UNIVERSITY OF CAMBRIDGE

Environmental and Economic Impacts of Proactive Energy Management: Evidence from the US Office Market

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Background

Energy consumption of commercial buildings is influenced by numerous factors…

Previous Literature and Gaps

- Green certified buildings use less energy (Pivo and Fisher, 2010) and improve occupant comfort (Miller et al, 2009)
- Green certifications yield higher economic value, with estimated rental premia around 5% for LEED and Energy Star certifications (Eichholtz et al. 2010; Fuerst and McAllister 2011; Reichardt et al. 2012; Wiley et al. 2010 among others)
- Features driving the premium
    - Evidence of both labelling effect and energy-savings component (Bond and Devine 2016; Eichholz, Kok and Quigley 2010; Reichardt 2014)
    - Rent premiums for both net and gross leases and positive correlation between Energy Star scores and rent premiums (Szumilo and Fuerst, 2015)

Aims and Contributions

Aims

- Investigate the differences between LEED types
- Establish if there is a business case for energy management and productivity enhancing features
- Assess the potency of these measures in reducing greenhouse gas emissions

Contributions

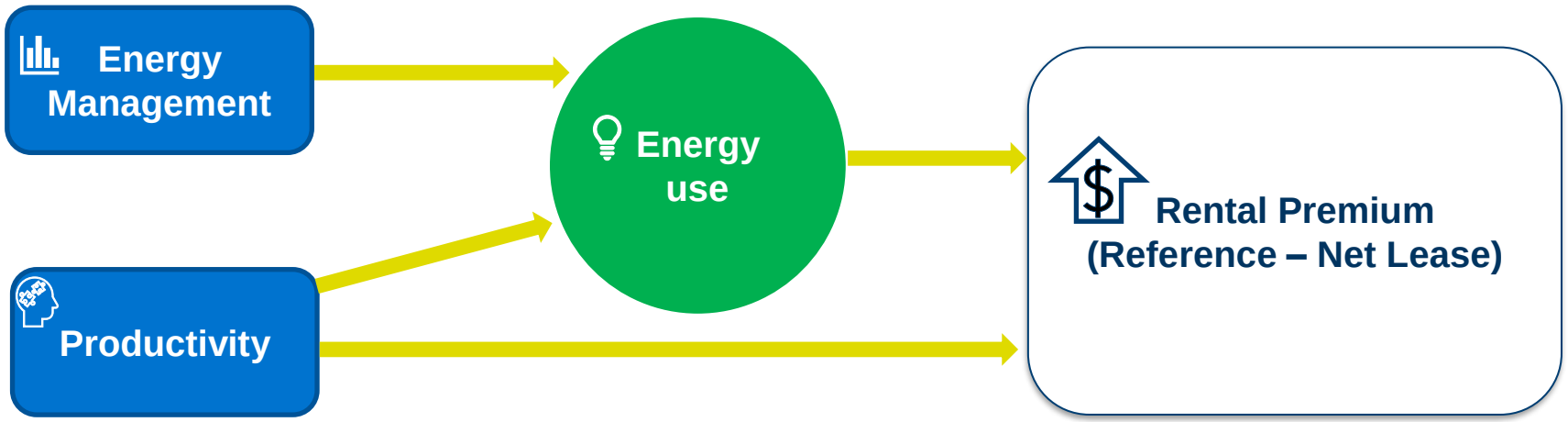
✓ Actual energy performance and achieved rents

