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Easy but not effective: Why "turning off the lights" remains a salient energy conserving behaviour in the United States

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ABSTRACT

When participants are asked how best to save energy in the home, the most frequent response since the 1980s has been "turning off the lights". Here, we use an online survey (N = 1418) to investigate why turning off the lights persists as a modal response despite decades of energy education promoting far more effective behaviors. We confirm that turning off the lights is still the modal response when participants are asked for the single most effective action they currently do to save energy (36.3% of participants). We find that being taught to turn off the light is an important reason for why turning off the lights has remained so popular. When participants are asked to make a recommendation to a friend between turning off the lights (curtailment action) or replacing incandescent bulbs with CFL or LED bulbs (efficiency action), we observe a remarkable shift towards efficiency (77%) rather than curtailment (23%). We find that participants explain their choice of turning off lights or replacing bulbs with different heuristics. Participants who choose turning off the lights state that energy savings occur when an appliance is completely turned off. Alternatively, those who pick replacing inefficient light bulbs state that far less energy can be used for a given task.

1. Introduction

Addressing climate change requires action at all levels, from international government organizations all the way to individual households. Household energy use in the United States alone accounts for 8% of global CO_2 emissions [1]. Nationally, residential CO_2 contributions account for 19% of total U.S. emissions from fossil fuel combustion [2]. Of this, nearly 70% of residential CO_2 emissions come from electricity generation [2]. As lighting accounts for nearly 10% of residential electricity use [3], reducing the total energy used by lighting has the potential to decrease carbon dioxide emissions.

1.1. Lighting policy

Policy and technological improvements are already reshaping the lighting sector's energy efficiency. In 2007, the Energy Independence and Security Act (EISA) provided legislation to gradually phase out inefficient light bulbs for higher performing varieties [4]. The energy performance of a light bulb is defined as how much visible light you get for a given amount of electricity i.e., the lumen output per watt of power input (lm/W). Incandescent bulbs currently measure about 10–18 lm/W, Compact Fluorescent Lights (CFL) are roughly 35–60 lm/W, and Light Emitting Diode (LED) lamps have a much higher efficiency: about 60–100 lm/W and upwards [5–7]. Under EISA, light bulb manufactures are required to meet increasingly stringent standards. By 2020, any general service lamp (GSL) sold in the United States must be at minimum 45 lm/W. While not banning specific lighting technologies, EISA's efficiency requirement would remove incandescent GSLs from the market by 2020. California proactively adopted a state-specific version of this regulation in 2017, which came into effect January 1, 2018 [8]. Any state regulated GSLs made and sold in 2018 or later in California must be a minimum of 45 lm/W.

The residential market saturation of incandescent lights decreased from 52% in 2010 to 27% in 2015 [5]. In the same time period, CFLs increased from 19% to 29%, and LEDs from less than 1% to 4% [5]. By 2050, the U.S. Energy Information Administration projects that LEDs will "meet most lighting demands" and will cost 70% less than 2015 prices [3]. Thus, state and federal regulations along with technological improvements are part of the market's move away from incandescent light bulbs, even though there are some consumers who still actively purchase and use incandescent bulbs.

Although the outlook for energy efficient lighting technologies are

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bright, these technology and policy advances struggle to gain consumer and political support. For example, consumer awareness about EISA ranged as low as 25% when polled between 2009–2011 [9]. Of those who did know about the regulation, perceptions were negative; nearly half of the consumers polled said they would stockpile extra incandescent bulbs in advance of the regulations taking effect. This *psychological reactance* [10], where people feel their freedom of choice is constrained, is a powerful barrier to eliminating older inefficient technologies. Consumers responded similarly in the short-term when phosphates were eliminated from laundry detergent [11]. Furthermore, the 2012 Consolidated Appropriations Act debilitated EISA by revoking the Department of Energy's use of funds to enforce lighting efficiency standards [12].

1.2. Long-lasting lighting misperceptions

Turning off the lights when they are not in use has potential to be a good energy conserving action, but the savings from switching to more efficient bulbs is significant and rarely thought of as an effective means of saving energy. Let us walk through a simple example to demonstrate the issue: A 100 W incandescent bulb currently produces the same lumen output as a 14 W LED bulb. If we have useful need of light for 2 h out of 10 h when the light remains on, the LED uses 28 Wh and the incandescent uses 200 Wh in the 2 h useful period, but the LED would only waste 112 Wh in the remaining 8 h when the user forgets to turn it off, whereas the incandescent would waste 800 Wh. If the LED were left on for 10 h (140 Wh) it would still use *less* energy than the total energy used by the incandescent bulb during just the 2 -h useful period (200 Wh). In this example, switching to a more efficient bulb saves more energy than using an inefficient bulb and being vigilant to turn it off. To be sure there are usage patterns where turning off the lights will save more energy than replacing inefficient bulbs with more efficient ones, and using them for more hours. However, replacing inefficient bulbs with more efficient ones *generally* would save more energy than turning off the lights, even though the best recommendation here is to do both: replace bulbs with more efficient ones and turn them off when they are not in use.

