Data-Driven Assessment of New York City Building Decarbonization

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Motivation

Recent New York State and City laws require deep greenhouse gas emissions overall and from buildings, specifically. Through analysis of a unique NYC building energy and a novel NYS electricity system model, we aim to identify emission reduction strategies in NYC buildings and with reduced electricity emissions rates and increased variable renewable energy supply. We focus on space heating, which is the largest single source of residential building emissions in the US (57%), NYS (68%) and NYC (82%)[1].

Analysis of NYC Building Energy Data

We classify NYC buildings over 25 ksf by high and low variance natural gas usage to identify current gas and electric heating and to model heating electrification[2].

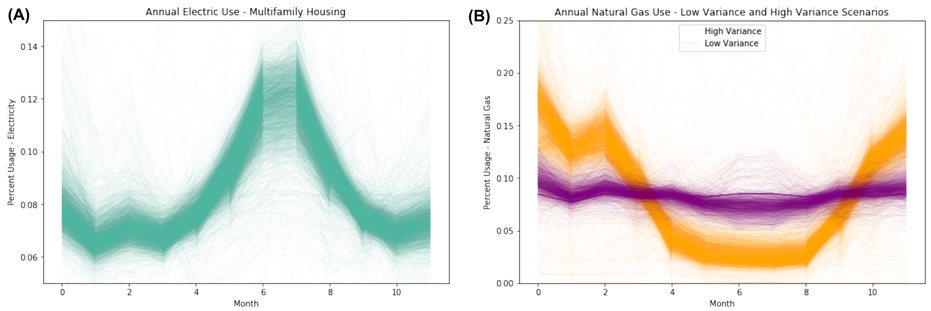

Figure 1. Monthly energy usage as a fraction of total annual energy usage for each NYC multifamily building >25ksf. (a) Electricity showing current cooling-drive summer peaks and (b) natural gas showing low and high monthly variance buildings.

We then classify multifamily buildings by electricity and gas usage to identify high and low electricity and gas usage buildings; apply model to identify heating and cooling loads and effects of heating electrification with electric heat pumps (HPs)[3].

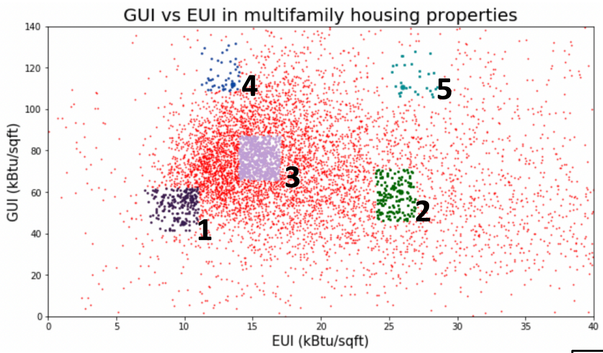

Figure 2. MF buildings by gas and electricity usage.

- Fossil Fuel Heating Response Equation:

$$\hat{F}_{b,t} = f_b^{const} + f_b^{-}(T_{ref} - T_t)^{+}$$

- Adapted Electric Heating/Cooling equation:

$$\hat{E}_{b,t} = e_b^{const} + e_b^{+}(T_t - T_{ref})^{+} + e_b^{-}(T_{ref} - T_t)^{+}$$

For emissions calculations: x baseload tCO2e/MWh; x non-baseload tCO2/MWh; x non-baseload tCO2/MWh

- Fossil Fuel to Heat Pump Conversion Electricity

$$\hat{E}_{b,t}^{HP} = f_b^{-}(T_{ref} - T_t)^{+} \frac{\eta_{FF}}{COP_{HP}(T_t)}$$

Group	Current GHT Emis. Intensity (tCO2e/1000sf)	% Change with Heating Electrification
Full Dataset	5.15	-21.7%
Group 1	3.69	-25.7%
Group 2	4.93	-19.1%
Group 3	5.23	-22.7%
Group 4	7.07	-26.6%
Group 5	7.95	-20.1%

➢ **Indicates significant potential emissions reductions with heating electrification, but cleaner grid needed to drive down further**

