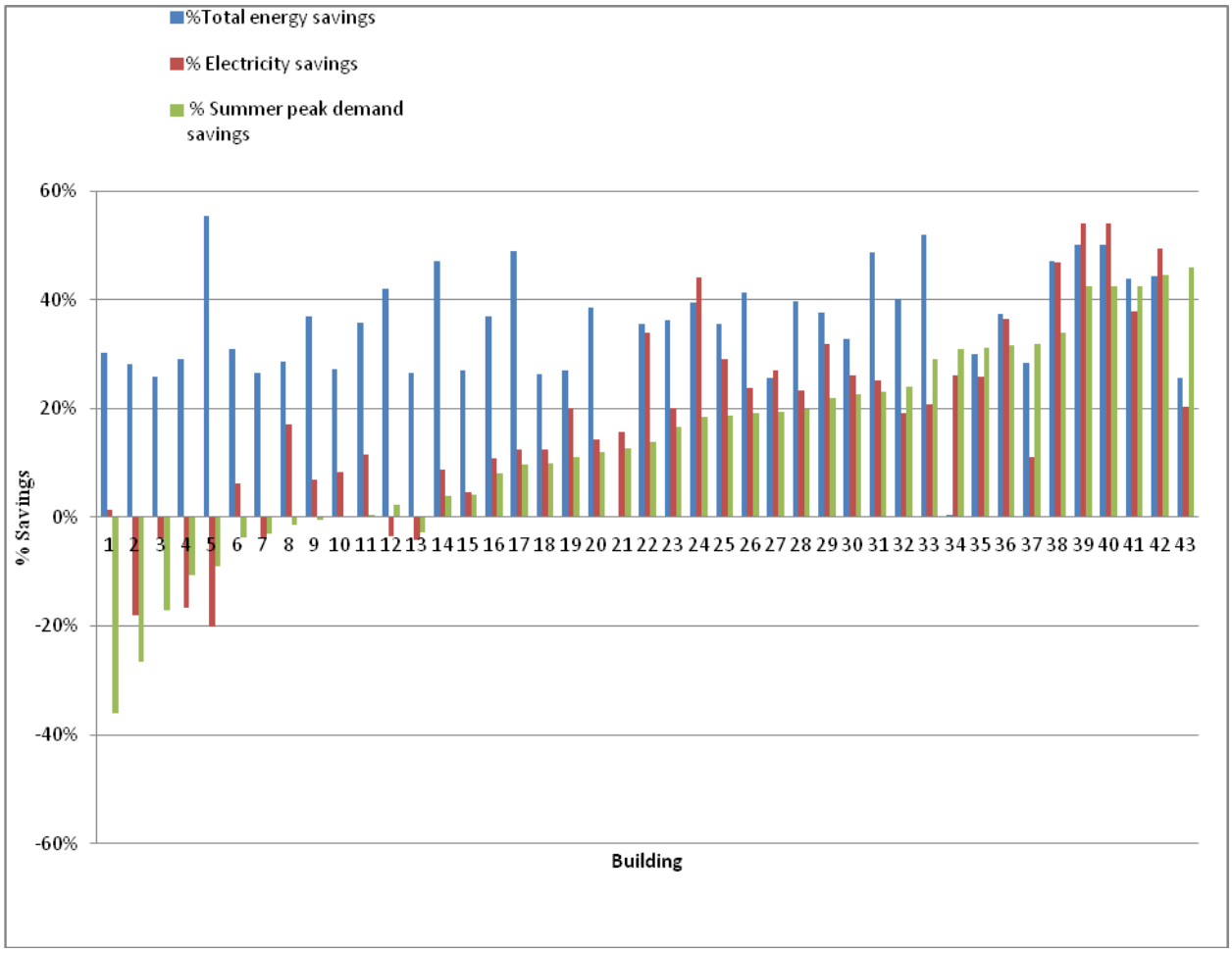


Figure 4: Summer Peak Demand Savings, Total Energy Savings, and Electric Energy Savings (Residential Buildings)

Table 2

Total Number of Buildings Achieved Peak Load Savings and Electricity Savings above MNECB (Residential Buildings)

	No. of buildings achieved savings ≥ 25%	% of buildings achieved savings ≥ 25%	No. of buildings achieved savings ≥ 36.25%	% of buildings achieved savings ≥ 36.25%
Summer Peak load savings	10	23%	7	16%
Electric energy savings	14	33%	8	19%

The data also showed that summer peak savings ranged between -36% and 46%, electric energy savings ranged between -20% and 54%, while total energy savings ranged between 25% and 55% above MNECB (Figure 4).