What concerns us is that despite the clear benefits gained by transitioning to more efficient light bulbs, public perception of how to save energy in the home has refused to budge. Kempton et al. in 1985 [13] and Attari et al. in 2010 [14] asked participants how they save energy in the home. In both cases, the most frequent response was "turning off the lights." Specifically, Kempton et al. discovered 59% of participants included "turning off the lights" as an energy-saving action a family could use to reduce household energy consumption. Likewise, Attari et al. found nearly 20% of participants listed "turning off the lights" as the single most effective thing they could do to save energy. Public perceptions seem to be fixed on turning off the lights, even while in the midst of an efficient lighting revolution [15].

In the same vein, Truelove et al. [16] found that participants preferred "turning off the lights" above many other environmental actions, including improving light bulb efficiency. After gathering 74 pro-environmental behaviors from a literature review, Truelove et al. asked participants to rank these behaviors on two axes: *environmental impact and financial savings*, and *financial and behavioral cost*. Across all 74 actions, participants ranked "turning off the lights" cheapest in *financial and behavior cost* and among the top three for *environmental impact and financial savings* [16]. Thus, turning off the lights occupies a unique and resilient niche among the hierarchy of energy-saving actions.

However, Gardner and Stern [17] state, "the behaviors that are easiest to remember and perform, for example, turning out lights when leaving rooms, tend to have minimal impact on climate change… and may even be counterproductive, if they lead people to feel satisfied that they have done their part after accomplishing very little." Additionally, behaviors that are more explicitly visible may invite others to sanction, shame, or make people feel guilty for not carrying out the behaviors [18]. Misplaced emphasis on less-effective energy-saving behaviors delay crucial progress on the issue of energy conservation and climate change. For this reason, we aim to examine why people report "turning off the lights" as the most effective means of saving energy in the home.

1.3. Behavior classification

Following the energy behavior classifications of Attari et al. [19] and Truelove et al. [16], we defined turning off the lights and replacing incandescent bulbs with more efficient CFL or LED lamps into two separate energy categories: curtailment and efficiency. Curtailment actions are typically defined as frequently occurring low-cost behaviors (i.e., doing the same behavior but less often *e.g. turning off unused appliances*) [14,16,20]. Efficiency actions involve greater upfront costs, but result in continuous savings without additional effort by the adopter (i.e., switch less efficient technology with a more efficient one (*e.g. replacing an old water heater with one that uses less energy*) [14,16,20].

Note that energy-saving behaviors are not limited to curtailment and efficiency classifications. For example, Karlin et al. [20] propose energy-saving behaviors fit into a 2 × 2 matrix. Distinguished by frequency and cost, behaviors can be either maintenance (low-cost, low-frequency), efficiency (high-cost, low frequency), curtailment (low-cost, high-frequency), or hardship (high-cost, high-frequency). While suggesting energy-saving behaviors can be evaluated through these four categories, Karlin et al. state "statistical analysis suggests that individuals may *engage* in conservation behaviors in a way that is consistent with the dimensions of curtailment and efficiency." Curtailment and efficiency classifications provide the first step in understanding common barriers and motivations for turning off the lights and replacing incandescent bulbs with LED or CFL bulbs.

1.4. Behavior motivation and barriers

To our knowledge, no previous study has explored why turning off the lights retains such a distinct place in the public's perceptions. However, some literature does provide an extensive look at the motivations and barriers behind a variety of energy-saving actions. Sweeney et al. [21] summarize many of these barriers, including: (1) non-supportive household members [22]; (2) perceived narrow locus of control [23]; (3) invisible and intangible nature of energy [24]; (4) personal comfort [25]; (5) appliance/technology advances and limitations [26]; (6) weather and building characteristics [27,28]; (7) psychological factors [29,30]; (8) economic and political climates [31], (9) influence of social and cultural practices [32–35]; and (10) financial expense.

In parallel, Gadeene et al. [36] cover many motivations of energy-saving actions, such as: (1) feelings of guilt induced by non-action [37]; (2) moral and social obligations [38–40]; (3) ease of adoption and personal relevance [40]; and (4) good feelings resulting from making a pro-environmental choice [41].

