University of Warsaw
Faculty of Economic Sciences

Working Papers
No. 5/2020 (311)

Preferences for Demand Side Management—A Review of Choice Experiment Studies

Bernadeta Gołębiowska

Warsaw 2020

UNIVERSITY OF WARSAW
FACULTY OF ECONOMIC SCIENCES
WORKING PAPERS

Preferences for demand side management—a review of choice experiment studies

Bernadeta Gołębiowska

Faculty of Economic Sciences, University of Warsaw
bgolebiowska@wne.uw.edu.pl

Abstract: This review of choice experiment (CE) studies deals with the valuation of electricity supply attributes in the residential sector. We consider the willingness to pay and the willingness to accept changes in the electricity supply. The results could be used to determine consumers' preferences for demand-side management (DSM) programs and could serve as a reference for formulating policies. DSM is an option for constructing a low-carbon electricity system, improving energy efficiency, and achieving the sustainable development of an economy. The results from CEs justify investment in new solutions. The research shows that consumers are open to DSM, but they prefer simple programs to complex ones. Decision-makers could introduce DSM programs that enable power outages and provide compensation for households. The societal advantages of DSM are not obvious to consumers, so the implementation of DSM requires communication and more research on peoples' preferences.

Keywords: choice experiments, demand-side management, energy, households, review

JEL codes: C25, D19, Q41, Q48

Acknowledgments: This study was supported by the National Science Centre under a contract 2017/25/N/HS4/01458 "Consumers' preferences for Demand Side Management in Poland". Funding support is gratefully acknowledged.

1. Introduction

Energy production from fossil fuels is the main contributor to anthropogenic climate change (see e.g., Intergovernmental Panel on Climate Change (IPCC 2019), and public concern about climate change is escalating. According to IPCC's 15th special report, limiting the rise in temperature requires far-reaching, unprecedented, and rapid changes in all aspects of society (IPCC 2019). To reduce CO_2 emissions, which serve as the primary driver of global warming, power systems that depend on fossil fuels must change.

To effect changes in power systems, environmental research interest has turned to renewable energy sources and energy management. Managing the power system could improve electrical efficiency. A well-established solution for energy management is demand-side management (DSM), which involves optimizing actions to efficiently manage energy consumption to cut the costs incurred for the provision of electrical energy. The most important instruments of DSM are demand-side response and time-varying tariffs.

DSM has multiple benefits. It increases flexibility on the demand side of the energy system and helps to achieve environmental targets through controlled consumption. Changes in load profiles decrease running costs of electric systems, for both production and delivery, and allow for deferring or even avoiding investments in supply-side capacity expansion. Energy management is expected to contribute significantly to climate change mitigation and energy security. However, the successful implementation of DSM depends on the willingness of residential consumers to accept the necessary measures. During the design of new solutions, negative effects on consumers' comfort and convenience need to be recognized so they can be addressed.

In this study we reviewed surveys that were designed to obtain consumers' evaluations of electricity services. Such information can help in designing DSM policies that are acceptable to society. We analyzed the values for the attributes of electricity supply and the trade-offs between daily comfort, system efficiency, and cost. The review provides useful data for policy-makers who design DSM programs because they need to know the values that people place on the attributes of electricity supply. We focused on the residential sector, which makes up a large share of total electricity consumption. The control of households' electricity consumption in the residential sector helps to achieve flexibility in the system and makes it more secure and sustainable. The newly amended Directive on Energy Efficiency (2018/2002) updates the policy framework to 2030 and beyond. The directive encourages end-users to actively participate in energy markets and profit from optimal price conditions. Consumers can make the grid more efficient and balanced, and thus contribute to the integration of renewable energy sources.

Designing DSM programs requires an in-depth analysis of the impact on end-users because access to a continuous and reliable supply of electricity is crucial for all economic activities. The customer value perspective is important for the implementation of DSM. In order to inform policy discussions and decisions, economists have developed methods for estimating the gains or losses that people may experience due to changes in provided goods. The stated preferences (SP) technique differs from traditional approaches for estimating economic value, which are based on revealed preference data obtained by observing individual choices in real markets. SP methods measure individuals' preferences based on decisions made in hypothetical choice situations. The choice experiment (CE) is an SP method that is often used in the valuation of environmental goods, and it enables estimating the value that people put on electricity services.

We identified CE studies that investigated individuals' preferences for electricity services and estimated the value they placed on specific electricity attributes. Our review included 40 CE studies from around the world that were published in 2000–2019. It summarizes the estimation for willingness to pay (WTP) or the willingness to accept (WTA) changes in electricity supply. The findings contribute to the literature about DSM and may aid in designing cost-effective programs that are acceptable to consumers. As such, the results are a base for effective DSM implementation. Furthermore, the review could help to improve the application of CEs in the context of electricity services. The review also summarizes recommendations for future CEs.

2. Material and methods

A systematic review of published CEs on electricity supply was conducted, using EBSCO,[1] to identify English language articles available in print or online between 2000 and 2019 from all around the world concerning DSM in households, or related to electricity services Search terms included three topics:

[1] EBSCO is a library discovery service that is the leading provider of research databases, e-journals, magazine subscriptions, and e-books.

1. DSM-related issues: "demand-side management," "direct load control," "tariff(s)," "critical peak pricing," "time-of-use," "real-time pricing," "electricity," "electric power," "power outage(s)," "blackout(s)".

2. Method: "discrete choice experiment(s)," "discrete choice model(l)ing," "stated preference," "conjoint analysis," "conjoint measurement," "conjoint studies," and "conjoint choice experiment(s)," "willingness to pay," "willingness to accept"

3. The subject: "households," "residential sector"

We identified 40 CE studies used in the DSM context. Exclusion criteria included discussion of small-scale R&D programs, private sector, public sector, and theoretical aspects of DSM policy; studies related to renewable sources of energy (if attributes were related to the energy generation only); and documents not written in English.

Detailed consideration was given to five issues:

- the experimental design;
- estimation procedures;
- attributes;
- willingness to pay (or willingness to accept); and
- implications for the policy.

These issues reflect the aims of the studies and possible usefulness of their results, with three of them providing details on the CE design and methods of estimation. These details provided an opportunity for comparing different approaches for the estimation.

In our review, we summarize the specific changes in the electricity supply that were analyzed in CEs and what the findings imply. In designing DSM programs, policymakers need to know the values that people place on attributes of the electricity supply. In particular, they need to know the following:

- which changes in the electricity supply are less harmful to society and require the lowest compensation (WTA), and
- which attributes of the electricity supply are the most important for people, that is, the attributes for which people are willing to pay more for improvement (WTP).

