Big Data Meets Local Climate Policy: Energy Star Time-of-Day Savings in Washington, D.C.'s Municipal Buildings

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See footnote at end of text.

Introduction

Municipal governments have a history of implementing a multitude of energy conservation policies over the past 30 years (Bulkeley (2010), Broto and Bulkeley (2013)). Local governments are desirable to evaluate a number of energy policies since over half of greenhouse gas (GHG) emissions originate in cities (Satterthwaite (2008), Bulkeley (2010)), and city governments manage or coordinate many policies with a direct impact on GHG emissions, such as energy codes, energy benchmarking ordinances, and transit investments.

Relatedly, a question that economists and policymakers have long considered important, but until recently could not precisely measure empirically, relates to whether energy conservation policies and investments deliver savings during peak demand times. This has changed with the advent of building-level smart meters and the resulting availability of high frequency energy consumption data.

The within-day distribution of energy savings is an important determinant of the benefits of energy conservation. Since the marginal cost of supplying electricity varies across hours of the day, energy-reducing programs with heterogeneous savings across hours will exhibit different values even if the aggregate quantity saved is the same. In particular, programs with a distribution of savings spread equally through the day are valued less than those that deliver more savings at peak price hours.

In most regional markets, there are key hours within a day with steep price increases, when marginal units coming online are frequently from fossil fuel-fired units. In the PJM regional market studied in this work, over the sample period the marginal fuel in any given hour is coal more than 50% of the time (Monitoring Analytics (2019)). Savings during these peak price hours will have higher net benefits, all else equal. For example, commercial heat pumps and chillers are 21% and 17% more valuable, respectively, than if the savings were spread equally across hours, and energy efficient air-conditioner investments are 16% more valuable. On the other hand, commercial lighting has a timing premium of only 2% (Boomhower and Davis (2019)).

This paper studies a benchmarking and public reporting `sunshine' policy adopted by the city of Washington, D.C., that has resulted in the availability of hourly electricity consumption data in the City's municipal buildings. I evaluate the distribution of hourly savings from changes in a building's monthly Energy Star score in Washington, D.C.'s municipal buildings. The results help to fill gaps in our understanding of the timing of energy savings from benchmarking policies in multi-tenanted institutional space.

The Energy Star portfolio manager, a building energy usage measurement tool developed by the U.S. Environmental Protection Agency, is the primary source for implementing benchmarking policies in the U.S. Over 450,000 buildings representing about half of commercial floor space have used the portfolio manager (EPA (2016)). While the Energy Star for buildings program has been estimated to reduce annual energy consumption per square foot by 2.5% per year (EPA (2012)), no work thus far have assessed the hourly distribution of savings from energy benchmarking.

Data

Since 2013, the D.C. municipal government has made public detailed data on hourly electricity consumption, building-level hedonic characteristics, and hourly outdoor temperature data as part of its Sustainable D.C. policy. For 139 of these municipal buildings, these data also include monthly Energy Star portfolio manager scores, which range between 0-100 and rank building energy use intensity (EUI) relative to a representative sample of buildings in the same sector, with a higher score representing more energy efficient buildings. A large share of these buildings are elementary, middle and high schools, while most of the rest are office buildings.

At the time the program was instituted, public statements by the City indicated the high frequency data availability would be used to identify equipment being inefficiently used past building occupancy hours, and to provide insight into which buildings require equipment retrofits.

Empirical Strategy

The estimating equation is:

$$Y_{i,h,d,m} = \beta_h(\text{Score}_{i,m-1} \cdot 1_h) + \theta T_{h,d,m} + \psi X_{d,m} + \eta_{i,h} + \gamma_c + \varepsilon_{i,h,d,m}, \quad (1)$$

where $Y_{i,h,d,m}$ is the level of energy consumption, in kWh, in building i during hour h on day d and month m. $\text{Score}_{i,m-1}$ measures the Energy Star portfolio manager score in building i for the entirety of the previous month, m−1. 1_h denotes a set of indicator variables equal to 1 in hour h, $T_{h,d}$ is the average Washington, D.C. temperature during hour h on day d, and $X_{d,m}$ denotes a vector of additional controls, namely dummy variables for weekend days and school holidays. The variable $\eta_{i,h}$ is a building-level fixed effect, γ_c is a calendar month fixed effect, and $\varepsilon_{i,h,d}$ is an error term. The variables of interest are the β_h coefficients that quantify the hourly savings profile of a one-unit increase in the portfolio manager score. In the preferred specification, with building-hour and calendar month fixed effects, the β_h are identified from within-building-hour and within-month differences between buildings with varying portfolio manager scores.