1.5. Research questions

Our paper provides a novel, in-depth assessment of turning off the lights. We seek to understand the current preferences of participants towards turning off the lights, and its efficiency counterpart, replacing incandescent bulbs with CFL or LED lamps. In particular, we aim to:

1. Assess whether novices perceive turning off the light to be the most salient energy-saving action
2. Compare perceived differences in attributes associated with turning off the lights versus replacing incandescent bulbs with CFL or LED bulbs
3. Examine participant's self-reported explanations for why they think turning off the lights has remained such a persistent and hard to correct response when asked about how to save energy in the home

2. Methods

2.1. Participants

In February 2018, participants were recruited via Amazon's Mechanical Turk Internet panel (www.mturk.com) to complete the survey ($N = 1418$). Participants received $1 USD in their Amazon account after completing the survey. The survey was restricted to participants over the age of 18 located in the United States. The median age of participants was 34 years (37.9 in the United States [42]) and 50% of participants were male (49.2% in the United States [42]); statements in parenthesis indicate population averages. The median family income was between US $40,000 and $80,000 ($57,617 in the United States [42]) and 60.2% had at least a college degree (42% have a bachelor's degree or higher in the United States [42]). Fifty-two percent of participants self-identified as liberals, 22% as moderates, and 23% as conservatives. Amazon Mturk has been shown to be a source of high quality data with a diverse participant pool [43,44]. Although education and political orientation suggest some selection bias, our variation in demographics provides enough heterogeneity to allow us to investigate our research questions [43].

This research was approved by Indiana University's Internal Review Board at the Office of Research Administration and informed consent was received from all participants.

2.2. Survey

Participants began the survey by answering two open-ended questions about the most effective thing they *currently* do and the most effective thing they *could* do to conserve energy in their lives. The first question tested whether Kempton et al. [13] and Attari et al.'s [14] finding still held: whether turning off the lights remained the most common response. The second question sought whether participants would provide responses of more effective behaviors when prompted to think critically, remove personal obstacles, or move beyond a "top-of-the-head" answer. As identified during pre-testing, both questions were presented simultaneously to highlight differences in the similarly worded questions.

To analyze responses from the first two questions, two coders created unique categories from an initial set of 100 responses. If multiple answers were provided, only the first given response was analyzed. Coders then independently assigned responses to the appropriate category. We analyzed only one set of codes to address instances of disagreement. We then labeled these categories as either curtailment actions (e.g., turn off lights) or efficiency actions (e.g., use efficient light bulbs). We left categories which could not be classified as either efficiency or curtailment blank (e.g., sleep more).

Pre-testing also showed many participants were unfamiliar with the differences between incandescent, CFL, and LED bulbs. Following the above questions, we addressed this issue by presenting on an infographic illustrating the progression of efficiency from incandescent to CFL to LED bulbs (see Fig. 1, which was adapted from [45]).

We then examined whether participants would demonstrate a self-other bias by recommending more effective behaviors for others rather than themselves [46]. We asked participants which action they would recommend to a friend who wanted to save energy: "turning off the lights [or] replacing incandescent bulbs with more energy efficient light bulbs, like CFL and LED bulbs". Participants then provided an open-ended explanation of their choice. We analyzed open-ended responses using the same method described above.

Next, we assessed participants' perceived differences between turning off the lights and replacing incandescent bulbs with CFLs or LEDs for twenty attributes. Participants rated twenty attributes of barriers and motivations to energy-saving actions on a five-point Likert scale. The scale ranged from strongly disagree to strongly agree. We averaged results from each attribute across all participants. Example attributes include "this is easy to do," "this requires too much effort," and "I was taught to do this." Each of these two blocks of actions were grouped by action presented to participants in a random order. We developed these attributes from literature reviews and by solicitations during multiple rounds of face-to-face open-ended pretesting with participants. These twenty attributes capture common barriers and motivations for the two energy-saving behaviors of interest. However, due to the wide variety of potential attributes of energy-saving behaviors alluded to in the introduction, they are not comprehensive.

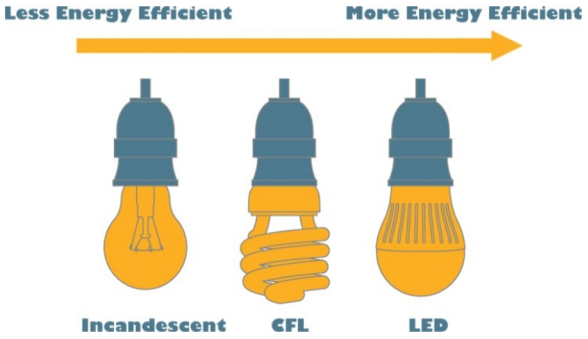

Fig. 1. Infographic showing light bulb comparison for participants (adapted from [45]).