Studies have shown that WTA is usually higher than WTP (Horowitz and McConnell 2002). One explanation is grounded in the theory of "loss aversion," which posits that losses are weighted more heavily than gains (Tversky and Kahneman 1991). Economic theory explains this resistance to loss is determined by the information costs arising from resolving the uncertainty about the real value of the good and the irreversibility of loss (Zhao and Kling

2001). The disparity between WTA and WTP could be minimized through the use of a realistic study design (Frondel et al. 2019). The choice between WTA or WTP as the appropriate measure of value depends on the presumed endowment of property rights.

3. Theory

3.1. Demand-side management

The term *demand-side management* was first introduced by Gellings (1985). DSM modifies consumers' demand for electricity through various methods, such as education and financial incentives. It includes the planning, implementation, and monitoring of the utility appliances and programs, and it ultimately influences electricity demand by changing the consumption patterns of individuals to attain the desired load shape. Examples include providing information to users to support efficient behavior and installing new smart technologies that can be automatically controlled, as well as load management, strategic conservation, building loads, and power marketing. The method can improve electric power efficiency, while accounting for technical constraints and the environment. Its use could increase flexibility on the demand side of the energy system and help achieve environmental targets through controlled consumption. Ordinarily, the goal of the DSM is to encourage consumers to use less energy during peak hours. Programs do not necessarily decrease total energy usage but could be expected to reduce the need for investments in distribution networks or power plants.

Residential consumers have the potential for balancing supply and demand in real-time because the domestic sector makes up a large share of total electricity consumption. According to World Bank (2018) estimates, energy conservation and increased efficiency at the household level can reduce energy needs by 15%. Households could thus allow additional capacity and energy for the market, while being paid for changing consumption patterns. Optimal implementation of DSM is equivalent to a "virtual power plant" because it helps to balance supply and demand, even in extreme cases. In fact, by reducing the overall load on an electricity network, DSM programs have many beneficial effects, including mitigating electrical system emergencies, increasing the reliability of the system, and reducing the number of blackouts. Additional benefits might also include deferring large investments in generation, transmission, and distribution networks. In sum, DSM improves energy efficiency and helps balance electricity supply and demand (Smart Energy Demand Coalition 2016).

DSM has value for both transmission system operators and market players; however, it is still surprisingly underdeveloped in most European countries. According to the literature, DSM has been successfully implemented in competitive markets when customer participation is significant (see Alasseri et al. 2017). The United States is the leader of incentivizing participation in the market by electricity providers who implement DSM. Some European markets have also embraced the importance of facilitating access to the energy market to ensure the security of electricity supply. Nevertheless, there is a need for further development. Most of the analyses of DSM come from the business sector, but researchers are increasingly interested in the concept and the conditions under which DSM is efficient and cost effective.

DSM affects the evolution of the electricity mix, which is increasingly characterized by high shares of renewable energy. The integration of renewable energy resources has led to large variations in energy supply and has added uncertainty to power systems. The introduction of more renewable energy sources necessitates more research on innovative DSM programs. The implementation of DSM may ensure more economical and safer operation, while also making the system flexible enough to accommodate the ebbs and flows in energy supply.

Demand flexibility in the electricity market could be fostered through cooperation with customers. One problem faced by policymakers is the lack of motivation for load shifting in the household sector because customers are reluctant to change their habits and way of life (Tomczykowski 2014). The social acceptance of DSM needs to be considered because the main challenge in implementing DSM is getting consumers to participate. Households might be willing to change their electricity consumption for monetary compensation, but this approach raises numerous questions. What is the value that people place on electricity supply attributes? How much are they willing to pay for improvement in the services? How much should consumers be paid to encourage them to change their daily habits? Economics techniques provide the tools to answer such questions.

3.2. Choice experiment method

Economic value is one measure of the benefit provided by a good or service to an individual. The interpretation of economic value is "the maximum amount of money a specific actor is willing and able to pay for the good or service." Economists use two methods to assess the non-market valuation of goods:

- revealed preference techniques, which explore preferences through people's actions in the market, and

• SP techniques, which involve asking people to state their preferences for alternative circumstances (Bennett, Blamey, 2001).

The SP techniques provide flexibility in estimating the total economic value associated with particular goods. As an SP method, CEs are often used in the valuation of environmental goods.

Choice techniques were introduced in psychology in the 1960s (e.g. Anderson 1962; Luce and Tukey 1964) and have been used in the marketing since the 1970s (e.g. Green et al. 1972; Green and Rao 1971). In marketing, the techniques are known as conjoint analysis (CA) (Green and Srinivasan 1978), which has played an important role in understanding and predicting consumers' decision-making and choice behavior. CA became popular in the late 1970s and the 1980s, and economics researchers developed a theoretical foundation for choice modeling using random utility theory (see Ben-Akiva and Lerman 1985). This foundation provides a comprehensive way to conceptualize market behavior. However, the term *conjoint analysis* is no longer used in economics literature to specify that CE approaches are founded in economic theory (as opposed to marketing). However, CEs share the following with CA:

• defining key attributes that are the base for preferences, with levels assigned to represent a range of variation relevant for the research purpose,

• using the experimental design or other technique to combine attribute levels into scenarios to be evaluated,

• analyzing respondents' answers with statistical models (Bennett and Blamey 2001, p.24).

CEs and CA differ with respect to task characteristics and the models used to analyze responses, but the main difference lies in their theoretic foundations. CA is based on the theory of "conjoint measurement," with most CA methods being based on statistical considerations, rather than behavioral theory. Typically, in a conjoint analysis, respondents evaluate the product configurations independently of each other and rate them on attractiveness scale. The cost attribute does not have to be included. CEs are more general than conjoint analysis and are based on random utility theory. Random utility theory allows eliciting preferences for complex multidimensional goods, from which models of preferences can be estimated (Manski 1977). The theory assumes that the utility (benefit, or value) that a consumer derives from item A over item B is a function of the frequency with which an individual chooses item A over item B in repeated choices (Duncan 1959). The CE method is consistent with the characteristics demand theory developed by Lancaster (1966). This theory states that people derive utility not from the goods themselves, but from their characteristics. Consequently, predictions of how consumers' behavior changes rely on studying the characteristics rather than the goods involved. Because there is some uncertainty about an individual consumer's choices, predicting them perfectly is impossible. Instead of identifying one alternative as the chosen option, probabilistic choice modeling assigns a probability of being chosen to each alternative.

CEs make estimating the marginal valuations of attributes possible, specifically, WTP or WTA for a unit change in each attribute estimated. The WTP reflects the maximum amount of money that an individual would pay to obtain a good and therefore identifies a purchase price for an improvement or gain. The WTA, which represents a loss, reflects the minimum amount of money required for a person to renounce the good and provides a selling price. Research shows the disparity between WTA and WTP—for most people, a reduction in losses is worth more than giving up gains (Horowitz and McConnell 2002). Correct framing of the valuation question and payment vehicle is crucial

CEs could be used to evaluate WTA in the context of DSM programs; for example, they can be used to assess WTA direct control over electricity usage. Further, compared with estimating WTP/WTA for the good or service as a whole, gathering detailed information on WTP/WTA by attribute is more applicable to DSM design (Hanley et al. 2001). Such information in the electricity sector would be useful for policymakers because the results can be analyzed by subgroup and it is possible to consider the extent to which individuals' characteristics affect the marginal valuations.

