Energy Demand Impacts of Climate Change Adaptation by the Urban Poor

A Preliminary View from New York City Public Housing

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Plan of Talk

Introduction

While it is admitted that our changing climate induced by the anthropogenic release of carbon dioxide emissions from fuel combustion will generate adverse impacts on the global economy, much less is known regarding the size and magnitude that those shocks will take along the energy channel in urban areas.

- Climate change is projected to increase the frequency and intensity of urban populations' exposure to extreme high temperatures (Vahmani et al, 2019).

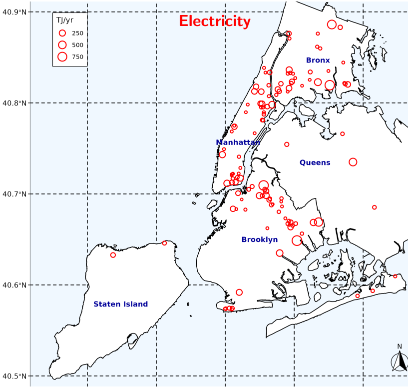
- Adaptation to such impacts will involve energy consumption as heating and cooling strategies are used to smooth the diurnal and seasonal effects of variations in temperature on human health (Deschenes and Greenstone, 2011; Barreca et al, 2016).

Opposite dynamics simultaneously operate and make the bigger picture fuzzy:

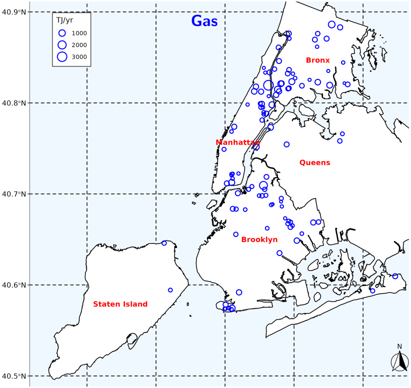
If buildings' energy productivity vary across both warmer and colder environments, could gas savings on heating induced by winters with more moderated cold-season low-temperature prevail over peak and total electricity demand for cooling triggered by hotter summers by mid-century? How do low-income individuals cope with temperature extremes, and do the shapes of their temperature-energy demand response functions differ from other socioeconomic categories? What are the energy implications of coping mechanisms for their capacity to adapt to a warming environment?

Data

Outcomes: Electricity and gas consumption and cost, billed by month, meter, building and property for New York City Housing Authority (NYCHA) developments, 2010-2019; Demographic and infrastructure-related information extracted from NYCHA Development Data Books 2019.



T_{years}=10; T_{months}=120;$N_{development}$=158; N_{meters}=3778; $N_{buildings}$=1257; Total population: 296,596.



T_{years}=10; T_{months}=120;$N_{development}$=112; N_{meters}=310; $N_{buildings}$=175; Total population: 199,637.

Weather: PRISM 4km daily temperature, dewpoint temperature, matched to development coordinates, billing cycles
Climate change projections: CMCC-ESM2 ssp585.

Empirical Approach

Indexes: i = property $\times$ building $\times$ meter, t = billing cycle (revenue-month and year)
Outcomes: per capita electricity (Q^E) and gas (Q^G) demand on meter-specific $\sim$ monthly billing cycles
Weather drivers: heating and cooling degree days ($\mathcal{H}$, $\mathcal{C}$, 18.3°C base), 90th percentile of specific humidity ($\mathcal{S}$), calculated over each billing cycle. We also control for average energy consumption (KWh Charges/Consumption(KWh)) and demand (KW Charges/Consumption(KW)) prices to set up energy demand functions.

Nonparametric generalized additive model (GAM) with location and time fixed effects:

$$\mathbb{E}\left[\ln Q^E_{i,t(i)}\right] = \Psi^{H,E}\left[\mathcal{H}_{i,t(i)};\boldsymbol{\theta}^{H,E}\right] + \Psi^{C,E}\left[\mathcal{C}_{i,t(i)};\boldsymbol{\theta}^{C,E}\right] + \Psi^{S,E}\left[\mathcal{S}_{i,t(i)};\boldsymbol{\theta}^{S,G}\right] + \mu^E_i + f^E[t] \tag{1a}$$

$$\mathbb{E}\left[\ln Q^G_{i,t(i)}\right] = \Psi^{H,G}\left[\mathcal{H}_{i,t(i)};\boldsymbol{\theta}^{H,G}\right] + \Psi^{S,G}\left[\mathcal{S}_{i,t(i)};\boldsymbol{\theta}^{S,E}\right] + \mu^G_i + f^G[t] \tag{1b}$$

Projections (CMCC-ESM2 ssp585): combine fitted splines ($\widehat{\Psi} = \Psi\left[\cdot;\widehat{\boldsymbol{\theta}}\right]$) with degree-days, observed and shifted due to mid-century climate change, $\widetilde{\mathcal{H}}_{i,t(i)} = \mathcal{H}^{Obs}_{i,t(i)} + \Delta\overline{\mathcal{H}}^{GCM}_{i,t(i)}$, $\widetilde{\mathcal{C}} = \mathcal{C}^{Obs}_{i,t(i)} + \Delta\overline{\mathcal{C}}^{GCM}_{i,t(i)}$

