A behavioral decision research approach to energy efficiency

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Even when the benefits far outweigh the costs, many building owners do not invest in energy efficency. We present a general framework for understanding energy efficiency investment decisions drawing on methods grounded in behavioral decision research. The approach begins with a normative analysis that characterizes how rational, self-interested agents or organizations should behave, follows with a descriptive analysis of actual decision-makers, and then concludes with policy recommendations for how to bridge that gap. We demonstrate the framework with a sample of class B and C office building owners, a population believed to systematically under-invest in energy efficiency. Using interviews and a survey, we find that while uncertainty and a lack of information about costs and energy savings play a critical role in their decision-making, a significant proportion of the population expressed aversion to debt and a lack of sensitivity to split incentives. Based on the results, we recommend providing owners of class B and C offices cost-benefit information and resolving energy savings uncertainty through grants that fully subsidize energy efficiency for a small part of a building. The approach can be applied to energy efficiency decision-making by anyone with training in behavioral research, bringing climate advocates and social scientists together.

Energy efficiency is one of the most important tools for mitigating climate change [1]. The commercial buildings sector has a large potential for implementing cost-effective energy efficiency improvements (e.g., occupancy sensors) [2], but has a track record of slow market diffusion [3, 4, 5]. This appears to be a particular problem for class B and C offices, that tend to be smaller and rent for a lower price than class A offices. In Pittsburgh PA, these small class B and C offices account for about one-fifth as much of the verified energy efficiency savings as class A offices, even though small and large offices account for roughly the same total square footage in the area. Currently, little is known about how these building owners make energy efficiency investments.

Behavioral decision research [6, 7] holds that the best way to know what people care about is to ask [8]. Using this approach we demonstrate how to include program participants directly in the program design process in order to inform the design of energy efficiency policy. We illustrate the approach using the energy efficiency investment decisions of owners of class B and C offices in Pittsburgh, PA. The approach has three components: 1) a normative analysis, considering when and why a rational building owner should invest in energy efficiency, 2) descriptive research, using interviews and a survey of owners of class B and C offices in Pittsburgh to identify the concerns that actually matter to them, and 3) a prescriptive analysis that suggests how energy efficiency program designers, such as utilities or regulators, might use our results to improve program performance.

Our normative analysis draws on previous research investigating influences on energy efficiency decision making [9, 10, 11, 12, 13, 14, 15], identifying four major factors that specify necessary conditions for investment by economically rational and self-interested agents: 1) uncertainty, 2) time discounting, 3) capital constraints, and 4) split incentives. These are normative influences on decision-making because they are consistent with the axioms of rational preferences [16], and how those preferences should be related over time [17].

First, energy savings are uncertain, meaning a building owner must determine whether, for her particular building, a more efficient technology will yield a lower monthly bill [9, 18]. For example, in one study of 447 commercial buildings that were retrofitted with energy saving measures, Greely *et al.* [19] found that less than one third of the realized savings came within 20% of the predicted savings. Furthermore, those who are more risk averse are less likely to invest in energy efficiency, although this evidence comes from homeowners in the residential sector [20, 21].

Second, rewards in the future are often discounted, tipping the balance against energy efficiency, that promises delayed rewards (energy savings) in exchange for immediate capital costs [22]. Previous economic studies have found that the discounting of energy savings is both large and variable [23, 24], with decisions reflecting more than pure time preferences [17].

Third, building owners may not purchase energy efficient equipment because they simply do not have enough money to pay [22]. There is evidence that some firms are unwilling (or unable) to use debt to finance energy efficiency investments [25], often citing a shadow price to financing.

Finally, building owners do not always directly benefit from investments that make their building more energy efficient because tenants often pay the utility bills. For example, Schleich [26] conducted a cross-sectional survey of 2,000 organizations in the commercial and services building sector in Germany and found that buildings with renters tended to be less likely to adopt at least half of the relevant energy efficiency measures for their building compared to owners that also occupied the building.

