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Abstract

We present the results of a 2019 online survey of 1,800 adults in the United States who recently purchased a light bulb to understand how consumers make decisions about purchasing light bulbs and how light bulbs are used in the residential sector. From our survey, we found that purchases of LED bulbs made up the largest percentage of sales by lighting technology and respondents generally had positive impressions of LEDs. We estimated the average daily hours of use for bulbs being purchased depending on bulb shape. We also provide an estimate for the lumen distribution of purchased light bulbs and the distribution of installation locations by bulb shape. We found that incandescent bulb purchasers were primarily replacing a failed incandescent bulb and these purchasers were less likely to have favorable impressions of LEDs. However, we found that the majority of participants replacing an incandescent bulb purchased either a CFL or LED. Using an adaptive conjoint analysis technique, we found that the five most important factors to consumers when choosing a light bulb are purchase price, bulb lifetime, energy cost savings relative to an incandescent bulb, light appearance, and energy savings relative to an incandescent bulb. The results of this study provide an in-depth look at the lighting market in 2019 and may provide a basis for developing models of the residential lighting market.

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1. Introduction

The rapid adoption of energy-efficient light-emitting diode (LED) technologies has transformed the United States (US) residential lighting market, replacing less-efficient incandescent and fluorescent lighting technologies. The Residential Energy Consumption Survey (RECS) administered in 2020 by the US Energy Information Administration (EIA) estimated that 47% of US households mostly use LEDs in their home, compared to only 4% doing so in 2015 (U.S. Department of Energy–Energy Information Administration, 2015a, 2020a). This has contributed to a corresponding 58% reduction in annual national residential lighting energy consumption from 147 TWh in 2015 to 62 TWh in 2020 (U.S. Department of Energy–Energy Information Administration, 2015b, 2020a). In terms of shipments the market share for LED A-line bulbs has grown from less than 0.1% in 2011 to 71% in 2020, while CFL market share dropped from 26% to 3%.

A significant factor in the growth of the LED lighting market can be attributed to the decreasing prices of LED light bulbs. Gerke et al. (2015) found that the price of LED light bulbs decreased at an annual rate of approximately 20-30% from 2011 to 2015. However, over this period, LEDs remained more expensive than other lighting technologies, suggesting that features other than bulb price must play an important role in the consumer purchasing decision. For example, incandescent and halogen options are typically less expensive, more energy consumptive, and have relatively short lifetimes. CFLs have historically offered a middle ground in price, lifetime, and energy consumption. Projecting the future of the residential lighting market requires an understanding of how consumers make decisions amongst these choices and which features consumers value the most.

In 2012, Pacific Gas and Electric Company (PG&E) published a study of California consumer purchasing behavior and perceptions of various lighting technologies for A-line medium-screw base bulbs (Optimal Strategies Group (OSG), 2011).[1] The goal of that study was to understand how to prioritize energy-efficiency programs. PG&E contracted with OSG to deploy an online survey that makes use of an adaptive conjoint analysis to estimate the value that consumers associate with various bulb characteristics. The authors found that at the time of the survey, California consumers were resistant to LEDs due to their high price point, but that consumers were generally positive about other LED features such as longer usable lifetime, absence of mercury, and better ability to dim, when compared to CFLs.

The rapid transformation of the residential lighting market necessitated a more current, nationally representative dataset that can be similarly used to understand how consumers choose and use light bulbs. We designed an online survey to determine the primary characteristics that drive consumer purchasing decisions for lighting products and also study lighting usage behaviors for consumers who had purchased a light bulb in the six months prior to being surveyed. Our team contracted with OSG to deploy the survey, which makes use of the same adaptive conjoint analysis used by the PG&E study. Our survey also expanded the scope of bulb shapes to include candle-shaped and reflector bulbs, in addition to A-line light bulbs. The results of this study will allow for more accurate projections of the US lighting market and a better understanding of how consumers choose and use light bulbs.

[1] A-line bulbs have a pear-like shape and are the most commonly used general service light bulb.

The purpose of this study is different from previous studies such as RECS and DOE's Lighting Market Characterization study (most recently conducted in 2015[2]) which serve to estimate the aggregate number of bulbs by shape and technology across the US. This study focuses specifically on details for consumers who recently purchased a light bulb that may differ from the general population of lighting users. In particular we seek to study the main drivers of recent light bulb purchasers and understand how they ended up using the light bulb from that purchase, rather than on U.S. lighting stock.

This report is organized as follows: section 2 of this report describes our survey design, sampling methodology, and weighting methodology. Section 3 reports the general survey results and consumer preferences from a series of interactive ranking exercises used to determine the most important attributes to participants when purchasing a light bulb. Finally, section 4 provides a summary of results and implications of this work.

2. Methodology

This study collected data for three types of light bulbs commonly purchased and used in US households: A-line, reflectors, and candle-shaped bulbs (see Figure 1). A-line bulbs are the most common omnidirectional bulbs used in the residential sector. CFL bulbs in this category typically have a distinctive spiral shape. Reflector or spot light bulbs provide directional lighting and are typically used in recessed can type fixtures, flood lighting fixtures, and other directional applications. Candle-shaped bulbs provide a decorative element and are often used in chandelier lighting and ceiling fan light kits.

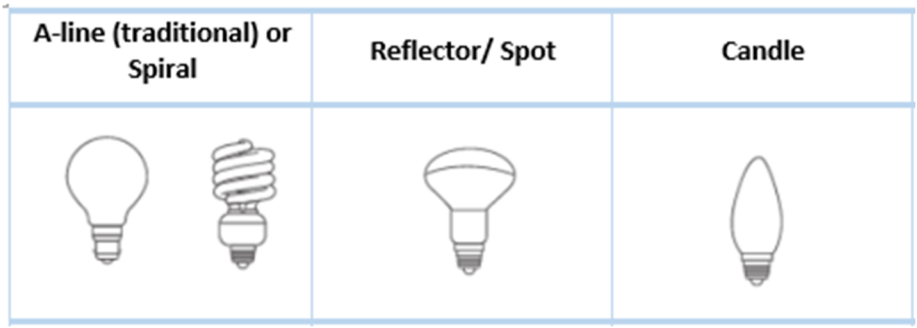

Figure 1. Depictions of the three bulbs shapes considered in this study

We wanted to investigate if there were significant differences in how consumers made their purchasing decisions and used these types of light bulbs in residential settings. Our team developed the survey content and sampling strategy, and then contracted OSG to lead respondent recruitment and screening, survey dissemination, and compilation of initial survey results. The online survey was designed to take respondents no more than 30 minutes to complete. The survey was deployed by OSG in May 2019 and we reached our goal of 1,800 respondents by June 2019.[3]

[2] https://www.energy.gov/eere/ssl/2015-us-lighting-market-characterization

[3] A sample size of 1,800 respondents results in a sampling error of ± 2.4% (95% confidence level).

In the rest of this section we describe the survey design, sample selection, and weighting methodology to make our sample representative of the US population.

2.1 Survey Design

Our target sample for this survey was US adults who had purchased either an A-line, reflector, or candle-shaped light bulb within six months prior to taking the survey. As part of our screening process, we limited our sample to recent light-bulb purchasers to ensure respondents would be able to reasonably recall the factors motivating their purchasing decision. Additionally, we screened out respondents that might be biased due to their career (e.g., employer affiliation) or participation in a previous study related to either the energy field or home appliances, which may potentially influence responses to questions about purchasing behavior.

Based on estimates of installed stock from the Department of Energy's (DOE's) 2015 Lighting Market Characterization (2015 LMC) survey, A-line shaped bulbs were much more popular than the reflector or candle-shaped bulbs and were therefore anticipated to represent the bulk of survey responses (Navigant Consulting, Inc., 2017). To ensure a sizable sample across bulb shapes, we placed a quota of the number of responses for each bulb type. We set a quota of 800 responses for A-line bulb, 500 for candle-shaped, and 500 for reflector.

Respondents who met the screening criteria in the first section of the survey progressed on to the general survey. The multiple-choice questions in the general survey were designed to understand purchasing behavior, typical light bulb usage, and usage of lighting with "smart" connected features.

The second portion of the survey contained a series of tradeoff exercises that makes use of OSG's Adaptive Self-Explication of Multi-Attribute Preferences (ASEMAP™) platform. ASEMAP™ is a trade-off methodology that offers a simple web-based approach for measuring customers' preference (Netzer and Srinivasan, 2011). The exercises are adaptive to the responses of each respondent to identify the attributes that matter most to each individual. Relative to other methodologies such as adaptive conjoint analysis (ACA), constant sum analysis, and MaxDiff analysis (i.e., best-worst scaling) that are currently used in the market research industry, ASEMAP™ allows for greater variability in attribute importance.

In the first ASEMAP™ exercise, participants were asked to rank 18 product attributes that they found most important during the purchasing process. The attributes were developed by reviewing marketing material, online reviews, and the previous PG&E study. The attributes were randomized when presented to participants for ranking. The light bulb attributes used in the ASEMAP™ ranking exercise were:

- Ease of disposal
- Energy Star labeled
- Energy efficiency of the bulb
- Bulb Technology
- Light Appearance
- Similar in physical appearance to current light bulb
- Expected lifetime of bulb
- Ability to adjust/dim light
- Bulb is controllable through a wireless connection to your smartphone, tablet, or smart home device
- Pack size availability while buying
- Where the light bulb can be purchased

- Ability to reflect true colors of the objects
- Distribution of light
- Flickering/buzz of the bulb
- User reviews and feedback of the bulb
- Warranty length for the bulb
- Purchase price of the bulb

In the second ASEMAP™ exercise, respondents were asked to rate desirability for different levels within a given attribute. For example, with the attribute of product price, we asked about the desirability of bulbs priced at $1, $3, and $5. This provides a measure of the respondent's sensitivity to different levels for each attribute. The full list of levels for each attribute are in Appendix A.

In the last ASEMAP™ exercise, respondents were asked to rank the likelihood of purchasing different combinations of attributes at different levels and asked to indicate how likely they were to purchase a light bulb for their home.

In the final section of the online survey, respondents were asked to rate their level of agreement with a number of statements about general purchasing behavior and LEDs. This provides us an understanding of how consumers view lighting technologies and consumer perceptions that may be hindering adoption of LEDs. The full survey instrument can be found in Appendix A.

2.2 Sample Selection

Potential respondents were randomly selected from an online consumer panel to participate in our lighting survey via an e-mail distributed by OSG. Initially, 8,774 respondents responded to at least one question of the survey. Of the initial pool of 8,774 respondents, 5,329 respondents (61 percent) completed the demographic section at the beginning of the survey. This sample of 5,329 respondents chosen randomly was used to perform the weighting of the final sample and is referred to as the "contact sample." (See section 2.3 for details.) From the contact sample, 2,170 respondents did not meet the screening criteria described above (e.g., did not purchase a light bulb within the last six months), and an additional 1,317 respondents did not fully complete the survey. This resulted in a sample of 1,842 respondents who met the screening criteria and completed the full survey. Data from these 1,842 respondents were examined to exclude any responses deemed unreliable.

We flagged and excluded data from 42 respondents that did not appear to be taking the survey with full attention. One criterion defined the time the respondent spent taking the survey compared to the expected survey time: responses were not included in the sample if the respondent's total survey response time was less than one-third of the expected survey time (10 minutes). Other criteria included inconsistent responses within the ASEMAP™ section, or illogical responses to free response questions (e.g., random words or randomly typed characters, rather than an intentional response in the response fields). The final sample of 1,800 respondents will be referred to as the "completes sample." Figure 2 shows the number of respondents eliminated at each step of the sample determination process.

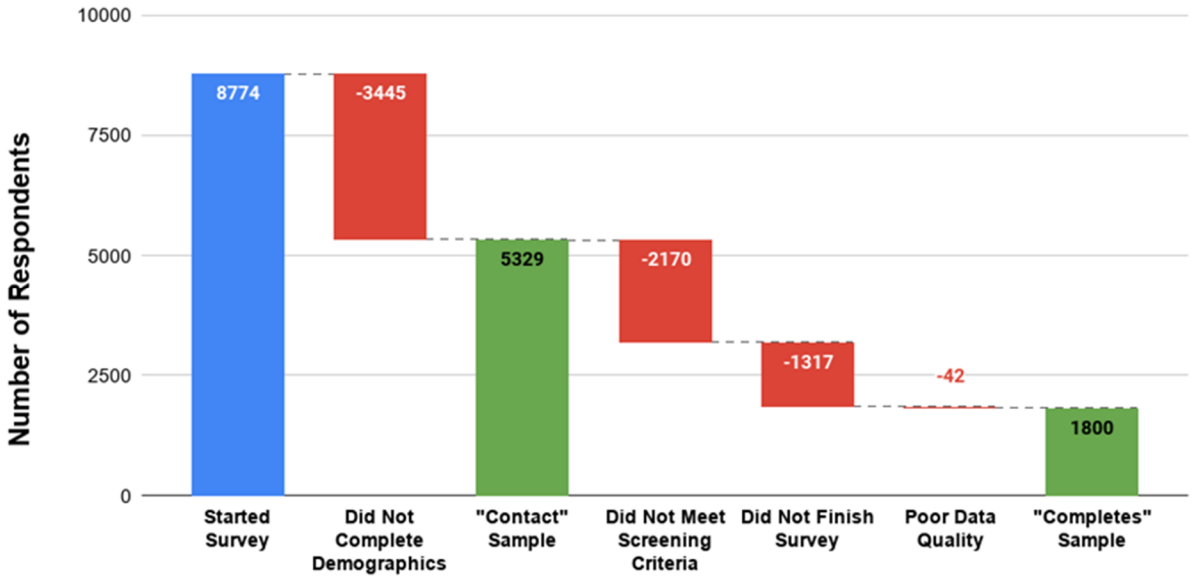

Figure 2. Waterfall chart depicting sample determination

2.3 Sample Weighting

We developed sample weights to make our estimates more representative of the US population. The weighting was accomplished by first comparing the contact sample (5,329 respondents) with the US population of adults as measured by the 2017 American Community Survey (ACS 2017) for six demographic variables: age, annual household income, education, marital status, ethnicity, and gender. The contact sample is used in developing weights because this sample is generally random and, hence, should align well with the demographics of the US adult population.

A random iterative method (RIM) approach was used to weight the contact sample so that it aligned with the ACS 2017 population. RIM is an iterative weighting technique which applies successive steps of multiplicative weights to reach a target goal (Kalton and Flores-Cervantes, 2003). The iteration process passes through each of the variables before beginning the next iteration. Typically, there is a limit on the number of iterations that can be performed in order to avoid skewing data, and it is possible that not all targets will be achieved. Weights were initially computed for each demographic characteristic and were then multiplied to derive a composite weight across all six demographic variables. Both individual and composite weights were constrained to avoid overweighting certain demographic groups and to ensure that all respondents were represented in the results. The final set of weighting parameters were mapped onto the complete sample of 1,800 respondents. The results of the demographic weighting comparing the raw and weighted proportions relative to the 2017 ACS can be found in Table 1.

