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Portfolio retrofit evaluation: A methodology for optimizing a large number of building retrofits to achieve triple-bottom-line objectives

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ABSTRACT

Buildings account for approximately 40% of the total energy consumption and associated GHG emissions globally. As buildings age and energy codes become more stringent, significant investment is required to bring their performance in line with market expectations and competition for newer, more sustainable buildings. In large portfolios, the challenge is not only to identify the optimal building retrofits, but also which buildings have the most improvement potential.

This paper presents a methodology to overcome this challenge. First, the building portfolio is screened using available data; potential energy improvement potential and commercial improvement potential are ranked to identify priority buildings. Second, a series of retrofit bundles (combinations of energy conservation measures and other improvements) is tested on the priority buildings to calculate estimated energy savings, undertake financial analysis and property/portfolio value impact, evaluate risks, and evaluate qualitative indicators affecting occupant comfort to inform a development appraisal or renovation business case. These estimates are refined using an energy model for the most promising retrofit bundle. Non-priority buildings are improved using portfolio-wide strategies to take advantage of low/no-cost interventions.

Four global case studies using this framework are presented: two at the portfolio scale and two at the building scale. In each case, the modelling approach and data used in this decision-making are described and resulting project recommendations are presented. Although developed primarily for commercial buildings, this approach is applicable to all building types and recommendations are offed for its adaptation across sectors.

1. Introduction

Buildings use approximately 48% of the world's energy and heat and contribute approximately 19% of the global total of energy-related CO_2 emissions (6.4% in direct emissions and 12% in indirect emissions) (IPCC, 2014) and over the past decade, fossil fuel combustion and cement production (both associated with building construction and operations) has increased by 2.5%/year on average (Friedlingstein et al., 2014). As noted by a UN study, "The building sector has more potential to deliver quick, deep and cost effective GHG mitigation than any other. Significantly increasing building energy efficiency can be achieved in the short-term." (UNEP, 2009 as awareness of the need for improved building performance is increasing, tenants are demanding sustainability certification and evidence of high energy performance in their leased space, and the Corporate Real Estate (CRE) industry is responding with increased investment in this area (Breslau & Fowles, 2007; Fuerst, 2009; Kok, McGraw, & Quigley, 2011; Eichholtz, Kok, & Yonder, 2012; Qiu, Tiwari, & Wang, 2015).

In parallel, information on actual energy performance is becoming increasingly available through the adoption of mandatory building energy labeling (Rajagopalan & Leung Tony, 2012; Cajias & Paizolo, 2013; Balaras et al., 2014). Several studies have demonstrated that high energy performance ratings lead to significant increases in both rental and sale values (GBCA, 2006; Fuerst & McAllister, 2011a; Fuerst & McAllister, 2011b; Parkinson & Cooke, 2012; EU, 2013), while low performance ratings correlate with reduced rental rates (Leopoldsberger, Bienert, Brunauer, Bobsin, & Schützenhofer, 2011; Kok & Jennen, 2012) and reduced tenant retention (Remøy & van der Voordt, 2014).

Building owners and occupiers alike thus recognize substantial economic benefits of energy retrofits. Direct benefits include