Results

The main result is presented in Figure 1. The Figure shows the point estimates for β_h. The hourly distribution of savings from a 1-unit improvement in the Energy Star score is effectively flat, with an average decrease of 0.65 kWh per hour. There is a small peak in savings at 6am, however it is not statistically different from the point estimates in other hours. Though not shown here, the savings profile for the summer months of June to September and the non-summer months are similarly flat.

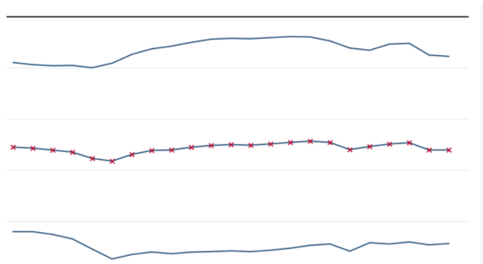

Figure 1: Annual Hourly Savings Estimates

Note: Blue lines represent 95% confidence interval. Standard errors are clustered at the building-month level. Building-by-hour and month fixed effects are included.

Comparing these estimates to hourly locational marginal prices (LMPs) in D.C., shown in Figure 2, it is clear that there is a mismatch in the profile of building Energy Star savings and hourly prices, particularly in the summer.[1]

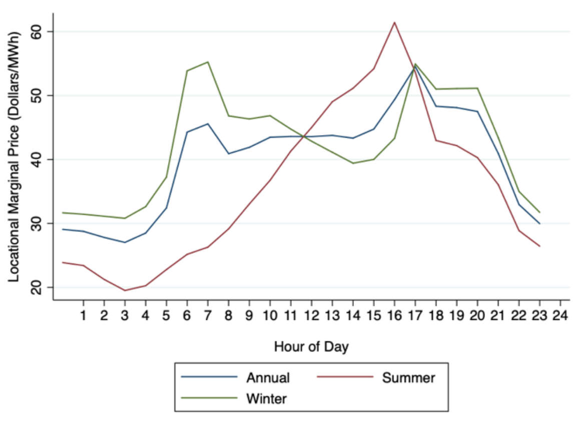

Figure 2: The hourly price of electricity in D.C.

This is further illustrated in Figure 3, which shows the profile of z-score standardized savings and prices, where each variable is normalized to have a mean of

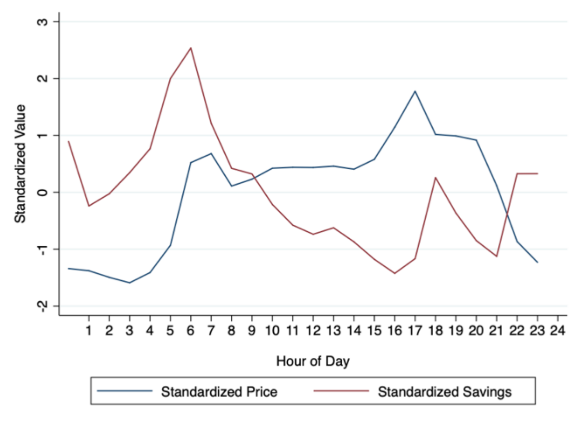

Figure 3: Comparing annual standardized prices and savings

zero and a standard deviation of one. Prices reach their peak at 5pm, and savings peak at 6am. The correlation between savings and prices is -0.41, indicating that prices tend to peak when savings are low and vice versa. In the summer months the correlation is -0.38, and in winter it is 0.55, so the negative correlation overall is primarily driven by a mismatch of savings and prices over the summer months.

Conclusion and future work

This case study of the hourly distribution of Energy Star score improvements in Washington, D.C. municipal buildings indicates a flat profile of hourly savings. Future work in this research project will incorporate capacity-payment adjusted price estimates and then assess total average savings versus savings adjusted for the hourly distribution of returns, in order to assess the value of the timing premium, if it exists.

Footnote

[1] These LMPs do not include capacity market payments, which suggests they represent an underestimate of peak-time prices and are therefore a conservative estimate of peak-off peak price differentials.

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