Participants then answered nine energy literacy questions. Each question contained one curtailment-based and one efficiency-based option. For example, choosing between "decreasing one incandescent light bulb's use from 4 h to 3 h [or] using one LED light bulb for 4 h instead of an incandescent light bulb". We created these questions to test whether we could create an energy literacy scale. We do not analyze these results here.

Next, participants were asked, "In general, do you believe that you can save more energy by: reducing how often you use an appliance [or] replacing an appliance with a more efficient model." An open-ended question measuring self-reported rationalizations followed, asking participants for their explanation as to why turning off the lights is such a common response when asked how to best save energy.

Afterwards, participants were asked two questions about light bulb use in the home: (1) how often the participant turned off the lights when they were the last to leave a room with the lights on, and (2) what percentage of light bulbs at their current residence were energy efficient, such as CFL or LED bulbs. We included these questions to assess whether self-reported behaviors impact self-reported perceptions and beliefs.

Participants then answered questions measuring pro-environmental attitudes using the New Ecological Paradigm scale [47] and numerical literacy using questions from the Berlin [48] and Schwartz et al. [49] numeracy tests. Previous studies have shown that pro-environmental values and numeracy have strong associations with perceptions of energy use and conservation [14,50,51]. Socio-demographic questions concluded the survey. The entire survey is available in the online supplemental text.

3. Results

3.1. Perceptions of energy savings

The most frequent response to the open-ended question, "what is the single most effective thing you currently do to save energy in your life" remains "turning off the lights" (see Table 1). Open-ended coding for this question yielded twenty-eight unique categories. Interrater agreement was strong: Cohen's $\kappa = 0.86$. The five most frequent responses include: (1) "turn off the lights;" (2) "adjust thermostat;" (3) "replace incandescent light bulbs with CFL/LED bulbs;" (4) "use appliances/electronics less;" and (5) "unplug or turn off appliances." "Sleep/relax

Table 1
Categorized responses to two open-ended questions about the single most effective thing that participants *currently* do and *could* do to save energy in their lives (N = 1418).

Categories	Percent of Responses		Curtailment (C) or Efficiency (E)
	Currently Do	Could Do	
Turn off the lights	36.3	6.6	C
Adjust thermostat	15.3	13.7	C
Replace incandescent light bulbs with CFL/LED bulbs	7.8	3.9	E
Sleep/relax more	7.1	7.7	–
Use appliances/electronics less	5.2	9.3	C
Unplug or turn off appliances	3.5	5.6	C
Broadly "use less energy"	3.0	4.4	C
Drive less	2.9	3.5	C
Conserve water	2.5	4.1	C
Use efficient appliances	2.5	6.4	E
Walk more	2.3	1.6	C
Use public transportation	2.2	1.9	C
Recycle	1.4	2.1	C
Use more efficient or electric vehicles	1.4	3.0	E
Other	1.1	3.1	–
Eat sustainably	0.9	0.9	C
Improve household envelope efficiency	0.9	4.7	E
Bike more	0.7	1.4	C
Use renewable energy	0.7	11.7	–
Carpool/rideshare	0.6	1.1	C
Lower water heater temperature	0.6	0.1	E
Hang laundry/Reduce dryer use	0.5	–	C
Nonsense answers	0.5	1.5	–
Work from home	0.2	0.1	C
Compost	0.1	0.1	–
Unsure	–	0.8	–
Limit airline use	–	0.4	C
Not living/Dying	–	0.3	–

Table 2
Open-ended coded responses explaining how participants recommended turning off the lights or replacing incandescent bulbs with efficient bulbs to a friend *(N = 1418)*.

Categories	Total (%)	By Response (%)	
		Turn off the Lights	Efficient bulbs
Efficiency of bulb key factor	13.7	0.6	17.5
Saves energy while lights are on	12.1	0.9	15.3
No energy is used when lights are off	11.3	48.1	0.5
Longer term savings or savings achieved quickly	8.5	3.7	9.9
Already practicing one action, so must adopt alternative	5.6	0.6	7.1
Action is "better"	4.7	5.0	4.6
Saves money	4.2	4.3	4.2
What works best for me works best for them	4.0	5.0	3.7
Considered situational context	3.9	4.3	3.8
Influenced by provided infographic	3.7	0.0	4.8
Restated given answer	3.7	4.0	3.6
Decided based on previous education	3.7	2.8	3.9
Practical/feasible, no life style change necessary	3.5	1.2	4.2
Ease/difficulty of remembering action	3.1	0.3	3.9
Felt right	2.9	4.3	2.5
Other	2.5	4.7	1.9
Would recommend both	2.1	1.2	2.4
Guessed	1.9	1.2	2.1
Habit	1.8	2.8	1.5
Given reason does not make sense	1.3	2.5	1.0
Easy to do	1.1	0.9	1.1
Relied on logic	0.5	0.6	0.5
Safer/Healthier	0.1	0.6	0.0
Total Percent of Responses	**100**	**22.7**	**77.3**

more" omitted from categorization as responses suggest an unintended understanding of "save energy". Curtailment behaviors account for 76% of all responses.