Table 1. Comparison of sample demographics distributions between ACS 2017 and final sample

	ACS 2017 (%)	Final Sample	
		Raw Data (%)	Weighted Data (%)
Ethnicity			
White	61	86	69
Hispanic or Latino	17	5	15
Black or African-American	12	7	14
Asian	5	4	5
American Indian/Alaska Native	1	1	1
Other	2	1	1
Gender			
Female	51	70	60
Male	48	30	40
Highest Level of Education			
Some high school	7	1	4
High school/GED	29	13	28
Some college	19	20	24
Associate degree	10	13	12
Bachelor's degree	20	33	21
Graduate Degree	11	20	11
Prefer not to answer	4	-	-
Age			
18-24 years of age	13	5	17
25-34 years of age	18	12	17
35-44 years of age	16	20	16
45-54 years of age	17	21	17

55-64 years of age	16	24	18
65 years or older	19	17	15
Marital Status			
Married/Living with partner	49	20	49
Single	34	66	37
Divorced/Separated	11	4	5
Widowed	6	10	9
Income			
Less than $15,000	11	4	12
$15,000-$24,999	9	5	12
$25,000-$34,999	9	8	9
$35,000-$49,999	12	12	14
$50,000-$74,999	17	20	19
$75,000-$99,999	12	16	11
$100,000-$149,999	13	18	12
$150,000-$199,999	5	7	5
$200,000 or more	6	6	5
Prefer not to answer	5	3	2

Our application of RIM weighting is generally able to produce sample weights consistent with ACS 2017 demographics. We find the largest discrepancy within gender. Our raw sample was heavily skewed towards “Female” responses. Although our weighting process was able to bring our sample into closer alignment with ACS 2017, “Female” respondents are still over-represented in our survey relative to the general population. Our raw sample is also skewed towards respondents that identified as “Single” relative to the ACS 2017 demographics, mostly at the expense of respondents that identified as “Married/Living with a Partner”. This may indicate that our sample underrepresents the full “Married/Living with a Partner” population due to limited responses which may due to the demographic profile of individuals that tend to participate in online surveys.

As a result of our weighting methodology, the final weighted sample for A-line, candle-shaped, and reflector bulbs reflect slightly different proportions of our total sample than our original target. For example, in terms of raw responses, we have 44% A-line (800 respondents), 28% for candle-shaped (500

respondents), and 28% for reflector (500 respondents). After weighting, we have 57% for A-line, 23% for candle-shaped, and 20% for reflector. The shift in proportions post-weighting may indicate that A-line bulbs are more commonly purchased by demographics assigned higher weights by the RIM routine relative to those in the candle-shaped and reflector categories.

3. Results

3.1 General Survey Results

In this section we discuss the results from our general survey that inquired about respondents' most recently purchased light bulb and lighting usage patterns in their household. In this report, we highlight a subset of results most applicable to understanding the lighting choices and energy use of light bulbs in residential housing stock. All results in this section make use of the weights derived in section 2.3.

3.1.1 Most Recent Bulb Purchased

Perhaps the most significant factor impacting the energy consumption associated with residential lighting is the bulb technology. We asked respondents to identify the technology of their most recent bulb purchase. Respondents were shown pictures of an incandescent, halogen, CFL, and LED bulb and asked to choose the option that represented their most recent purchase. Although we differentiated between incandescent and halogen technologies in our survey, because of the similarity in technology, potential inability for consumers to differentiate between these options, and response results, they are grouped together throughout this report. Note that the typical bulb lifetime plays a significant role in determining the frequency of replacement with shorter lifetime bulbs requiring more frequent replacement leading to a higher sales volume. Incandescents typically have rated lifetimes of 1,000 hours, CFLs with 8,000 hours, and LEDs between 10,000-25,000 hours.

Table 2 shows the technology breakdown of respondents' most recently purchased bulb for each of the bulb shapes studied in this analysis.

Table 2. Light bulb technology for the most recently purchased light bulb

	A-Line (%) N = 800	**Candle-Shaped (%)** N = 500	**Reflector (%)** N = 500	**All Respondents (%)** N=1,800
Incandescent/Halogen	32	31	26	30
CFL	31	21	21	27
LED	37	47	53	43

Across all bulb shapes, LED bulbs comprised the largest portion of respondents' most recent purchases, followed by incandescent/halogens, and lastly CFLs. A-line bulbs had the lowest percentage of LED purchases and highest percentage of CFL purchases relative to the other bulb shapes.

Incandescent/halogen purchases are relatively consistent between different bulb shapes, making up between 26-32% of purchases.

The distribution of technology type for A-line bulbs estimated from our survey differs from quarterly estimates published online from the National Electrical Manufacturers Association (NEMA) shipments indices for A-line bulbs from the same time period.[4] For the first two quarters of 2019, NEMA estimated higher market share for LEDs (~60%) and incandescents (~25%), and lower for CFLs (~15%). One likely explanation for the discrepancy is that our survey does not capture purchases from the commercial sector, which may be responsible for a larger percentage of LED sales. Additionally, since purchases reflect what is available in stores rather than what is shipped by manufacturers, our survey likely reflects shipments from previous quarters where CFLs were a larger fraction of shipments according to NEMA data.

3.1.2 Lumen Distribution by Bulb Shape

Respondents were asked to choose the lumen output (i.e., the brightness) of their most recent light bulb purchase. When describing different brightness options in the survey, we provided both the lumen output as well as the incandescent wattage equivalent, which is often used to describe light bulb brightness. For example, an 800 lumen bulb was also described as a 60 watt incandescent equivalent.[5] We also provided respondents an option to choose a 3-way bulb, which has 3 levels of brightness, and a free response option to capture all other responses. Table 3 shows the lumen output results broken out by bulb shape.

Table 3. Lumen distribution for the most recently purchased light bulb

	A-Line (%) N = 800	**Candle-Shaped (%)** N = 500	**Reflector (%)** N = 500	**All Respondents (%)** N=1,800
Less than 40 W-equivalent	2	4	2	2
40 W-equivalent (approximately 450 lumens)	7	20	9	10
60 W-equivalent (approximately 800 lumens)	43	40	30	40
75 W-equivalent (approximately 1,125 lumens)	24	16	26	23

[4] https://www.nema.org/analytics/lamp-indices

[5] For simplicity, the incandescent wattage equivalencies included with the lumen output were based on values for A-line lamps which are the most common type of light bulbs. The incandescent wattage equivalencies may not necessarily reflect candle-shaped and reflector bulbs and could potentially bias results.

100 W-equivalent (approximately 1,400 lumens)	18	16	23	18
150 W-equivalent (approximately 2,250 lumens)	2	3	7	3
3-way bulb	3	2	2	2
Other	1	0	2	1

Across all bulb types, 60 W-equivalent (approximately 800 lumens) was the most common choice. There are some small, but notable differences in the distributions between A-line and the other bulb shapes. Candle-shaped bulbs, typically marketed for use in decorative applications, were slightly more skewed toward lower lumen outputs and reflector bulbs toward higher lumen outputs, relative to A-line bulbs. Figure 3 shows a visual representation of the lumen distribution by bulb shape.

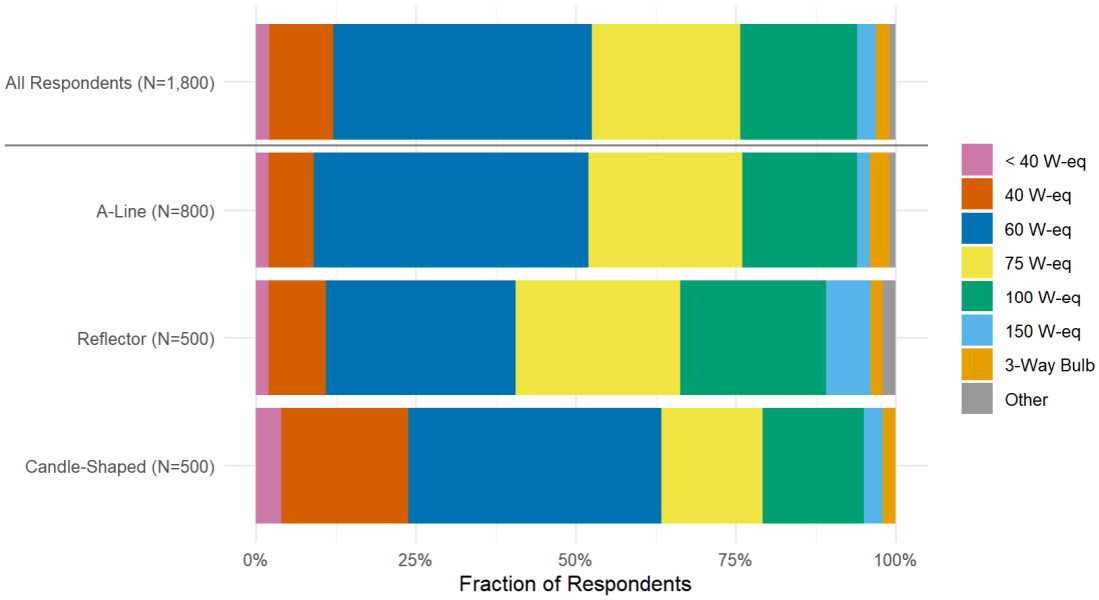

Figure 3. Lumen distribution for the most recently purchased bulb by bulb shape

Notably, the A-line lumen distribution from our sample of recent purchases is very similar to the lumen market share distribution published in the 2016 Department of Energy Notice of Proposed Rulemaking (NOPR) for comparable general service lamps (U.S. Department of Energy, 2016).[6] Table 4 reproduces the values used in that analysis, which was based on sales data provided by the National Resources Defense Council (NRDC), along with the results from this survey for A-line bulbs.

[6] A-line lamps were included in the scope of the 2016 GSL NOPR but candle-shaped and reflector lamps were not.

Table 4. Comparison of lumen distribution between 2016 GSL NOPR and this work

Lumen Range	Wattage Equivalence	GSL NOPR Residential (%)	This Work [A-Line]* (%)
310-749	40 W	13	9**
750-1049	60 W	43	44
1050-1489	75 W	25	25
1490–1999	100 W	18	19
2000-2600	150 W	1	2

*Values in this column are re-normalized to exclude responses for "3-way" and "Other."
**Estimate combines responses for "Less than 40 W-equivalent" and "40 W-equivalent"

The distributions are very similar between the 60-100 W-equivalent lumen range. Our survey found a slightly higher percentage of consumers purchased 150 W-equivalent bulbs and a lower percentage of 40-W equivalent bulbs compared to the 2016 GSL NOPR.

3.1.3 Reason for Purchase

Respondents were asked to provide the reason for the most recent purchase and allowed to choose more than one option to accommodate respondents who may have purchased multiple bulbs at the same time in a multipack. The results, broken down by light bulb shape, can be found in Table 5.

Table 5. Reason(s) for purchasing the most recently purchased light bulb(s)

	A-Line (%) N = 800	**Candle-Shaped (%)** N = 500	**Reflector (%)** N = 500	**All Respondents (%)** N=1,800
Replacing an existing light bulb	85	84	87	85
Preparing to replace an existing light bulb	22	20	23	22
Buying a light bulb for a new fixture	9	14	16	12

Note: Respondents were allowed to choose more than one option.

The overwhelming majority of purchases were either to replace a failed bulb or in anticipation of a future replacement. Purchases for new fixtures account for 9-16% within our sample with slightly more respondents purchasing candle-shaped and reflector bulbs for new fixtures compared to A-line bulbs. This result is suggestive of an increase in popularity for non A-line bulbs.

3.1.4 Type of Light Bulb Replaced

A key aspect of understanding lighting purchasing behavior is understanding how consumers chose to replace a previous bulb. We asked respondents about the technology of the light bulb being replaced for those respondents who indicated their most recent purchase was to replace or prepare to replace an existing light bulb. In Table 6 we show the distribution of the technology of the failed light bulb based on the technology of the most recently purchased bulb.

Table 6. Distribution in the technology of the replaced light bulb by technology of the most recently purchased light bulb

	Purchased an Incandescent (%) N =534	**Purchased a CFL (%)** N = 449	**Purchased an LED (%)** N = 816	**All Respondents (%)** N = 1,800
Replacing a Failed Incandescent	93	50	54	65
Replacing a Failed CFL	7	44	22	23
Replacing a Failed LED	1	6	24	12
Total	100	100	100	100

The majority of consumers were replacing an incandescent bulb, regardless of the most recently purchased bulb technology. This likely reflects the shorter lifetime of incandescent bulbs necessitating more frequent replacement. Notably, 93% of respondents who purchased an incandescent bulb were replacing a failed incandescent bulb, indicating a strong desire for incandescent bulb purchasers to stay with the same technology. Households that purchased CFLs and LEDs showed more diversity in the technology of the bulb being replaced, although in both cases the plurality of respondents were replacing incandescents.

In Table 7, we used responses to the same question to look at which technology respondents ended up purchasing based on the technology of the bulb they were replacing.

Table 7. Distribution in the technology of the most recently purchased light bulb by the technology of the light bulb being replaced

	Replacing a Failed Incandescent (%) N = 958	**Replacing a Failed CFL (%)** N = 358	**Replacing a Failed LED (%)** N = 179
Purchased an Incandescent	44	9	2
Purchased a CFL	21	52	13
Purchased an LED	35	39	85
Total	100	100	100

Of respondents replacing an incandescent bulb, 44% chose to purchase another incandescent bulb, 21% chose a CFL, and 35% chose an LED. Notably, this indicates that the majority of participants replacing an incandescent bulb purchased either a CFL or LED rather than replacing it with an incandescent.

In the case of CFL replacements, respondents mostly chose another CFL (52%) or an LED (39%). Viewed in this light, it is clear that LEDs are a relatively popular replacement bulb for non-LED technologies. However, for each technology, participants were most likely to match the technology between the failed and replacement bulb (44%, 52%, and 85% for incandescent, CFL and LED respectively). This may indicate that a significant percentage of consumers are most comfortable replacing their failed bulb with the matching technology. In particular, respondents replacing an LED light bulb opted overwhelmingly to purchase another LED bulb reflecting that these participants are likely satisfied with the performance of this technology. Additionally, less efficient incandescent bulbs were not a popular replacement choice for either failed CFLs (9%) or LEDs (2%).

3.1.5 Reason for Purchase

We asked respondents who were replacing a failed non-LED bulb with an LED bulb why they did so. Respondents were allowed to choose multiple options. Table 8 shows the results by bulb shape.

Table 8. Reasons for choosing an LED bulb for replacement of a failed non-LED bulb

	A-line (%) N = 301	**Candle-Shaped (%)** N = 169	**Reflector (%)** N = 194	**All Respondents (%)** N = 664
LED light bulbs last longer than other light bulb types	65	77	64	68
LED light bulbs use less energy than other light bulb types	63	63	73	66
LED light bulbs save me money on my utility bill	56	56	53	55
I find the quality of light from an LED light bulb is superior	42	50	52	47
I like the appearance of LED light bulbs	30	32	39	33
LEDs appear to dim the same way as incandescent/halogen light bulbs	6	9	19	10
LED light bulbs have more features than other light bulb types	9	6	11	9
For some other reason	5	4	4	4

Note: Respondents were allowed to choose more than one option.

The top three reasons for choosing LEDs were longer expected bulb lifetimes, the energy savings associated with LEDs, and the money saved on utility bills. Given the relationship between energy savings and cost savings, it is interesting to see some slight difference in terms of responses, suggesting there is a subset of households that care more about saving energy than the associated cost savings. Results are similar across the three bulb shapes; however, candle-shaped bulb purchasers were more likely to give expected bulb lifetimes as a reason for switching to an LED bulb when compared to the A-line and reflector bulb purchasers.

Given the growing popularity of LED bulbs, we wanted to identify potential reasons participants that purchased non-LED options were not interested in purchasing an LED. The results can be found in Table 9 by bulb shape.