4. Results

4.1. The review data

The literature search for CEs in DSM related to electricity supply generated several dozen possible references. Based on the abstracts, 40 references met the inclusion criteria. Figure 1 shows the number of selected CE studies published by year from 2000 to 2019.

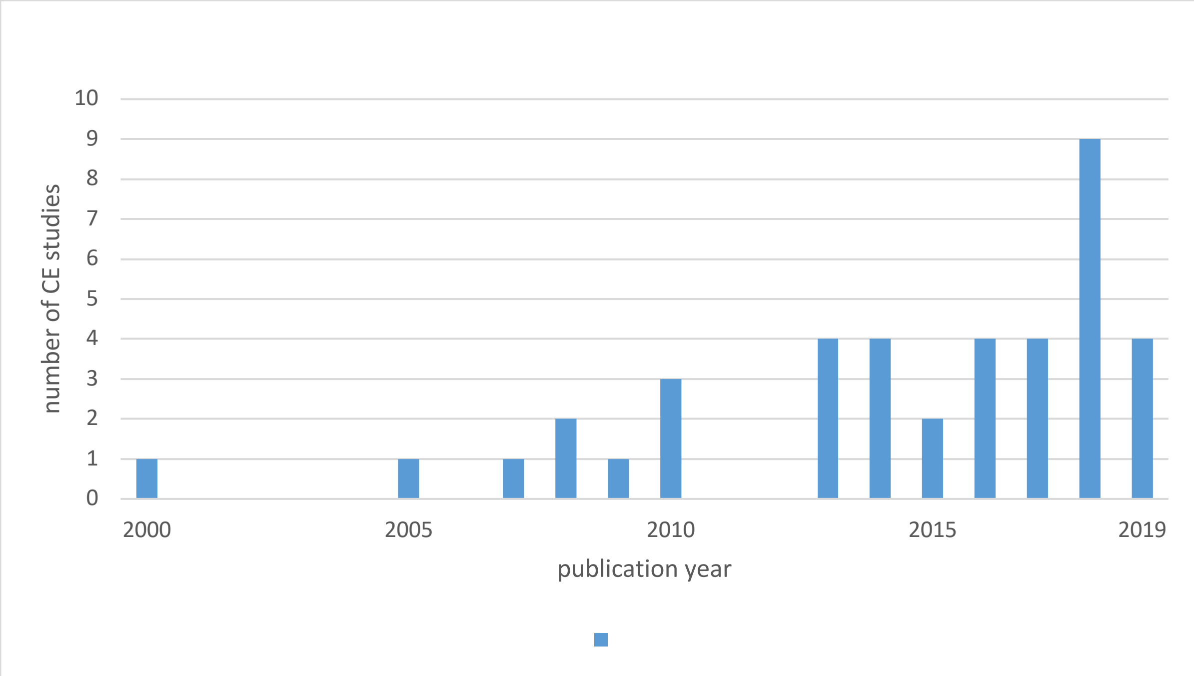

Figure 1. Number of CE studies by the year of publication

Most of the selected studies were published in 2018. We included five studies that used choice-based CA. Table 1 summarizes the studies' characteristics.

Table 1. CE studies in DSM context – background information[2]

Item	Category	Number of studies
Country of origin	Germany	6
	Japan	4
	Great Britain	4
	Sweden	3
	Switzerland	3
	Korea	3
	US	3
	India	3
	Kenya	2
	Belgium	2
	Italy	1
	Spain	1
	Austria	1
	Bangladesh	1
	Finland	1

[2] The number of studies does not add up to 40 for each item because of lack of the data

	New Zealand	1
	Greece	1
	Israel	1
The sample size	200>	3
	200-399	13
	400-599	6
	600-999	5
	1000-1999	9
	2000<	5
Number of attributes (including the cost attribute)	2-3	6
	4	7
	5	11
	6	11
	7	2
	>7	2
Number of choices per respondent	<4	2
	4-6	14
	7-9	10
	>=10	10
Cost attribute	WTP for electricity service improvements	34
	WTA payment for service reductions	6
Methods	Conditional logit model	12
	Mixed logit model	15
	Multinomial logit	6
	Hierarchical Bayes	4
	Random effects probit model	1
	Regressions	2
	Cluster analysis	2
	Latent class model	1
	Maximum simulated likelihood	1
	Logit regression	1

Most of the analyzed CEs were conducted in Europe (23 studies).

Most of the analyzed CEs were conducted in Europe (23 studies). Sixty-two percent of the studies included five or fewer attributes, 28% of the studies used six attributes, and four studies used seven or more attributes to define utility or preference. The mean number of attributes was five.

All CEs included a monetary attribute in the form of a fee (an annual or monthly increase in the electricity bill), an increase in electricity prices, an additional cost of the service, or a compensation. WTP was used in the studies in which respondents considered an improvement in the electricity supply, for example, avoiding an increase in the average duration of a power outage by 1 minute or visualization of electricity consumption (rebate in the electricity bill). WTA was estimated for a deterioration in the supply, for example, the control of household electricity during peak hours.

Among the analyzed studies, 85% and 13% provided estimations of WTP and WTA, respectively, and 2% (CA studies) did not include the cost parameter.

Among 40 analyzed studies, five CEs estimated the WTA compensation for a change in the supply. Consumers were offered a reduction in their electricity bill if they accept a change in their electricity supply. Below we list the attributes evaluated by using WTA:

- duration of power outage (Abrate et al. 2016);
- dynamic tariffs (Buryk et al. 2015);
- control of electricity consumption, data sharing (Broberg, Persson 2016);
- control of electricity consumption, data sharing (Daniel et al. 2018); and
- electricity distribution contract, electricity sales contract, remote control of heating remote, control of electricity system-level, emissions reduction (Ruokamo et al. 2018).

We found one study (Accent 2007) that combined both types of cost attributes: a fee and a form of compensation.

For many attributes analyzed in the CEs, significant differences existed between customers' WTP for electricity service improvements and their WTA payment for service reductions. Customers required higher payments for service reductions compared with service improvements, which was in line with CE literature (Horowitz and McConnell 2002). One study that used CA (Dütschke and Paetz 2013) did not include the cost parameter.

The mean number of choice sets in the analyzed was 8, while the most frequently used number of choice sets was 4 (7 studies) or 6 (6 studies). The most popular methods for analyzing the data were a mixed logit model (15 studies) and a conditional logit model (12 studies). A mixed logit model relaxes the assumptions of standard logit, the assumption of normal distributions (for the coefficients associated with the attributes of the utility variables), and the same coefficients for all individuals (McFadden and Train 2000). This model is more flexible and allows for correlation in unobserved factors over time, substitution patterns, and random taste variation. It can approximate any random utility model.