✓ Panel data methods to address endogeneity

✓ Novel variables capturing operations and productivity

Mechanism and Hypotheses

Mechanism



Hypotheses

H1: Energy management practices reduce energy usage

H2: To make up for the savings made by the tenant, a greater premium is incurred

H3: Productivity practices increase energy consumption

H4: Productivity practices incur a premium

Empirical Data

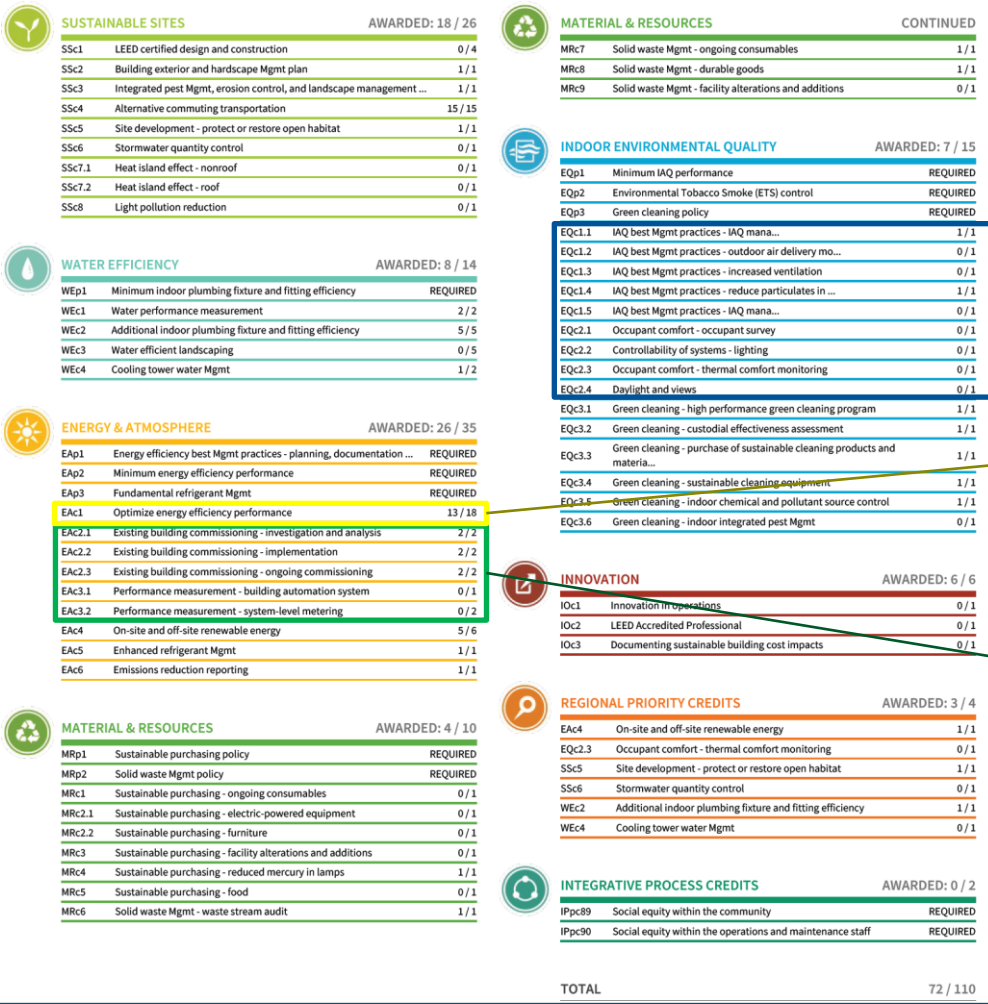
CompStak	• Achieved rents in New York, San Francisco, Chicago, Boston and Washington DC over 2000-2021 • Lease characteristics and concessions • Tenant characteristics • Building-level characteristics
LEED	• Scorecard information • Energy & Atmosphere and Internal Environmental Quality
Energy Reports	• Publicly available environmental performance benchmarking data over a period of **2011-2020** • **Source** and **site** energy usage and **Energy Star** score (on a scale of 1 to 100)

Matching Process

1) Addresses (unique identifiers) matched using machine learning library (Dedupe) in Python to identify record pairs
2) Excel matching of certificates to leases based on lease execution and certification dates

→ Longitudinal dataset covering a period of 2000-2021 (unbalanced panel)

LEED Scorecard – Example



SUSTAINABLE SITES		AWARDED: 18 / 26
SSc1	LEED certified design and construction	0 / 4
SSc2	Building exterior and hardscape Mgmt plan	1 / 1
SSc3	Integrated pest Mgmt, erosion control, and landscape management ...	1 / 1
SSc4	Alternative commuting transportation	15 / 15
SSc5	Site development - protect or restore open habitat	1 / 1
SSc6	Stormwater quantity control	0 / 1
SSc7.1	Heat island effect - nonroof	0 / 1
SSc7.2	Heat island effect - roof	0 / 1
SSc8	Light pollution reduction	0 / 1

WATER EFFICIENCY		AWARDED: 8 / 14
WEp1	Minimum indoor plumbing fixture and fitting efficiency	REQUIRED
WEc1	Water performance measurement	2 / 2
WEc2	Additional indoor plumbing fixture and fitting efficiency	5 / 5
WEc3	Water efficient landscaping	0 / 5
WEc4	Cooling tower water Mgmt	1 / 2

ENERGY & ATMOSPHERE		AWARDED: 26 / 35
EAp1	Energy efficiency best Mgmt practices - planning, documentation ...	REQUIRED
EAp2	Minimum energy efficiency performance	REQUIRED
EAp3	Fundamental refrigerant Mgmt	REQUIRED
EAc1	Optimize energy efficiency performance	13 / 18
EAc2.1	Existing building commissioning - investigation and analysis	2 / 2
EAc2.2	Existing building commissioning - implementation	2 / 2
EAc2.3	Existing building commissioning - ongoing commissioning	2 / 2
EAc3.1	Performance measurement - building automation system	0 / 1
EAc3.2	Performance measurement - system-level metering	0 / 2
EAc4	On-site and off-site renewable energy	5 / 6
EAc5	Enhanced refrigerant Mgmt	1 / 1
EAc6	Emissions reduction reporting	1 / 1