When asked what participants *could* do (as opposed to what they *currently* do), the frequency of "turn off the lights" dropped from 36.3% to 6.6%. Curtailment responses decreased by only 11%. "Use renewable energy," an ambiguous behavior that is neither curtailment nor efficiency, increased by 10%. These results suggest that while turning off

Table 3
Attribute statements and means. *Scale: 1 = strongly disagree to 5 = strongly agree.* Given the multiple comparisons, the Bonferroni corrected alpha is 0.0025 ($\alpha = 0.05/20$).

		Means		Paired *t* test	
Label	Attribute	*Turn off lights*	*Efficient bulbs*	*t* value	*p* value
Able	I am able to do this where I live	4.6	4.5	6.11	< 0.0001
Advocacy	I do this because of public advocacy (advertisements, media, etc.)	2.6	2.9	−8.81	< 0.0001
Carbon	This significantly reduces my carbon footprint	3.9	4.0	−5.55	< .0001
Easy	This is easy to do	4.5	4.2	12.12	< 0.0001
Effective	This is the most effective method I know to save energy	3.3	3.4	−1.86	0.0624
Effort	This requires too much effort	1.6	1.9	−9.44	< 0.0001
Environment	This helps the environment	4.3	4.3	4.14	< 0.0001
Ethical	This is ethical to do	4.2	4.2	2.21	0.0275
Everyone	Everyone else does this, so I do it too	3.1	2.8	11.98	< 0.0001
Example	This will set a good example for people around me	4.0	3.8	7.29	< 0.0001
Future	This will help future generations	3.9	4.1	−8.26	< 0.0001
Good	Doing this makes me feel good	3.9	3.8	0.64	0.5235
Guilty	I will feel guilty if I do not do this	3.7	3.2	14.91	< 0.0001
Habit	This is my habit	4.4	3.4	25.78	< 0.0001
Logical	This is logical to do	4.6	4.4	8.09	< 0.0001
Longer	This will make my light bulbs last longer	4.3	4.3	0	1
Money	This saves me money on my electricity bill	4.4	4.4	0.92	0.3554
Pressure	Friends pressure me to do this	1.9	1.8	3.56	< 0.0001
Taught	I was taught to do this	4.4	3.1	36.03	< 0.0001
Time	This takes too long to do	1.8	2.0	−5.03	< 0.0001

the lights has been the most salient energy-saving behavior for at least thirty years, participants today are aware that it may not be the most effective energy-saving action they could do. We also acknowledge that this finding could represent a conversational norm of not repeating an answer already provided for the pervious question [46,52].

When participants were provided with just two options to recommend to a friend for energy conservation: "turning off the lights" or "replacing incandescent light bulbs with more efficient bulbs," 77% of participants recommended replacing incandescent light bulbs with more efficient lamps. Only 23% of participants choose "turning off the lights."These recommendations of efficiency rather than curtailment deviate from responses in the original open-ended questions, but are confirmed by responses asking participants to choose between

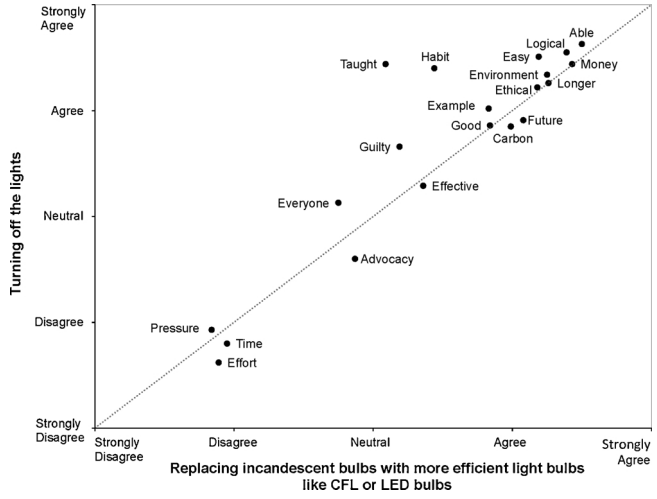

Fig. 2. Mean barrier and motivation attribute ratings associated with replacing incandescent light bulbs with more efficient lights plotted on the x-axis; mean barrier and motivation attribute ratings associated with turning off the lights plotted on the y-axis. The diagonal dotted line indicates when the attributes ratings matched for both these behaviors. Attributes that are more strongly associated with the action of replacing incandescent bulbs with LED and CFL bulbs fall below the line. Attributes above the line are more strongly associated with the action of turning off the lights. Figure labels are detailed in Table 3. Standard error bars did not meaningfully extend beyond markers.