Table 9. Reasons for not choosing an LED for most recent purchase among respondents that did not purchase an LED

	A-Line N = 532	**Candle-Shaped** N = 243	**Reflector** N = 208	**All Respondents** N = 983
LEDs are more expensive than other light bulb technology types	37	42	43	39
I wanted to have the same technology type of light bulb as I had previously	38	38	40	38
I find the quality of light from my current lightbulb is superior	26	27	32	27
LEDs don't appear to dim the same way as other light bulb types	9	15	9	10
For some other reason	9	11	9	10

Note: Respondents were allowed to choose more than one option.

Across all bulb shapes, most respondents did not purchase an LED due to the higher price point relative to other technologies, as well as desire to purchase a bulb with the same technology they were replacing. The former suggests that as LEDs decrease in price, more consumers may consider them as an acceptable option. The latter reason suggests that consumers may be making purchasing decisions in part due to familiarity with the existing technology and/or a potential lack of familiarity with LEDs.

3.1.6 Usage of Most Recently Purchased Bulb

Respondents were asked to report their typical usage for their most recently purchased bulb. The results by bulb shape are reported in Table 10.

Table 10. Daily operating hours of use by shape of the most recently purchased light bulb

	A-line (%) N = 800	**Candle-Shaped (%)** N = 500	**Reflector (%)** N = 500	**All Respondents (%)** N=1,800
Less than 30 minutes	5	6	6	5
30 minutes to 1 hour	6	8	10	7
1 to 2 hours	13	17	15	15
2 to 3 hours	18	16	19	18
3 to 6 hours	31	25	25	28
6 to 9 hours	16	16	14	16
9 to 23 hours	7	7	6	7
24 hours	3	4	4	4

In general, we do not see a significant difference in hours of use between different light bulb shapes. The plurality of households reported usage in the 3 to 6 hour range. Taking the midpoint of each bin, we find an average hours of use of about 5.2 hours per day for A-line, 5.1 hours per day for candle-shaped, and 4.9 hours per day for reflector bulbs.

In Table 11, we show the usage for the most recently purchased bulb broken out by light bulb technology.

Table 11. Daily operating hours of use by technology of the most recently purchased light bulb

	Incandescent/Halogen (%) N = 534	**CFL (%)** N = 449	**LED (%)** N = 816	**All Respondents (%)** N=1,800
Less than 30 minutes	4	7	6	5
30 minutes to 1 hour	7	6	9	7
1 to 2 hours	17	15	13	15
2 to 3 hours	16	21	17	18
3 to 6 hours	28	28	29	28
6 to 9 hours	13	17	17	16
9 to 23 hours	10	4	6	7
24 hours	5	3	3	4

Overall, we do not see significant differences between operating hour distributions by bulb technology relative to the results for "All Respondents". More incandescent bulb purchasers indicated they use their most recently purchased bulb for 9 to 23 hours and 24 hours relative to other technologies. This could potentially reflect that incandescent bulbs, which typically have significantly shorted rated lifetimes than comparable CFL or LED bulbs, with higher hours of use will need more frequent replacement and will subsequently be purchased more frequently (U.S. Department of Energy, 2016).

The daily hours of use reported in this section reflect the most recent purchase in the household, which is not necessarily representative of the hours of use across all light bulbs installed in residential stock. Bulbs with higher operating hours fail sooner, leading to more frequent replacement. As such, the average hours of use based on sales of bulbs should be higher than the average hours of use of bulbs in the installed stock. For example, the LMC 2015 reports an average daily operating hour of 1.9 hours per day for residential stock.

3.1.7 Installation Location of Most Recent Purchase

Respondents were asked where they installed their most recently purchased light bulb. Table 12 shows the results by bulb type. Respondents were allowed to choose multiple options to accommodate multipack purchases.

Table 12. Installation location by shape of the most recently purchased light bulb

	A-line (%) N = 800	**Candle-Shaped (%)** N = 500	**Reflector (%)** N = 500	**All Respondents (%)** N=1,800
Living room	46	37	40	43
Kitchen	23	24	34	26
Master bedroom	26	21	26	25
Bathroom	21	16	20	20
Dining Room	15	26	11	17
Another bedroom	18	15	15	17
Hallway	11	10	11	11
Den/office/study	8	6	10	8
Outside porch/balcony	5	5	12	7
Laundry room	4	6	8	5
Garage	3	3	6	4

The plurality of bulbs were installed in living rooms across all bulb shapes. Candle-shaped bulbs, which tend to be marketed as decorative, were more likely to be installed in dining rooms compared to other bulb shapes. Reflectors, which are ideal for providing directional lighting, were more likely to be installed in an outside porch/balcony and kitchens compared to A-line or candle-shaped bulbs. We do not see significant differences between room type distribution by bulb technology type relative to the results for "All Respondents" and hence we do not provide a separate table.

3.1.8 Frequency of Purchase

Respondents were asked about how often they purchase light bulbs for their household. Table 13 shows the results based on the bulb technology.

Table 13. Frequency of purchases by the technology of the most recently purchased light bulb

	Incandescent/ Halogen (%) N = 534	**CFL (%)** N = 449	**LED (%)** N = 816	**All Respondents (%)** N = 1,800
Less than once a year	9	13	14	12
Once a year	22	22	28	25
Once every 6 months	37	45	42	41
Once every 3 months	24	17	13	17
Once every month	6	1	2	3
More than once a month	2	2	0	1

Households that purchased incandescent or halogen bulbs tend to purchase bulbs more frequently than respondents who recently purchased CFL or LED bulbs. This observation is consistent with incandescent bulbs having a shorter typical lifetime than CFL or LED bulbs, thereby requiring more frequent replacement. As discussed in section 3.1.4, the vast majority of respondents that purchased an incandescent bulb were replacing a failed incandescent bulb, which is consistent with the finding that these consumers will need to purchase new bulbs more often.

3.1.9 Smart Technologies in the Home

The introduction and fast adoption of smart technologies[7] into the residential sector provides households an alternate way to interact with home appliances and lighting. As part of our usage survey, we asked participants about the presence of smart devices and their application to lighting. Table 14 shows the report the percentage of respondents that indicated that own smart home technology of any kind.

[7] "Smart home technologies" were defined to survey participants as technologies that "allow you to control your home appliances and/or lighting through a wireless connection to your smartphone, tablet, smart speaker/display, or other device."

Table 14. Percentage of households with smart home technology by the technology of the most recently purchased light bulb

	Incandescent/ Halogen (%) N = 534	CFL (%) N = 449	LED (%) N = 816	All Respondents (%) N = 1,800
Yes, I have smart home technologies	33	39	48	41
No, I do not have smart home technologies	67	61	52	59

Overall, 41% of our sample have some type of smart home device. Notably, households that recently purchased an LED bulb were more likely to have smart home technologies relative to incandescent or CFL purchasers, suggesting these households may be more open to purchase newer technologies. Incandescent purchasers in our sample of recent bulb purchases were the least likely to have smart home technologies (33%).

We next asked respondents to identify the different types of smart home technologies in their household. Respondents were allowed to choose multiple options. Table 15 shows the percentage of all households with different types of smart home technologies within our sample.

Table 15. Percentage of households with smart home devices by the technology of the most recently purchased light bulb

	Incandescent/ Halogen (%) N = 534	CFL (%) N = 449	LED (%) N = 816	All Respondents (%) N = 1,800
Any Smart Technology	33	39	48	41
Smart speakers/displays	24	27	33	29
Smart thermostat	7	12	16	12
Smart light bulbs	7	12	14	11
Smart appliances	6	7	11	9
Smart plugs	4	6	12	8
Other	3	2	2	2

Note: Respondents were allowed to choose more than one option.

Across our entire sample, 41% of respondents indicated that they had a smart device of some type, with 29% using a smart speaker and 12% using a smart thermostat. This is in good agreement with RECS

2020, which reported 32% of US households with smart speakers and 10% with smart thermostats (U.S. Department of Energy–Energy Information Administration, 2020b).

In Table 16, we show the responses to the previous question relative to the number of respondents who indicated they had smart devices.

Table 16. Percentage of households with smart home devices by the technology of the most recently purchased light bulb among households that have smart home technologies

	Incandescent/ Halogen (%) N =212	**CFL (%)** N =201	**LED (%)** N =409	**All Respondents (%)** N =823
Smart speakers/displays	74	69	70	70
Smart thermostat	23	31	33	30
Smart light bulbs	22	30	29	27
Smart appliances	18	19	23	21
Smart plugs	11	14	26	19
Other	8	4	4	5

Note: Respondents were allowed to choose more than one option.

Among households with smart devices, 70% had smart speakers or displays. Smart devices were generally more popular in households that recently purchased an LED bulb relative to other technology types, except for smart light bulbs where a slightly higher percentage of CFL purchasers reported using smart light bulbs. However, we note that the difference is not statistically significant.

We next asked respondents if they use smart technology with any of their household lighting. The results are presented in Table 17.

Table 17. Percentage of households that use smart technology to control lighting by technology of the most recently purchased light bulb among households that have smart home technologies

	Incandescent/ Halogen (%) N =212	**CFL (%)** N =201	**LED (%)** N =409	**All Respondents (%)** N =823
Yes	26	22	36	30
No	74	78	63	69
I don’t know	0	0	1	1

Of households with smart home technology, 30% use a smart device to control one or more light bulbs (about 12% of the total sample). Note that this does not necessarily represent their most recent purchase, but rather the penetration of smart lighting in installed residential lighting stock. A higher percentage of respondents who purchased an LED were likely to use smart lighting relative to other technologies, possibly indicating LED purchasers are more likely to adopt smart technologies earlier.

Notably, more respondents indicated using smart technology to control their lighting (30% as shown in Table 17) than indicated they use smart light bulbs (27% as shown in Table 16). This could indicate that some households use smart plugs or smart dimmers to control light bulbs that are not inherently "smart".

3.2 ASEMAP™ Results

In the ASEMAP™ section of the survey, respondents indicated which attributes were most important to them when making a lighting purchase decision (the list of attributes presented to respondents is provided is available in section 2.1). These attributes were thought to potentially matter to consumers in their lighting purchase decision based on product reviews and other relevant literature. Some of these attributes are directly related to energy consumption, whereas others provide useful context for understanding other considerations and tradeoffs consumers make in their purchase decision.

Each attribute selected by a respondent received a score depending on the level of importance the respondent assigned that attribute relative to the other attributes. The ASEMAP™ scores are indexed to 100. A score of 100 is considered to be of average importance among all of the possible purchase attributes. An attribute with a score of 200 means that attribute is twice as important as one that has a score of 100. In Table 18, we show the attributes ranked by their ASEMAP™ score for all bulb shape types.

Table 18. ASEMAP™ score for light bulb attributes in descending order by "All Respondents"

	A-Line N = 800	**Candle-Shaped** N = 500	**Reflector** N = 500	**All Respondents** N = 1,800
Purchase price of the bulb	182	171	155	173
Expected lifetime of bulb	155	142	152	151
Energy bill cost savings	151	150	148	150
Light appearance	141	150	160	148
Energy efficiency of the bulb	138	133	144	138
Bulb Technology	127	126	126	126
Distribution of light	109	110	109	110
Similar in physical appearance to current light bulb	91	98	103	96
Pack size availability while buying	92	93	92	92
Where the light bulb can be purchased	94	88	93	92
ENERGY STAR® labeled	89	97	92	92

	A-Line N = 800	**Candle-Shaped** N = 500	**Reflector** N = 500	**All Respondents** N = 1,800
Ability to reflect true colors of the objects	86	86	80	84
Flickering/buzz of the bulb	82	72	77	78
Warranty length for the bulb	77	76	73	76
Ability to adjust/dim light	67	73	80	72
Ease of disposal	71	70	64	69
User reviews and feedback of the bulb	52	50	51	51
Bulb is controllable through a wireless connection to your smartphone, tablet, or smart home device	34	44	41	38

In the following subsections we discuss the top five chosen characteristics and provide details regarding consumer sensitivity to the different levels analyzed within each feature using "preference curves." A preference curve captures the relative value of improvements for a particular attribute. The values on each curve are scaled across attributes to allow for comparison within and across attributes. The index is referred to as the preference index, and it is created by anchoring the level with highest utility value for the most important attribute to a value of 100. The least preferred level is set at 0. A steeper slope from one level to another is indicative of higher gain in value when improving from one level to another level within the attribute. Preference curves for attributes other than the top five from Table 18 are available in Appendix B.

Note that the results presented here are not directly comparable to the PG&E study which was conducted at a much earlier time period when LEDS were less widespread, focused only on A-line light bulbs, and a sample restricted to California households.

3.2.1 Purchase Price

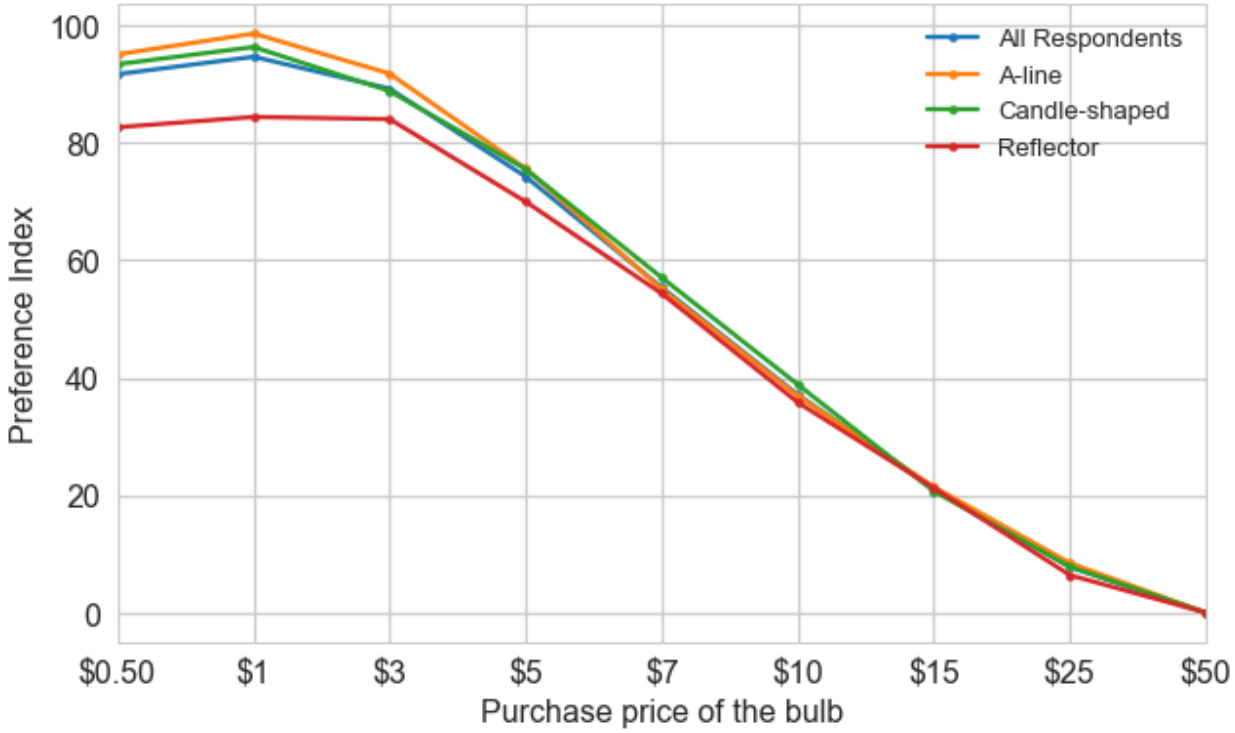

Figure 4. Preference curve for purchase price of the light bulb by shape of the most recently purchased light bulb

On average, respondents listed the purchase price as the most important attribute when choosing a light bulb for all bulb types (see Table 18). As shown in Figure 4, the desirability of a light bulb increases with decreasing price until the price per bulb reaches $1 for candle-shaped and A-line bulbs and $3 for reflector bulbs. At that point, bulb desirability decreases slightly, indicating that participants are less concerned about price below these values and may question the quality or reliability of a bulb that is priced too low. For prices above $3, we see very similar responses across bulb types.