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Nomenclature

η	Equipment efficiency
BAU	Business as usual
BOMA	Building owners and managers association
BESt	Building environmental standards (BOMA standard)
C_{CAP}	Capital (construction) expense
C_{CO2}	Cost per unit of CO_2 emissions
C_{elec}	Electrical cost
C_{energy}	Energy cost
C_{energy}	Cost of building energy use
C_{heat}	Heating cost
C_{OM}	Operations and maintenance costs
C_P	Performance for qualitative indicator
C_R	Performance for risk indicator
C_{source}	Unit cost for source fuel
$C(t)_{elec}$	Electrical cost as a function of time
C_{TAX}	Carbon/energy tax
C_{tenant}	Tenant fit-out allowance
CO_2	Carbon dioxide (representative of greenhouse gas emissions generally)
COP	Coefficient of performance
CRE	Corporate real estate
D	Duration before rent is collected/owned space is occupied
D_c	Construction period
D	Rent-free period
D_v	Vacancy period
E	Energy (when indicated with subscript elec, this includes all electrical sources excluding heat
EER	Energy efficiency ratio
ENV_L	% building envelope life elapsed
ENV_X	Building envelope type constant based
EUI	Current energy use intensity
EUI_{90}	Model ideal baseline EUI
GHG	Greenhouse gas emissions
GHG_s	Greenhouse gas use per unit of source fuel
heat	(Subscript) from all heat sources)
H_x	HVAC system constant based on system type
H_L	% HVAC life elapsed
HVAC	Heating, ventilation and air conditioning
i	Bundle indicator
id	Discount rate
I_{rent}	Rental rate
IRR	Internal rate of return
j	Electrical end-use indicator
k	Heating fuel type indicator
L_x	Lighting system type constant
L_L	% Lighting life elapsed
LEED	Leadership in Energy & Environmental Design
max	(Subscript) maximum of all values of type
M_x	Market favourability for the asset class
N	Number of elements of type
NPV	Net present value
O_L	Occupancy duration (expected ownership or lease term with renewal(s) as appropriate)
O_R	Occupancy rate
O_x	Occupancy type (type of lease)
OBC	Ontario building code
Q_i	Qualitative score
r	Risk factor indicator
R_C	Current capitalization rate (measure of future income risk)
R_i	Risk score of bundle i
R_{OC}	Historic occupancy rate
t	Time period indicator
Wc	Cost weighting factor
W_{ENV}	Envelope improvability weighting factor
W_I	Income weighting factor
W_{GHG}	Greenhouse gas emission weighting factor
W	HVAC improvability weighting factor
W_L	Lighting improvability weighting factor
W_{OCC}	Occupancy weighting factor
W_{pq}	Qualitative indicator priority weighting factor
W_{pr}	Risk indicator priority weighting factor
W_Q	Qualitative assessment rating factor
W_R	Risk weighting factor
X_{TOT}	Overall rating score for a bundle

decreased operational costs or repositioning of assets to a higher building class; indirect economic benefits are associated with developing a Green "brand" for their buildings, as 77% of corporate tenants will pay a premium for "green" space (Breslau & Fowles, 2007).

The fundamental challenge facing portfolio owners is how to prioritize investment in their existing building stock and target the right buildings with the right retrofit. This paper presents a framework has been developed to address this problem, which considers both the commercial improvability and potential for energy savings, along with a measure of risk exposure and human factors. This framework is limited in that the impact of occupant behavior on retrofit success is considered only indirectly – as a potential risk – and evaluated by expert judgment rather than empirical data. Similarly, the extent to which different approaches will impact the building occupants from a disruption, accessibility, or comfort perspective is again considered only through the qualitative evaluation where expert judgment is used to estimate the extent to which each potential retrofit achieves positive outcomes (or minimizes negatives) in this regard. The supporting methodology and underlying mathematical model are presented and applied to four case studies: two demonstrating the sorting of larger portfolios, and two demonstrating the building-specific holistic analysis.

2. Framework description

This process consists of three steps, referred to as "filters", in order to differentiate the portfolio into disparate components for action, as indicated in Fig. 1. The first stage, referred to as Filter 1, sorts the portfolio and identifies priority buildings to be further explored. Filter 2 investigates each of the priority buildings separately and evaluates the business-as-usual approach as well as four levels of retrofit of increasing capital investment and occupant disruption to identify the most appropriate level of investment in a building. Finally, Filter 3 optimizes the retrofit of each of the selected buildings and develops a calibrated energy model and market-verified cost estimate to inform a go-no/go decision on the optimized retrofit.

2.1. Filter 1: portfolio sorting and building prioritization

- Purpose: To evaluate the overall improvement potential of each building in the portfolio using readily-available information.
- Description: Each building is evaluated using the methodology described in Section 3.1 and normalized commercial improvability (I_c), representing the relative potential for improving asset value, and normalized technical improvability (I_T), representing relative achievable energy or CO_2 savings, scores are calculated for each building.