The average and median summer peak savings for residential buildings is 14%. The average and median electric energy savings is 18% and 19%, respectively. This indicates that currently, there is limited feasible potential for requesting for more peak savings above the current OBC requirements for residential buildings.

Figure 5 shows that there is a positive weak correlation between total energy savings and peak demand savings among the buildings analyzed, while Figure 6 shows that there is a medium

positive correlation between electric energy savings and peak demand savings.

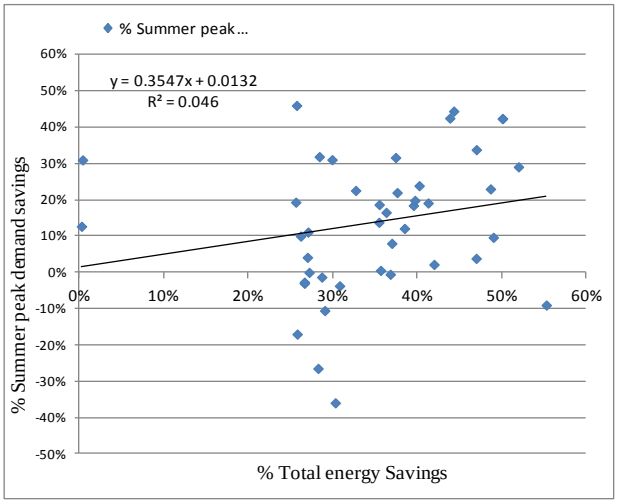


Figure 5: Summer Peak Demand Savings Relative to Total Energy Savings (Residential Buildings)

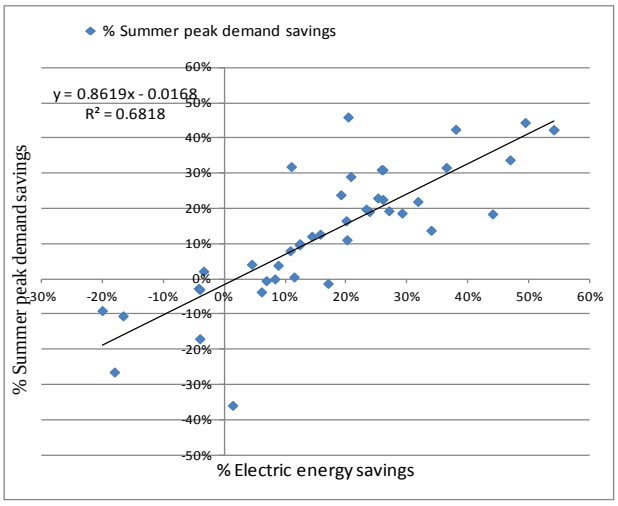


Figure 6: Summer Peak Demand Savings Relative to Electric Energy Savings (Residential Buildings)

4.2 The Relationship between Total Energy Savings, Electric Energy Savings, and Summer Peak Load Savings for Commercial Buildings

The data revealed that out of the 17 commercial buildings analyzed, 7 buildings could achieve 25% above MNECB for electric energy savings and 7 buildings could achieve the same percentage for summer peak load savings. See Table 3. Five buildings could achieve 36.25% above MNECB, while only 2 buildings could achieve the same percentage for electric energy savings, and only 3 buildings could achieve the same percentage for summer peak load savings.

Table 3

Total Number of Buildings that Achieved Peak Load Savings and Electricity Savings above MNECB (Commercial Buildings)

	No. of buildings achieved savings ≥ 25%	% of buildings achieved savings ≥ 25%	No. of buildings achieved savings ≥ 36.25%	% of buildings achieved savings ≥ 36.25%
Summer Peak load savings	7	41%	3	118%
Electric energy savings	7	41%	2	12%

The data also showed that summer peak savings ranged between 5% and 45%, electric energy savings ranged between 9% and 42%, while total energy savings ranged between 25% and 52% above MNECB (Figure 7).