Our normative analysis specifies what building owners should care about, if rational self-interest is their only concern. We contrast that with descriptive research using interviews and a survey of class B and C office building owners in Pittsburgh, to determine whether and to what extent our normative analysis captured their concerns.

1 Respondents

Survey respondents included 132 of 327 (40%) of owners of class B and C offices in Pittsburgh. Additional details on the sample, population, and recruitment approach are available in the methods section and Supplementary Tables 1-4.

2 Results

2.1 Choices

We began our survey with two hypothetical choices about energy efficient lighting improvements to respondents' buildings. We chose lighting because it accounts for about one-third of energy used in offices, and many lighting improvements are cost-effective. Each choice provided respondents with information about the costs and benefits of a new energy efficient technology (details on costs and benefits are in Supplementary Section 2), and asked whether they would prefer the new technology or the status quo. While rational self-interest does not dictate any particular response to these questions, we use their choices for later comparisons and to measure interest in energy efficiency, finding a high level. The choices are shown in Tables 1 and 2, with the number of respondents choosing each option shown in brackets below each table. Table 1 shows that, of the 117 responses to the question about occupancy sensors (89% responding), 67 respondents indicated they would invest in occupancy sensors (57% of respondents). At the end of the survey we asked respondents whether they had already installed occupancy sensors, with 34 indicating that they had already made that upgrade (26%).

Table 2 shows that, of the 116 responses to this question (88% responding), a substantial majority (76) indicated that they would upgrade the linear fluorescents (66% of respondents). Individuals' choices for the two lighting upgrades were also strongly correlated (Pearsons $r = .47$, $p < .01$). In sum, we find that most respondents were favorable toward investing in their building's lighting systems yet had not made the investment, suggesting that other issues stood in the way of making that choice.

2.2 Uncertainty and Information

To better understand whether uncertainty was one of those issues, we measured respondent attitudes toward a number of services that could help make it easier for them to invest in energy efficient lighting systems. Consistent with our normative analysis, we find that uncertainty played a critical role in their decision-making. Respondents were asked the following question:

> "Suppose the following services could be provided to help you improve the energy use of your buildings lighting systems. Tell us what you think about each of them using a rating from 3 to +3 described in the scale below."

The scale was 7 points with labels "very unhelpful" (−3), "moderately unhelpful" (−2), "slightly unhelpful" (−1), "neither helpful nor unhelpful" (0), "slightly helpful" (+1), "moderately helpful" (+2), and "very helpful" (+3). The services were described in the following order:

- *Energy Saving Comparables*: Data on the energy savings in buildings comparable to yours that improved their lighting systems.
- *Energy Savings Assessment*: Assessment by an engineer or architect about the energy saving potential of improved lighting systems.
- *Economic Assessment*: A cost-benefit analysis of lighting system improvements most relevant for your building.
- *Contractor Vetting*: Vetting of potential contractors based on quality, reliability, and customer satisfaction.
- *Energy Tracking*: Assistance in tracking your building's energy use with energy management software.
- *Contractor Scorecard*: A public scorecard showing how well potential lighting contractors have performed in the past.

- *Guarantee*: A guarantee that you will save a certain percent on your electricity bills if you improve your lighting systems.

- *Lease Structuring*: Assistance in creating a lease structure that allows tenants to pay for part of the cost of the lighting systems. (skip this question if your building is not multi-tenant)

As seen in Table 3, respondents were most favorable toward the energy savings guarantee, which would reduce the uncertainty associated with project benefits (in the form of energy savings). They were equally favorable toward an economic assessment that would provide information about the costs and benefits of energy efficiency investments (respectively). To see whether the guarantee reflected the same concern as the economic assessment, we used a maximum likelihood factor analysis (details in Supplementary Section 3) [27]. A two factor solution provided two grouping factors [28], with the economic assessment, energy assessment, and energy comparables all loading on the first factor, while the guarantee, contractor vetting, and contractor scorecard loaded on the second factor. As expected from our normative analysis, these results suggest that respondents were concerned about the uncertainty in the savings from an energy efficiency lighting investment. We also find that they wanted information about the costs and benefits of those investments, and that uncertainty and information are separable concerns.

