IMPACTS OF CLIMATE CHANGE ON BUILDING ENVELOPE ENERGY EFFICIENCY

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CLIMATE CHANGE AND BUILDING ENERGY CODES

New York City Energy Conservation Code 2016 (NYCECC 2016) references the requirements of ASHRAE 90.1 2013 – Energy Standard for Buildings Except Low-Rise Residential Buildings, as an energy efficiency compliance path for commercial buildings. This standard allows the use of the Energy Cost Budget Method to evaluate if a proposed building complies with the Code's energy use requirements. The Energy Cost Budget Method makes use of building energy simulation software, in which the building systems are virtually represented, and using input variables such as occupancy and local climatic data, calculates the building's yearly energy consumption. A Typical Meteorological Year (TMY) data file for the proposed building location is used as the local climatic data input, and these files are based on weather data records from 1976-2005 where available, and from 1991-2005 for all other locations. Based on observed trends and modeled future projected climate data, temperatures in New York City are rising, and using historic weather data for building energy modeling and building envelope design will likely result in discrepancies between the weather that the building was designed for and the weather that it will be affected by. By using future projected climate data in building energy models, risks of efficiency losses and opportunities for efficiency gains from projected future local climate change can be better understood.

FUTURE CLIMATE PROJECTION

A variety of techniques can be used to project future climate, including statistical manipulation of existing climate records, and dynamic downscaling of global climate models into regionally specific weather research forecasts. Each method of generating future climate data has certain advantages and disadvantages that must be understood when selecting the appropriate data to inform building design decisions. Sophisticated future projected climate data may be necessary to understand climate extremes; however, acquiring this data may be costly and time consuming, and less detailed data may be adequate and obtained more economically.

The magnitude of climate change to come is uncertain, since the volume of future GHG emissions depends on unpredictable human behaviour, and a range of future climate scenarios must be considered during the building design phase.

BUILDING ENERGY MODELING EXERCISE

Method

To evaluate the impact of increasing local temperatures, a case study on an archetypal high-rise commercial office tower was completed. Created using IESVE, the following key parameters were used in the simulation exercise:

- Gross floor area: 100,300 m^2 (1,080,000ft^2)
- EUI (current climate): 222 kWh/m^2
- Height: 44 storeys
- Window-to-wall ratio (WWR): 80%
- Air leakage rate: 0.35 $L/s/m^2$
- Glazing U-value: 2.26 $W/m^2/K$
- Spandrel U-value: 0.94 $W/m^2/K$
- Glazing solar heat gain coefficient (SHGC): 0.4
- Chiller coefficient of performance: 5.0
- Boiler efficiency: 90%

New York-Central Park TMY3 was used as the current climate input and, energy modelling results from a selection of future projected climate data were compared. A statistically shifted weather file created by Weathershift with the following parameters was used as the future projected climate input for detailed energy modelling exercises: Central Park TMY3, 2041-2060, RCP 8.5, 90th percentile scenario.

BUILDING ENERGY USE AND GHG EMISSIONS – CURRENT VS. FUTURE PROJECTED CLIMATE SCENARIOS

Results of the energy modeling exercise showed that total building energy use in the future projected climate, when compared to the current climate, decreased by 1.5%, total electricity use increased by 3.25%, and total natural gas use decreased by 23.5% (see Table 1). Natural gas makes up 19% of total energy use in the current climate and 15% of total energy use in the future projected climate (see Table 2), and therefore the 23.5% decrease in natural gas use does not offset the 3.25% increase in total electricity use.

Total GHG emissions increased by 3.49% despite an overall total energy use decrease in the future projected climate, due to the higher emissions factor for electricity than for natural gas in New York City.

