Energy Information and E-Commerce: Evaluating the Effect of Life-Cycle Cost Information on Consumer Behavior[1]

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ABSTRACT

The European energy label for household appliances does not contain any reference to monetary operating cost. But the question whether or not to incorporate such information has been considered frequently. The objective of this evaluation was to assess whether the disclosure of life-cycle cost (LCC) information—i.e. purchase price plus lifetime operating cost—makes consumers opt for more energy-efficient household appliances. We contrast the results from two distinct randomized field experiments conducted at the websites of an online shop for washing machines and a price comparison for cooling appliances. In both experiments, the treatment groups received LCC estimates in addition to the regular energy label information mandated by the European Union. Consumers in the control groups received the regular information only. Consumer reactions were tracked by recording their click behavior. The difference in behavior between treatment and control was evaluated with multiple regressions by controlling for several product characteristics. Our evaluation indicates that LCC disclosure reduces the mean specific energy use of the appliances consumers choose ($p<0.01$), which makes it an interesting approach for promoting the purchase of energy-efficient appliances. On the other hand, LCC information in the format described here is unlikely to bring about higher sales revenue for the online retailer or the price comparison website that supplies the information. Future research should validate this finding.

Introduction

How can information about the energy use of household appliances be provided to consumers as effectively as possible? This old question has recently been reconsidered in the United States and the European Union. While the US has re-emphasized the role of monetary information in the form of yearly operating costs on its Energy Guide label[2], EU stakeholders have spoken out against using monetary costs on energy labels (EC 2008a; FTC 2007).

But does the EU forego a lot of potential energy savings by not integrating operating cost estimates into its energy label? In other words: what is the value added of translating physical operating costs (in kWh) into monetary cost estimates (in euros)?

When shopping for energy-consuming goods, consumers have to compare a wealth of product attributes, including *price* and *energy performance*. Translating physical (kWh) into money figures may simplify energy information by providing a common unit of measurement (Deutsch 2009). Such a reduction in information complexity may contribute to reducing the "energy efficiency gap", that is, the systematic gap between the products demanded in the market and the techno-economic potential (cp. Jaffe & Stavins 1994; Wilson & Dowlatabadi 2007). In fact, research with US consumers has shown that they often demand money units when asked about their preferred energy information format (Deutsch 2009).

This paper summarizes the findings from two online field experiments regarding the effectiveness of monetary and life-cycle cost disclosure that have been conducted in Germany. The remainder of this paper is organized as follows. We first compare energy labeling in the US and the EU to see that the option of providing operating cost has been under discussion for quite some time. Subsequently, we

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[1] Funding for this research was provided by the German Federal Environmental Foundation (DBU).

[2] Note that this article does not refer to the ENERGY STAR label, an endorsement label which was introduced in the United States in the 1990s and which has been adopted by other countries as well (du Pont et al. 2005).

describe our experiment with life-cycle cost disclosure and draw conclusions regarding its potential application.

Energy Labeling and Operating Cost Disclosure in the US and the EU

Fundamentally, the US Energy Guide and the EU energy label resemble each other: Both are mandatory comparative labels for household appliances. They differ, however, in how they present a given appliance's energy use to locate it within the range of products available in the market. While the US Energy Guide employs a continuous linear bar scale, the EU energy label consists of a categorical step ranking system from A (best) to G (worst) with supplementary continuous physical energy units (du Pont et al. 2005; US EPA 1998). In the example shown in figure 1, the EU label's categorical value is "A", and the additional continuous energy information amounts to "325 kWh/year".