The average and median summer peak savings are 27% and 24%, respectively, while the average and median electric energy savings is 26% and 25%, respectively. This indicates that there is a limited feasible potential for requesting more peak savings.

As shown in Figure 8**,** there is a negative weak correlation between the percentage of total energy savings and peak demand savings among the buildings analyzed, while Figure 9 shows that there is a strong correlation between electric energy savings and peak demand savings.

There are a number of observations that can be taken from this:

– Energy use in Toronto's buildings, especially MURBs, is predominantly met by natural gas (Clarissa, 2012) and most of the buildings analyzed complied with the energy efficiency requirements, mainly by reducing natural gas consumption not electric consumption.

– Currently, there is a limited feasible potential for requesting more peak savings above the current code.

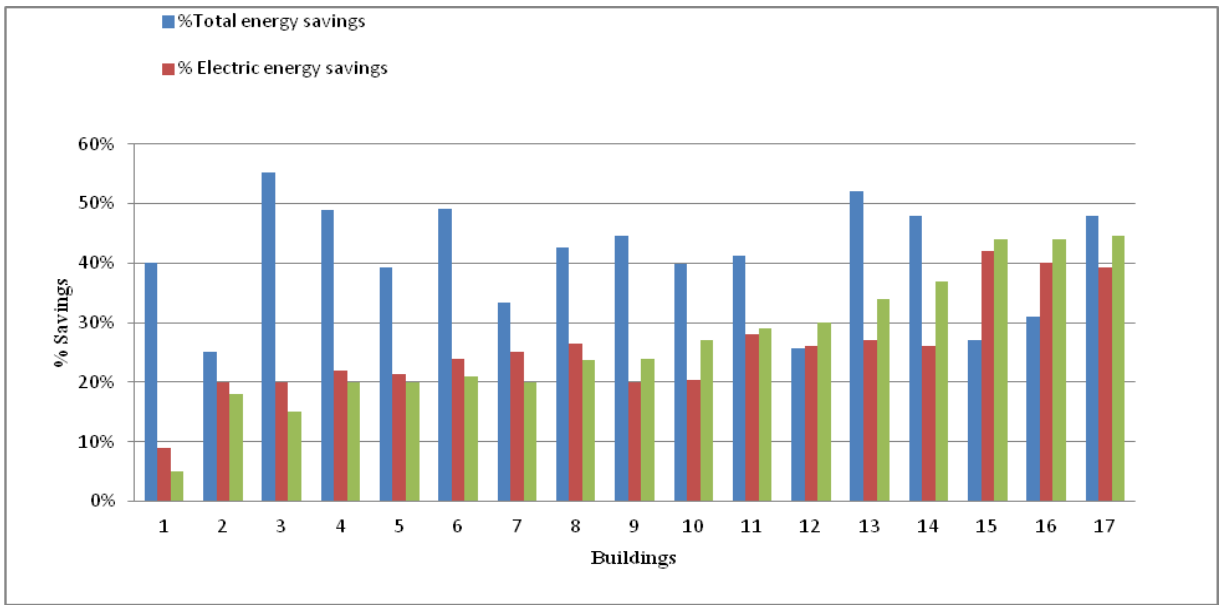


Figure 7: Summer Peak Demand Savings, Total Energy Savings, and Electric Energy Savings (Commercial Buildings)

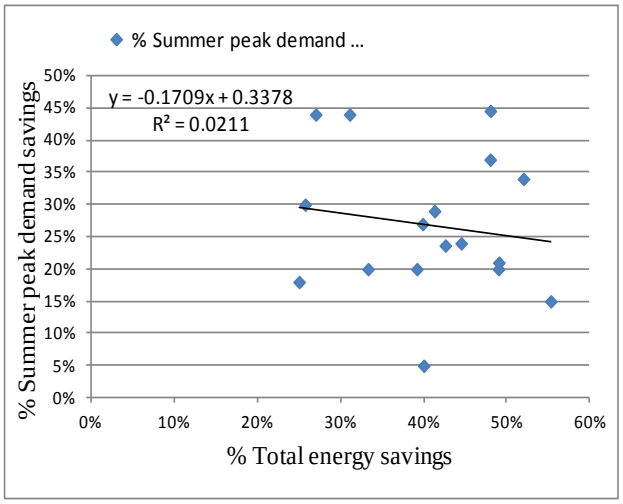


Figure 8: Summer Peak Demand Savings Relative to Total Energy Savings (Commercial Buildings)