4.2. Areas of application

The quality of electricity distribution services is an important aspect of the provision of electricity. Households require fulfillment of their electricity needs at any time. Service quality measures for electricity include reliability (the number of interruptions and the total time off supply), quality of supply (voltage fluctuations, continuous and waveform distortion), and customer service. Poor quality of the supply can not only be a nuisance but also cause financial losses.

This review describes how domestic customers value a range of potential improvements and deteriorations in the distribution of their electricity services in different countries. The review also details the organization of the power market. Findings could be used by policymakers when introducing a new policy and by utilities in designing new contracts or identifying customer groups. Most authors point out the practical nature of the results from CEs. For example, studies that identify the damage caused by the poor quality of electricity supply help in determining desirable investments. However, a better understanding of people's preferences for services is needed prior to making improvements in electricity efficiency.

In the reviewed papers, the reasons underlying CEs for electricity can be categorized as follows:

- managerial or policy decisions, justifying investments, helping decision-makers in the utility companies design new products and services (Abrate et al. 2016, Bliem 2009, Broberg and Persson 2016, Abdullah and Mariel 2010, Accent 2007, Dütschke and Paetz 2013, Goett, Hudson and Train 2000, Huh et al. 2015, Kaenzig et al. 2013, Mengelkamp et al. 2019, Morrissey et al. 2018, Nakai et al. 2018, Ndebele et al. 2019, Ozbafli, Jenkins 2019, Pepermans 2011, Ruokamo et al. 2019, Schlereth et al. 2018, Shim et al. 2018, Tanaka, and Ida 2013, Yoshida et al. 2017),
- improving the methodology for CEs (Blass et al. 2010, Carlsson, Martinsson 2008, Daniel, et al. 2018),

- examining the preferences for smart equipment and smart electricity services (Ida, Murakami 2014, Kaufmann, et al. 2013, Pepermans 2014, Richter, Pollitt 2018)
- clustering the customers (Albani et al. 2017)
- analyzing emerging markets in developing countries (Amador, et al. 2010, Breit et al. 2016, Graber et al. 2018, Sagebiel, Rommel 2014, Zemo et al. 2019),
- helping to achieve environmental goals through efficiency gains and the use of renewable sources of energy (Buryk, et al. 2015, Longo et al. 2008, Mahmoodi et al. 2018, Shin et al. 2014)

Most CEs aimed to provide an argument for improving electricity services. In most studies authors not only estimated the WTP/WTA but also analyzed the impact of households' characteristics on these values.

4.3. The main findings

4.3.1. The attributes

A key aspect of designing a CE is defining the attributes and their levels. Most researchers apply qualitative methods (e.g., focus groups, individual interviews) to define attributes and their levels. Pilot studies were used to develop the questionnaires and CE designs and to better understand CE responses. Table 2 presents the attributes related to the electricity supply analyzed in recent studies (see detailed data in the Appendix).

Table 2. Electricity (non-price) attributes analyzed in CEs

The attribute	The number of studies
duration of outages	17
number of planned outages	14
tariff model	11
power mix/the share of renewable energies	10
type of distribution provider	6
customer service	6
load control	6
data usage/information sharing	5
emissions reduction	5

Billing options	5
electricity monitoring/feedback/visualization of the consumption	4
time of the outage	4
electricity savings/technical support	3
advance notification of an outage	3
smart meter	3
contribution of the electric power company	2
location of generation	2

Other attributes included in the CEs were the following:

• short power interruptions, provision of information, and restoration of supply,

• notice for planned interruptions,

• undergrounding of overhead lines for amenity reasons,

• network resilience to flooding, resilience of the network to storms,

• communication channel, sign-up bonuses, websites,

• bundled services,

• off-peak discount, peak surcharge,

• certification,

• price guarantee,

• cancellation period,

• remote meter reading,

• home security and surveillance services with alert functions,

• the number of employees in the power sector,

• co-determination rights,

• transparent pricing policies, and an electric utility's profit distribution,

• investment (initial investment a customer is willing to take when changing electricity procurement),

• call waiting time,

• length of the fixed-rate contract,

• loyalty rewards,

• introduction of e-prosumer groups,

• forest damage,

• institutional set-up,

• hours of supply, and quality of supply (voltage fluctuations, dimming of lights,

• burning of small electronic equipment).The change in electricity attributes evaluated in CEs could be a part of DSM programs.

For example, allowing short load interruptions can balance energy services, particularly in extreme situations. Installation of smart meters and feedback is an initial step for the implementation of DSM.

Almost all analyzed studies presented sufficient details of how choice sets were created (the number of alternatives, the number of choice sets, the order and the way that tasks were presented). Several papers omitted detailed information about the choice design. Using a full factorial design enables analyzing preferences for all combinations of attributes and levels. However, this approach poses too many questions for a single respondent, making the cognitive burden too unwieldy. In addition, including all possible combinations of attributes and levels may present "useless" choice situations or lead to heuristic response strategies. The majority of analyzed studies were based on fractional factorial designs or efficient design, maximizing the precision of estimated choice-model parameters for a given number of choice sets. The D-efficiency criterion was most commonly used as an efficiency measure.

4.3.2. Willingness to pay and willingness to accept

Most papers estimated WTP for a change in the electricity supply. Studies showed that people are willing to pay a higher price for electricity to internalize the external costs with respect to energy security, air pollution caused by the production of energy, and climate change (see: Longo et al. 2008). They are also willing to pay for the installation of smart meters, feedback information about electricity usage, and technical support services (e.g. Albani et al. 2017, Huh et al. 2015, Ida et al. 2014, Kaufmann et al. 2013). Some consumers see the advantages of the introduction of dynamic tariffs and would pay for changing the tariff plan (Yoshida et al. 2017). However, the status quo bias and discomfort connected with load shifting make people reluctant to make changes. Some researchers estimated WTA multi-part tariffs (e.g., Buryk et al. 2015). People are more willing to accept new tariff plans if they see environmental and system benefits.

The estimated WTP and WTA illustrate the relative ranking of attributes' levels. WTP reflects the upper boundary of what people would pay in a real market to improve the electricity supply (e.g. to reduce the number and duration of outages). The WTA relates to the compensation people require for accepting changes in the electricity supply (e.g., more outages, losing the flexibility of consumption). The choice between WTP and WTA determines the policy offered to the consumers. Decision-makers could communicate the potential benefits of DSM and (a) ask people to pay for the new solutions or improvements in the system reliability, or (b) offer them compensation for accepting the change in supply. Both options (a fee and compensation) could be combined.

4.3.3. The value of power outages

Supply reliability was the most frequently analyzed attribute of electricity in analyzed studies. We concluded that it is the most crucial characteristic of the electricity supply for households. Researchers sought to identify what is the WTP to avoid power outages. However, DSM could allow for blackouts in order to reduce the cost of balancing the system (e.g., when an extreme situation occurs). Results from CE studies provide the values people place on power outages that they experience (e.g. the value of the duration, frequency, and timing of power outages).