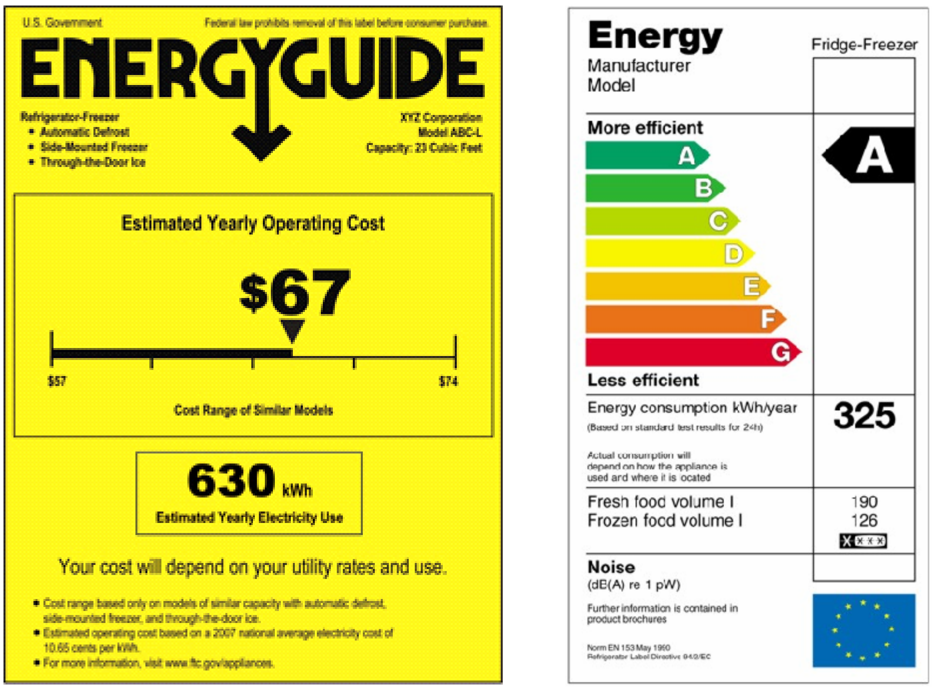

Figure 1. US Energy Guide label versus EU energy label

Historically, energy labeling has varied more strongly in the US than in the EU with respect to its principal format of information (see table 1 below). Introduced in 1979, the US label started out with showing estimated annual operating cost as primary information. But this information was deemed a source of confusion because of the spatial and temporal variance in energy prices and operating cost. Therefore, the US label was revised in 1994, and physical energy units took the place of monetary operating cost (which was retained, but only as secondary information) (Banerjee & Solomon 2003; US EPA 1994). More than ten years later, after consultations with stakeholders regarding the appropriate label information format, the label got revised again, and annual operating costs returned as principal information, seconded by physical information. During the subsequent stakeholder consultation, the Federal Trade Commission (FTC) also discussed the idea of displaying operating cost for several years instead of just one year. This idea, however, was opposed by most stakeholders. They saw problems in the necessity to use a broader set of underlying assumptions and to communicate those assumptions to consumers without creating confusion and skepticism (FTC 2007). As a consequence, the FTC did not pursue the multi-year cost provision any further.

Table 1. The development of comparative energy efficiency labeling in the US and the EU

Label	1979	1994	2007	2008
US Energy Guide label	Annual operating cost as primary information on continuous label	Shift to physical units as dominant information (annual operating cost in smaller figure at bottom)	Return to annual operating cost as primary information (with supplementary physical information)	
EU energy label		Categorical label with supplementary physical units	Annual operating cost considered for inclusion in label	Most stakeholders reject inclusion of annual operating cost

The European Union introduced its first energy labeling directive for household cooling appliances in 1994, followed by directives for other appliances (Europe Economics et al. 2007a). Some years later, the first EU-wide evaluation of the energy label found that operating costs were a frequent issue in shoppers' discussions with the sales personnel (Schiellerup & Winward 1999). Picking up this theme, two studies for the European Commission on potential changes in the label considered the inclusion of running costs (Europe Economics et al. 2007b; Tipping et al. 2006). During a subsequent stakeholder consultation with EU consumer and industry groups, however, it became clear that most participants opposed the idea of including annual operating costs into the energy label (EC 2008b, 2008a). These developments in the US and the EU show very different approaches to energy labeling with respect to monetary information.