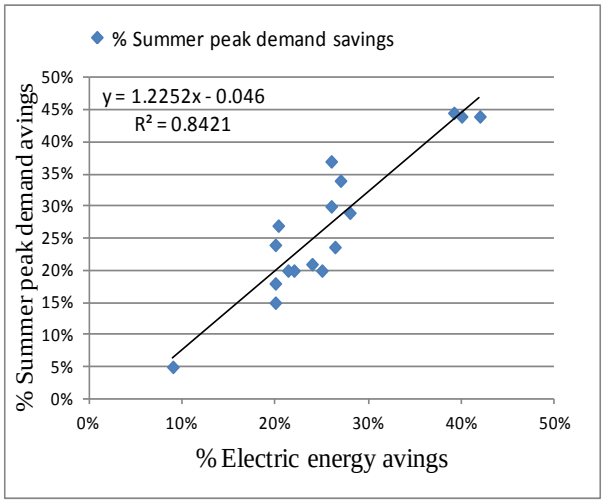


Figure 9: Summer Peak Demand Savings Relative to Electric Energy Savings (Commercial Buildings)

– There is a weak correlation between the percentage of the total energy savings and peak demand savings among the buildings analyzed, while there is a strong correlation between electric energy savings and peak demand savings.

5. Summer Peak Load End-Use and Electric Energy End-Use

Detailed end-use peak load and electric energy end-use data is aggregated for the following end use purposes: lighting, space cooling, domestic hot water, ventilation fans, pumps, and other miscellaneous equipment. After that, the data is analyzed and the composition of electric energy end-use and summer peak load end-use was examined. The data revealed the following:

For all the buildings analyzed, space cooling and lighting are the main contributors to summer peak loads--33% and 31% respectively. Ventilation fans, pumps, and miscellaneous equipment account for 17%, 11%, and 4% of summer peak loads, respectively (Figure 10).

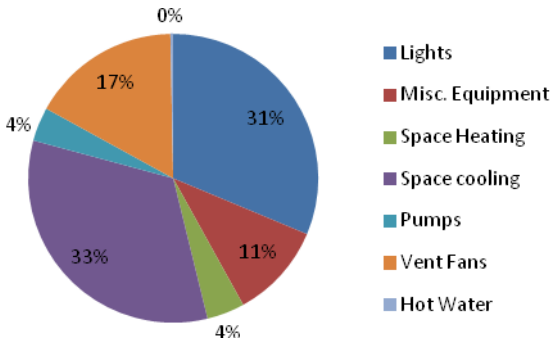


Figure 10: Summer Peak Load End-Use (All Buildings)

For all the buildings analyzed, ventilation fans and lighting are the leading electric energy consumers at 34% and 30%, respectively. Miscellaneous equipment, space cooling, and pumps account for 21%, 9%, and 2% of electric energy consumption (Figure 11).

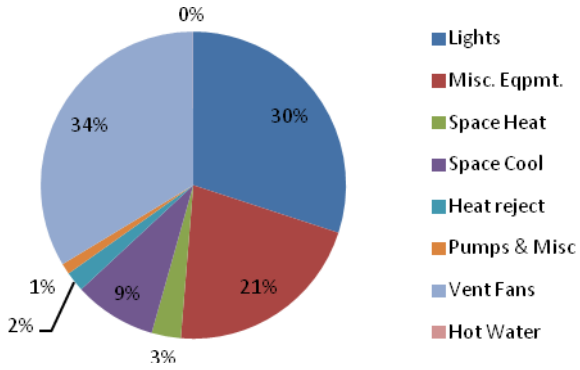


Figure 11: Electric Energy End-Use (All Buildings)

A number of observations can be taken from this:

- Space cooling is the largest contributor to summer peak loads.
- Lighting is the seconded largest contributor to both summer peak loads and electric energy consumption.
- Cooling loads and lighting represent 64% of the summer peak load and present a great opportunity for improvement.
- Ventilation fans and lighting represent 64% of the electric energy consumption and also present a great opportunity for improvement.