MATERIAL & RESOURCES		AWARDED: 4 / 10
MRp1	Sustainable purchasing policy	REQUIRED
MRp2	Solid waste Mgmt policy	REQUIRED
MRc1	Sustainable purchasing - ongoing consumables	0 / 1
MRc2.1	Sustainable purchasing - electric-powered equipment	0 / 1
MRc2.2	Sustainable purchasing - furniture	0 / 1
MRc3	Sustainable purchasing - facility alterations and additions	0 / 1
MRc4	Sustainable purchasing - reduced mercury in lamps	1 / 1
MRc5	Sustainable purchasing - food	0 / 1
MRc6	Solid waste Mgmt - waste stream audit	1 / 1

MATERIAL & RESOURCES		CONTINUED
MRc7	Solid waste Mgmt - ongoing consumables	1 / 1
MRc8	Solid waste Mgmt - durable goods	1 / 1
MRc9	Solid waste Mgmt - facility alterations and additions	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 7 / 15
EQp1	Minimum IAQ performance	REQUIRED
EQp2	Environmental Tobacco Smoke (ETS) control	REQUIRED
EQp3	Green cleaning policy	REQUIRED
EQc1.1	IAQ best Mgmt practices - IAQ mana...	1 / 1
EQc1.2	IAQ best Mgmt practices - outdoor air delivery mo...	0 / 1
EQc1.3	IAQ best Mgmt practices - increased ventilation	0 / 1
EQc1.4	IAQ best Mgmt practices - reduce particulates in ...	1 / 1
EQc1.5	IAQ best Mgmt practices - IAQ mana...	0 / 1
EQc2.1	Occupant comfort - occupant survey	0 / 1
EQc2.2	Controllability of systems - lighting	0 / 1
EQc2.3	Occupant comfort - thermal comfort monitoring	0 / 1
EQc2.4	Daylight and views	0 / 1
EQc3.1	Green cleaning - high performance green cleaning program	1 / 1
EQc3.2	Green cleaning - custodial effectiveness assessment	1 / 1
EQc3.3	Green cleaning - purchase of sustainable cleaning products and materia...	1 / 1
EQc3.4	Green cleaning - sustainable cleaning equipment	1 / 1
EQc3.5	Green cleaning - indoor chemical and pollutant source control	1 / 1
EQc3.6	Green cleaning - indoor integrated pest Mgmt	0 / 1

INNOVATION		AWARDED: 6 / 6
IOc1	Innovation in operations	0 / 1
IOc2	LEED Accredited Professional	0 / 1
IOc3	Documenting sustainable building cost impacts	0 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 3 / 4
EAc4	On-site and off-site renewable energy	1 / 1
EQc2.3	Occupant comfort - thermal comfort monitoring	0 / 1
SSc5	Site development - protect or restore open habitat	1 / 1
SSc6	Stormwater quantity control	0 / 1
WEc2	Additional indoor plumbing fixture and fitting efficiency	1 / 1
WEc4	Cooling tower water Mgmt	0 / 1

INTEGRATIVE PROCESS CREDITS		AWARDED: 0 / 2
IPpc89	Social equity within the community	REQUIRED
IPpc90	Social equity within the operations and maintenance staff	REQUIRED

TOTAL	72 / 110

Productivity

air delivery + controllability of lighting and temperature + access to daylights and views + minimization of internal pollutants + thermal comfort

Optimization

- *Points are awarded based on achieved Energy Star rating (or similar rating measure based on actual performance)*

Energy management

Metering + investigation + commissioning

Mixed Effects Panel Data Model

- Mixed Effects Multi-Level model to adjust for the nested-level error structure
- Three-level model: lease observations at level one, buildings at level two and state effects at level three

✓ High Intraclass Correlations detected

$$Y_{its} = \underbrace{\beta_0 + \beta_1 LEED_{its} + \beta_2 X_{its} + \beta_3 YEAR_t}_{\text{Fixed Effects Component}} + \underbrace{u_{0i} + u_{1j} LEED_{its} + u_s + e_{its}}_{\text{Random Effects Component}}$$

Key

$Y_{its} - starting\ rent\ p.s.f.(logarithm)\ /\ Energy\ Usage\ p.s.f.$
$LEED_{it} - LEED\ certificate\ /\ Continuous\ Scorecard$
$X_{its} - vector\ of\ lease\ and\ tenant\ characteristics$
$YEAR_t - year\ dummies$
$\varepsilon_{its} - error\ term$