3.2.2 Lifetime of Bulb

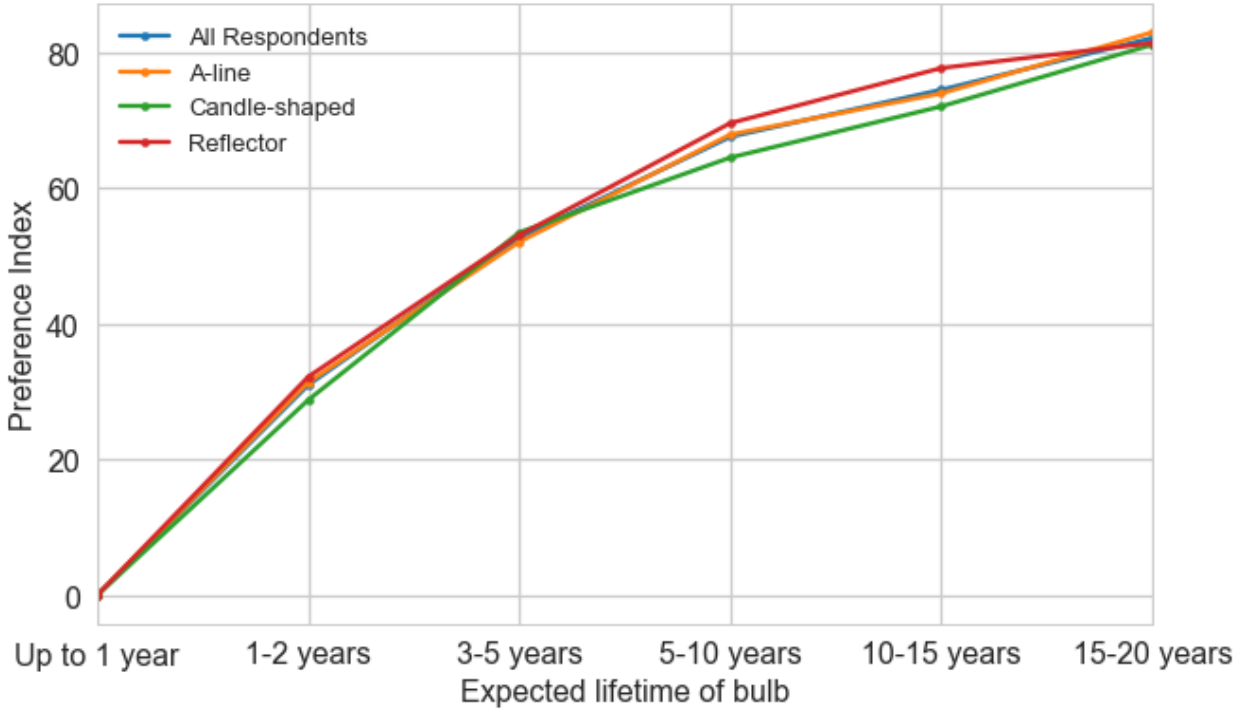

Figure 5. Preference curve for bulb lifetime by shape of the most recently purchased light bulb

Figure 5 shows the preference curve for the second-ranked attribute in our survey was the bulb lifetime (i.e., the expected duration of usability before the bulb fails). Respondents preferred longer lived light bulbs, although the gradual softening of the slope with increasing lifetime indicates that the marginal increase in desirability decreases with each incremental lifetime level.

3.2.3 Energy Cost Savings and Bulb Efficacy

Energy cost savings and energy savings were ranked as the third and fifth most important attributes from our list. In the ASEMAP™ exercise these two attributes were listed separately to determine how respondents ranked the financial benefit of a more efficient product relative to the actual energy savings. Although energy bill savings was ranked higher within ASEMAP™, given that increased energy efficiency leads directly to energy bill savings, the preference curves for both attributes are presented together.

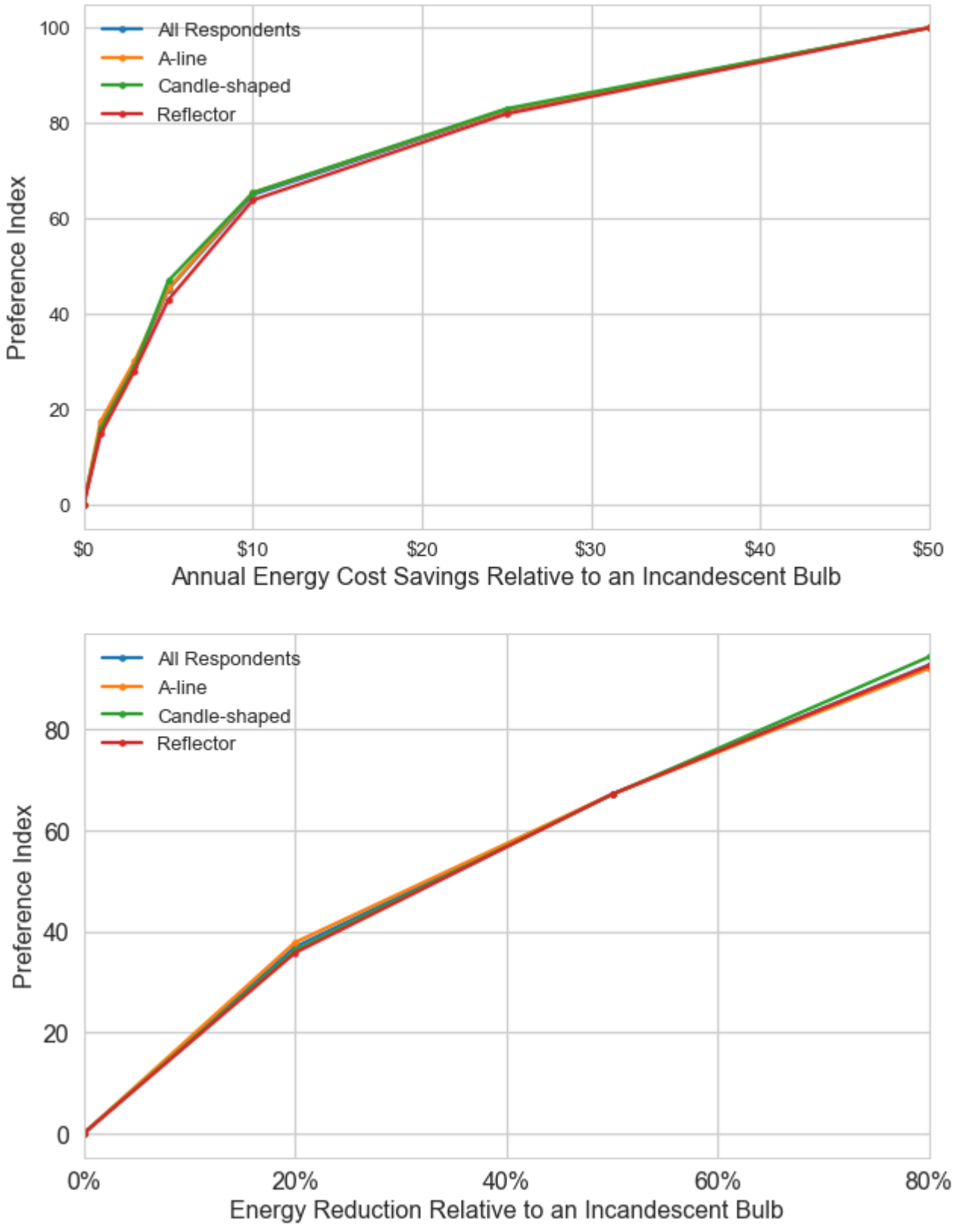

Figure 6. Preference curves for annual energy cost savings (top panel) and energy savings (bottom panel) relative to an incandescent bulb by shape of the most recently purchased light bulb

Figure 6 shows the preference curves for energy cost savings (top) and energy savings (bulb) relative to an incandescent bulb. Both curves increase monotonically in desirability with increased savings and efficiency. It is clear in both cases that respondents value reduced energy consumption and the associated cost savings with no obvious plateau, as was observed for bulb price and lifetime.

3.2.4 Light Appearance

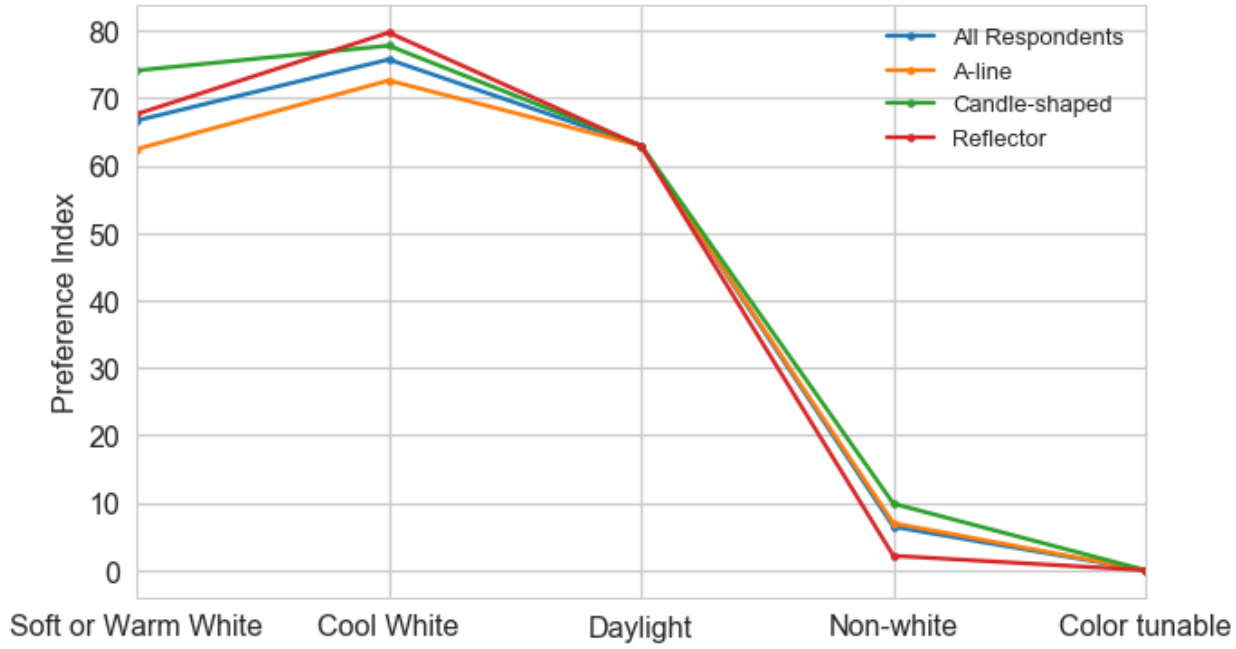

Figure 7. Preference curves for light appearance by shape of the most recently purchased light bulb

Figure 7 shows the preference curve for light appearance of the light bulb. Light appearance captures desirability for various color temperatures, non-white color, and the ability to change color ("color tunable"). The color temperature is a way to describe the appearance of the light.[8] A glossary of terms was provided to respondents with definitions of terms used in the survey.

Respondents preferred bulbs with white light that was either "soft white" (2000 - 3000 K), "cool white" (4000-5000 K), or "daylight" (5000-6000 K). All households preferred cool white more than other options. Respondents who had most recently purchased candle-shaped and A-line bulbs next preferred soft white, with daylight being the least desirable. Respondents who had most recently purchased reflector bulbs rated soft white and daylight approximately equal. The small differences between the different bulb shapes is likely driven by the different applications typically served by each shape.

[8] Color temperature describes the equivalent blackbody temperature of an idealized opaque, non-reflective surface measured in Kelvin (K).

3.3 Attitudes Toward LED Technology

In this section of the survey, respondents were asked to rate statements about LED bulbs using the following options: “strongly disagree”, “somewhat disagree”, “neutral”, “somewhat agree”, or “strongly agree.” In Table 19, we show the percentage of respondents who selected “somewhat agree” or “strongly agree” for each statement by the technology of their most recent light bulb purchase.

Table 19. Percentage of respondents indicating some or strong agreement with attitude statements on LED light bulbs

Attitude Statement	Incandescent/ Halogen (%) N =534	CFL (%) N = 449	LED (%) N = 816	All Respondents (%) N = 1,800
I prefer to purchase a light bulb that looks similar in appearance to my old one.	67	59	63	63
I find the quality of light from an incandescent is superior than LEDs	48	41	30	38
LEDs don’t have the same warm appearance when dimmed as an incandescent light bulb	43	39	31	36
LEDs cannot be dimmed to as low a level as an incandescent light bulb	28	31	24	27
I am confident that I can find a LED that will work well with my dimmer switch(es)	33	48	55	47
I like the way incandescent light bulbs look	65	49	45	52
I will only buy LED bulbs if they guarantee more energy savings compared to incandescent light bulbs	49	65	63	60
I will only buy LED bulbs if I can install them myself	56	70	73	67
I always prefer to buy LED bulbs over other technology types	24	40	65	47
LED bulbs are the safest bulb for the environment	37	48	57	49
I will buy LED bulbs if they are proven to last longer	62	76	85	76
LED bulbs are too expensive	67	56	43	53
I don’t believe that LEDs will last as long (or work as well, or save as much energy) as advertised	37	34	26	31

In general, respondents that most recently purchased LED or CFL light bulbs shared more positive attitudes toward LED bulbs.

4. Conclusion

In this work, we provide the results of a 2019 consumer survey of 1,800 respondents that investigated how households purchased and used light bulbs in the residential sector.

We find that the vast majority of bulb purchases were to replace a light bulb or in preparation for a bulb to fail. From our results, we estimate that the average hours of use for bulbs being purchased is between 4.9 and 5.2 hours per day, depending on bulb shape. We emphasize that this value does not represent the average hours of use for a typical light bulb in installed stock because purchased light bulbs will be skewed toward bulbs with higher hours of operation, which tend to need more frequent replacement. In this work, we also estimated the lumen distribution of purchased light bulbs and the distribution of installation locations by bulb shape.

From our sample, 93% of respondents who had most recently purchased an incandescent as a replacement bulb were replacing a previous incandescent bulb. These purchasers were also more likely to be wary of the higher price point of LEDs and exhibited a desire to match the style of their current lighting. It is possible that these consumers may be won over as the price of LEDs continues to fall. In particular, we note that the majority of our sample that were replacing a failed incandescent bulb purchased either a CFL or an LED as a replacement.

Respondents who had most recently purchased a CFL bulb shared many of the same opinions on LEDs as respondents who had most recently purchased an LED bulb, as seen in their similar ratings of LED technologies. In line with shipments estimates from NEMA, LED technology comprises the majority of recent purchases. This is observed across A-line, candle-shaped, and reflector bulb shapes. Respondents in our sample that had most recently purchased LED bulbs were drawn to LEDs due to their long lifetime and energy efficiency.

Our estimates for the adoption of smart technologies match results from RECS 2020, with approximately 29% of households using smart speakers or displays. However, we find that only 12% of respondents use any kind of smart device to control lighting in their home.

