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Modeling the energy retrofit decision in commercial office buildings

Constantine E. Kontokosta

Assistant Professor of Urban Informatics; Head, Quantified Community Research Lab; Deputy Director for Academics, Center for Urban Science and Progress & Tandon School of Engineering, New York University

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ABSTRACT

Retrofitting existing buildings has emerged as a primary strategy for reducing energy use and carbon emissions, both nationally and in cities. Despite the increasing awareness of retrofitting opportunities and a growing portfolio of successful case studies, little is known about the decision-making processes of building owners and asset managers with respect to energy efficiency investments. Specifically, the research presented here examines the effects of ownership type, tenant demand, and real estate market location on building energy retrofit decisions in the commercial office sector. This paper uses an original, detailed survey of asset managers of 763 office buildings in nineteen cities sampled from the CBRE, Inc. portfolio. Controlling for various building characteristics, the results demonstrate that ownership type and local market do, in fact, influence the retrofit decision. Overall, this analysis provides new evidence for the importance of understanding ownership type and the varying motivations of differing types of owners in building energy efficiency investment decisions. The findings of both the survey analysis and the predictive model demonstrate additional support for the targeting of energy efficiency incentives and outreach based on ownership entity, local market conditions, and specific physical building characteristics.

1. Introduction

Ambitious building energy efficiency goals across local, state, and federal governments have directed significant attention to the potential to retrofit existing buildings to improve their energy performance, while generating new investment and job creation opportunities. According to the U.S. Department of Energy (DOE), the U.S. buildings sector accounts for 40% of greenhouse gas (GHG) and energy use, a sizeable figure that could be reduced by as much as 30% using existing technologies and energy conservation measures (ECMs) (Brown et al. 2008) [33]. This is especially true for large buildings in cities; in New York City, for instance, buildings account for 79% of all GHG emissions and energy use and fully half of that is attributable to buildings over 50,000 square feet, even though buildings of this size represent only 2% of the total number of buildings in the City [11,12,13]. Similarly, the building sector in Chicago accounts for fully 71% of its total urban GHG emissions [10]. As a result, major cities have adopted significant building energy efficiency and GHG reduction plans to not only address issues of climate change and sustainability, but also to stimulate economic growth, encourage technology innovation, and mitigate potentially negative economic, environmental, and public health impacts.

Although the need and potential benefits of energy retrofits have been well-documented, the pace of adoption of energy efficient practices and technologies has been slow, and significant barriers – both perceived and actual – persist to limit building energy investments [39,44]. New policy initiatives have been introduced to address some of these barriers and catalyze market transformation around the benefits of energy performance improvements [7,29]. Energy disclosure laws now enacted in over a dozen U.S. cities provide a new stream of building energy data and peer-group benchmarking to overcome marketplace information asymmetries and knowledge gaps in building sustainability best practices [26,28]. Energy audit and retro-commissioning requirements have also begun to emerge, providing owners, tenants, and policymakers with detailed accounting of building systems and energy end-use, as well as the energy savings and cost savings potential of the implementation of specific ECMs. These requirements have come in several forms, from policies similar to New York City's Local Law 87 (LL87) that obligate large buildings to conduct an audit every ten years, to energy audit requirements by lenders at time of sale or re-finance.

Despite the increasing knowledge base around retrofitting opportunities and a growing portfolio of successful case studies, little is known about the decision-making processes of build-

E-mail address: ckontokosta@nyu.edu

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ing owners and asset managers with respect to energy efficiency investments. Specifically, the research presented here examines the effects of ownership type, tenant demand, and market competitiveness on building energy retrofit decisions in the commercial office sector. This paper uses an original, detailed survey of asset managers of 763 office buildings in nineteen cities as part of the CB Richard Ellis portfolio and a machine learning prediction model to quantify the factors associated with energy retrofit activity. The survey was designed to collect energy performance, space use, and retrofit/ECM data, as well as information on the ownership structure and motivations and constraints to implementing ECMs. This analysis provides new evidence on the factors that influence the decision to pursue – or avoid – building energy improvements, as well as to classify buildings by design components, ownership type, and energy profile to predict the likelihood of energy retrofits in other similar buildings. The paper begins with a discussion of the recent literature, then follows with a description of the survey and empirical methodology and findings. The results of the classification and prediction model are presented together with implications of the findings for advancing the pace of adoption of energy efficiency investments in office buildings.

2. Literature review

There is an extensive body of research on the opportunity that energy retrofitting of commercial buildings creates to reduce national energy use and carbon emissions [8,31,32]. Given that commercial buildings account for approximately 20% of national energy use, ambitious, but potentially achievable, 30–50% efficiency gains in existing commercial buildings through retrofitting would yield a 6–10% reduction in energy consumption for the U.S. as a whole [5]. This would equate to a reduction of approximately 3000 to 5000 trillion Btu per year, based on 2015 consumption estimates (U.S. Energy Information Administration, Monthly Energy Review, Table 2.1).