Table 1: Total energy, electricity and natural gas use, and GHG emissions in current and future projected climates

Parameter	Current Climate	Future Projected Climate
Total Energy Use - % Change	Base	-1.47%
Total Electricity Use - % Change	Base	3.61%
Total Natural Gas Use - % Change	Base	-23.52%

Total GHG Emissions - % Change	Base	3.49%

Table 2: Total Electricity Use and Total Natural Gas Use in current and future projected climates

Parameter	**Current Climate**	**Future Projected Climate**
Total Electricity Use - % of Total Energy Use	81%	85%
Total Natural Gas Use - % of Total Energy Use	19%	15%

SENSITIVITY ANALYSIS

General

Window-to wall-ratio (WWR), glazing U-value, glazing SHGC, and building envelope air infiltration rates were modulated in the energy model (see Table 3 for performance values), using both the current and future projected climate inputs. Outputs from this exercise were compared to determine how performance improvements of these parameters impact total energy use and GHG emissions, in both the current and future projected climate scenario.

Table 3: Modelled building envelope parameter performance values

Parameter	**Low Performance Value**	**Mid Performance Value**	**High Performance Value**
WWR	80%	60%	40%
Glazing U-value	0.42 Btu/(hr·ft^2·°F)	0.33 Btu/(hr·ft^2·°F)	0.25 Btu/(hr·ft^2·°F)
SHGC	0.4	0.3	0.23
Air Infiltration	0.35 L/s/m^2 @ 50Pa	0.23 L/s/m^2 @ 50Pa	0.1 L/s/m^2 @ 50Pa

Impacts on Total Energy Use

Glazing U-value was found to have the largest impact on total energy use, in both the current and future projected climate scenarios; however, its impact was significantly reduced in the future projected climate (see Figure 1). SHGC improvements resulted in increased energy use in the current climate, and caused no significant energy use change in the future projected climate. WWR and air infiltration improvements resulted in modest energy use reductions, with slightly less energy use impact in the future projected climate than in the current climate.

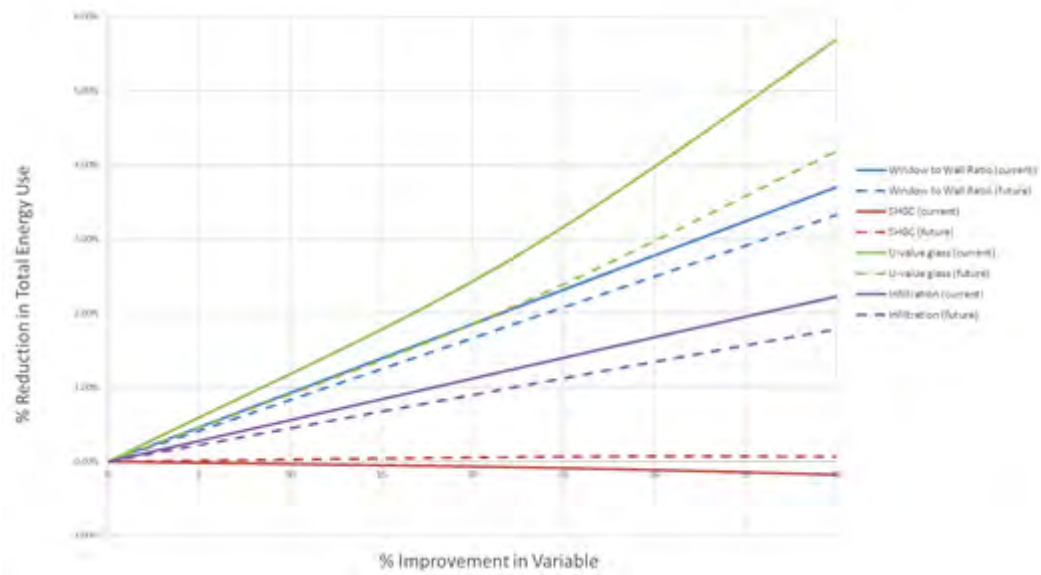

Figure 1: Impacts of building envelope improvements on total energy use.

Impacts on Heating Energy Use

Glazing U-value improvements resulted in the greatest heating energy use reductions, in the current and future climate scenarios, followed by WWR and then air infiltration (see Figure 2). SHGC improvements increased the cooling energy use in both climates. Effects of improvements for each parameter were nearly identical in both climate scenarios.