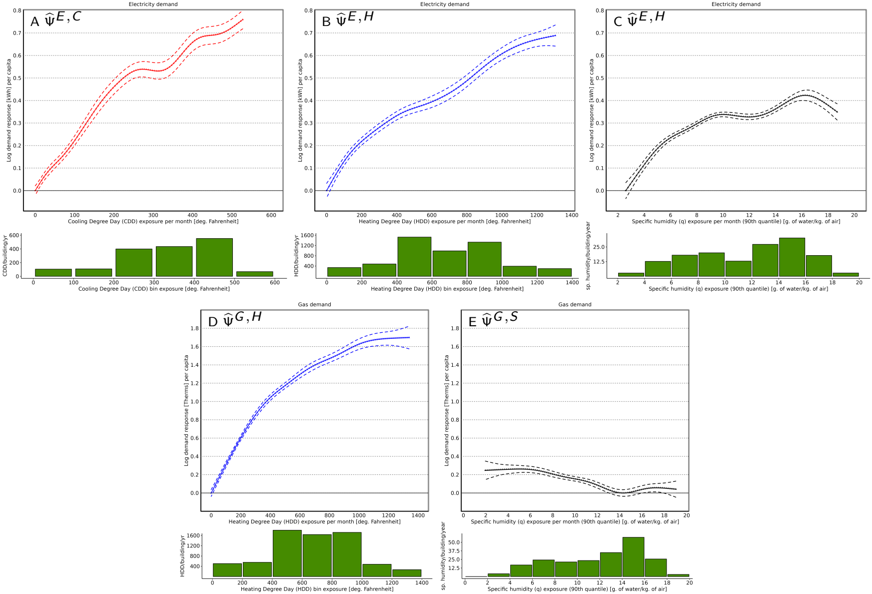
$$\begin{aligned}\Delta Q^E_{i,t(i)} = \exp&\left\{\widehat{\Psi}^{H,E}\left[\widetilde{\mathcal{H}}_{i,t(i)}\right] + \widehat{\Psi}^{C,E}\left[\widetilde{\mathcal{C}}_{i,t(i)}\right] + \widehat{\Psi}^{S,E}\left[\mathcal{S}^{Obs}_{i,t(i)}\right] + \widehat{\mu}^E_i + \widehat{f}^E_t\right\}\\ &- \exp\left\{\widehat{\Psi}^{H,E}\left[\mathcal{H}^{Obs}_{i,t(i)}\right] + \widehat{\Psi}^{C,E}\left[\mathcal{C}^{Obs}_{i,t(i)}\right] + \widehat{\Psi}^{S,E}\left[\mathcal{S}^{Obs}_{i,t(i)}\right] + \widehat{\mu}^E_i + \widehat{f}^E_t\right\}\end{aligned} \tag{2a}$$

$$\begin{aligned}\Delta Q^G_{i,t(i)} = \exp&\left\{\Psi^{H,G}\left[\widetilde{\mathcal{H}}_{i,t(i)}\right] + \widehat{\Psi}^{S,G}\left[\mathcal{S}^{Obs}_{i,t(i)}\right] + \widehat{\mu}^G_i + \widehat{f}^G_t\right\}\\ &- \exp\left\{\widehat{\Psi}^{H,G}\left[\mathcal{H}^{Obs}_{i,t(i)}\right] + \widehat{\Psi}^{S,G}\left[\mathcal{S}^{Obs}_{i,t(i)}\right] + \widehat{\mu}^G_i + \widehat{f}^G_t\right\}\end{aligned} \tag{2b}$$

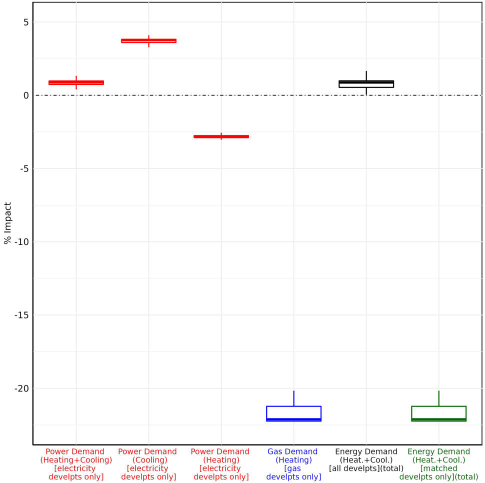
Impacts: demand shocks weighted by properties' resident populations (n)

$$\textstyle\sum_i n_i\mathbb{E}_t\left[\Delta\widetilde{Q}^E_{i,t}\right] / \sum_i n_i\mathbb{E}_t\left[Q^{E,Obs}_{i,t}\right], \quad \sum_i n_i\mathbb{E}_t\left[\Delta\widetilde{Q}^G_{i,t}\right] / \sum_i n_i\mathbb{E}_t\left[Q^{G,Obs}_{i,t}\right] \tag{3}$$