2.3 Capital Constraints and Time Discounting

In the next section we explored whether respondents faced capital constraints, finding that most could pay for energy efficiency investments themselves. Specifically, we asked respondents:

1. "How much do you think it would cost to buy and install new linear fluorescent lamps, ballasts, and fixtures in your entire building?"

2. "Could you pay for that without getting external financing?"

Out of 110 responses to the second question, 87 (79%) indicated that they could pay for the lighting improvements out of pocket, while 22 said they could not. Although most respondents could pay for the improvements themselves, whether they prefer to pay themselves (or use debt) should normatively depend on their time preferences, which we elicited with the following question:

> "Suppose you could lend that same amount of money to a commercial bank. The bank would pay you back in monthly installments, plus interest. What is the minimum annual interest rate you would have to be paid to lend this money? Assume the bank will definitely pay you back (there is no risk)."

The answer to this question identifies the next best investment respondents can make with their money, or the time value of their money. We denote the answer to this question as δ^*, the respondent's risk-free discount rate or rate of pure time preference. Of the 132 respondents, 79 answered this question. Respondents' δ^* ranged from 0% to 15% (median = 5%, mean = 5.3%, SD = 2.8%). Because the rate of return from the linear fluorescents and occupancy sensors was above the risk-free discount rate for all respondents (20% and 42%, respectively), every respondent who could pay for the lighting improvement themselves should. However, 26 of the 76 respondents (34%) who could pay for the linear fluorescents indicated they would not invest, suggesting other factors contributed to the energy savings being discounted. We assessed whether other factors were at play with the following question:

> "If you were to take out a loan from a commercial bank to finance this, what is the maximum annual interest rate that you would be willing to pay?"

Respondents should only be willing to take out a loan (paying some annual amount for sure) in exchange for this investment if they think the annual benefits are greater than the annual costs. Thus, the maximum annual interest rate at which respondents are willing to borrow identifies the point where these annual benefits and costs are perceived to be equal. There were 82 responses to this question with respondents giving a range of maximum borrowing interest rates from 0% to 10% (median = 4%, mean = 3.63%, SD = 1.8%). Using a Wilcoxon Rank Sum test (W_{rs}), those who rejected the occupancy sensors gave lower annual interest rates, suggesting they expected lower benefits ($W_{rs} = 2.6$, $p = .01$). A similar pattern held for linear fluorescents ($W_{rs} = 1.8$, $p = .08$).

Using the measured risk-free discount rate δ^* and the maximum interest rate respondents indicated they were willing to pay on a loan, we can compare the contribution of the rate of pure time preference relative to other factors that might reduce the perceived value of the energy savings, denoted δ^o (computational details provided in Supplementary Section 4). It was possible to estimate δ^o for 63 respondents, with Figure 1 showing the bivariate scatterplot of δ^* and δ^o. As can be seen, δ^o varied from 13% to 25%, with a mean of 16% (SD = 2.3%). For almost all respondents δ^* was smaller than δ^o (Wilcoxon Signed Ranks test: $W_{sr} = 2013$, $p < .01$), suggesting that other factors mattered more than the time-value of respondents money. Respondents with higher δ^o were also less likely to invest. The median δ^o was 15% among those who chose linear fluorescents, and 16% among those who did not. Although the difference was small, it was statistically significant ($W_{rs} = 220$, $p = .038$).

2.4 Split Incentives

The last factor found in the literature that potentially influences decision making are split incentives. A respondent is classified as facing a split incentive if the tenant paid all the electric bills. We find little relationship between split incentives and respondents hypothetical decision to invest. We find that 58% (= 19(19 + 14)) of respondents who faced split incentives indicated they would invest in occupancy sensors, as did 57% (= 48(48 + 36)) of respondents who did not face split incentives, suggesting no relationship between split incentives and the decision to invest. Similarly, 71% (= 22(22 + 9)) of respondents who faced split incentives indicated they would invest in linear fluorescents, as did 64% (= 54(54 + 31)) of respondents who did not face split incentives. If anything, the result suggests that those facing split incentives were slightly more likely to invest in linear fluorescents.