The challenge with providing annual operating costs is that energy prices may differ across regions and over time (Europe Economics et al. 2007b; FTC 2007). In liberalized energy markets such as Germany, where consumers can choose between competing energy suppliers, variance in energy prices may occur even between neighboring households. In addition, annual operating cost may depend on an individual's usage behavior, as in the case of washing machines and dishwashers. Such variance and dynamics cannot be captured by an energy label that is static in nature. While price changes over time can be compensated for by means of label updating (FTC 2007), a given households' deviation from national average values for energy prices and usage behavior cannot be coped with. Consequently, annual operating cost figures on energy labels will, in many instances, not be a good estimate of an individual's true energy consumption. Still, they can give consumers a "general idea" of the energy consumption of an appliance under consideration (FTC 2007).

In sum, annual operating cost disclosure comes with several pitfalls. The crucial question for the European Union is: if those problems could be overcome through tailoring operating cost information to individuals, would that information format have a stronger effect on consumer behavior than the physical energy information currently available on the EU energy label?

Previous Experimental Evaluations

Typically, energy labels have been evaluated in regard to consumers' perception, their awareness and comprehension of labels, while much less is known about actual consumer behavior, and how energy information is linked to it (Deutsch 2009; Vine, du Pont & Waide 2001).[3]

When concentrating on physical versus monetary energy information on labels and their differential impact on consumer behavior, only two relevant experimental studies have been published as

[3] Recently, a conceptual model of the effect of life-cycle cost information on consumer behavior was presented (Kaenzig & Wüstenhagen 2010).

journal articles.[4] (Anderson & Claxton 1982; McNeill & Wilkie 1979). Both experiments used variation in information format ("dollars" vs. "kilowatt-hours") as independent variables, and both employed the mean specific energy use of the chosen appliances as dependent variables. In neither of the two experiments, however, did changes in information format bring about significant differences ($p<0.05$) in consumer behavior.

Moreover, no comparable experimental studies have been conducted with more recent energy prices and available appliances, or for the European energy label in particular.[5]

Data, Hypotheses and Approach

Recently, a special kind of operating cost provision, i.e. *life-cycle cost (LCC) disclosure*, has been evaluated with respect to its impact on consumer behavior and its implications for business. LCC refers to the sum of purchase price and lifetime operating cost. Covering different types of household appliances, the evaluation consisted of two distinct randomized field experiments with cross-sectional data from different internet users. The experiments were carried out on commercially operating websites to track actual consumer click behavior anonymously without obtaining consumers' informed consent.

The first experiment for cooling appliances took place in a major German price comparison website. Consumer behavior was measured as clicks on products from the price comparison to final online retailers. The second experiment focused on washing machines, and was conducted in a German online shop, that is, an online retailer. Here, user reactions to LCC disclosure were evaluated by analyzing the characteristics of washing machines that consumers had put into the virtual shopping cart (Deutsch 2010b, 2010a).

Since LCC disclosure promises to make the trade-off between current and future cost more transparent, we hypothesized that LCC would lead to the choice of more energy-efficient appliances.

Research Hypothesis 1: LCC disclosure makes consumers choose household appliances with a different specific energy use.

We could not specify a direction of the hypothesized change in specific energy use *a priori* because the change might have occurred in both directions. On the one hand, LCC information facilitates the comparison of today's and tomorrow's costs regarding appliances. On the other hand, research on decision-making indicates that decision aids, such as, for example LCC disclosure, may actually worsen performance under certain circumstances (Sharda, Barr & McDonnell 1988)[6].

Research hypothesis 2: LCC disclosure changes the sales revenue for the website that supplies the information.

Again, this was a non-directional hypothesis. On the one hand, LCC information may make the website more valuable to consumers and increase its attractiveness, leading to increased sales revenue from household appliances. On the other hand, LCC figures raise the website's information load.

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[4] A similar evaluation problem arises in the context of feedback information on households' electricity consumption, which may be presented in physical figures, or alternatively, in monetary figures. According to a recent review of 21 feedback studies, the analyses available do not allow for separating the effects of physical and monetary energy figures (Fischer 2008).