5.1 Residential Buildings Summer Peak Load End-Use and Electric Energy End-Use

The data was broken down to investigate summer peak load end-use and electric energy end-use in the residential buildings, as seen in Figure 12. The data reveals that space cooling and lighting are the main contributors to summer peak loads at 40% and 31%, respectively. Ventilation fans, miscellaneous equipment, and pumps, account for 14%, 13%, and 2% of summer peak loads.

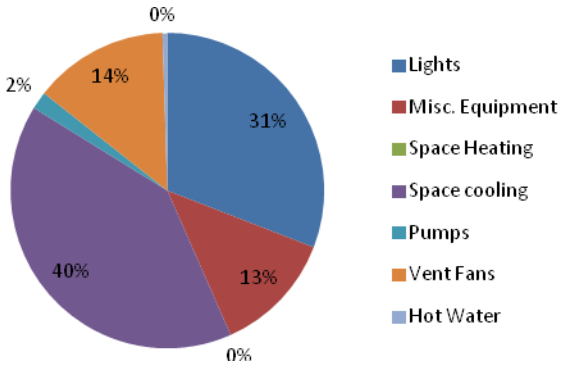


Figure 12: Summer Peak Load End-Use (Residential Buildings)

Ventilation fans and lighting are the leading electric energy consumers at 34% and 30%, respectively. Miscellaneous equipment, space cooling, and pumps account for 21%, 9%, and 2% of electric energy consumption (Figure 13).

A number of observations can be taken from this:

- Cooling loads and lighting represent 71% of the summer peak load and present a great opportunity for improvement.

– Ventilation fans and lighting represent 64% of the electric energy consumption and also present a great opportunity for improvement

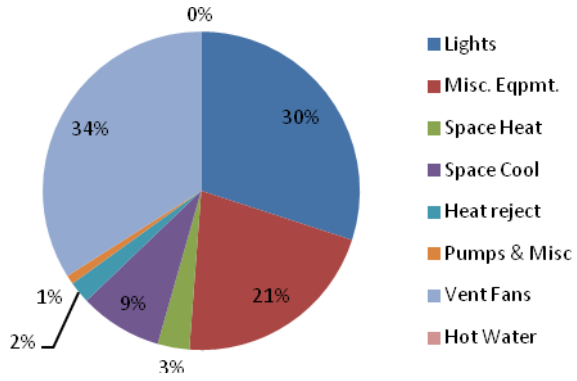
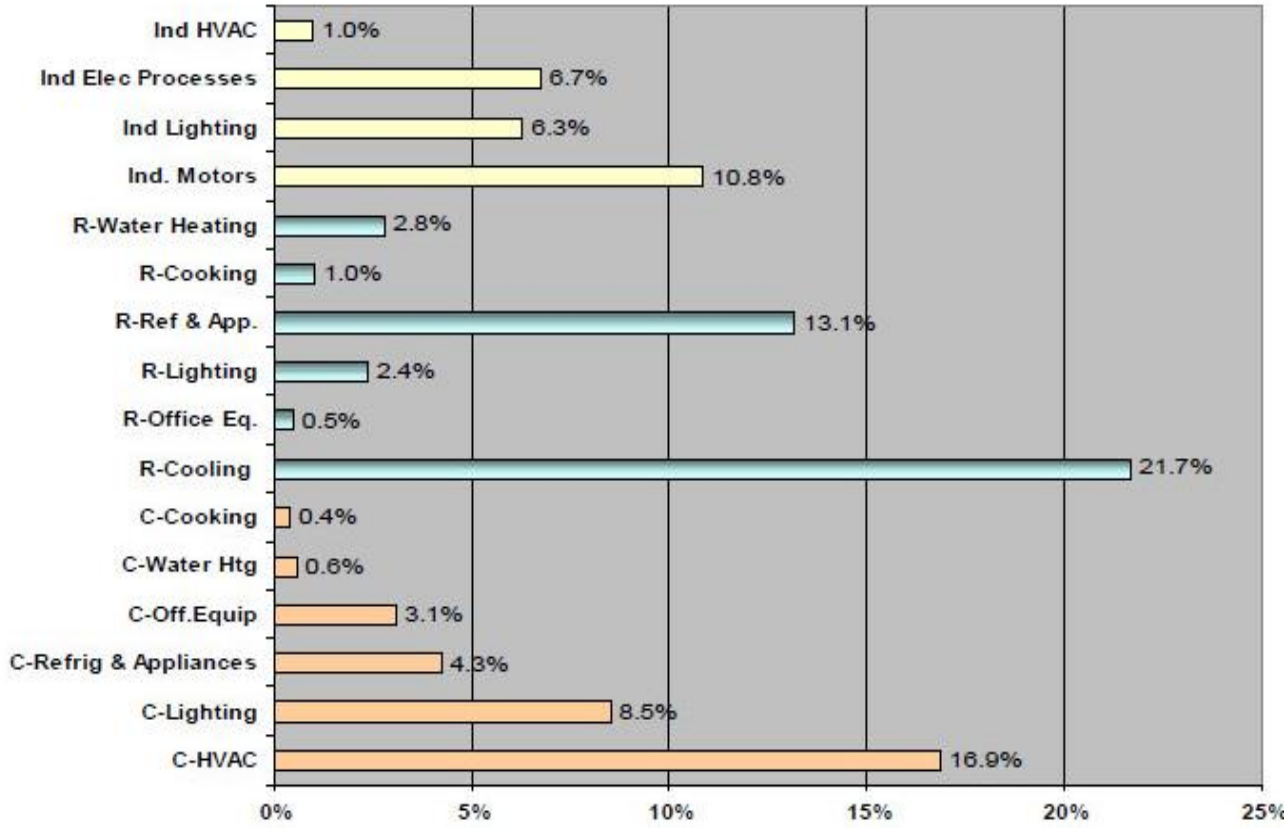