From the ASEMAP™ portion of the survey, we do not see significant differences in the most desired attributes between respondents who had most recently purchased bulbs of different shapes. For each bulb shape, the five most important factors are purchase price, bulb lifetime, energy cost savings relative to an incandescent bulb, light appearance, and energy savings relative to an incandescent bulb. Using the ASEMAP™ algorithm developed by OSG Analytics, we estimated preference curves for each attribute ranked by respondents. These curves may provide a basis for developing models to estimate the likelihood of purchasing light bulbs with different characteristics.

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Appendix A. Survey Instrument

SQ00. Have you or any of your immediate family members been employed in the following sectors in the past 12 months?

(Please select all that apply)
[Randomize]
[1] Marketing or Market research department/company [Thank and Terminate]
[2] Electric Utility [Thank and Terminate]
[3] Gas Utility [Thank and Terminate]
[4] Household Appliances Manufacturer [Thank and Terminate]
[5] E-commerce/Online retail company
[6] Public Relations [Thank and Terminate]
[7] Bank/banking related organization
[8] Travel/Tourism
[9] None of the above [EXCLUSIVE] [CONTINUE]

SQ01. In the past three months, have you participated in any of the following types of market research studies?

(Please select all that apply)
[1] Power or electricity [Thank and Terminate]
[2] Household appliances purchase [Thank and Terminate]
[3] Automotive services
[4] Home cleaning services
[5] Cellular telephone providers
[6] Internet providers
[7] None of the above [EXCLUSIVE] [CONTINUE]

SQ02. What is your age?

(Please select one)
[1] Under 18 years of age [Thank and Terminate]
[2] 18-24 years of age
[3] 25-34 years of age
[4] 35-44 years of age
[5] 45-54 years of age
[6] 55-64 years of age
[7] 65+ years of age

[SAMPLE DISTRIBUTION: IN ACCORDANCE TO US CENSUS DATA]

_____

SQ03a. In which state do you live currently?

_____ [DROP DOWN MENU OF 50 US STATES]

_____

SQ03b. What is the highest level of education you have completed?
(Please select one)

[1] Some high school
[2] High school/GED (General Education Development)
[3] Some college
[4] Associate's degree
[5] Bachelor's degree (e.g., BA, BS, etc.)
[6] Graduate degree (e.g., JD, MA, MS, PhD, etc.)
[99] I prefer not to answer

_____

SQ03c. Which of the following best describes your marital status?
(Please select one)

[1] Single
[2] Married / Living with Partner
[3] Widowed
[4] Divorced / Separated
[99] Prefer not to answer

_____

SQ03e. Which of the following categories best describes you?
(Please select all that apply)
[Randomize except OTHERS]

[1] American Indian / Alaska Native
[2] Asian
[3] Black or African--American
[4] Native Hawaiian or Other Pacific Islander
[5] Hispanic or Latino
[6] White
[7] Other (Please specify_____)
[8] Prefer not to answer

_____

SQ03f. Please specify your gender.

[1] Male
[2] Female
[3] Other (Please specify _____)
[99] Prefer not to answer

_____SQ03g. Which of the following best describes your total annual household income before taxes?
(Please select one)

[1] Less than $15,000
[2] $15,000 - $24,999
[3] $25,000 - $34,999
[4] $35,000 - $49,999
[5] $50,000 - $74,999
[6] $75,000 - $99,999
[7] $100,000 - $149,999
[8] $150,000 - $199,99
[9] $200,000 or more
[99] I prefer not to answer

_____

SQ04a. Is your primary home:
Your primary home is the residence where you live for most of the year
(Please select one)

[1] Owned
[2] Rented

_____

SQ04b. Is your primary home:
Your primary home is the residence where you live for most of the year
(Please select one)

[1] Mobile home
[2] Single Family detached house
[3] Single Family attached house
[4] Apartment or flat with 2 to 4 units
[5] Apartment or flat with 5 or more units
[6] Other (please specify: _____) [THANK AND TERMINATE]

_____

SQ05. Please describe your level of familiarity or usage with each of the following light bulb shapes.
(Please select all that apply)

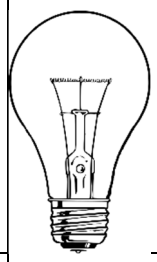
BULB SHAPES	A. Not aware/Don't know this type of light bulb	B. Have heard of it, but have never used	C. Have used in the past, but not currently using	D. Currently using in my home
[1] A-line (traditional) or Spiral	O	O	O	O

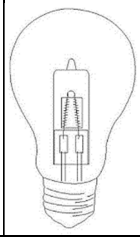
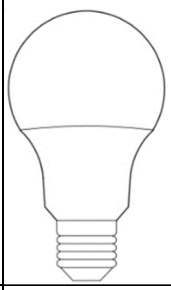
				
[2] Reflector/ Spot 	O	O	O	O
[3] Candle 	O	O	O	O
[4] Globe 	O	O	O	O
[5] Others (Please specify____)	O	O	O	O

[THANK AND TERMINATE IF OPTION 1, 2, OR 3 IS NOT SELECTED AS COLUMN D (MUST HAVE AT LEAST ONE OF THESE OPTIONS SELECTED TO QUALIFY)]

SQ06. Please describe your level of familiarity or usage with each of the following light bulb technology types.

(Please select one option per row)

	BULB TYPES	A. Not aware/Don't know this type of light bulb	B. Have heard of it, but have never used	C. Have used in the past, but not currently using	D. Currently using in my home
[1]	Incandescent (traditional) 	O	O	O	O
[2]	Halogen	O	O	O	O

					
[3]	CFL 	O	O	O	O
[4]	LED 	O	O	O	O
[5]	Other Bulb Types (Please Specify: ____)	O	O	O	O

[THANK AND TERMINATE IF ALL OPTIONS (1,2,3,4) ≠ D (CURRENTLY USE)]

SQ05a. When was the last time you purchased the following light bulb shapes for your primary home?

	[INSERT ONLY IF SQ05=D]	A. Less than 3 months ago	B. 3-6 months ago	C. 6-12 months ago	D. 12+ months	D. Never	E. Don't know/ Not sure
[1]	A-line (traditional) or Spiral 	O	O	O	O	O	O

[2]	Reflector/ Spot 	O	O	O	O	O	O
[3]	Candle 	O	O	O	O	O	O
[4]	Stick 	O	O	O	O	O	O
[5]	Globe 	O	O	O	O	O	O
[6]	Others (Please specify____)	O	O	O	O	O	O

[Thank and terminate if options SQ05a_1, 2, AND 3 ≠A or B (at least one option (1, 2, or 3) must = A or B)]

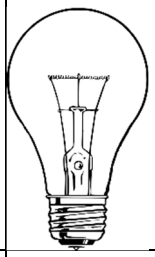
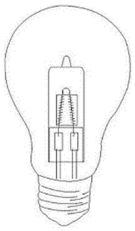
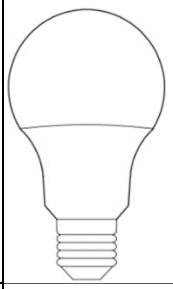
[QUOTA: if respondent falls into multiple quotas, least fill quota group

QUOTA as “A-line” if SQ05a_1=A or B; n= 800

QUOTA as “Reflector” SQ05a_2=A or B; n=500

QUOTA as “Candle” if SQ05a_3=A or B; n=500]

SQ06a. When was the last time you purchased the following light bulb technology types for your primary home?

	[INSERT ONLY IF SQ06=D]	A. Less than 3 months ago	B. 3-6 months ago	C. 6-12 months ago	D. 12+ months	E. Don't know/ Not sure
[1]	Incandescent (traditional) 	O	O	O	O	O
[2]	Halogen 	O	O	O	O	O
[3]	CFL 	O	O	O	O	O
[4]	LED 	O	O	O	O	O
[5]	Other Bulb Types (Please Specify: ____)	O	O	O	O	O

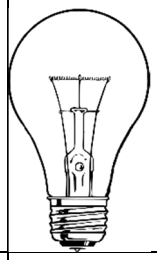
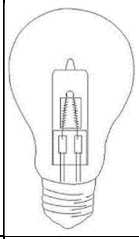
[Thank and terminate if all options SQ06a_1 through 4 ≠A **or** B (at least 1 option must = A or B)]

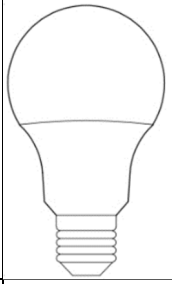
SECTION A: CURRENT BEHAVIOR AND USAGE

First, let’s think about [pipe in quota from SQ05a (Reflector/A-line/Candle)] your most recent light bulb purchase.

Please click 'Next' (>>) to continue...

AQ02a. Please think about your last [pipe in quota from SQ05a (Reflector/A-line/Candle)] light bulb purchase. Which of the following bulb technology types did you purchase last?
(Please select one option.)

	[ONLY SHOW BELOW OPTIONS IF SELECTED IN SQ06a=A or B; if only one option selected in SQ06a=A or B; autofill answer and skip question]
[1]	Incandescent (traditional) 
[2]	Halogen 
[3]	CFL 
[4]	LED

	
[5]	Other Bulb Types ([pipe in response from SQ06a only if = A or B])

Now, we would like you to answer some questions about your most recently purchased [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. "A-line LED"] lightbulb.

AQ02b. Please think about your last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. "A-line LED"] light bulb purchase. How bright was the lightbulb?
(Please select one option.)

[1] 150W equivalent (Approximately 2250 lumens)
[2] 100W equivalent (Approximately 1400 lumens)
[3] 75W equivalent (Approximately 1125 lumens)
[4] 60W equivalent (Approximately 800 lumens)
[5] 40W equivalent (Approximately 450 lumens)
[6] Less than 40W equivalent
[7] 3-way lamp
[8] Other (Please specify: _____)

AQ02c.
When you purchased your last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. "A-line LED"] light bulb, did you purchase a single light bulb or multiple?
(Please select one option.)

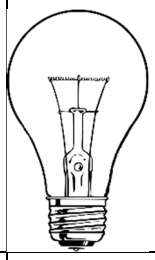
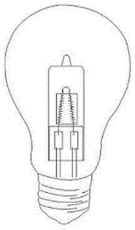
[1] 1 bulb
[2] 2 pack of bulbs
[3] 3 pack of bulbs
[4] 4 pack of bulbs
[5] 5-8 pack of bulbs
[6] More than 8 pack of bulbs

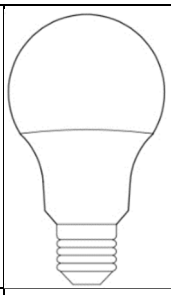
AQ03a.

When you purchased your last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. “A-line LED”] light bulb, were you replacing a light bulb or buying a bulb for a new fixture?
(Please select one option.)

[1] Replacing a light bulb
[2] Buying light bulb for a new fixture

AQ03b. [ask if AQ03a=1]
When you purchased your last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. “A-line LED”] light bulb, which type of light bulb were you replacing?
(Please select one option.)

[1]	Incandescent (traditional) 
[2]	Halogen 
[3]	CFL 
[4]	LED

	
[5]	Other Bulb Types (Please Specify: ____)

AQ04a. [ask if AQ02a≠4]
Why did you not purchase a LED light bulb?
(Please select all that apply)

[1] LEDs are more expensive than other light bulb types.
[2] I find the quality of light from an [insert AQ03b] is superior.
[3] LEDs don't appear to dim the same way as other light bulb types.
[4] I like the appearance of LEDs.
[5] I wanted to have the same type of light bulb as I had previously.
[6] For some other reason (Please specify: _____)

AQ04b. [ask if AQ02a=4 and AQ03b≠4]
Why did you switch to a LED light bulb? Please select the reasons why you switched to LED light bulbs.
(Please select all that apply)

[1] I find the quality of light from an LED light bulb is superior.
[2] LEDs appear to dim the same way as incandescent/Halogen light bulbs.
[3] I like the appearance of LED light bulbs.
[4] LED light bulbs last longer than other light bulb types.
[5] LED light bulbs use less energy than other light bulb types.
[6] LED light bulbs have more features than other light bulb types.
[7] LED light bulbs save me money on my utility bill.
[8] For some other reason (Please specify: _____)

AQ06. For the last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. "A-line LED"] light bulb you purchased, approximately how long is the lightbulb on, in total, over a 24-hour duration?
(Please select one option.)
[1] Less than half an hour
[2] Half hour to 1 hour

[3] 1 to 2 hours
[4] 2 to 3 hours
[5] 3 to 6 hours
[6] 6 to 9 hours
[7] 9 to 23 hours
[8] 24 hours (all the time)

AQ07.
When you purchased your last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. "A-line LED"] light bulb, which brand light bulb did you buy?

(Please select one option.)

[1] Philips
[2] GE
[3] Sylvania
[4] Westinghouse
[5] Cree
[6] Feit
[7] TCP
[8] Store brand (or private label)
[9] Others (please specify: _____)
[10] Don't know/not sure

AQ06a. For the last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. "A-line LED"] light bulb you purchased, what room did you purchase the light bulb for?
(Please select one option per row)
[1] Living room
[2] Kitchen
[3] Dining Room
[4] Den/office/study
[5] Master bedroom
[6] Another bedroom
[7] Hallway
[8] Bathroom
[9] Garage
[10] Laundry Room
[11] Outside porch/balcony
[12] Other (Please specify_____)

_____AQ08.

What is your overall satisfaction with the last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. “A-line LED”] light bulb you purchased?
Please use a scale of 1 to 5, where 1 is ‘Completely Dissatisfied’ and 5 is ‘Completely Satisfied’.

(Please select one per row)

	[1] Completely Dissatisfied	[2] Somewhat Dissatisfied	[3] Neither Satisfied nor Dissatisfied	[4] Somewhat Satisfied	[5] Completely Satisfied
[pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. “A-line LED”] light bulb	O	O	O	O	O

AQ09.
How likely are you to recommend the last [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. “A-line LED”] light bulb you purchased to your friends or colleagues?
Please use a scale of 1 to 5, where 1 is ‘Completely unlikely’ and 5 is ‘Completely Likely’.
(Please select one per row)

	[1] Completely unlikely	[2] Somewhat unlikely	[3] Neither likely nor unlikely	[4] Somewhat Likely	[5] Completely Likely
[pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. “A-line LED”] light bulb	O	O	O	O	O

Now, I would like to talk about all of the lighting that you have in your primary home.

Please click 'Next' (>>) to continue...

AQ05a. Do you currently have any integrated LED lighting fixtures (LED fixtures without separate light bulbs) in your primary home?

[1] Yes
[2] No

[3] Don't know/not sure

AQ05. Thinking about your primary home, please indicate how many light bulbs and the type(s) of light bulb technology are used in each room.
(Please insert number of bulbs for each row. Your rough estimate is fine.)