2.5 Debt Aversion

The analyses presented above suggests that respondents were considering more than the time value of money when discounting the energy savings from an energy efficiency investment. However, because of the non-response patterns in the data (with more than half not responding to all three questions about loans and loan length), these results cannot be taken at face value. Here we provide some explanation of the other issues that respondents considered and the non-response pattern, using a question that was designed to explore an extreme aversion to debt, in that choosing to pay the full cost up front implies the complete rejection of the use of debt to finance building improvements (and a negative discount rate):

> "Imagine that you have enough money to pay the full cost of the lighting improvements up front, but also have the option of making payments evenly divided across a fixed number of years. Assume there is 0% interest on the delayed payments. Which would you prefer? (Full cost up front or even payments over several years)."

- Full cost up front [$\frac{35}{115}$]
- Even payments over several years [$\frac{80}{115}$]

As can be seen, approximately one-third of respondents preferred to pay the full cost of the improvement up front. Those who rejected the loan outright also tended to not respond to the interest rate question. Overall, of the 80 who indicated they wanted the delayed payment, 26 did not respond to both questions about interest rates (33%). In contrast, of the 35 who indicated they wanted to pay the cost up front, 22 did not respond to both interest rate questions (63%) ($\chi^2(1) = 8$, $p = .005$). Thus, a substantial proportion of respondents (32% = 42/132) refused to specify an interest rate at which they would be willing to borrow or lend money. Confirming this, we also asked respondents about their support for lower interest rates on a loan, finding that those who preferred to pay up front gave a lower median rating of 0 than those who preferred the delayed payment, with a median rating of 1 ($W_{rs} = 1682$, $p = .04$). Likewise, we asked respondents about how comfortable they felt borrowing money from a number of different organizations, again finding that those who refused loans also felt less comfortable borrowing from large banks ($W_{rs} = 1752$, $p = 0.003$). We also included measures to elicit respondent attitudes toward debt that did not assume respondents knew the interest rates they would be willing to accept or pay precisely [29, 30]. Specifically, respondents were asked to:

> "Tell us what you think about using each of the following financing methods to pay for improving the energy use of your buildings lighting systems using a rating from 3 to +3 described in the scale below."

The scale was 7 points with labels "very undesirable" (3), "moderately undesirable" (2), "slightly undesirable" (1), "neither undesirable nor desirable" (0), "slightly desirable" (+1), "moderately desirable" (+2), and "very desirable" (+3). The financing mechanisms were described as follows:

- Self-funding: Pay for the lighting systems yourself. No financing.
- Commercial loan: A loan from a federally regulated for-profit commercial bank.
- Small bank loan: A loan from a not-for-profit small bank or credit union that is not federally regulated.
- Local government financing: The local government loans you the money, then increases your buildings property taxes for a fixed time period, until the money is paid back.

- Utility financing: A local utility company loans you the money and takes a portion of the energy savings for a fixed time period, until it has recovered the cost.
- Energy contract: A private energy service company loans you the money and takes a portion of the energy savings for a fixed time period, until it has recovered the cost.

As seen in Table 5, self-funding was the most preferred financing method. There were 122 responses to both questions about self-financing and the commercial loan, with 54 rating the loan higher than self-financing, and 68 rating the self-financing higher than the loan. Of the 76 respondents who indicated they would accept the 0% interest loan, 38 rated self-financing higher than the commercial loan (50%). In contrast, of the 35 respondents who indicated they would reject the 0% interest loan, 25 rated self-financing higher than the commercial loan (71%), ($\chi^2(1) = 3.7$, $p = .056$).