Table 4
Responses by participants explaining *why* they think turning off the lights is the most common response when asked how best to save energy.

Category	Percent of Responses
Easy to do	26.6
Taught to do this	18.1
Lack of knowledge	6.2
Common behavior, everyone does this	6.1
No energy is used when lights are off	6.1
Effective	4.4
First response they think of	4.3
Money is a key factor	3.5
Habit	3.3
Tangible action	2.7
Other	2.6
Age old/cultural knowledge	2.5
Participant's answer did not make sense	2.4
Logical	1.7
Media advocacy	1.7
Turning off the lights is the best action	1.6
Encountering lights left on jogs memory	0.9
Easy to remember	0.8
Unimportant	0.8
Did not know	0.8
No special tools or knowledge needed	0.7
No additional resources needed	0.6
Quick, time to do action	0.6
Relevant to their lifestyle	0.5
Have not yet adopted new, efficient appliances	0.4
Able to do action	0.4
Feels good	0.4
Reported action as "good"	0.1
Immediate savings	0.1
Total	**100**

curtailment and efficiency actions more broadly, where 67% of participants state that replacing an appliance with a more efficient model saves more energy than reducing how often you use an appliance. In initial responses, 36% of participants listed "turn off the lights" as the most effective energy-saving action they *currently* do, while only 8% listed "replacing incandescent light bulbs with CFL/LEDs." We acknowledge that these differences arise after participants see an infographic that highlights the efficiency of the different lightbulbs. When asked to explain their choice, only a small group of participants (3.7%)

directly referenced the infographic's influence when explaining their response (see Table 2). In total, twenty-three categories were coded. Interrater reliability was somewhat weak, where Cohen's $\kappa = 0.55$. A lower interrater reliability may be due to the broad nature of the open-ended question leading to wide-ranging responses.

In addition to preferring LED or CFL bulbs for their friends, opened-ended responses suggest participants based their recommendations on how they conceptualize the mechanism behind energy savings. Unlike how experts' focus on the frequency of use and cost of efficiency and curtailment behaviors, participants focused on the *how* of energy savings – whether energy was saved when the appliance was in use or when it was turned off.

For participants suggesting turning off the lights to their friend (23%), nearly half of these participants (48%) rationalized their choice in the same way: turning off the lights results in zero energy use, therefore, it must be the best choice. Summarizing this perception, one participant elaborated, "*No matter how efficient a light bulb is, it will still use energy if left on when not needed. Unlike if turned off when unnecessary it'll use no energy.*"

In contrast, a third of those who recommended installing efficient light bulbs conceptualized that energy savings occurred while lights are in use ("efficiency of bulb key factor "[17.5%] and "saves energy while lights are on" [15.3%]). In one participant's own words, "*Well the lights are going to be on sometimes, might as well be always saving energy rather than just saving it when it's off.*"

Combined, these results suggest that there are different heuristics at play for these two actions of how to save energy and what is most effective.

3.2. Perceived differences in barriers and motivations of turning off the lights and replacing incandescent bulbs with CFL or LED bulbs

Paired *t* tests between curtailment and efficiency values revealed significant differences for most attributes of energy-saving barriers and motivations (see Table 3). Fifteen of twenty attributes tested were statistically significant using a Bonferroni corrected alpha of 0.0025 ($\alpha = 0.05/20$). Non-statistically significant attributes were: (1) "this saves me money on my electricity bill"; (2) "this makes my light bulbs last longer"; (3) "doing this makes me feel good"; (4) "this is ethical to do"; and (5) "this is the most effective method I know to save energy." Table 3 presents means for each attribute in both the curtailment and efficiency scenarios, along with label keys and paired *t* test results.

Attribute ratings were generally grouped by influence type (see Fig. 2). Motivations, such as such as "easy", "able", and "good", were clustered towards "strongly agree." Barriers, including "pressure", "time" and "effort" tended towards "disagree."

The widest disparity for an attribute was "I was taught to do this." Open-ended responses to why turning off the lights is the most frequent answer to "*what's the most effective way you know to save energy in the home*" reveals a common experience (see Table 4). Variations on "*I think of my dad saying, 'Turn off the lights, you're wasting electricity*" and "*It's what our parents taught us"* peppered responses explaining participant's choices. The attribute "this is my habit" exhibited the second greatest difference and is strongly associated with turning off the lights.

