“How many economists does it take to buy a lightbulb?”

By Joe Hayes

Selecting a product should be easy. Economists (and your parents) believe that the one product that will give you the best bang for the lowest buck should be the one you select. However, this doesn’t seem to be the case for energy efficient products. People tend not to invest in energy efficiency, even though it would pay off in the long run with lower energy costs. This is the basis for the “energy paradox” (Jaffe and Stavins, 1994). The energy paradox is the apparent reality that some energy-efficiency technologies (and thus cheaper alternatives in the long run) are perplexingly not adopted. This paradox is true for lightbulbs, and lightbulbs serve as a lightning rod of debate. LED (Light Emitting Diode) lighting is vastly more efficient compared to traditional incandescent lightbulbs, and yet historically their rate of adoption has been low. However, the energy paradox masks the straight forward cost savings, and makes for irrational behavior. Identifying the extent and trying to solve the energy paradox is an important step in our sustainable energy future.

This contradiction is an expanding area of research due to its complexity and irrational failings. It spans almost all energy efficient reductions from refrigerators (Gately, 1980), air conditioners (Hausman, 1979), and more recently heavy-duty trucking (Klemick et al. 2015). There must be some reason for the disconnect between the future savings of energy efficiency and consumer choices. Economists generally believe that the reason for the irrational behavior is due to heuristics (Gillingham and Palmer, 2013). In other words, people have ingrained experiences that affect their choices. Nonstandard preferences are an example of these. For example, these could be thought of as beneficial investments for the future that you want to do but keep putting off, analogous to eating healthier foods. You know you should, but you just don’t want to. This could be a similar story to investing in energy efficient products (Tvetanov and Segerson, 2011). As the time to invest in energy efficient product nears, the consumer puts it off “until next time”. Another possible explanation is the behavioral aspect of people, including imperfect information regarding the savings earned or economic myopia. It seems that consumers choosing products are less attentive to additional costs. Research has found that people are less elastic to shipping and handling on eBay than to the price of the item itself (Hossain & Morgan, 2006). This may be a corollary to lower prices with the upfront cost of the incandescent bulbs, even though their future electricity bills would go up. Or, an uninspiring last possibility, the energy paradox is the result of economists overestimating the benefits of switching to energy efficient technologies (Fowlie et al., 2018).

LEDs produce less heat than incandescent light bulbs (“Learn about LED lighting”), which allows them to emit more light, last longer (“The Lightbulb Revolution”), yet are only slightly more expensive. Since these energy efficiency savings are not being realized, some governments have initiated energy efficiency standards, effectively phasing out the incandescent lightbulb. However, LEDs have gotten some surprising pushback in the United States. It seemed that the US would follow the lead of other countries, such as Argentina, Australia, Brazil, Canada, China, Cuba, the European Union, Israel, Malaysia, Russia, and Switzerland banning the incandescent lightbulb after the “**Energy Independence Act”** of 2007. This legislation sought to make lightbulbs 25 to 30 percent more efficient than the 2008 standards by 2012-2014. The bill was passed overwhelmingly in Congress and signed by George W. Bush. Yet, the ban on low efficiency incandescent lightbulbs has faced considerable opposition. This is evidenced by the failed bills: “**The Better Use of Light Bulbs Act”** of 2011 and the “**Lightbulb Freedom of Choice Act**” of 2011. Since 2011, when LEDs became available for residential usage, there has been a widespread push for LEDs to be more readily available. According to the U.S. Department of Energy, 34.6% of households owned incandescent lightbulbs in 2015, compared to the 48.1% of LEDs and CFL lighting (Bucitelli, 2017). LEDs have a large share of the residential lighting marketplace, but it seems many people still want to hold onto the least efficient incandescent bulbs. This leads us to the heuristics conclusions that the economists have put forward.

University of Wisconsin undergraduate Travis Cao set out to try to model this behavior. Using a Monte Carlo simulation, Cao attempted to explain why people are not as willing to switch to LED lightbulbs. He modeled middle class U.S. consumers who are interested in buying a lightbulb for home use. He tried to find with what lightbulb would consumers would be better off with. For this, he used data from Walmart and Target to get the average prices and price difference between the two bulbs, and corrected for brightness. Cao used many other inputs into his model including: the price for electricity, discounting for the future, an “unfamiliarity of using the LED bulbs” cost, along with how long the bulb would be on for and the probability of it failing. He used all this information to try to predict where the income cutoff was for people switching from incandescent bulbs to LEDs. Using these multiple factors and running the statistical simulation 500 times to reduce bias, we arrive at Figure 1.