Figure 13: Electric Energy End-Use (Residential Buildings)

A previous, Ontario-wide study conducted by Hydro One showed that the summer peak demand is dominated by residential air conditioning 21.7% and appliances 13.1%, while lighting contributed with only 2.4% (Hydro One, 2003) (Figure 14).

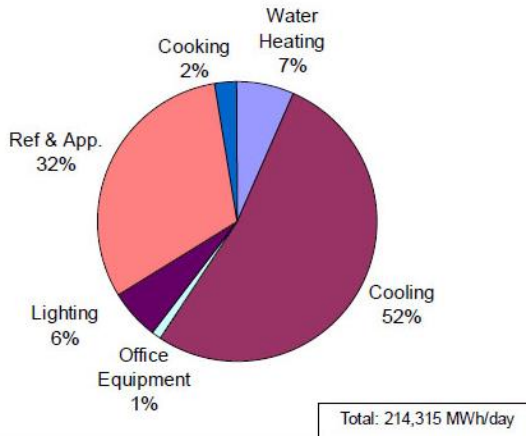
Another study conducted by the City of Toronto, showed the summer peak demand is dominated by cooling loads with 52%, refrigerators and appliances 32%, and water heating 7%, while lighting is only 6% (City of Toronto, 2007) (Figure 15).

When comparing the findings of these two studies with this paper`s findings, which analyzes energy models for new construction, it is noticed that all three studies agree that cooling loads are the main contributor to peak loads but with different shares. It is also noticed that there are great differences regarding the rank and share of lighting loads. The data here suggests that lighting loads are the second contributor to summer peak loads with a higher peak load share.



(Hydro One, 2003)

Figure 14: Summer Peak Day Profile by Sector and by End Use (R: Residential, C: Commercial, Ind: Industrial)



(City of Toronto, 2007)

Figure 15: Summer Peak Load End-Use. Ontario Residential Sector, 2002

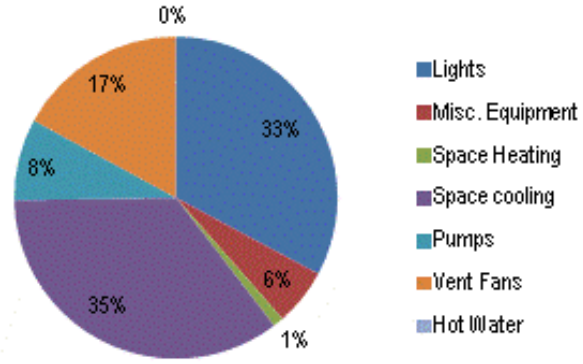


Figure 16: Summer Peak Load End-Use (Commercial Buildings)