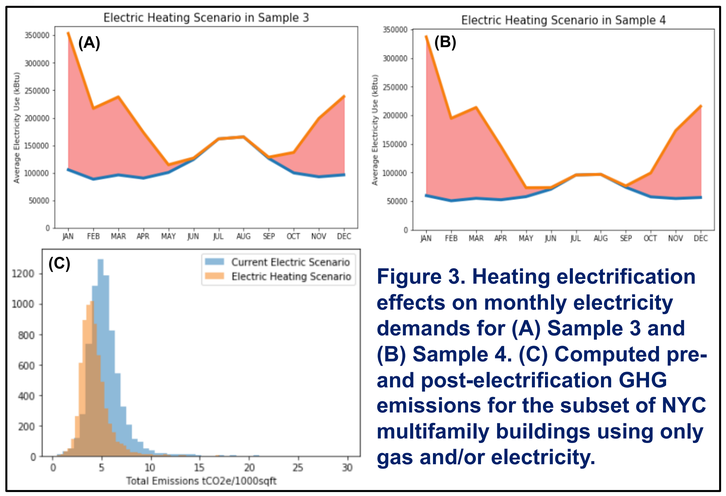

Figure 3. Heating electrification effects on monthly electricity demands for (A) Sample 3 and (B) Sample 4. (C) Computed pre- and post-electrification GHG emissions for the subset of NYC multifamily buildings using only gas and/or electricity.

New York State Renewable Energy Capacity Expansion Model

A linear program optimization based on NYS's current electricity system and models for renewable supply and heating/vehicle electrification, indicates a pathway that prioritizes electrification could achieve emissions reductions with lower costs than the renewable prioritization pathway required by CLCPA. If new gas turbines are to be avoided, there are significant potential benefits from dual source systems that maintain current fossil fuel heating for limited use with new HPs the primary source.

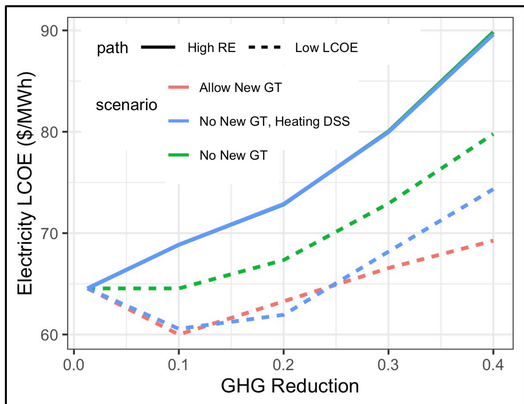

Figure 4. Levelized cost of electricity (LCOE) of modeled NYS emission reduction pathways with and without heating DSSs and new gas turbines

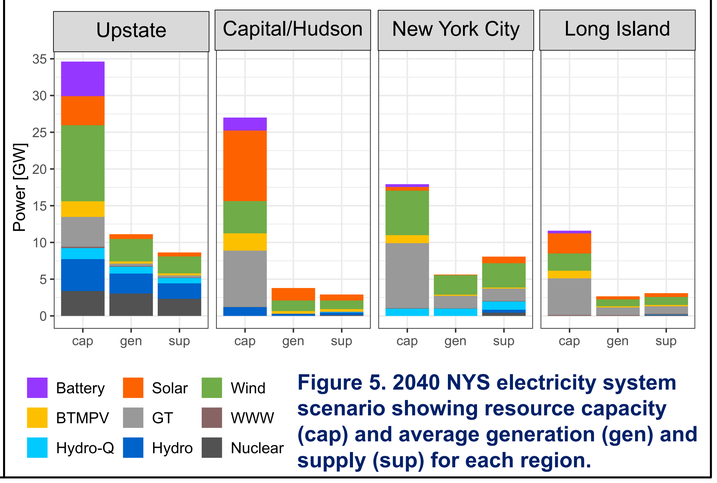

Figure 5. 2040 NYS electricity system scenario showing resource capacity (cap) and average generation (gen) and supply (sup) for each region.

➢ **Results suggest several implications for future NYC building emission reductions:**
1. **Cost-effective *total* emissions reductions will require massive heating electrification**
2. **DSS is a flexible heating option with both systemwide and building-level benefits**
3. **Deep emissions reductions >>> majority variable renewable NYC electricity supply**
4. **Grid-interactivity of flexible systems to utilize renewables likely to be beneficial**

Further Research

Integrate current data-driven analytical efforts to evaluate how individual buildings, NYC and NYS will achieve deep emissions reductions and state and city laws: (1) NYS energy system optimization model, (2) applying machine learning to building-level benchmarking data to assess emissions from different building and system-level changes, (3) heating electrification and DSS load and control models, and (4) electricity distribution system constraint data and expansion modeling.

References

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2. https://qsel.columbia.edu/assets/uploads/blog/2020/publications/achieving-deep-emission-reductions-from-space-heating-in-the-us.pdf
3. Waite and Modi. Joule 2020; 4(2): 376-394 DOI: 10.1016/j.joule.2019.11.011

Acknowledgments

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