A notable difference exists between, "doing this makes me feel good" and "I will feel guilty if I do not do this." As mentioned above, participants agreed that they felt good after completing both actions. However, feelings of guilt were more closely associated with not turning off the lights than with replacing light bulbs. This is reflected in attributes such as "friends pressure me to do this" and "everyone else does this so I do it too." While these results are correlational, taken together they suggest normative feelings such as "people expect I should do this" motivate curtailment more so than for efficiency. Meanwhile, attributes including "this will help future generations," "this significantly reduces my carbon footprint," and "this is the most effective way I know to save energy" were more strongly associated with efficiency, even though these differences are small. Whereas curtailment seems associated with addressing social expectations, efficiency attributes appear to be oriented towards long-term impact.

3.3. Examining why turning off the light is so persistent and hard to correct

3.3.1. Self-reported explanations

Participant responses led to 29 coded categories when asked why "turn off the lights" remains the most frequent response to the question, "What is the single most effective thing you could do to save energy" (See Table 4). Two coders categorized these responses yielding strong interrater reliability; Cohen's $\kappa = 0.80$. "This is easy to do" (26.6%) and "I was taught to do this" (18.1%) were the two most common responses. As one participant put it, "*Probably because it is the easiest thing to do and that is what most of us were taught growing up by our parents.*" Together, these two factors address why participants think this action is popular and why it is thought to be effective. Other factors seem related to these perceptions: "a lack of knowledge" (6%) could be associated with "I was taught to do this" as both actions pertain to energy education. Some saw turning off the light's widespread adoption ("common behavior, everyone does this") as proof that it must be effective (6%). The low cost of turning off the lights ("money is key factor") was the primary

Table 5
Logistic regression predicting listing turning off the lights as the most effective action in the opening question.

Predictor	Scale of Variable	Estimate	Wald χ^2	Odds ratio estimate
Intercept	Logit scale	−0.33	0.30	
Frequency of turning off the lights	1–4 (hardly ever to always)	0.25**	6.7	1.30
Percent of efficient bulbs in home	0–100	−0.0083***	19.5	0.99
New Ecological Paradigm	1–5 scale	0.031	0.11	1.03
Numeracy score	0–7 scale	−0.032	0.94	0.97
Political affiliation	1–7 (very liberal to very conservative)	0.0078	0.041	1.01
Male	0 = female; 1 = male	−0.25*	4.0	0.78
Age	18–78	−0.025***	20.5	0.98
Engineering degrees	0 = no; 1 = yes	−0.40*	4.4	0.67
Level of Education	1–6 (Some schooling, no diploma to graduate degree)	−0.095	2.6	0.91
Income	1–7 (0 to greater than or equal to $200,000)	0.08	1.8	1.08
Rent	0 = no; 1 = yes	0.064	0.25	1.07
Electricity bill	1–9 (under $20 to above $200)	0.90*	6.3	1.09

Odds estimates predict the likelihood of participants choosing option of "turning off the lights." Excluded responses of "other" in Male, and Rent; excluded "do not know," "not applicable," and "I don't pay my bill" in Electricity bill giving N = 1309.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

explanation for only 4% of participants.

3.3.2. Self-reported behavior and demographic analysis

We used a logistic regression to explore factors associated with whether participants would respond with "turning off the lights" when answering our survey's first question: "What is the single most effective thing you *currently* do to save energy in your life?" Table 5 shows results of our logistic regression.

The logistic regression revealed six statistically significant demographic and self-reported behavior variables when "turning off the lights" was given as the first response to the survey's first question. These variables are: (1) frequency of turning off the lights; (2) percentage of CFL or LED bulbs in the home; (3) gender; (4) age; (5) having a math, science, or engineering degree; and (6) cost of electricity bill. Odds ratio estimates show the variables' impact on the odds of listing "turning off the lights". The impact is found by subtracting 1 from the odds ratio estimate and multiplying the remainder by 100. For example, frequency of turning off the lights had an odds ratio of 1.3. While holding all other variables constant, we would expect a one-unit increase in the frequency of turning off the lights to result in a 30% increase in the odds of listing "turning off the lights" as the most energy efficient action one can do to save energy. Thus, the more you turn your lights off, the more likely you are to report this action. Conversely, with an odds ratio of 0.99, for every one-unit increase in the percent of energy efficient bulbs installed in the home, we expect a 1% decrease in the odds of the participant to list "turning off the lights" as the most effective action.