[5] Current research rather focuses on a revision of the categorical EU labeling format (Heinzle & Wüstenhagen 2009).

[6] In their review of decision support effectiveness, Sharda, Barr & McDonnell (1998) refer to a laboratory study in which participants had to make decisions about advertising expenditures and in which their performance was measured by profits. Here, the users of a decision-support system earned less profit than the nonusers. The review does not report any more details on this particular study, however.

Consumers may perceive such increase in information as cognitively demanding (Chiang, Dholakia & Westin 2005), which, in turn, may impair their shopping experience and reduce sales revenue.

In both experiments, the control group received regular product information, including letter grades for energy performance (A^{++} to F) and specific physical energy use information (kWh/year or kWh/standard washing cycle) as required by the respective EU energy labeling directives. The treatment group received lifetime operating cost and LCC estimates (i.e., the sum of purchase price and estimated operating cost) in addition to regular product information.

Figure 2 below illustrates schematically how consumers in the treatment group could more easily identify appliances with lower operating and life-cycle cost. In this example, product Z has lower life-cycle cost than product A.

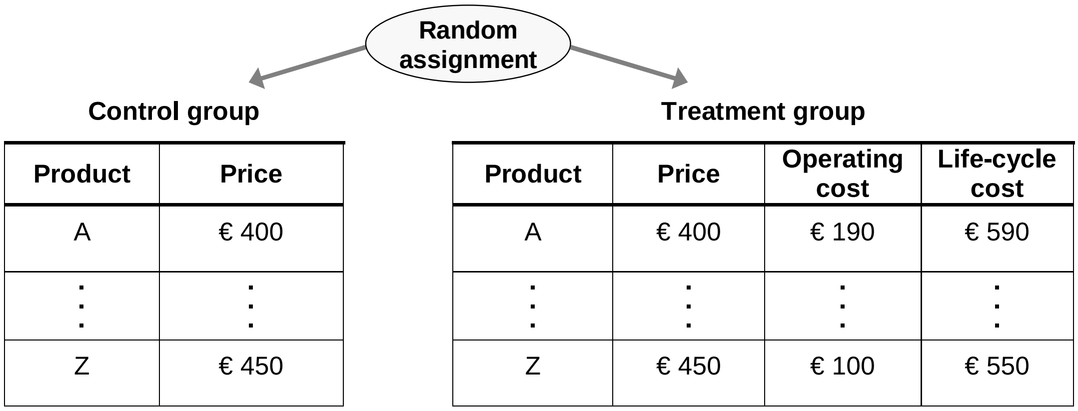

Figure 2. Schematic illustration of procedure and visual stimuli in the two experiments

The key dependent variable was the specific energy use of those products that consumers had clicked on. Operating cost estimates were derived from default assumptions regarding usage behavior, applicable time horizon and prices for energy (and water for washing machines). Users in the treatment group could adjust the assumptions according to their preferences. The default assumptions are given in the table below. They represent mean values for German consumers and are drawn from other publications, as detailed in Deutsch (2010b, 2010a).

Table 2. Default assumptions in the two experiments

Experiment with	Cooling Appliances (Price Comparison)	Washing Machines (Online Shop)
Price of electricity [Euro/kWh]	0.16	0.16
Price of water [Euro/m³]	n/a	3.95
Frequency of use [cycles/week]	n/a	3
Service life [years]	14.4	12.7
Time horizon for estimating operating costs [years]	5	9
Corresponding implicit discount rate (%)	18	6
Reference	Deutsch 2010b	Deutsch 2010a

Operating costs were discounted indirectly by using an equivalent time horizon that was shorter than the service life (i.e. known average value for Germany), reflecting an underlying positive implicit discount rate (see table 2). For a derivation see (Deutsch 2007; Liebermann & Ungar 1983). We calculated LCC as follows

$$LCC = P + ETH * (C_E + C_W) \quad (1)$$

where P = appliance purchase price [€], ETH = equivalent time horizon [years], C_E = annual cost of electricity [€/year], C_W = annual cost of water [€/year], with C_W=0 for cooling appliances.