	[SHOW COLUMN OPTION ONLY IF SQ06=D, EXCEPT COLUMN 1 – SHOW FOR ALL]	[1]I don't have this room in my home [EXCLUSIVE]	[2]Incandescent	[3]Halogen	[4]CFL	[5]LED	[6] Other bulb types [PIPE IN FROM SQ06]	[7] Integrated LED Lighting Fixtures [SHOW ONLY IF aq05a=1]
[1]	Living room	O	__	__	__	__	__	__
[2]	Kitchen	O	__	__	__	__	__	__
[3]	Dining Room	O	__	__	__	__	__	__
[4]	Den/office/study	O	__	__	__	__	__	__
[5]	Master bedroom	O	__	__	__	__	__	__
[6]	All other bedrooms	O	__	__	__	__	__	__
[7]	Hallways	O	__	__	__	__	__	__
[8]	Bathrooms	O	__	__	__	__	__	__
[9]	Garage	O	__	__	__	__	__	__
[10]	Laundry Room	O	__	__	__	__	__	__
[11]	Outside porch/balcony	O	__	__	__	__	__	__
[12]	Other (Please specify_____)	O	__	__	__	__	__	__

[AUTOFILL 0 IF LEFT BLANK]

AQ10a.
On average, how many times a year do you purchase light bulbs for your primary home?
(Please select one option)
[1] Less than once a year
[2] Once a year
[3] Once every 6 months
[4] Once every 3 months
[5] Once every month
[6] More than once a month

AQ10.
How often do you purchase light bulbs in bulk (more than one in a box)?
(Please select one option)
[1] Never
[2] Rarely
[3] Often

[4] Always

AQ10a.
Where do you typically purchase light bulbs?
(Please select one option)
[1] Online
[2] Grocery store
[3] Local hardware store
[4] Discount wholesale club (i.e. Sam's Club, Costco)
[5] Commercial big box store (i.e. Walmart, Target)
[6] Home improvement store (i.e. Home Depot, Lowe's)
[7] Other (Please specify: _____)

Now we would like to ask you about your use of smart home technologies. Smart home technologies allow you to control your home appliances and/or lighting through a wireless connection to your smartphone, tablet, smart speaker/display, or other device.

Click Next (>>) to Continue.

AQ11a. Do you have any of the following smart home technologies in your primary home?
(Please select all that apply)

[1] Smart speakers/displays (i.e. Alexa, Google Home)
[2] Smart thermostats
[3] Smart light bulbs
[4] Smart appliances
[5] Smart plugs/power strips
[6] Others (please specify_____)
[7] I do not have any smart home technologies in my home [exclusive]

AQ11. [do not show if AQ11a=7]
Is any of your lighting currently connected to your smart home technologies?
(Please select one option)
[1] Yes
[2] No
[3] Don't know/Not sure

AQ11a. [ASK ONLY IF AQ11=1]
How do you use your smart home technology to control your lighting?
(Please select all that apply)
[1] I use it to control dimming.
[2] I use it to control the color of my bulb.
[3] I use it to turn the lights on and off.
[4] I use it to set a timer to schedule when lights are turned on and off.
[5] Others (Please specify_____)

AQ12. [ASK ONLY IF AQ11=1]

Thinking about the last [INSERT OPTION SELECTED AT AQ02a] lightbulb you purchased, was this a smart bulb?
(Please select one option per row)
[1] Yes
[2] No
[3] Don't know/Not sure

AQ13. [ASK ONLY IF AQ12=1]
Thinking about the last [INSERT OPTION SELECTED AT AQ02a] lightbulb you purchased, do you use a hub to connect your smart bulb to your smart home technologies?
(Please select one option per row)
[1] Yes, there is a specific hub that connects just this smart bulb
[2] Yes, there is one hub that connects all the smart bulbs
[3] No
[4] Don't know/Not sure

SECTION B: ASEMAP™ TRADE-OFF EXERCISE

Thank you for your responses so far. In this section, you will see a list of attributes that might be important to you in choosing light bulbs for your home. We will ask you to rate the importance of these benefits.

PLEASE NOTE THAT THIS SECTION MUST BE COMPLETED IN ONE SITTING. YOU WILL NOT BE ALLOWED TO RETURN BACK TO THE QUESTIONNAIRE IF YOU LOG OUT DURING THIS SECTION.

If you need to pause and return later, please do so before starting this section. This section will take approximately 10 minutes to complete.

Click Next (>>) to Continue.

SECTION C: PRODUCT PERCEPTIONS (5 MINS)_____
Please rate the [pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. "A-line LED"] light bulb that you most recently purchased on how well they meet your expectations on the attribute/feature below. Please use a scale of 1 to 5, where 1 is "Much worse than I expected" and 5 is "Much better than I expected".
[PIPE IN TOP 10 BENEFITS, ONE PER SCREEN]
(Please select one per row)

	1 = Much worse than I expected	2 = Somewhat worse than I expected	3 = About the same that I expected	4 = Somewhat better than I expected	5 = Much better than I expected

[pipe in quota from SQ05a (i.e. Reflector/A-line/Candle wording) and option selected in AQ02a (wording only): i.e. “A-line LED”] light bulb	O	O	O	O	O

SECTION D: ATTITUDES (5 MINS) _____

DQ01.

Please rate your level of agreement with the statements below on a scale of 1 to 5, where 1= “Completely Disagree” and 5 = “Completely Agree”.

(Please select one per row)

	[1] 1= Completely Disagree	[2] 2 = Somewhat Disagree	[3] 3 = Neither agree nor disagree	[4] 4 = Somewhat Agree	[5] 5 = Completely Agree
Refer to list below	O	O	O	O	O

[RANDOMIZE]

A#	Theme	Attitude Label
1	Price Conscious	I want a product that is affordably priced with no unnecessary bells and whistles
2	Price Conscious	The products with promotional prices are most attractive to me
3	Price Conscious	I will buy the item I think best suits my needs regardless of price
4	Energy efficiency	Energy guide information and ENERGY STAR label play a significant role in my product purchasing decisions
5	Energy efficiency	I am willing to pay more money upfront for a product that saves on electricity/gas/water costs over the lifetime of the product
6	Environment friendly	I will pay a premium for an environmentally-friendly product
7	Environment friendly	While I am in favor of protecting the environment, other product aspects take priority for me when deciding on a purchase
8	First mover	If I heard about a new product, I would look for ways to try it
9	First mover	Among my peers, I am usually the first to try out new products
10	First mover	I like to try new technologies

11	Selection criteria	Product appearance is of great importance to me
12	Selection criteria	I like to have the same brand for all my appliances
13	Selection criteria	I think brands reflect the reliability and performance of appliances
15	Purchasing habit	I always do my research by looking at consumer reviews and product ratings before buying an appliance
16	Purchasing habit	I prefer to purchase a new appliance instead of repairing the broken one
17	Purchasing habit	I prefer to purchase a light bulb that looks similar in appearance to my old one.
18	Purchasing habit	My choices are limited by the available models of my most familiar retail store
19	Imitator	I usually try out new products if I see that they are working well for my peers
20	LED specific	I find the quality of light from an incandescent is superior than LEDs
21	LED specific	LEDs don't have the same warm appearance when dimmed as an incandescent light bulb
22	LED specific	LEDs cannot be dimmed to as low a level as an incandescent light bulb
23	LED specific	I am confident that I can find a LED that will work well with my dimmer switch(es)
24	LED specific	I like the way incandescent light bulbs look
25	LED specific	I will only buy LED bulbs if they guarantee more energy savings compared incandescent light bulbs
26	LED specific	I will only buy LED bulbs if I can install them myself
27	LED specific	I always prefer to buy LED bulbs over other technology types
28	LED specific	LED bulbs are safest bulb for the environment
29	LED specific	I will buy LED bulbs if they are proven to last longer
30	LED specific	LED bulbs are too expensive
31	LED specific	I don't believe that LEDs will last as long (or work as well, or save as much energy) as advertised
32	LED specific	So far, I have had good experiences with LED light bulbs

SECTION F: DEMOGRAPHICS

FQ02. Do you have solar panels installed in your primary home to generate electricity?

(Please select one option)

[1] Yes
[2] No
[3] I don't know/not sure

_____

FQ04. Who is your current electricity provider for your primary home?

_____ [OE TEXTBOX]

FQ05. Thinking about the last year, what was your average monthly electric bill?
(Please select one)

[1] less than $25
[2] $25-50
[3] $51 - $100
[4] $101 - $150
[5] $151 - $200
[6] $201 - $250
[7] $251 - $300
[8] $301 - $400
[9] $401 - $500
[10] More than $500
[11] Don't know
[99] Prefer not to answer [exclusive]

FQ06. When was your house built?
(Please select one)

[1] 2018
[2] 2015-2017
[3] 2010-2014
[4] 2000-2009
[5] 1990-1999
[6] 1980-1989
[7] 1970-1979
[8] 1960-1969
[9] 1950-1959
[10] Before 1950
[11] Don't know

FQ07. Approximately, what is the size (square footage) of your primary home?
(Please select one)

[1] Less than 600 sq. ft
[2] 600 sq. ft to less than 1,000 sq. ft
[3] 1,000 sq. ft to less than 2,000 sq. ft
[4] 2,000 sq. ft to less than 3,000 sq. ft
[5] 3,000 sq. ft to less than 4,000 sq. ft
[6] 4,000 sq. ft to less than 5,000 sq. ft
[7] More than 5,000 sq. ft
[8] Don't know

FQ08. Who currently resides in your household with you?

(Please select all that apply)

[1] Significant Other/Spouse/Partner
[2] Children
[3] Other Relatives (extended family)
[4] Roommates (non-family members)
[5] Other_____
[6] No one other than me [EXCLUSIVE]
[99] Prefer not to answer [EXCLUSIVE]

FQ09. How many household members (including you) lives in your home in the following age ranges?

	# of members
[1] Less than or equal to 5 years old	
[2] Between 6 and 17 years old	
[3] Between 18 and 64 years old	
[4] 65 or older	

[99] Prefer not to answer [EXCLUSIVE]

FQ11. Which of the following best describes your current employment status?
(Please select one)
[1] Employed full-time (30+ hours/week)
[2] Employed part-time (less than 30 hours/week)
[3] Stay at home worker without salary
[4] Student
[5] Retired
[6] Business Owner
[7] Other
[99] Prefer not to answer

This completes the survey. We appreciate you taking the time to share your opinion.

Appendix B. Additional ASEMAP™ Preference Curves

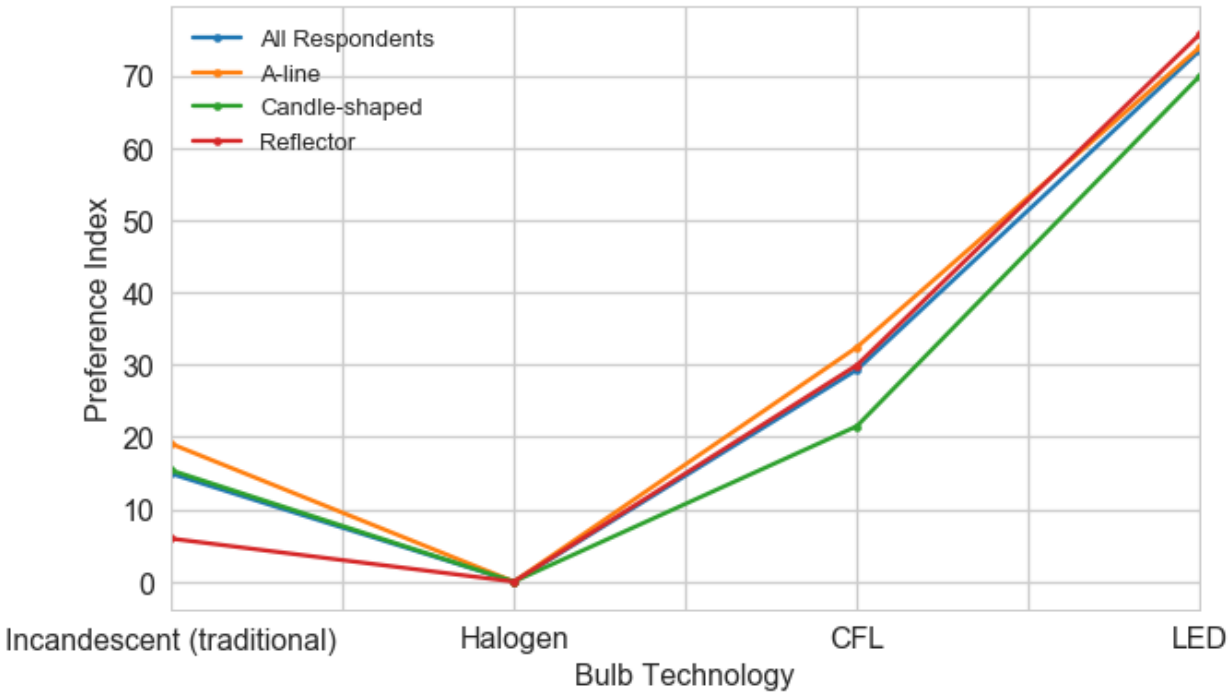


Figure B - 1. Preference curve for bulb technology by shape of the most recently purchased light bulb

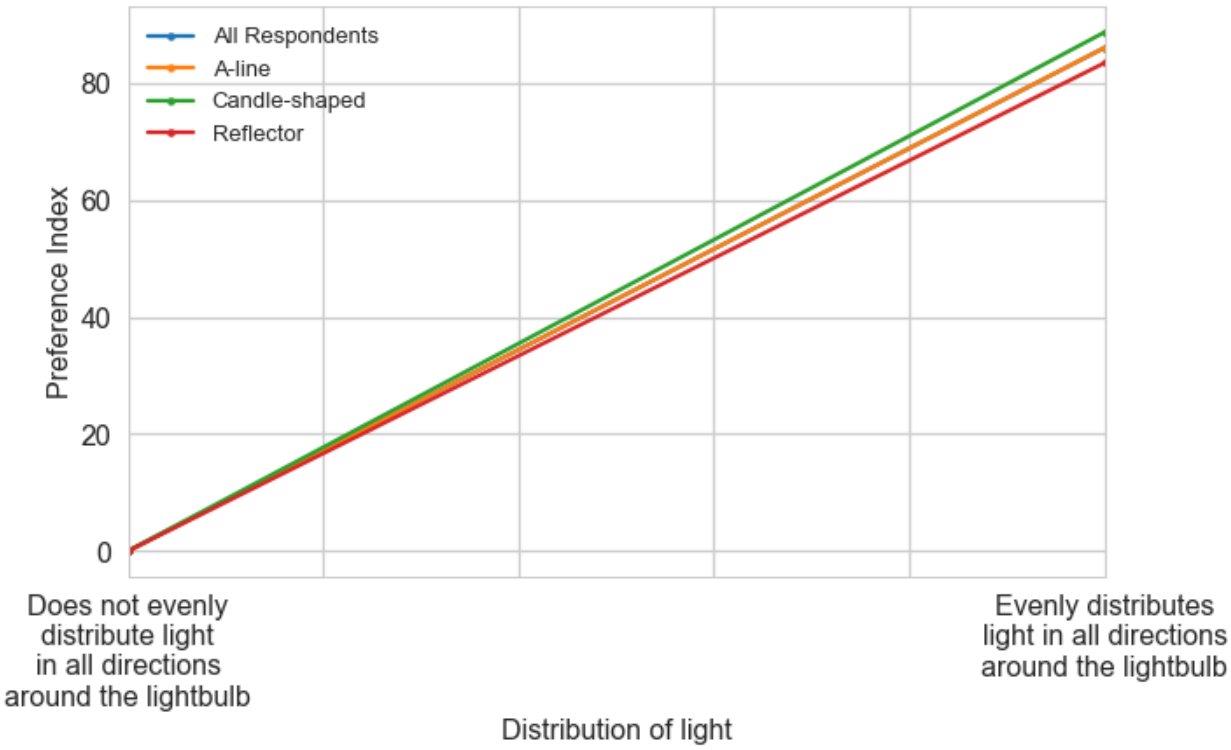


Figure B - 2. Preference curve for distribution of light by shape of the most recently purchased light bulb

In the above figure, reflector purchasers may have interpreted the attribute as the distribution light within the intended beam angle for reflectors rather than evenly around all angles.