The authors provide estimations for WTP or WTA for the changes in the services. Table 3 summarizes WTP estimated for the power outages. Extended data are presented in the appendix.

Table 3. WTP for the power outages estimated in the CEs

Authors	Analyzed attributes	WTP - € per month (WTP converted with purchasing power parity rate[3])
Abdullah, Mariel (2010)	frequency of outage duration of outage community provider private provider	0.46 (14.77) 0.54 (17.33) 0.51 (16.37) 0.50 (16.37)
Accent (2007)	the number of power cuts, the average duration of power cuts, number of short power interruptions and resilience of the network to storms	values depending on the characteristics of supply;

[3] Purchasing power parities factor for the country where the study was conducted – for the year of publication. Data from OECD: https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm#indicator-chart

		for maximum improvements: 1.56 (London) (1.11) 2.62 (non-London) (1.86)
Amador, González, Ramos-Rea (2010)	number of non-scheduled outages,	(-2.47,-1.25) (-1.80,-0.91)
	average length of outages	(-0.23,-0.12) (-0.17,-0.09,)
Blass, Lach, Manski (2010))	Reduction in duration of outages (1 min); Weekday, Peak	0.80 (3.18)
	Reduction in frequency of outages (30min length); Weekday, Peak	0.11 (0.44)
Bliem (2009)	duration of outages, frequency, time of day, day of the week, advance notification of an outage	
Breit, Komatsu, Kaneko, Ghosh (2016)	frequency of outages ,duration of outages, one-day prior notification	0.01-0.03 (reducing power outage per one time) 0-0.01 (shortening power outage per one min)
Carlsson, Martinsson (2008)	avoiding outages (November-march) – 4h weekdays	0.7 (6.15)
	avoiding outages (November-march) – 8h weekdays	1.98 (17.38)
	avoiding outages (November-march) – 24h weekdays	8.95 (78.57)
	avoiding outages (November-march) – 4h weekend	2.72 (23.88)

	avoiding outages (November-march) – 8h weekend	3.58 (31.43)
	avoiding outages (November-march) – 24h weekend	11.81 (103.68)
Frondel, Sommer, Tomberg, (2019)	Avoiding outage, 1/year, max 4h	2.1 (1.6)
Goett, Hudson, Train (2000)	No fluctuations in voltage	1 cent/kWh
	Reducing outages from four to two (duration 30 min)	1.21 cent/kWh
Huh, Woo, Lim, Lee, Kim (2015)	electricity mix, smart meter, number of the blackout, duration of the blackout, social contribution of the electric power company	2.1 (installation of the smart meter)
		5.20 (4,458.31) number of blackouts/year
		6.62 (active social contribution)
		0.05 (42.8684) duration of blackout - minutes)
		0.01 (increasing the share of renewable energy)
Layton, Moeltner (2005)	Power outage (1h shortage)	1.22
Morrissey, Plater, Dean (2018)	annual length of electricity shortages in minutes	−0.14 (−0.1)
	avoiding power outages in peak periods	6.11 (4.28)
	having outages during the week rather than the weekend or bank holiday,	8.52 (5.96)
	avoiding power outages in winter	36.25 (25.38)

Ozbafli, Jenkins (2016)	Frequency of outages	0.07 (summer) (0.04) 0.04 (winter) (0.02)
	Duration of outages (1h)	0.07 for summer (0.04); 0.32 for winter (0.19)
	Time of outages	0.05 (winter) (0.03)
		0.08 (summer) (0.05)
	Prior notification of outages	0.15 (summer) (0.09) 0.11 (winter) (0.07)
Pepermans (2011)	avoiding power outages in peak periods	1.68 (1.27)
	having power outages in summer rather than in winter	2.31 (1.74)
	having power outages announced rather than unannounced	1.29 (0.97)
	avoiding a one-unit increase in the frequency of power outages per year	1.47 (1.11)
	avoiding an increase in the average duration of a power outage with one minute	0,03 (0.02)
Zemo, Kassahun, Olsen (2019)	Frequency of outages	-18.571 (1 time)
	Duration of outages	-11.155 (1h)
	Time of outages	-5.797 (weekday) -5.262 (weekend)
	Prior notification of outages	6.084 (one week)

	Method of notification of power outage	-7.08 (text message)

1 EUR = 0.864970 GBP
1 EUR = 113.592 KES
1 EUR = 10.4436 SEK
1 EUR = 94.2813 BDT
1 EUR = 78.9837 INR
1 EUR = 1,305.47 KRW
1 EUR = 1.10220 CHF

The WTP for avoiding 1 minute of power outage amounted to 0.01€–0.8€ per month (converted with purchasing power parity rate), depending on the country and context. The WTP for a reduction in the frequency of outages amounted to 0.01€–14.77€ per month (converted with purchasing power parity rate). In the case of DSM, determining consumers' WTA power outages (compensation people need to accept DSM programs allowing power outages) would be beneficial. Table 4 summarizes WTA estimated in the CEs for the power outages.

Table 4. WTA for the power outages estimated in the CEs

Authors	Analyzed attributes	WTA - € per month (WTA after purchasing power parity conversion[4])
Abrate, Bruno, Erbetta, Fraquelli, Lorite-Espejo, (2016)	power outages, 2h	17.12/kWh (12.22)
Broberg, Persson (2016)	accepting external control during extreme occasions – 1 day	0.35 (3.15)
Daniel, Persson, Sandorf (2018)	control in extreme conditions – 1 day	1.62 (14.35)
Frondel, Sommer, Tomberg, (2019)	avoiding outage, 1/year, max 4h	7.46 (5.7)

1 EUR = 10.4436 SEK

Power outages were analyzed in various ways in the reviewed CEs. Some researchers focused on the value of the duration and frequency of power outage. Some studies differentiated

[4] Purchasing power parities factor for the country where the study was conducted – for the year of publication. Data from OECD: https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm#indicator-chart

the values for the seasons, type of the day, time of the day (peak/off-peak, morning/evening), and the predictability of interruption (prior notification). The attributes' levels differed across studies (e.g., min/hours). Fifteen studies analyzed WTP for avoiding power outages. Four papers presented the estimation for WTA, meaning that people were offered compensation for experiencing load interruptions. Comparing the value people place on the attributes of reliability of electric power supply enables identifying what is most important for people and the extent to which they are flexible when it comes to electricity consumption.

4.3.4. The implications for DSM

Many reviewed articles present econometric models with insufficient detail. Most researchers use models reflecting heterogeneity (i.e. they include a stochastic term in the attribute coefficients), indicating a preferences for each of the individuals. Comparing results requires an in-depth analysis of the electricity market as well as the social context and awareness of environmental issues in the countries in which the studies were conducted. Nevertheless, this paper provides a useful review, and in our interpretation, we would like to emphasize general, qualitative trends in the research and provide country-specific results.