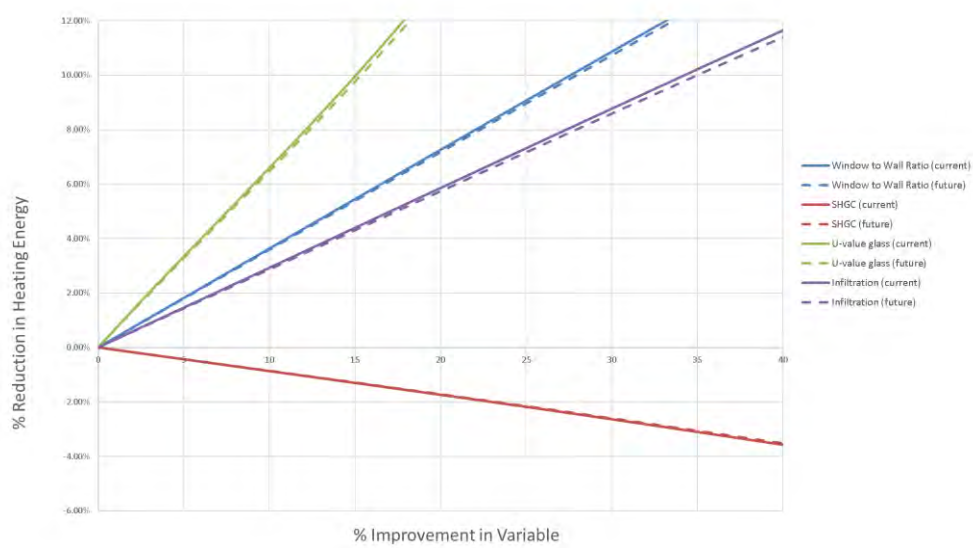

Figure 2: Impacts of building envelope improvements on heating energy use.

Impacts on Cooling Energy Use

WWR resulted in the greatest reductions cooling energy use, in the current and future climate scenarios; however, with marginally less effect in the future climate (see Figure 3). SHGC improvements decreased the cooling energy use in both climates, with marginally less effect in the future climate. Improving air infiltration had little effect on cooling energy, with marginally less effect in the current climate.