3 Discussion

We began with a normative analysis of the energy efficiency investment decision, finding that decisions should depend on uncertainty in the energy savings, the degree to which the future energy savings of investments are discounted, capital availability, and whether the tenant pays the energy bills. This helped frame descriptive research that included interviews and a survey of owners of class B and C offices in Pittsburgh, which revealed that respondents: 1) were concerned about uncertainty in the energy savings and desired measures to reduce that uncertainty (a guarantee), 2) discounted the future energy savings of energy efficiency investments, but only a minority of this discounting was due to time preferences, 3) had enough capital to pay for the investments themselves, and preferred to pay themselves, with some respondents even rejecting a no interest loan, and 4) rarely cared about split incentives. Although the result merits further research, one explanation for the debt aversion is that respondents felt uncomfortable borrowing from a commercial bank, possibly reflecting previous negative experiences with debt. Speculatively, the relative insensitivity to split incentives likely reflected the desire for small owner-occupiers to retain their tenants rather than fuss about their energy bills.

There are several issues with the study that limit its generalizability. Although we made our best effort to recruit the entire population of class B and C office building owners in Pittsburgh into our survey, we achieved only a

40% response rate, with over-representation from owner-occupiers. This over-representation was due to the difficulty determining who owned the building, with owner-occupiers being much more easy to identify. Furthermore, as we have no data on class B and C office building owners in other cities, the conclusions are necessarily limited to Pittsburgh.

We envision the following program for owner-occupiers of class B and C offices in Pittsburgh. Based on our interviews and the survey, local contractors were the most trusted source of information (methods and result are in Supplementary Section 5). Reflecting respondents' desire for cost-benefit information, a local non-profit would educate these contractors about the costs and benefits of energy efficiency, including how to convey that information to building owners in a credible manner. To maintain that credibility, the approach would be non-persuasive, providing the facts and uncertainties candidly [8]. To help reduce the uncertainty in energy savings, a local utility, government, or non-governmental organization would offer seed grants that fully subsidized small projects, such as making a single floor of a building energy efficient. This would allow building owners to gain valuable information about project uncertainties. For example, for each seed grant that fully subsidized an occupancy sensor, the building owner would gain $728 over the 14-year lifetime of the sensor, at a cost of $125 to the granter. If the savings yielded from each sensor reduced the perceived uncertainty, this approach could yield two or three times the energy savings for a constant program cost. If all class B and C offices in Pittsburgh were given a free occupancy sensor to reduce that uncertainty, the total cost would be $40,500 ($= 125 \times 327$) yielding about 6 times that in direct economic benefits, and more if the sensors spurred further investment by reducing perceived uncertainty. While grants are fairly straightforward, other uncertainty mitigation strategies, such as the use of financial instruments [18], might be viable alternatives. While these recommendations apply to the specific population of owners of class B and C offices in Pittsburgh, our method is general, applicable to any program, in any sector, in any city.

The approach described in this paper risks errors of believing what people say when they may not be able to express (or know) what they want, or may not be candid with us. We believe this is the lesser of two risks, compared to assuming people can't (or won't) tell us what they want, and using behavioral approaches to manipulate them. A manipulative approach at best trades long-term cooperation for short-term effectiveness. When people find out they are being manipulated, they are unlikely to engage in future collaboration, creating an adversarial environment. By listening to what people have to say, the approach we've outlined builds good will, trust, and a chance for future collaboration through a systematic and inclusive energy efficiency program design process.

4 Methods

4.1 Population and Sample Frame

We obtained building class and owner contact information from a combination of data provided by the commercial real estate database firm CoStar, real estate searches using the Allegheny County Assessment, deed searches in the Allegheny County records, and other internet sources (e.g., Googling). Our sample frame included the entire population of class B and C offices in Pittsburgh, including 327 owners of 504 buildings.

Survey

Following initial formative and pretesting interviews, we conducted a survey to evaluate whether the views that emerged from the interviews were reflected in the broader population. Using this database we attempted to recruit all 327 building owners to participate in the survey. They were sent an initial recruitment mailing in early November 2014, including the survey, cover letter, an addressed stamped return envelope, and a $10 cash incentive. The cover letter included the building owners name or the name of the building owner's holding company if the name could not be determined. If owners had not responded in two weeks they were sent a follow-up postcard reminding them to return the survey. The postcard also provided them a link to participate online. Two weeks after the postcard was sent, we attempted to contact owners in person. After these in-person visits, we attempted to contact non-responders by phone or email. Approximately one month after the in-person contacts we sent a second mailing wave with the survey, cover letter, an addressed stamped return envelope, and a $10 cash incentive. In total, 132 of 327 (40%) building owners responded to the survey.