DSM in the United States

In the United States, DSM was legislated nationally in 1975 through the Energy Policy and Conservation Act (EPCA). The policy was followed by the National 37 Energy Conservation Policy Act (NECPA) and the Public Utility Regulatory Policy Act (PURPA) (McNerney 1998, p. 27). DSM in the United States plays an important role in contributing to meeting policy objectives. According to the American Council for an Energy-Efficient Economy (ACEEE), about 200 billion kWh of electricity were saved in the United States in 2015 due to demand response programs (Nadel 2015). Research in the United States, where the peak load is a real threat to the power system, concentrates on dynamic pricing efficiency (Hu et al. 2015). However, we found only one study conducted in United States using a CE for dynamic pricing analysis (Goett, Hudson and Train 2000). Twelve percent of consumers preferred time-of-use tariffs and 4% of consumers preferred hourly rates. Eighty percent of respondents were willing to pay (0.38 cents for kWh on average) for customized billing, which provides options for the frequency of bills, the billing date, and the information to include with the bill (Goett, Hudson and Train 2000). Customers were willing to pay to reduce the number of outages and power fluctuations.

DSM in Europe

Unlike other countries in Europe, the United Kingdom has steadily developed DSM since the 1970s (Warren 2015), which is observable from the laws. Among CEs related to DSM policies in the United Kingdom, Accent (2007) provided detailed valuations of potential improvements and deteriorations in the electricity services in England. Longo et al. (2008) showed that people are willing to pay a higher price for electricity to increase energy security, or reduce air pollution caused by the production of energy and mitigate climate change. On average, respondents were willing to pay 29.65£ to decrease the greenhouse gas emissions by 1% a year; 0.36£ to reduce the shortages of energy by 1 minute a year; and 0.02£ to increase the number of jobs in the energy sector. Another study showed that domestic customers in United Kingdom are willing to pay 5.29£ to avoid having power outages during peak hours, 7.37£ to have power outages during the week rather than on the weekend or bank holiday, and 31.37£ to avoid having power outages in winter (Morrissey et al. 2018). Households are also willing to pay for shortening the time of a power outage (1.17£ to have a 20-minute outage, 0.05£ to have a 480-minute outage). Socio-demographic and household characteristics have an impact on respondents' WTP. Older people have lower WTP for preventing electricity outages, possibly because of tighter budget constraints. Respondents with full-time employment had the second-lowest value of WTP, which may be due to the fact that they spend more time out of the house. Richter and Pollitt (2018) showed that consumers in Great Britain are willing to pay for technical support services. They require compensation to share private data and participate in automated demand response programs (monitoring, control of electricity consumption). Buryk et al. (2015) found that environmentally conscious consumers require a lower discount to switch to dynamic tariffs.

Price-based DSM tools are the most popular and the oldest solution for managing electricity supply and demand. Time-of-use tariffs provide the monetary incentives for domestic consumers to flatten their load profile. Among the different schemes, time-of-use tariffs are preferred because it is the simplest plan, the price of electricity consumption is fixed for different periods of the day, and the installation of smart meters is not essential.

The acceptance of dynamic pricing varies between groups of customers because their risk aversion levels are different; that is, some customers are not willing to be exposed to wholesale market price volatility and prefer stable energy prices. Several studies analyze preferences for electricity tariff designs using CEs. For example, Schlereth, Skiera, and Schulz (2018) used a discrete CE and hierarchical Bayes covariate extended logit estimation to analyze respondents' probability of switching from a flat tariff to a time-variant pricing plan. The results suggest that economic antecedents (e.g., price consciousness and flexibility) have a stronger effect on the choice than price fairness considerations. Researchers have proposed new ways to target prospective customers, and cost insurance seems to be a promising tool for increasing the acceptance of dynamic pricing plans.

Mahmoodi et al. (2018) analyzed consumers' preferences for tariffs that apply a combination of rewards and (or) penalties for electricity consumption. Results from a sample of Swiss consumers showed that consumers prefer tariffs that reward reductions in electricity consumption, rather than tariffs that penalize increases in usage. Tariffs that combine rewards and penalties achieve substantial social acceptance. Direct tariff attractiveness ratings support findings showing that consumers perceive combined tariffs as sufficiently attractive. (Mahmoodi et al. 2018).

The Nordic Council of Ministers (2017) estimated the potential saving for demand-side flexibility resources at 1520 GW. The feasible potential in Sweden amount to 8 GW if time-of-use tariffs are implemented. However, we did not find CEs related to dynamic pricing in Nordic countries. CEs conducted in Sweden relate to the value of direct load control. Electricity customers surveyed in Sweden expressed a willingness to pay 8–10 SEK for reducing power outages for 4 hours (21–27 SEK for 8 hours, 77–94 SEK for 24 hours) (Broberg and Persson 2016). According to Carlsson and Martinson (2008), Swedish people who live in big cities (31% of the analyzed sample) and those living in a detached or terraced house (64% of the sample) are willing to pay less for reducing power outages. Older Swedish consumers had a higher WTP than younger respondents, but there was no significant difference between male and female respondents. WTP for avoiding the power outage increased for weekends and was higher for winter months (Broberg and Persson 2016).

DSM in developing countries

The results from Europe and the United States show that consumers are willing to internalize the external costs of the electricity production if they see potential benefits (financial, environmental). Significant differences are observable between these studies and those conducted in developing countries. In India, 90% of surveyed consumers were not willing to pay for improving electricity quality. Only the minority were reform-oriented (Sagebiel and Rommel 2014). However, another study by Graber et al. (2018) showed that the reliability of the power supply is important for consumers, especially in evening hours, and they are willing to pay a higher rate to ensure microgrid reliability. The study indicated variability in consumers' satisfaction with electricity provision. In India, household preferences for improved electricity quality and renewable energy are highly heterogeneous. This variability needs to be taken into account when designing DSM programs.

Abdullah and Mariel (2010) showed that socio-demographic factors influence the WTP for improving electricity services in Kenya. People who are older or unemployed and those who have resided in one place longer would not pay above their monthly electricity bill to improve the reliability of the service. In Kenya the mean WTP for the frequency of outage was estimated to be 51.79 Kenyan Shilling (KSh); mean WTP for the duration of the outage, 61.87 KSh; WTP for community provider, 57.69 KSh; and WTP for private provider, 56.38 KSh (Abdullah, Mariel 2010). The authors found relationships between mean WTP and characteristics such as the age of respondent, employment status, whether the respondents were bank account holders, the household size, years of residence in the area, and farming activities.