In addition to the energy use implications, improving energy efficiency in the commercial building sector has been estimated to be a sizeable catalyst for capital investment and driver of economic activity. Studies by the Rockefeller Foundation, Deutsche Bank, and McKinsey Consulting suggest commercial building energy retrofits could be an estimated $72 billion investment opportunity, one that could generate as many as 857,000 job-years over a ten year period [40]. Energy retrofits have also been shown to produce both direct and indirect benefits for building occupants and owners. In addition to possible energy savings and associated lower operating costs, benefits include reductions in equipment maintenance, improved air quality, improved rental rates, higher tenant retention, and higher occupancy rates [2,15,18,27].

Despite what appear to be significant positive outcomes from energy retrofits in the commercial building sector, the adoption of energy efficiency projects and practices continues to be slow [42,43]. Barriers to the adoption of energy retrofit measures include information asymmetries between stakeholders, uncertainty over future savings, lack of knowledge in energy technologies, and economic dis-incentives including the “split-incentive” problem between owners and tenants and the decreasing cost of oil and natural gas [22,25]. These perceived and actual barriers have been exacerbated by a case-study approach to retrofit strategies, often due to the lack of comprehensive, robust data and large-scale pre/post studies of consumption following ECM installation.

Several studies have attempted to better understand optimal ECM strategies for commercial buildings. Doukas et al. [14] introduce an intelligent operations management software that accounts for building operational data and external factors to identify energy efficiency opportunities. Asadi et al. [3] utilize a multi-objective mathematical model to simultaneously evaluate a range of ECMs applicable to single-family homes. Focusing on material and building construction factors, the model identifies trade-offs between cost and energy savings across multiple alternatives. A similar study by Verbeeck and Hens [45] looks at the existing housing stock in Belgium to identify optimal ECMs through the use of building simulation models. The authors conclude by presenting a hierarchy of ECMs in this context. Beyond physical and technological features of energy retrofits, Menassa [34] uses cost-benefit analysis and option pricing theory to provide decision-makers with guidance for sequencing individual ECMs over time. The study examines single-stage and multi-stage investment scenarios to develop alternatives to net present value decision criteria. Marasco and Kontokosta [48] utilize actual energy audit report data for more than 2,000 buildings in New York City to predict the likelihood of ECM recommendations for a particular building. Using a machine learning classifer, the authors develop an äutomated auditp̈rocedure to estimate ECM eligibility given a specific set of building and systems characteristics.Additional studies have focused on modeling and optimization of potential energy retrofit measures under differing degrees of uncertainty [24,41].

Few studies have looked comprehensively at the decision and motivations to implement an energy retrofit in commercial buildings. In a study of homeowners in Canada, the decision to move from energy audit to retrofit investment was influenced by the projected energy savings, the up-front cost, and incentives available, as well as building age and householder demographics [21]. In a study of retrofit activity of homeowners in Germany, Achtnicht and Madlener [1] find similar results as the Canadian study, with financial capacity, favorable payback periods, and timing of system replacement shown to increase the likelihood of retrofit implementation. In an examination of retrofit adoption by ECM type in manufacturing facilities, Anderson and Newell [46] find that firms are more sensitive to initial costs rather than expected future savings. As expected, firms are found to be more likely to implement ECMs that have lower costs, shorter payback periods, and relatively higher energy savings. While all important findings, these studies address the residential and manufacturing sectors, respectively, and the generalizability of the findings to the commercial sector may be limited due to the varying regulatory, ownership, and financial structures of office buildings in the U.S.

3. Theoretical framework

Within the context of the expected benefits and perceived constraints of energy efficiency investments, the decision by a commercial building owner to invest in energy improvements and implement energy conservation measures is driven by a range of endogenous and exogenous factors. These include regulatory context and compliance risk, increased resilience and business continuity, knowledge and awareness, and tenant and occupant demand for energy efficient space. The relationship and interaction of these factors (as shown in Fig. 1) ultimately impacts the retrofit decision through economic/financial considerations and technical feasibility, potentially mediated by social and moral influences. Below, each is discussed in turn and a series of propositions to be tested in the empirical model are outlined.

Factors in Retrofit Decision-making- Increasingly, firms require certain energy or sustainability certifications (LEED, Energy Star, etc.) as a prerequisite for leasing space in particular building [35]. For instance, the General Services Administration will only lease space in buildings that have achieved an Energy Star label (U.S. General Services Administration Realty Services Letter, RSL-2010-02). In the private sector, firms are adopting corporate and social responsibility policies that encourage or require leasing in build-