Characteristics of the population and sample are described in detail in Supplementary Section 1. The sample was mostly composed of owner-occupiers. Even though owner-occupiers accounted for the majority of the population, the sample was biased toward owner-occupiers, likely because their contact information was easier to obtain from county records and other sources.

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Author Contributions

A.D. conceived and designed the data collection, performed the data collection, analyzed the data, contributed data collection materials, and wrote the paper. G.W.P conceived and designed the data collection and wrote the paper. T.K. conceived and designed the data collection and wrote the paper.

Competing Financial Interests

The authors declare no competing financial interest.

Figure Legends

Figure 1. Risk-free and other discount rate. The risk-free discount rate is shown on the horizontal axis, and the discount rate from other factors is shown on the vertical axis. Circles and triangles indicate whether respondents accepted or rejected the linear fluorescents in the hypothetical choice (respectively).

Tables

Table 1: Occupancy sensors choice.

	Option A	Option B
	Occupancy Sensors	No Change
Installed Cost	$125 per sensor	$0
Annual Energy Cost Savings	$52 per year, per sensor	$0
Lifetime	14 years	
Time to pay back	2.40 years	
	[67]	[50]

Table 2: Linear fluorescent choice.

	Option A	Option B
	New Linear Fluorescent	No Change
Installed Cost	$55 per fixture	$0
Annual Energy Cost Savings	$11 per year, per fixture	$0
Lifetime	14 years	
Time to pay back	5 years	
	[76]	[40]

Table 3: Attitudes toward decision-making services. Items with different superscripts denote $p < .05$ according to the Wilcoxon Signed Ranks Test.

Service	−3	−2	−1	0	+1	+2	+3	Mean	SD	n
Guarantee	1	1	1	14	12	27	69	2.1^{a}	1.2	125
Economic Assessment	1	1	0	12	13	39	61	2.1^{a}	1.1	127
Energy Assessment	1	1	1	13	25	34	52	1.9^{b}	1.2	127
Energy Comparables	4	2	0	19	25	29	47	1.7^{c}	1.5	126
Energy Tracking	1	3	1	35	28	20	38	1.4^{d}	1.4	126
Contractor Vetting	2	3	3	36	20	22	38	1.3^{d}	1.5	124
Contractor Scorecard	1	1	1	41	29	21	33	1.3^{d}	1.3	127
Lease Structuring	5	4	1	33	12	14	23	1.3^{e}	1.3	92

Table 4: Factor analysis of service attitudes.

Item	Factor 1	Factor 2	Uniqueness
Guarantee	0.11	**0.50**	0.74
Economic Assessment	**0.88**	0.14	0.21
Energy Assessment	**0.86**	0.16	0.23
Energy Comparables	**0.53**	0.37	0.58
Energy Tracking	**0.42**	0.35	0.70
Contractor Vetting	0.27	**0.60**	0.57
Contractor Scorecard	0.15	**0.90**	0.18
Eigenvalue	2.1	1.7	
% Variance Explained	0.3	0.24	
Cumulative Variance	0.3	0.54	

Table 5: Attitudes toward financing and debt. Items with different superscripts denote $p < .05$ according to the Wilcoxon Signed Ranks Test.

Financing Mechanism	−3	−2	−1	0	+1	+2	+3	Mean	SD	n
Self Financing	16	6	7	17	17	15	46	0.95^{a}	2.1	124
Utility Financing	24	10	5	29	21	16	19	0.1^{b}	2	124
Energy Service Contract	28	13	8	22	21	20	12	-0.17^{c}	2.1	124
Small Bank Loan	30	11	8	43	18	8	6	-0.55^{d}	1.8	124
Commercial Bank Loan	35	13	6	38	18	8	6	-0.69^{d}	1.8	124
Local Government Loan	58	6	12	21	13	4	10	-1.2^{e}	2	124