CEs are alternatives to costly field studies. Using CEs before the implementation of DSM could result in higher social acceptance of programs and lead to desirable effects for the power systems. The results from CEs justify investment in DSM solutions. Among the analyzed studies, the term DSM is mentioned seven times (Broberg and Persson 2016, Daniel et al. 2018, Dütschke and Paetz 2013, Ida et al. 2014, Richter and Pollitt 2018, Ruokamo et al. 2019, Shim et al. 2018). In other papers, the valuation for electricity supply attributes was not linked to the energy management directly. It would be advantageous to bring together the results from CE studies with the new DSM policies.

5. Conclusions

This paper presents the results from the first review of CEs estimating the economic value of electricity supply attributes. It summarizes WTP/WTA for electricity services estimated for the residential sector. Results may help in designing DSM policies that are acceptable by the public.

The number of CE applications in the electricity market is growing rapidly. The technique has been used to value electricity services and investigate trade-offs between daily comfort, the efficiency of the system, and electricity price. The attributes estimated in the analyzed CEs vary, as shown by the specific research questions asking about, for example, the cost-effectiveness of different tariffs, the impact of household characteristics on WTP for avoiding power outage, and the value people place on the installation of smart meters.

DSM programs are of great interest to utility companies and politicians because they help to ease the operation of the electric power system and many governments therefore promote their use (Zarnikau 2010, Infield et al. 2007, Torriti 2011). DSM programs improve the reliability, stability, and financial performance of the electrical power system. DSM involves consumers in the process of minimizing the cost incurred by the electrical power system through changing their behavior. Decision-makers are looking for a way to encourage consumers to participate in DSM, as well as understand under what conditions consumers will accept new contracts. Studies using CEs could help to design efficient strategies in the electric power system. In recent years, there has been an increasing interest in electricity supply costs in many countries.

Results from CEs can help decision-makers and utility companies design new products and electricity services, which is an urgent policy issue. They can be used as the groundwork for DSM in the residential sector. In CEs, observing real choices is not necessary. We can design programs and investigate consumers' preferences without running costly field studies involving new equipment. This paper may facilitate the research about applicable methods for implementers and decision-makers. For example, Daniel et al. (2018) proved that considering elimination-by-aspects behavior in CE leads to a downward shift in elicited WTA.

Research shows that the value of electricity service is closely related to the combination of its attributes. When we consider the improvements in electricity services, disparities in preferences occur depending on the season and timing. For example, people prefer to have a more reliable electricity supply during peak evening hours rather than the peak morning hours (Broberg and Persson 2016, Graber et al. 2018, Ruokamo et al. 2018), on weekends and holidays rather than weekdays (Bliem 2009, Morrissey et al. 2018), and in winter rather than in the summer (Morrissey et al. 2018). Consumers prefer positive to negative incentives for electricity savings (Mahmoodi et al. 2018). However, the results depend on the context and the experience with DSM. In addition, WTP and WTA for changes in electricity supply differ between countries.

The new solutions in electric power system are not only profitable for utilities but also attractive for consumers. The research shows that consumers are open to new solutions, but they prefer simple programs to complex ones (e.g., Yoshida et al. 2017, Richter and Pollitt 2018, Schlereth, Skiera and Schultz 2018). However, the societal advantages of DSM are not obvious to consumers (see Dütschke and Paetz 2013). The implementation of a new solution needs convincing communication (Dütschke and Paetz, 2013, Buryk, et al. 2015).

The most frequent attributes in the studies relate to power outages. Researchers estimated WTP for avoiding blackouts or WTA the blackout. People are willing to pay for avoiding power outage (Morrissey 2018, Carlsson and Martinsson 2008, Abdullah and Mariel 2010, Pepermans 2011). WTP depends on the duration and frequency of outage, and WTP increases with the duration of a power cut. People who experienced more outages in the past have a higher WTP to reduce the risk of blackouts (Amador et al. 2010). People prefer to have an outage in the summer rather than in the winter, and they prefer off-peak hours to peak hours (Pepermans 2011). People require compensation to accept blackouts. Comparing the WTP for avoiding blackout with the value people place on the change in their electricity consumption (e.g. WTA for reducing the consumption in peak hours) reveals a trade-off between such solutions.

DSM programs are developed together with new technologies. Smart metering could be an instrument for encouraging consumers to cooperate with the distribution company. According to ESMA (2012), energy savings from new technologies, such as smart meters, and information feedback depend on consumers' acceptance and understanding. The experiences with DSM are useful for the future design and implementation of programs. As the focus of the CEs reviewed in this paper is DSM, the findings are useful for decision-makers around the world that are designing or implementing demand-side policies. The WTP and WTA values estimated in CEs could be the basis for designing DSM with minimal impact on consumers' comfort. We expect that other studies are in progress and soon will be available.

References

Abdullah, S., Mariel, P., 2010. Choice experiment study on the willingness to pay to improve electricity services. Energy Policy 38(8), 4570–81.

Abrate, G., Bruno, C., Erbetta, F., Fraquelli, G., Lorite-Espejo, A., 2016. A choice experiment on the willingness of households to accept power outages. Utilities Policy 43, 151–64.

Accent. Expectations of DNOs & willingness to pay for improvements in service final report. https://www.ofgem.gov.uk/ofgem-publications/47387/1704rep04final-pdf (accessed 17 February 2020).

Alasseri, R., Tripathi, A, Rao, T. J., Sreekanth, K. J., 2017. A review on implementation strategies for demand-side management (DSM) in Kuwait through incentive-based demand response programs. Renew Sustain Energy Rev 77, 617–35.

Albani, A., Domigall, Y., Winter, R., 2017. Implications of customer value perceptions for the design of electricity efficiency services in times of smart metering. Inf Syst E-Bus Manag 15(4), 825–44. https://doi.org/10.1007/s10257-016-0332-9. (accessed 11 November 2018).

Amador, F.,J., González, R.M., Ramos-Real, F.J., 2013. Supplier choice and WTP for electricity attributes in an emerging market: The role of perceived past experience, environmental concern and energy saving behavior. Energy Econ 40, 953–66.

Anderson, N., H., 1962. On the quantification of Miller's conflict theory. Psychological Review 69.5, 400.

Ben-Akiva, M., E., Lerman, S., R., 1985. Discrete choice analysis: theory and application to travel demand. Vol. 9. MIT press.

Bennett, J., Blamey, R., (eds.), 2001. The choice modelling approach to environmental valuation. Cheltenham, UK: Edward Elgar Publishing.

Blass, A., Lach, S., Manski, C., F., 2010. Using elicited choice probabilities to estimate random utility models: preferences for electricity reliability. Int Econ Rev 51(2), 421–40.

Bliem, M., 2009. Economic valuation of electrical service reliability in Austria—a choice experiment approach. Institute for Advanced Studies Carinthia, Working Paper, 1.

Breit, J., Komatsu, S., Kaneko, S., Ghosh, P., 2016. Evaluating households' preferences regarding reducing power outages in rural areas: cases in the Ganges Floodplain in Bangladesh. Environ Develop Sustain 18(1), 73–94. https://doi.org/10.1007/s10668-015-9624-3 (accessed 12 September 2019).