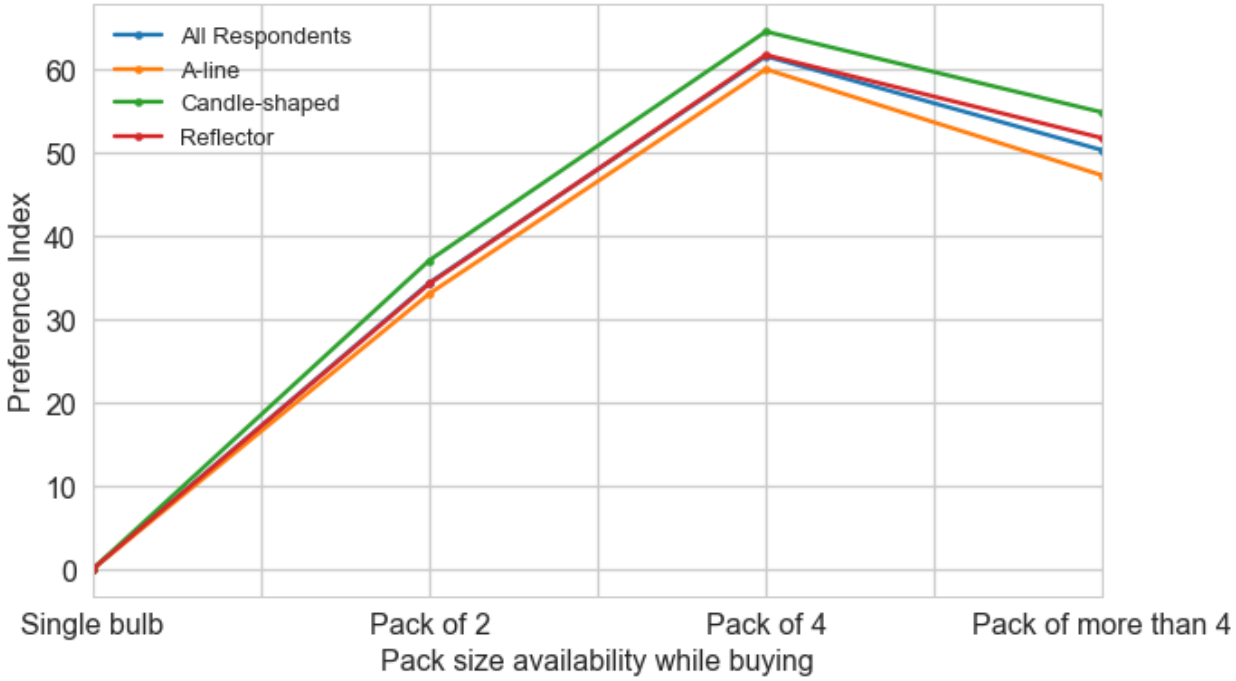


Figure B - 3. Preference curve for multi-pack purchases by shape of the most recently purchased light bulb

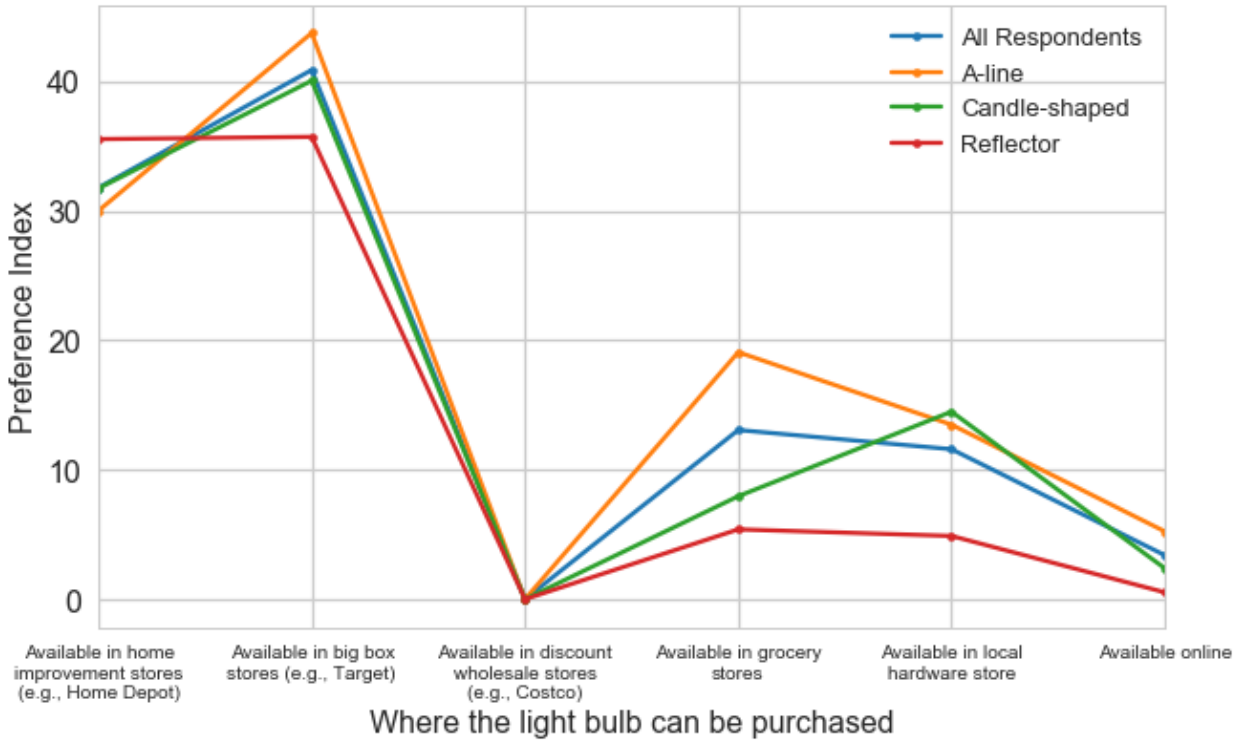


Figure B - 4. Preference curve for where the light bulb can be purchased by bulb shape by shape of the most recently purchased light bulb

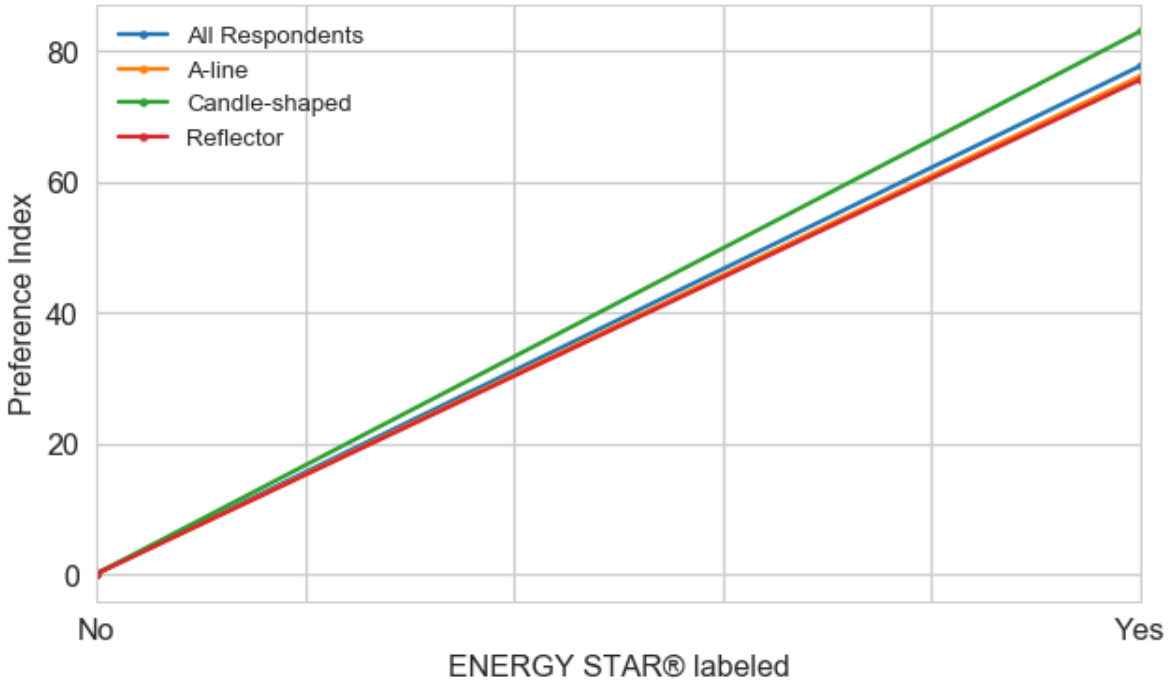


Figure B - 5. Preference curve for Energy Star® label by shape of the most recently purchased light bulb

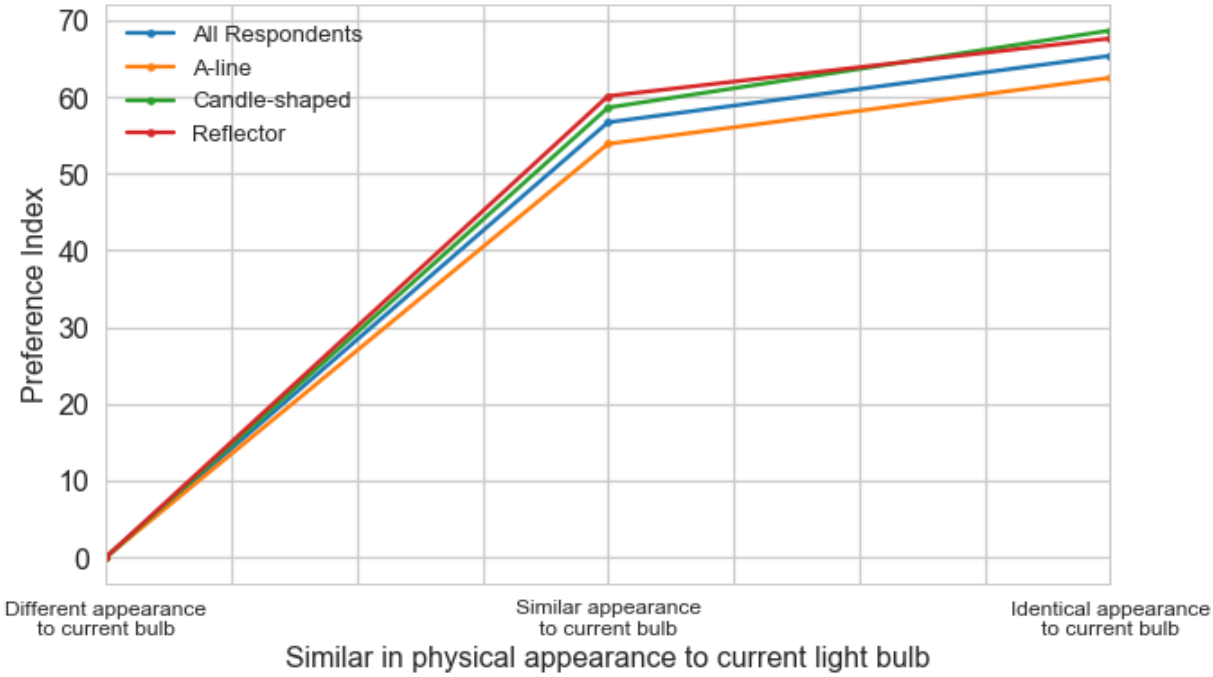


Figure B - 6. Preference curve for similarity in bulb appearance by shape of the most recently purchased light bulb

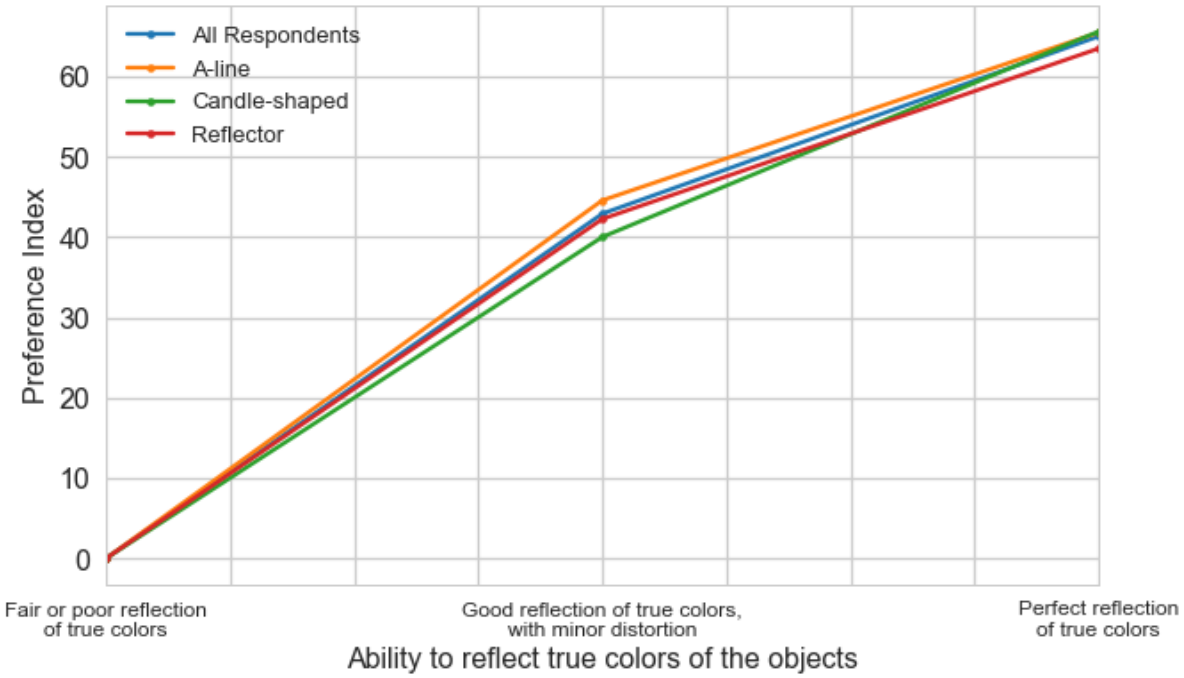


Figure B - 7. Preference curve for similarity in ability to reflect true colors of object by shape of the most recently purchased light bulb

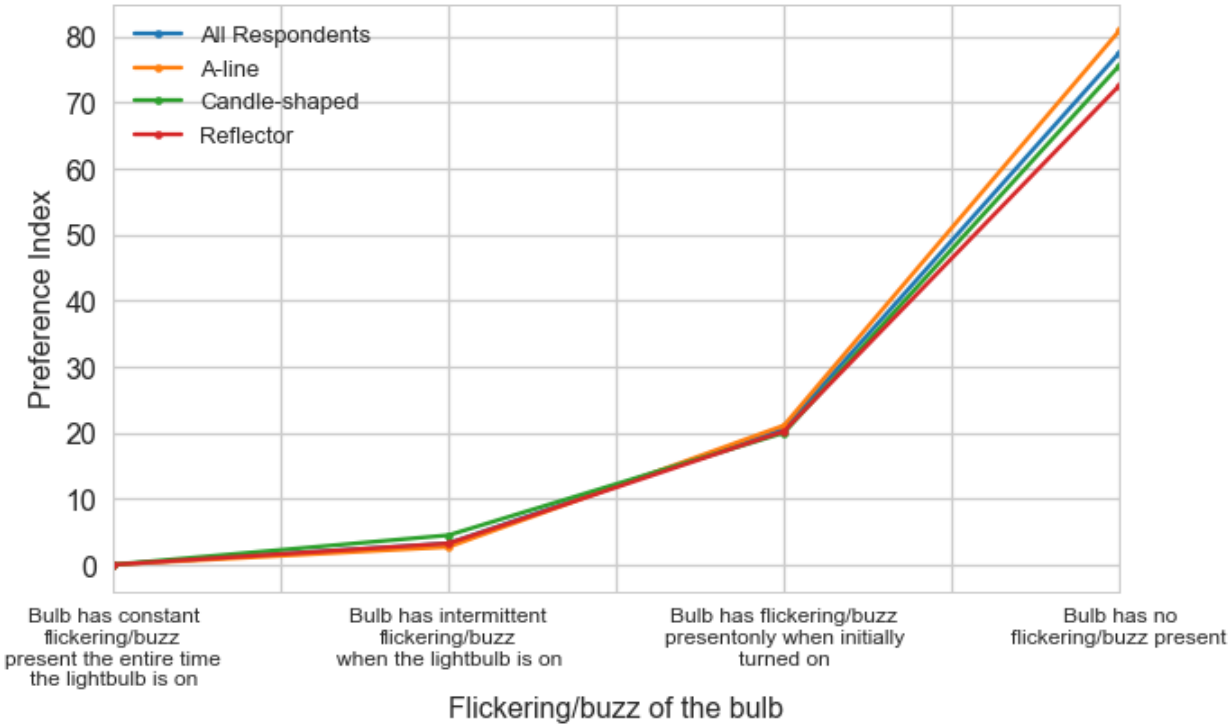


Figure B - 8. Preference curve for flickering or buzz of bulb by shape of the most recently purchased light bulb