**Figure 1:**

**A screenshot of a social media post

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Each point in the Figure 1 graphs represent an income cutoff point given a discount rate, meaning that each point is the income where consumers switch from incandescent lightbulbs (INC) to LEDs. As the discount factor (x axis) goes up, the more patient the person would be. The more you value your future, you save over the long run, but to the increased of price in the present. The 40-Watt bulbs converge faster than the 60-Watt lightbulbs due to the lower prices of the 60-Watt LED bulbs. 60-Watt bulbs are only 1 to 1.50 dollars more than their incandescent counterparts, while the 40-Watt bulbs are about 3 dollars more. The shaded blue color on each of the points demonstrates how long each consumer has the lightbulb on for. With the larger cost difference, only the high income and patient consumers would buy LEDs.

**Figure 2:**

**A screenshot of a social media post

Description automatically generated**

If we assume that the hours with the lights on are the same for all bulbs, we get the graphs in Figure 2. If consumers even slightly discount the future, they will buy incandescent lightbulb. The line does not cross the average US income for 2016 (Current Population Survey 2017). Therefore, only a small, high income, and patient fraction of consumers will purchase LEDs. This shows the energy paradox in action! Since people do not value the future as much as current costs, they are missing out on savings that could be bought using an LED, and instead go for the cheaper upfront option.

**Figure 3:**

A screenshot of a social media post

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On the other hand, assuming the prices of the LED and incandescent lightbulbs were the same, you would get the graphs in Figure 3. Using the model, the income cutoffs for switching to LED drastically changes. When consumers perceive future savings, or the discount factor is close to one, almost everyone would prefer the LED lightbulb. Essentially, as LEDs get cheaper, the more people will buy them (supply and demand, right?). If the lightbulbs were cheaper, then they could be adopted by the average income, but patient, US consumer. Although this seems to be very optimistic given what we’ve seen, it isn’t without merit. According to the Department of Energy in 2013, LED prices have dropped 85% from 2008 to 2013. (Buccitelli et al, 2017). With the falling price, Cao predicted more people would buy LEDs, as shown by the cutoff line intersecting the average US income in Figure 4. This could cause some of the associated costs that Cao had in his model, like a cost for unfamiliarity for using LEDs, to also decrease, making them even cheaper in the real world.

**Fig 4:**

A screenshot of a map

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However, even in the best-case scenario, where the price of LEDs are the same as incandescent bulbs, some assumptions are problematic. The model assumes rational human beings, so a possible place for error is the assumption that when LEDs get cheaper, more people would be willing to risk switching over to LEDs. To put it another way, Cao assumed that people had no innate preference between LEDs and incandescent lightbulbs. Yet, as seen in the legislative history, people love what’s familiar.

Cao’s work fits squarely in the research for exploring energy paradox. Researchers attempt to model the problem that is ruled by a multitude of both irrational and rational factors. This model does show that the most patient consumers do indeed prefer the LEDs, something that can be logically reasoned. If you value your future more, why shouldn’t you save a few dollars over the long run? Intuitively, it also makes sense that as the price for LEDs get closer to the incandescent bulbs, that the more lower income consumers would want to buy LEDs**.** This model suggests that it is mostly upfront costs that keeps LEDs from becoming much more prevalent. Whether through a subsidy for LEDs, or a tax on incandescent bulbs, governments could encourage LED sales, without an outright ban.

The model expands on the previous knowledge of the energy paradox, by correctly identifying some of the underlying factors for the energy paradox. The main factor is that people don’t take their future into account when buying lightbulbs, and only see the price in front of them. We then could transfer the idea of this model to other inexpensive energy saving appliances. However, more empirical data should be collected to further to refine the model itself, and to also understand its limitations. In addition, more models should be explored on larger, big-ticket items like cars. Given the larger purchase, the more opportunity for savings and with the larger upfront costs, the consumer would be more likely to weigh the future as much as the past. Unlocking the energy paradox could make energy and environmental policies more targeted, and lead to a sustainable and energy efficient future.

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