5.2 Commercial Buildings Summer Peak Load End-Use and Electric Energy End-Use

In commercial buildings, space cooling and lighting are the main contributors to summer peak loads at 35% and 33% respectively. Ventilation fans, pumps, and miscellaneous equipment account for 17%, 8%, and 6% of summer peak loads, respectively (Figure16).

While lighting and ventilation fans are the leading electric energy consumers at 31% and 27%, miscellaneous equipment, space cooling, and pumps account for 23%, 13%, and 5% of electric energy consumption (Figure 17).

A number of observations can be taken from this:

- Cooling loads and lighting are responsible for the largest share of summer peak loads with 67% of the total summer peak load and present a great opportunity for improvement.
- Lighting loads and ventilation fans are responsible for the largest share of electric energy consumption with 58% of the total electric energy consumption and also present a great opportunity for improvements.
- Lighting loads are responsible for the second largest share of summer peak loads and the second largest share of electric energy consumption and present a great opportunity for improvement.

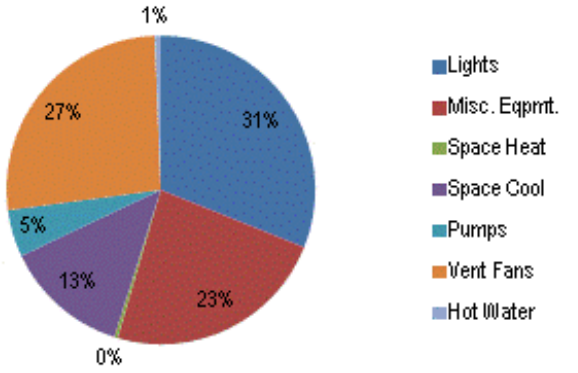


Figure 17: Electric Energy End-Use (Commercial Buildings)

In the previous study conducted by Hydro One to identify what end-users are the major contributors to the summer and winter peaks, Hydro One found that cooling loads (HVAC) are the main contributor to summer peaks with 16.9% of the total summer peak loads, while lighting loads contributed with 8.5% (Hydro one, 2003).

When comparing the findings of Hydro One's study with what the data in this paper has suggested, it is noticed that the two studies agree that cooling loads and lighting loads are the main contributors to peak loads but the proportions varied in the two studies.

5.3 Factors Contributing to Summer Peak Load End-Use and Electric Energy End-Use Trends

Several factors could have led to these findings which include, but are not limited to, the following:

- Toronto has the most high-rise buildings under construction in North America (Tara, 2012).
- Most of the buildings include large windows with high window-wall area ratios which allowed summer heat gains and did not benefit from daylight (John, 2011).
- MURBs in Toronto are designed by professsionals who are typically requested to only comply with minimum codes and standards.
- Energy conservation requirements are defined in a way that can be achieved without adherence to best sustainable building architectural practices (Edna, 2008).
- Most of the new MURB's corridors, hall ways, collective spaces, parking garages, and amenities are artificially lit and ventilated. Also, lighting and ventilation fans are running through the entire day. Even in the residential units itself, many spaces, such as dens, bathrooms, kitchens, and corridors are completely artificially lit or ventilated.
- When buildings are designed and constructed, energy efficiency is one concern amid many other concerns that may be given higher priority by architects. These can be structural or fire safety, room size, and even the view from the windows. Energy efficiency in buildings may be low on the list of requirements (International Energy Agency, 2008).

6. Energy Efficiency Requirements in Building Codes and Standards for New Buildings in the City of Toronto

To identify how future energy conservation requirements best help in addressing peak demand and high electric energy consumption, the existing energy codes and standards for new buildings in the City of Toronto are discussed.

The energy performance of a building is influenced by many elements. The elements that are most integrated in building codes are building envelope and HVAC systems. The treatment of the energy consumption of lighting, service water heaters, and installed equipment and appliances varies from code to code.