Gender had a larger than expected impact on the odds of listing "turning off the lights"; being male decreased the odds of listing "turning off the lights" by 22%. Degrees in math, science, or engineering also decreased the odds of listing "turning off the lights" by 33%. This supports science education as a viable method to correct misperceptions on effective ways to save energy. Age is negatively correlated with listing turning off the lights; for every additional year of age, the odds of listing "turning off the lights" over efficiency decreased by 2%.

4. Discussion

This paper is the first to investigate why turning off the lights has remained so ingrained in people's perceptions of energy savings. While our study is correlational in nature, several novel findings are of interest.

Turning off the lights remains the most frequent and salient response when asking participants about the most effective thing they *currently* do to save energy in the home. This finding remains consistent since 1985. However, when elicited to think more broadly about what participants *could* do to save energy, responses of turning off the lights exhibited a marked decrease in frequency. This may be due to participants moving from a top-of-the-mind response to thinking more deeply about the question. Another factor that could contribute to this decrease is conversation norms. In most instances people are unlikely to repeat an answer previously given [53]. Future research could pose these two questions in random order to more accurately account for this finding and pattern.

We observed a remarkable shift towards replacing incandescent bulbs with CFLs or LEDs (77%) rather than turning off the lights (23%) when participants recommended an energy-saving action to a friend after seeing an infographic. We are not confident in which factor or factors caused this shift towards efficiency. One factor could be the influence of the immediately preceding infographic helping to prime and potentially correct participant's earlier misperceptions of what is effective. Another factor could be the intended framing of the question, which asks participants to remove personal barriers by making a recommendation for a friend. Prior work shows a self/other bias that exists in recommending energy-saving strategies for oneself versus others, where people recommend easier actions for themselves than for others. For example, Attari et al. [46], in two studies, found participants endorsed turning off the lights more frequently for themselves than for others (Study 1: 20%–13%; Study 2: 14%–10%). More difficult actions to implement and maintain, such as driving less, were recommended for others to adopt rather than themselves (19% endorsed driving less for self, versus 32% recommending others to driving less). This self/other bias may have been at work here too. As shown in Fig. 2, replacing light bulbs is perceived to be more difficult than turning off the lights, and participants may think that their friends should do it instead of themselves.

When asking about *why* participants recommended turning off the lights or installing efficient light bulbs, we find that participants provide different answers for each of these two recommendations. The majority of participants who recommend turning off the lights focus on forgoing the task altogether, i.e., not using energy when the light is off. Likewise, the majority of participants who recommend efficient light bulbs focus on expending less energy for a given task. Future research could explore these heuristics of how and why people come to perceive energy savings as an event taking place by using less energy to accomplish the same task, and those who perceive energy saving as occurring mainly by minimizing the frequency of use.

Attribute ratings (see Fig. 2) support previous findings of social circumstances influencing overt behaviors (i.e. forgetting to turn off the light) more strongly than covert behaviors (i.e. what type of bulb is installed). When asked, participants ascribed socially influenced motivations to turning off the lights (being taught, feeling guilty). Meanwhile, participants connected motivations related to longer-term outcomes with installing efficient bulbs (future outcomes, effort). This social context was also reflected in our participants' belief of education (being taught to do this action) as a root cause of the enduring salience of turning off the lights.

Finally, women were more likely to respond that turning off the lights was the most effective action they currently do to save energy. Lee et al. [54] also found women were less likely than men to purchase energy efficient lighting. They found women perceived incandescent lighting to be more important to their well-being, work performance, and mood than men.

Although turning off the lights was the most common response when asked about the most effective thing participants currently do to save energy, the average participant's lightbulb inventory was self-reported to be more than two-thirds CFL or LED. Many participants may be saving more energy than they may realize.

We acknowledge there are several limitations to our study. Our sample included more educated, more left-leaning participants than the general population, but appeared similar to national average levels of age, gender, and income (see [43]). Including an infographic displaying the spectrum of lighting efficiency clarified light bulb differences for participants who were not be aware of these technologies but may have also influenced subsequent responses. While open-ended responses provide insights into perceptions, self-reported responses may not match real-world behaviors. Our results are correlational in nature.

Turning off the lights saves energy and should be included in everyone's energy conservation toolkit. However, if we want to achieve significant household-level responses to climate change [1], we need to transition away from the perception of turning off the lights as a highly-effective action. The good news is that many of our participants were aware and acknowledged that there were more effective actions available that they could do, if desired.

Author contributions

D.L, J.T., and S.Z.A. designed the research; S.Z.A collected the data; D.L and J.T. analyzed the data; D.L, J.T., and S.Z.A. wrote the paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.erss.2019.101257.

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