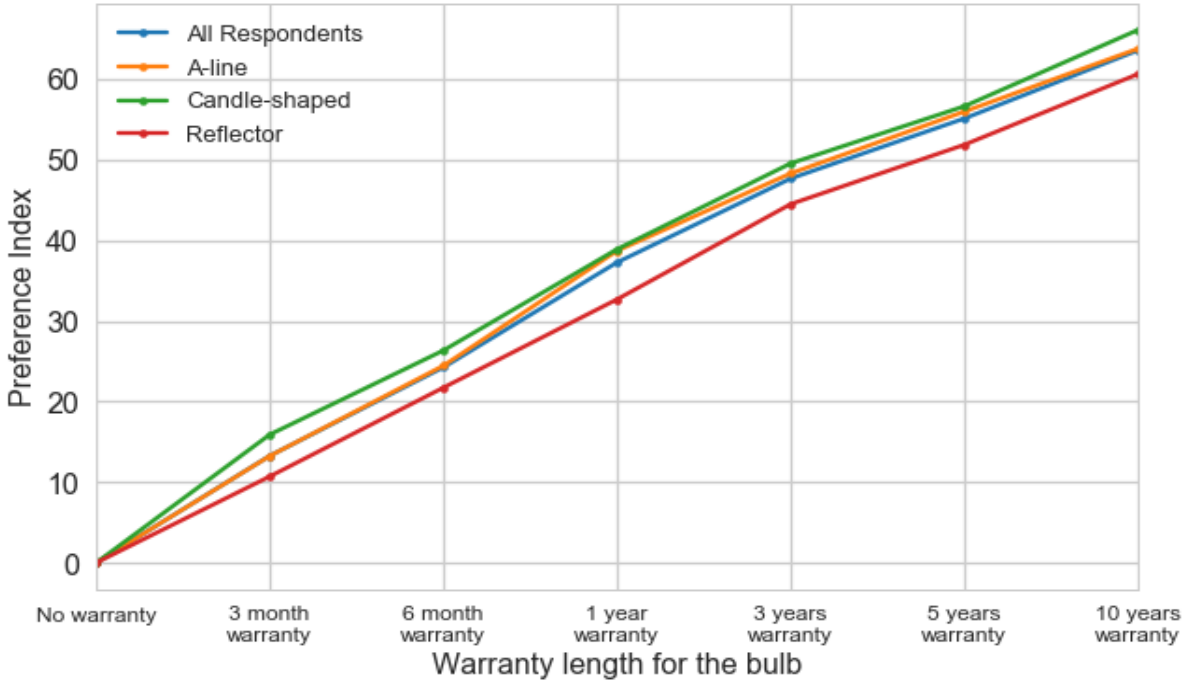


Figure B - 9. Preference curve for bulb warranty length by shape of the most recently purchased light bulb

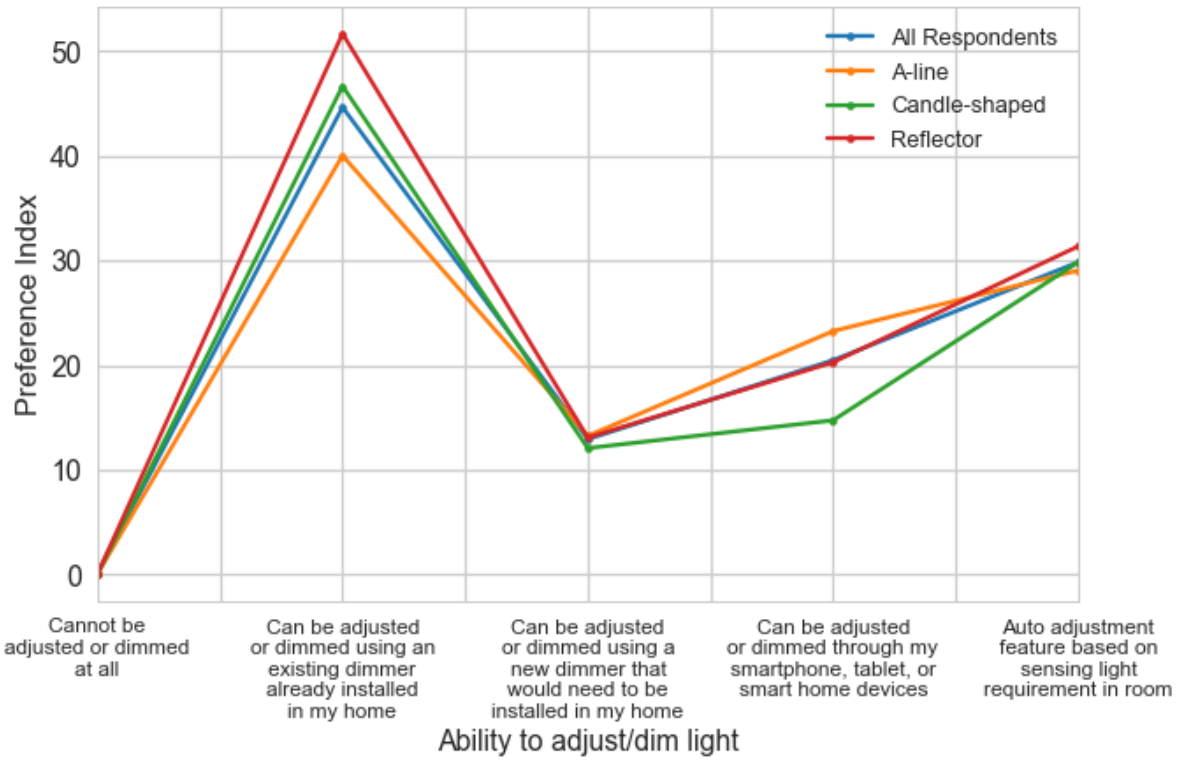


Figure B - 10. Preference curve for ability to dim by shape of the most recently purchased light bulb

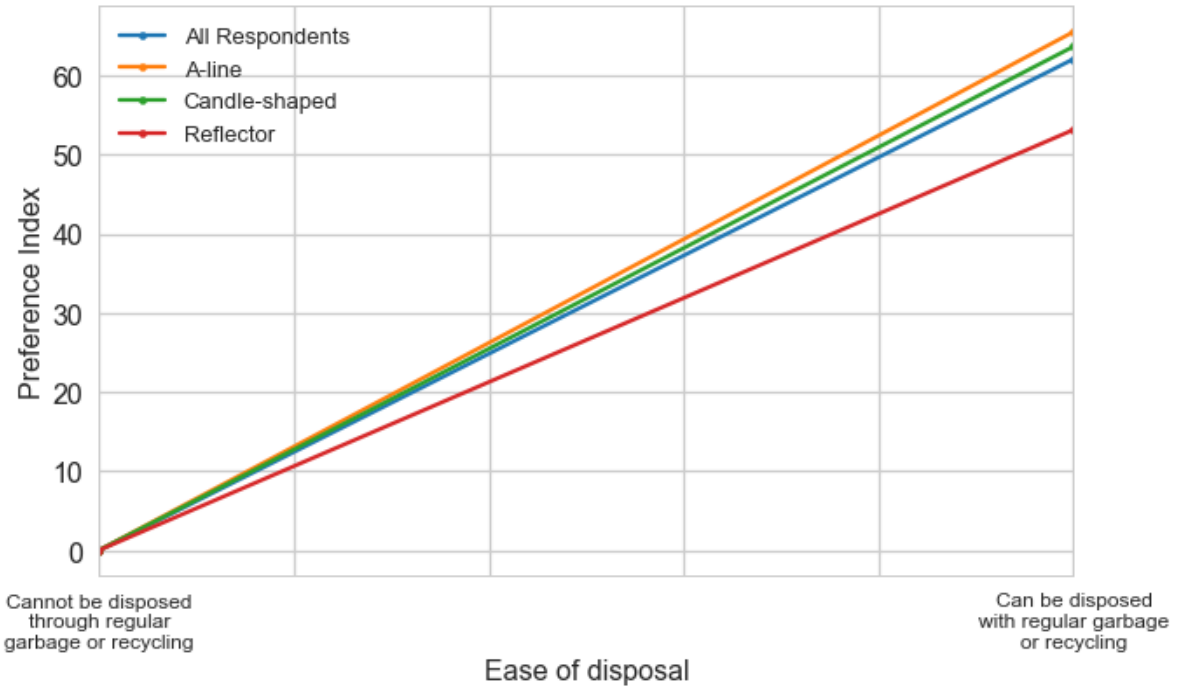


Figure B - 11. Preference curve for ease of disposal by shape of the most recently purchased light bulb

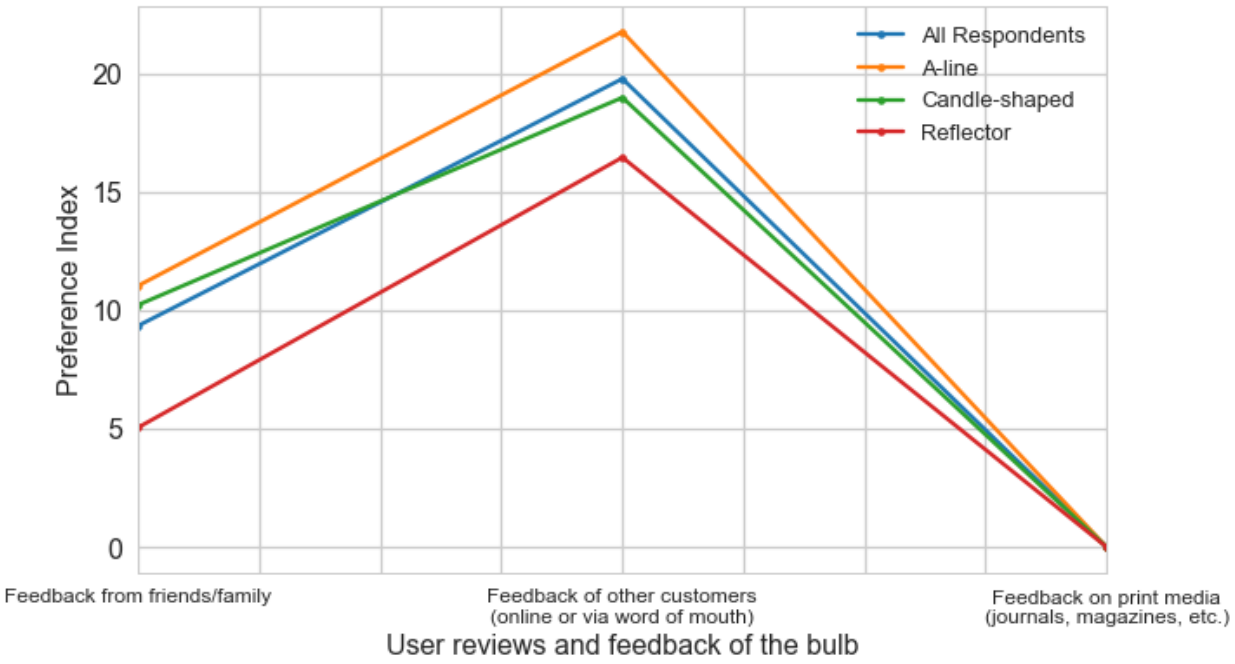


Figure B - 12. Preference curve for user reviews and feedback by shape of the most recently purchased

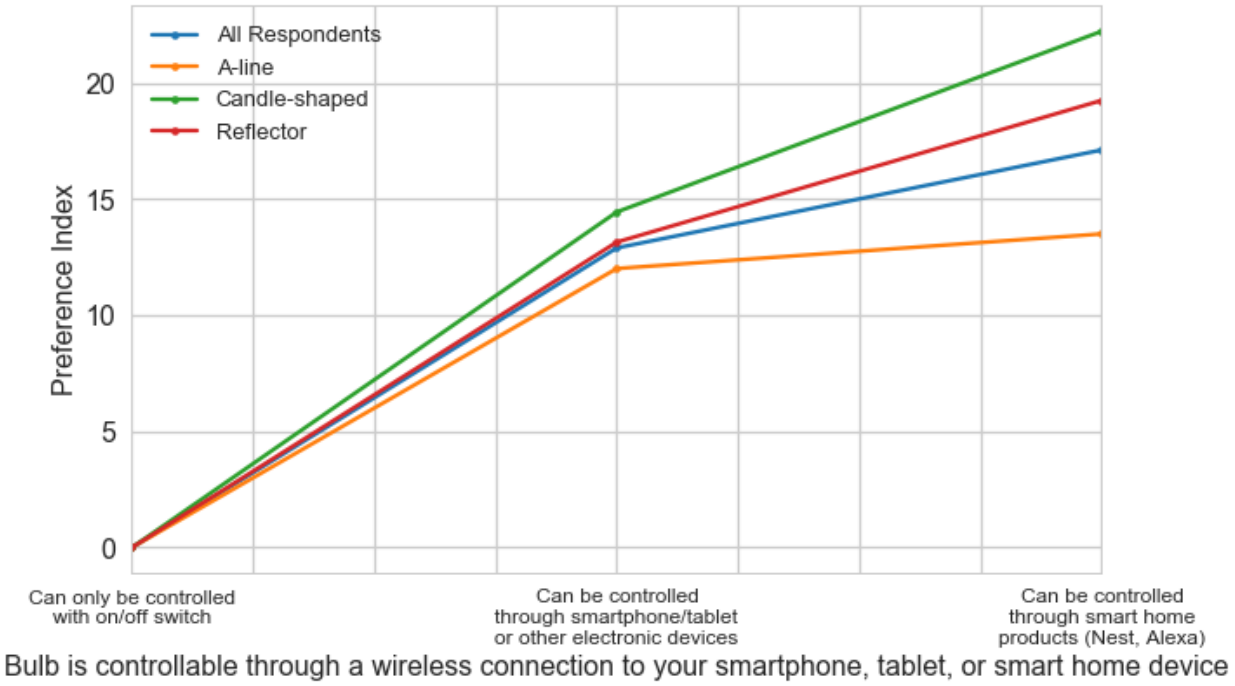


Figure B - 13. Preference curve for ability to control bulb with a smart device by shape of the most recently purchased light bulb