For continuously operating cooling appliances, C_E was calculated as the product of annual energy consumption (given on the EU energy label) and the price of electricity. For discontinuously operating washing machines, the annual cost of energy and water resulted from multiplying the cost of a single standardized washing cycle with the number of cycles per year. In both experiments, we disregarded any other cost components such as, for example, shipping, installation, or maintenance.

Models

To test whether LCC disclosure affects the specific energy use of chosen appliances, we evaluated consumers' click behavior by means of multiple regression:

$$\ln(energy)_i = \beta_0 + \beta_1 LCC_i + \beta_2 Z_i + \mu_i \quad (2)$$

where *energy* = specific energy use [kWh/unit] of appliance *i*, *LCC* = LCC disclosure treatment dummy variable, *Z* = vector of covariates (including appliance capacity, energy efficiency class, brand, and—in the online shop experiment—additional user preferences), and *u* = error term. For washing machines, a similar model was estimated for specific water use.

Moreover, we used a negative binomial regression model to estimate the effect of LCC disclosure on the number of clicks (count data).

$$ctcount_i = \beta_0 + \beta_1 LCC_i + \beta_2 Z_i + \mu_i \quad (3)$$

where *ctcount* = number of clicks per user *i*, *LCC* = LCC disclosure treatment dummy variable, *Z* = vector of covariates, and *u* = error term.

Data Processing

The original experimental data obtained in this experiment consisted of users' clicks. The observations were stored in the form of server log files, that is, recordings of all users' requests to a given server. Server log files may require data cleaning for two important reasons, first, the existence of non-human user agents, and second, repetitive clicking of human internet users.

One general problem with log files is that they track *all* website activity including website requests from robots, spiders, and crawlers—software that automatically scans the internet for information (Jamali, Nicholas & Huntington 2005; Mullarkey 2004). Such information from "non-human user agents" cannot be easily distinguished from that of human internet users (Peterson 2004). For the purpose of our experiment, these invalid requests had to be filtered out. Generally, non-human user agents may be excluded from the analysis when they identify themselves as such, or when they can be recognized through their Internet Protocol address and further information that is compiled in special blacklists (Nicholas & Huntington 2003). By means of such blacklists, the implementing software company identified non-human user agents in our data set, and subsequently made the processed log files available to the researcher. Unfortunately, the updating of blacklists for robot detection cannot keep pace with the development of new robots. Moreover, some robots mask their user information, allowing them to look like standard internet browsers. Also, “offline browsers” that download entire websites for offline viewing may behave similarly to search engine robots, thereby complicating any differentiation (Tan & Kumar 2002). This problem had to be addressed in the ensuing data cleaning and analysis.[7] To ensure that non-human user agents would not go unnoticed, we looked at each user’s total number of clicks. If this number exceeded a certain threshold, it appeared to be highly inconsistent with human behavior.[8] As a result, we dropped all observations associated with this particular user.

A second problem with server log files is that they may contain interrupted requests. If a user requests a page, then subsequently decides to cancel the operation, the request may, nonetheless, be recorded (Mullarkey 2004). In order to detect such misleading recordings, we scrutinized the log files for repeated clicks from the same internet user. If such behavior occurred, we only kept the first recorded click in the data set.

After data cleaning, the two distinct data sets encompassed 2065 observations for washing machines and 1969 observations for cooling appliances. Still, even after data cleaning, we had no absolute guarantee that all observations caused by non-human user agents had actually been extracted from the data set. In order to minimize the biasing effect of potentially remaining observations from non-human user agents as much as possible, we performed the following robustness check: The relevant regressions were run a second time with a subset of the respective data, with the subset containing only each user’s *final* click. In that way, each user’s influence had equal weight, and a potentially remaining non-human user agent with many clicks could not impact the results that much.