Other passive/active renewable energy, such as passive cooling, heating, and ventilation are not often included. Despite the fact that passive cooling, heating, and ventilation can reduce energy consumption substantially, it is not commonly found in energy codes. The reason is that it is difficult and complicated to address these elements in building codes or standards for new buildings (International Energy Agency, 2008).

Currently, the most advanced energy efficiency codes for buildings include all these aspects while others are aiming to include most of these elements in the energy performance compliance calculations. Including these elements can prevent the need for additional requirements or sub-optimization of the demands for some other improvements needed.

New construction in the City of Toronto must comply with the Ontario Building Code (OBC). The energy efficiency requirements in the OBC were increased from 1st January 2012, leading to an energy performance improvement of about 25% in large residential and non-residential buildings above the 2006 code. This is achieved through an increase in the requirements for insulation and windows and efficiency in gas boilers. Estimates for the costs and feasibility of increased requirements for new buildings show that the increase in 2012 could be paid back in only 5 – 8 years for typical new buildings (International Energy Agency, 2008).

The OBC energy efficiency requirements can either be fulfilled by meeting a number of requirements (prescriptive rules) or by a calculation based on a comparison with fixed values and the fulfilment of the prescriptive rules (energy model building or a trade of model).

Currently, compliance with the OBC can be achieved in four different ways (Ministry of Municipal Affairs and Housing, 2012):

- Exceeding by not less than 25% the energy efficiency levels attained by conforming to the CCBFC, "Model National Energy Code for Buildings"
- Exceeding by not less than 5% the energy efficiency levels attained by conforming to the ANSI/ASHRAE/IESNA 90.1, 2010 "Energy Standard for Buildings Except Low-Rise Residential Buildings"

- Achieving the energy efficiency levels attained by conforming to the ANSI/ASHRAE/IESNA 90.1 2010 "Energy Standard for Buildings Except Low-Rise Residential Buildings" as modified by some prescriptive requirements included in Chapter 2 of the code
- Achieving the energy efficiency levels attained by conforming to the National Energy Code for Buildings (NECB)

In an effort to encourage energy efficiency further in the City of Toronto, the TGS raised the energy efficiency targets from 1st January 2014 to 15% over the OBC (City of Toronto, 2014).

The current OBC and the TGS requires a percentage of improvement above a reference code but does not include additional qualifiers that specify the electric energy savings proportion of the total savings required.

The current OBC includes requirements for building envelope, VAC systems, service water heating, power, lighting, electric power systems, and motors but does not include any specific requirements that address passive cooling, natural ventilation, or any other passive elements. The current OBC also includes additional requirements to address peak loads. The requirements focus on cooling equipment, fan power limitations for cooling and ventilation systems, and interior lighting power density (Ministry of Municipal Affairs and Housing, 2012). However, the current OBC does not include any requirements that could improve the architectural designs and yield substantial peak reduction.

7. Conclusions and Recommendations

In consideration of this paper's findings, a number of recommendations are presented as follows:

- There is a weak correlation between total energy savings and peak demand savings among the buildings analyzed, while there is a strong positive correlation between electric energy savings and peak demand savings. The current OBC and the TGS requires a percentage of improvements above a reference code but does not include additional qualifiers that specify the electric energy savings proportion of the total savings required. Going forward, and to use energy conservation as a resource to address electric grid stress issues, it is recommended to specify additional qualifiers that state the proportion of electric energy savings required.
- According to what the data in this paper has suggested, the largest potential for peak load savings in Toronto is space cooling and lighting, while the largest potential for electric energy savings in Toronto is lighting and ventilation.
- Passive cooling, daylighting, and natural ventilation have the potential to substantially reduce mechanical system and artificial lighting demand. If appropriate, architectural design, especially fenestration and sun shading strategies, are employed (International Energy Agency, 2008).
- It would be useful if the current energy efficiency regulations included additional sub-optimization requirements for passive heating /cooling, natural ventilation, and daylighting.
- The current energy conservation requirements do not require adherence to best practices in sustainable building architectural design. It is recommended to provide guidelines that address and encourage passive solutions, especially ones that can yield substantial peak reductions.

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