Summary Statistics

	NON-CERTIFIED			CERTIFIED		
Main Variables*	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**
Starting rent p.s.f.	10,157	42.99	19.99	5,470	50.48	21.16
Effective rent p.s.f	10,157	41.40	19.98	5,470	48.29	22.39
Transaction size (s.q.f.)	10,157	14,602	38,135	5,470	18,992	42,425
Lease term (years)	10,157	6.03	3.56	5,470	6.44	3.63
Building size	10,157	398,917	463,439	5,470	732,946	640,575
Weather normalised source energy**	10,157	181.19	79.64	5,470	171.67	51.87
Landlord pays opex (Gross / MG leases)	7,101			3,829		
Tenant pays opex (Net, NN, Net of Electric)	3,056			1,641		
Scorecard variables**						
Productivity score (norm.)				5,470	0.42	0.18
Optimization score (norm.)				5,470	0.53	0.31
Energy Management score (norm.)				5,470	0.43	0.30
Starting Rent by City:						
New York	2,625	42.33	17.14	1,622	58.72	19.53
San Francisco	1,940	43.16	9.43	932	49.22	10.24
Washington DC	1,544	20.86	7.16	1,159	25.48	7.43
Chicago	1,391	40.42	14.10	634	52.94	14.23
Boston	2,657	57.72	23.11	1,123	64.04	20.97

*Concessions and tenant variables are excluded from the summary table

**Sample of certified buildings containing scorecard information

Energy Regression – Preliminary Results

Operating variables available

MODEL		ALL CITIES			NEW YORK ONLY		
		(1) All build. Types	(2) – (3) Certified		(4) All build. Types	(5) – (6) Certified only	
	Reference category	*Net lease in non-cert. build.*	*Net lease in CI (cert.) building*		*Net lease in non-cert. build.*	*Net lease in CI (cert.) building*	
	Variables	**Dependent Variable: Weather Normalized Source Energy Use**					
LEED	LEED Commercial Interiors	-3.679			-5.753***		
LEED	LEED Existing Building	-6.697***			-4.134***		
LEED	LEED Other	34.514***			19.383**		
SCORES	Optimize						
SCORES	Energy Management		4.823***			-2.17	
SCORES	Productivity			9.395**			28.458*
CTRL	Tenant Characteristics	YES	YES	YES	NO	NO	YES
CTRL	Lease Characteristics	YES	YES	YES	NO	NO	NO
CTRL	Building Characteristics	YES	YES	YES	YES	YES	YES
CTRL	State Controls	YES	YES	YES	YES	NO	NO
CTRL	Occupancy Characteristics	NO	NO	NO	YES	YES	YES
CTRL	Year Dummies	YES	YES	YES	YES	YES	YES
MODEL STATS	Observations	15,627	7,159	7,159	5,470	5,470	5,470
MODEL STATS	Number of groups	1,643	535	535	766	152	152

Note: The standard errors for the above models have been adjusted for heteroscedasticity using Huber-White error estimation in STATA. Likelihood ratio tests rejected the null hypothesis of no random effects. Residuals have been checked for normality.

Rent Regression – Preliminary Results

MODEL		(1) All building types	(2) – (4) Certified Buildings with scorecards released		
	Reference category	*Net lease in non-cert. building*	*Net lease in CI (cert.) building*		
	Variables	**Dependent Variable: Logarithm of starting rent per square foot**			
LEED	LEED Commercial Interiors	0.063**			
	LEED Existing Building	0.056**			
	LEED Other	0.089*			
SCORES	Optimize		0.032***		
	Energy Management			0.016	
	Productivity				0.022
CTRL	Building-level controls	YES	YES	YES	YES
	Tenant Characteristics	YES	NO	NO	NO
	Lease Characteristics	YES	YES	YES	YES
	State Controls	YES	YES	YES	YES
	Year Dummies	YES	YES	YES	YES
MODEL STATS	Observations	15,627	8,184	8,184	8,184
	Group Variable (building)	1,643	521	521	521
	Group Variable (state)	5	5	5	5

Note: Standard errors are adjusted for heteroscedasticity using Huber-White error estimation in STATA. Likelihood ratio tests rejected the null hypothesis of no random effects. Intraclass correlation confirmed the appropriateness of the models. Residuals have been checked for normality.

Conclusions

Tradeoff between productivity features and energy consumption

- Green certified buildings may come at the expense of higher energy consumption, for the points scored in the productivity category
- Contrasting coefficient signs in the operating vs non-operating certificate labels
- No support of the negative effect of energy management tools on energy consumption

Premium observed for optimized buildings

- Different premium magnitudes observed in the studied certificate types, as expected
- Premium for the presence of optimization points, but not for other categories

Remaining work

- Test the sensitivity of the findings to different matching assumptions
- Study the effect of other LEED scorecard features (i.e. water efficiency)