Results

The following table compares the experimental results for cooling appliances and washing machines. All effects reported here refer to multivariate estimates with additional explanatory variables that control for, for example, an appliance’s capacity, its efficiency class or brand. The estimated coefficients for energy use were analyzed for potential bias induced by clicks from non-human user agents as described above, and they were deemed to be fairly robust.

[7] Another potential bias inherent in internet research could not be avoided: Server logs do not provide the full picture of user activity because some elements of a website may be stored on a user's hard disk so that subsequent requests for the same elements may be directed to the hard disk and not to the remote web server (Mullarkey 2004). Such local caching is particularly relevant for backward navigation in a user’s browser. Requests that are cached at the local level are not counted in the sever log under consideration and cannot be adjusted for (Nicholas, Huntington & Williams 2002). In this research, we assumed that local caching was evenly distributed across control and treatment groups so that it did not affect the results significantly.

[8] We chose a threshold of 20 clicks as the cut-off point for an unusually high number of clicks. This threshold was not derived from statistical method but represented subjective judgment. Since there is no fail-safe way of identifying non-human user agents, we also carried out a robustness check as described below.

Table 3. Effects of life-cycle cost disclosure on consumer behavior

Experiment with	Cooling Appliances (Price Comparison)	Washing Machines (Online Shop)
Inferential statistics		
Effect on specific energy use [kWh/unit[a]]	-2.5%**	-0.83%***
Effect on specific water use [L/standard cycle]	n/a	-0.74%*
Effect on indicator of retail volume[b]	-23% **	n/s
Descriptive statistics		
Number of observations	1969	2065
Range of specific energy use [kWh/unit[a]]	84 – 770	0.57 – 1.36
Range of specific water use [L/standard cycle]	n/a	34 – 60
Range of life-cycle cost estimates [EUR]	122 – 4439	549 – 2043
Assumptions and presentation		
Time horizon for estimating operating costs [years]	5	9
Presentation of life-cycle cost relative to product price in the treatment group	very prominent	secondary
Reference	Deutsch 2010b	Deutsch 2010a

Note: *** p<0.001; ** p<0.01; * p<0.05; n/a – not available; n/s – not significant
a) unit: [year] for cooling appliances, and [standard cycle] for washing machines;
b) number of clicks for price comparison, and combination of clicks and appliance prices for online shop

LCC disclosure consistently reduced the specific energy use of the appliances consumers chose in both experimental settings, with the reduction in specific energy use ranging from 2.5% in the price comparison case to 0.83% in the online shop. Moreover, the LCC treatment made consumers choose washing machines whose specific water use was 0.74% lower, relative to the control group. Indicators of retail volume, that is, proxies for the business impact of the treatment, showed a negative effect (-23%) or no effect at all. For the price comparison website, the business impact was measured by the number of clicks from the price comparison to final retailers because each such click generates sales revenue. This number of clicks got reduced by 23% through LCC disclosure. For the online shop (i.e. an actual retailer), the business impact depends on both appliance prices and the number of appliances sold. Here, none of the two indicators differed between experimental groups regarding the chosen appliances; that is, we could not detect any effect of LCC disclosure on business impact in the online shop.

When comparing the effects on energy use, however, one has to bear in mind the different experimental stimuli as well. In the price comparison for cooling appliances, the treatment consisted of placing life-cycle cost at a very prominent position; that is, in the same line and with equal font size as the purchase price. Moreover, operating cost was estimated on the basis of a relatively short default time horizon (5 years) that corresponds to a high implicit discount rate.

In the online shop for washing machines, the reduction in specific energy use occurred in a setting in which life-cycle cost always appeared as secondary information with a smaller font size. Also, the estimated operating cost figures were based on an underlying default time horizon of 9 years, which reflected a lower implicit discount rate. In an ideal world, we would have had full control over all aspects of the experimental design. By varying each influencing factor such as time horizon and prominence of LCC information separately, we would have been able to ascribe differences in outcomes to differences in those factors. Given the field character and the real business setting, however, this was not possible because we had to meet the obligations of our experimental host websites.