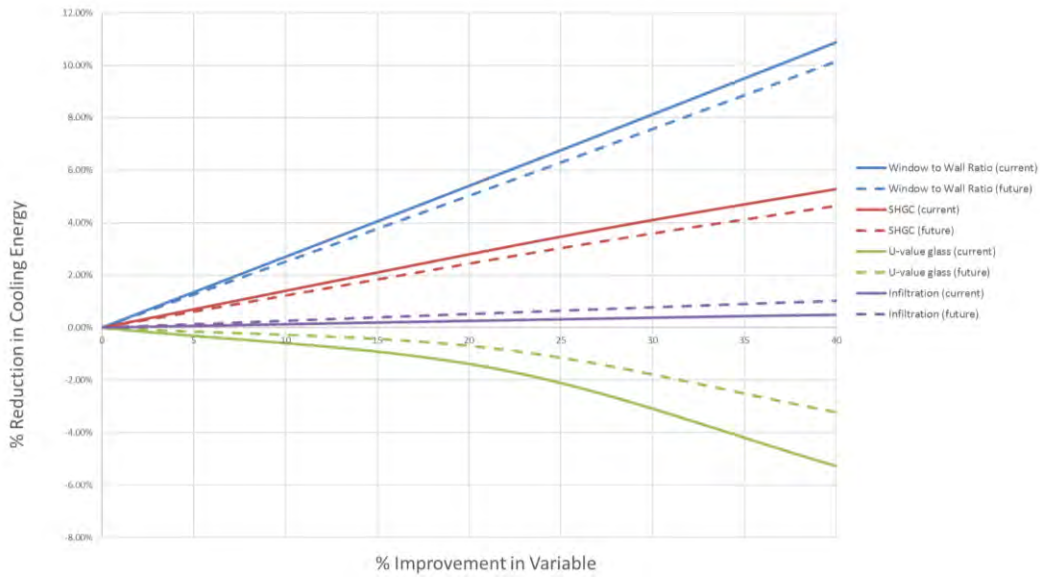

Figure 3: Impacts of building envelope improvements on building cooling energy

Impacts on Building GHG Emissions

A sensitivity analysis to determine effects of building envelope improvements on GHG emissions was done using the emissions factors of 292.74 kgCO2e/MWh for electricity and 50.41 kgCO2e/GJ for natural gas (source: Inventory of New York City Greenhouse Gas Emissions in 2014). The electricity emissions factor is based on the current electricity production mix for the New York grid, and the emissions factor will change as this mix changes over time.

Glazing U-value improvements resulted in the greatest reductions GHG emissions in the current climate, and WWR improvements resulted in the greatest GHG emissions reductions in the future climate. (see Figure 4). Glazing U-value improvements became significantly less effective at reducing GHG emissions in the future climate.

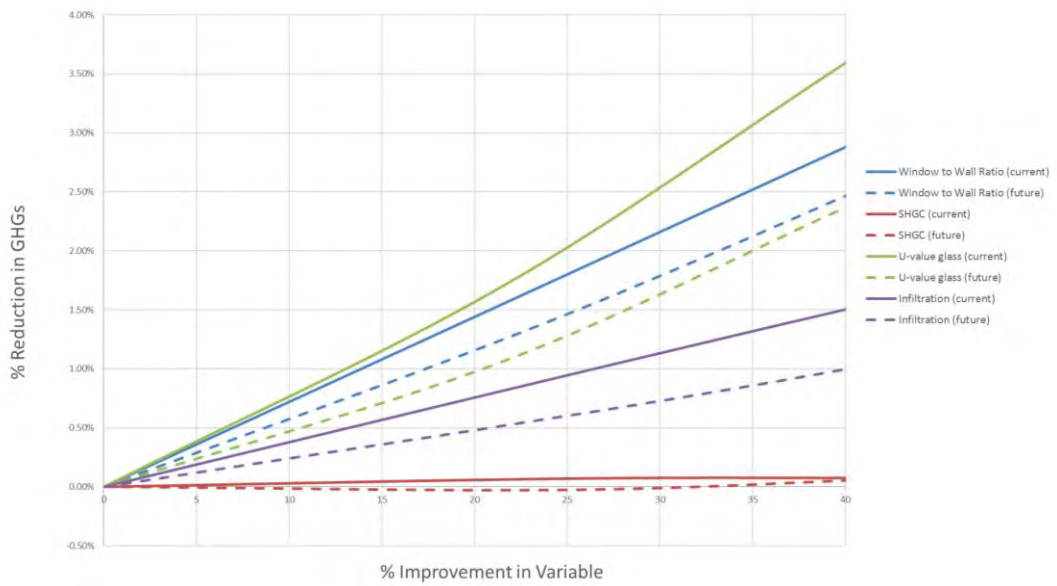

Figure 4: Impacts of building envelope improvements on building GHG emissions

CONCLUSION

Total building energy use in the modeling exercise was shown to drop in the warmer future projected climate, most significantly from reduced demand for heating, which is powered by natural gas. Although total energy use decreased in the future projected climate, GHG emissions increased due to higher cooling demands increasing use of electricity, which is emissions-intensive in New York City.

The impact that specific building envelope thermal performance parameters have on energy use and GHG emissions varies between the current and future projected climate data scenarios. Future projected climate scenarios should be considered during the building design phase, and throughout the building's life cycle, to adapt the building to changing climate futures and to mitigate further climate change by reducing GHG emissions.

REFERENCES

Cventure LLC, Cathy Pasion, Mikael Amar, and Yun Zhou, April 2016. Inventory of New York City Greenhouse Gas Emissions in 2014. Mayor's Office of Sustainability, New York.