Energy Demand Responses to Weather

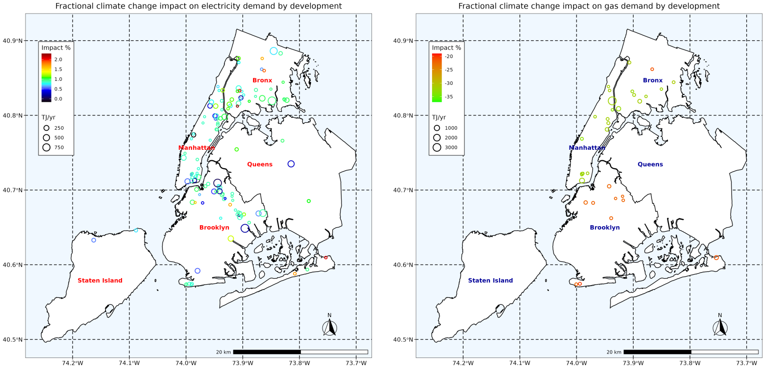


Climate Change Impacts on Energy Demand Circa 2050



Distribution of percentage shifts in property-level fuel demands due to SSP585 warming, 2050-2060 vs 2025-2024 (CMCC-ESM2)

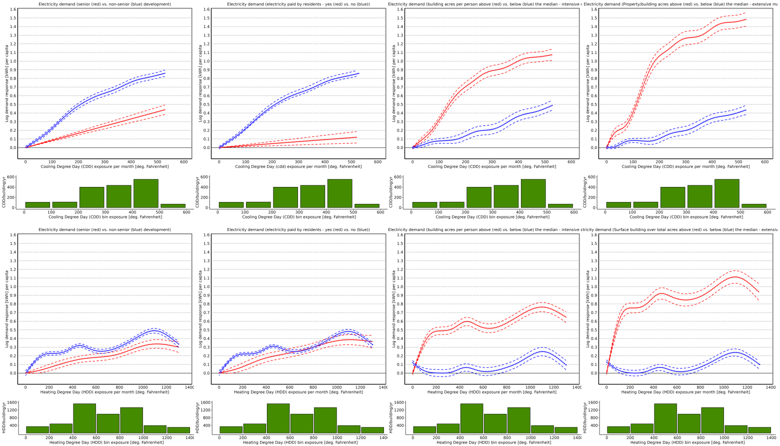
Energy Demand Impacts by Development



Distribution of development-level percentage impacts on fuel demands due to SSP585 warming, 2050-2060 vs 2025-2024 (CMCC-ESM2).

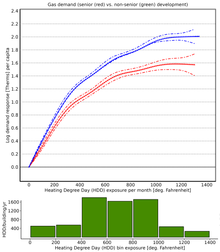
Stratified Electricity Demand Responses

Senior vs Non-senior building | Residents pay for electricity vs Not | Area per resident: > Median vs < Median | Property/building acres: > Median vs < Median

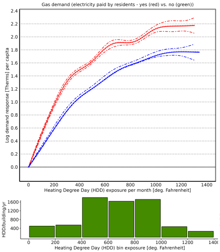


Stratified Gas Demand Responses

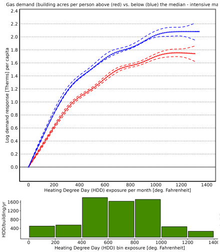
Senior vs Non-senior



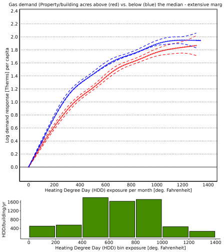
Residents pay elec. vs Not



Area per resident: > Median vs < Median



Property/building acres: > Median vs < Median



Next Steps

So far, we observe a general pattern in the data but we do plan to explore potential inequality stories:

- Conducting further stratification and estimations of climate impacts on sub-groups *including but not limited to*: senior development, whether residents pay for electricity, size and shape of responses at the extensive vs. intensive margins, monthly rent median, share of population in public housing, ratio of fixed income over total number of households, ratio of surface building over total acres, population density... ect. Possibility to work with deciles instead of median-based sub-groups although it put additional constraints on the data.

- Heat seems to be included in rent, but climate change reduces the benefit of this for everyone while increasing electricity expenditures for the fraction of residents who have to pay for it.

- We do not have access to individual-specific information (NYCHA keeps most of its information confidential for obvious privacy protection reasons) and do not observe behaviours (only energy consumption/meter), which suggests that there are limited individual-specific heterogeneities operating within-flats that we can control for using monthly bills extracted at the meter-level.

- Given the comparatively small number of properties with gas heat (NYCHA Gas and Electricity developments do not symmetrically match), we are interested in looking at steam heating consumption if data availability allows that, to get complementary dynamics to gas.

- There is still the hope to access information on threshold income levels below which residents fall into the NYCHA category "Electricity not paid by residents"; the % share of senior-residents in non-senior developments; or the average age of residents for each development. Nonetheless, there is still a risk of getting time-invariant information through NYCHA Development Data Books.

Acknowledgements

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