Validity of the results

A particular strength of our analysis lies in its high external validity which is due to the fact that consumer behavior was observed in an actual shopping environment. Since consumers were concentrating on appliances and cost figures, we did not have to worry about experimenter effects that experiments in physical environments often have to deal with. Moreover, unlike simulated laboratory experiments, our web-based setting offered real incentives to consumers who were actually intending to buy an appliance. Still, the results from web-based experiments cannot be generalized to the entire population as long as only a subset of the population uses the internet. Moreover, the consumers visiting our experimental websites may have been different from the larger population of internet users. Those are the limits to external validity.

A threat to internal validity is associated with our use of cookies—identification numbers stored on participants' computers (Birnbaum 2004)—to separate control and treatment groups. Since internet users are technically able to delete cookies at will, we did not have full experimental control. This problem may have biased the results, but the most likely resulting bias is conservative in nature, leading to an underestimate of the effect of LCC disclosure on consumer behavior (Deutsch 2010a).

Finally, measurement validity was limited because our instruments were consumers' clicks on appliances. In the price comparison, consumers clicked through to final retailers; in the online shop, they clicked on appliances to put them into the virtual shopping cart. Due to data restrictions, we were not able to measure a consumer's actual final act of purchase—which would have maximized measurement validity.

Conclusions

This evaluation provides evidence from two distinct experimental settings indicating that consumers choose more energy-efficient appliances if LCC information is made available to them. Our finding holds under different conditions regarding the prominence of LCC presentation and the underlying time horizon for estimating LCC. Given that consumer behavior was observed in actual shopping situations, the finding has high external validity and suggests the use of LCC disclosure for promoting the purchase of energy-efficient appliances.

According to our results, however, LCC information is unlikely to bring about higher sales revenue for the online retailer or the price comparison website that provides the information. Due to limitations in measurement validity, this finding needs to be validated with actual data on final purchases. If it holds true, the relevant market actors have no direct incentive to supply LCC information[9]. Under such circumstances, the only conceivable gains might accrue to a website operator who is the first to establish LCC disclosure in his domain, who uses the new feature for marketing, and who may benefit from this distinguished position in the sense of a first-mover advantage.

If it can be consistently shown that the market is unlikely to provide LCC information, policy might may mandate its disclosure. Such a measure would need a consensus regarding the underlying default parameters (electricity price, time horizon, etc). Even if a consensus could be reached here, the question would still be whether the benefits of mandatory LCC disclosure would exceed the costs of implementation. Regarding benefits, the size of the effect of LCC disclosure on specific energy use is relatively small. As a consequence, it holds only small potential for CO_2 abatement. This potential

[9] Note that in our case, the website operators had an additional incentive to take part in the experiment. Since we relied on external research funding (see footnote 1), the cost of providing LCC information was considerably reduced for them. Regarding the effect of LCC on consumer behavior, the website operators' initial assumption was that LCC disclosure would be beneficial for them.

would not warrant an implementation of LCC disclosure in the format described here, in addition to the already existing EU energy label for appliances, as simple cost-benefit estimations show (Deutsch 2007).

Still, there is ample scope for research on the effects of LCC disclosure. The most important question is whether it can be integrated in the sales process in such a way that it would make a positive contribution to sales revenue. To this end, alternative LCC formats may be tested, such as, for example, *annualized* LCC (Quack 2008). Moreover, one could vary the framing of costs because operating costs may be framed as costs, or, alternatively, as savings relative to a reference appliance.[10] Finally, LCC disclosure may be assessed in different settings to strengthen external validity. And internal validity could be improved by getting as close as possible to the final consumer action—by collecting and analyzing data about actual final purchases.

[10] A recent analysis that compared those two options concluded that presenting energy expenses as costs was more efficient that presenting them as savings (Faure 2009). This study, however, did not attempt to assess the business implications of LCC disclosure for the information supplier.

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