Broberg, T., Persson, L., 2016. Is our everyday comfort for sale? Preferences for demand management on the electricity market. Energy Econ 54, 24–32.

Buryk, S., Mead, D., Mourato, S., Torriti, J., 2015. Investigating preferences for dynamic electricity tariffs: The effect of environmental and system benefit disclosure. Energy Policy 80, 190–95.

Carlsson, F., Martinsson, P., 2008. Does it matter when a power outage occurs?—A choice experiment study on the willingness to pay to avoid power outages. Energy Econ 30(3), 1232–45.

Daniel, A.,M, Persson, L., Sandorf, E.D., 2018. Accounting for elimination-by-aspects strategies and demand management in electricity contract choice. Energy Econ 73, 80–90.

Duncan, L., R., 1959. Conditional logit analysis of qualitative choice behavior. New York, NY: John Wiley Sons.

Dütschke, E., Paetz, A-G., 2013. Dynamic electricity pricing—Which programs do consumers prefer? Energy Policy 59, 226–34. https://doi.org/10.1016/j.enpol.2013.03.025 (accessed 12 September 2019).

ESMA (European Smart Metering Alliance), 2012. Smart metering. http://www.esma-home.eu/smartMeter ing/issues.aspS (accessed 12 September 2019).

Frondel, M., Sommer, S., Tomberg, L., 2019. WTA-WTP disparity: the role of perceived realism of the valuation setting. Ruhr Economic Papers 832.

Gellings, C.,W., 1985. The concept of demand-side management for electric utilities. Proc IEEE 73, 1468–70.

Goett, A., A., Hudson, K., Train, K., E., 2000. Customers' choice among retail energy suppliers: the willingness-to-pay for service attributes. Energy J 21(4), 1–28.

Graber, S., Narayanan, T., Alfaro, J., Palit, D., 2018. Solar microgrids in rural India: consumers' willingness to pay for attributes of electricity. Energy Sustain Dev 42, 32–43. https://doi.org/10.1016/j.esd.2017.10.002 (accessed 10 January 2018).

Green, P., E, Rao, V., R., 1971. Conjoint measurement-for quantifying judgmental data. Journal of Marketing research 8, 3, 355-363.

Green, P., E, Srinivasan V. 1978. Conjoint analysis in consumer research: issues and outlook. Journal of consumer research 5.2, 103-123.

Green, P.,E., Wind, Y., Jain, A.,K., 1972. Consumer Menu Preference: An Application of Additive Conjoint Measurement. ACR Special Volumes.

Gunatilake, H.,M., Patil, S., Yang, J.,C., 2012. Valuing electricity service attributes: a choice experiment study in Madhya Pradesh, India. Asian Development Bank Economics Working Paper Series 316.

Hanley, N., Mourato, S., Wright, R.,E., 2001. Choice modeling approaches: a superior alternative for environmental valuation? J Econ Surveys 15(3), 435–62.

Horowitz, J.,K., McConnell, K.,E., 2002. A review of WTA/WTP studies. J Environ Econ Manag 44(3), 426–47.

Hu, Z., Kim, J., Wang, J., Byrne, J., 2015. Review of dynamic pricing programs in the U.S. and Europe: status quo and policy recommendations. Renew Sustain Energy Rev 42, 743–51.

Huh, S.,Y., Woo, J., Lim, S., Lee, Y.,G., Kim, C.,S., 2015. What do customers want from improved residential electricity services? Evidence from a choice experiment. Energy Policy 85, 410–20.

Ida, T., Murakami, K., Tanaka, M., 2014. A stated preference analysis of smart meters, photovoltaic generation, and electric vehicles in Japan: implications for penetration and GHG reduction. Energy Res Soc Sci, 2, 75–89.

Infield, D.,G., Short, J., Horne, C., Freris, L.,L., 2007. Potential for domestic dynamic demand side management in the UK IEEE Power Engineering Society General Meeting, Tampa, FL.

Kaenzig, J., Heinzle, S.,L., Wüstenhagen, R., 2013. Whatever the customer wants, the customer gets? Exploring the gap between consumer preferences and default electricity products in Germany. Energy Policy 53, 311–22.

Kalkbrenner, B.J., Yonezawa, K., Roosen, J., 2017. Consumer preferences for electricity tariffs: Does proximity matter? Energy Policy 107, 413–24.

Kaufmann, S., Künzel, K., Loock, M., 2013. Customer value of smart metering: explorative evidence from a choice-based conjoint study in Switzerland. Energy Policy 53, 229–39. https://doi.org/10.1016/j.enpol.2012.10.072 (accessed 2 February 2018).

Knoefel, J., Sagebiel, J., Yildiz, Ö., Müller, J.,R., Rommel, J., 2018. A consumer perspective on corporate governance in the energy transition: evidence from a discrete choice experiment in Germany. Energy Econ 75, 440–8. https://doi.org/10.1016/j.eneco.2018.08.025 (accessed 10 January 2018).

Lancaster, K., J., 1966. A new approach to consumer theory. J Political Econ 74(2), 132–57.

Layton, D.,F., Moeltner, K., 2005. The cost of power outages to heterogeneous households. In: Scarpa, R, Alberini, A. (eds.) Applications of simulation methods in environmental and resource economics. The economics of non-market goods and resources. Vol 6. Dordrecht: Springer.

Longo, A., Markandya, A., Petrucci, M., 2008. The internalization of externalities in the production of electricity: willingness to pay for the attributes of a policy for renewable energy. Ecol Econ 67(1), 140–52.

Luce, R.,D., Tukey, J.,W., 1964. Simultaneous conjoint measurement: A new type of fundamental measurement." Journal of mathematical psychology 1.1:1-27.

Mahmoodi, J., Prasanna, A., Hille, S., Patel, M.,K., Brosch, T., 2018. Combining "carrot and stick" to incentivize sustainability in households. Energy Policy 123, 31–40. https://doi.org/10.1016/j.enpol.2018.08.037 (accessed 12 September 2019).

Manski, C.,H., 1977. The structure of random utility models. Theory Decision 8, 229–54.

McFadden, D., Train, K., 2000. Mixed MNL models for discrete response. J Appl Econometrics 15(5), 447–70.

McNerney, R.,A., 1996. Changing structure of the electric power industry: an update, Chapter 4. Darby (PA): DIANE Publishing, pp. 27–28.

Mengelkamp, E., Schönland, T., Huber, J., Weinhardt, C., 2019. The value of local electricity—a choice experiment among German residential customers. Energy Policy 130, 294–303. https://doi.org/10.1016/j.enpol.2019.04.008

Morrissey, K., Plater, A., Dean, M., 2018. The cost of electric power outages in the residential sector: a willingness to pay approach. Appl Energy 212, 141–50.

Nadel, S., 2017. Demand response programs can reduce utilities' peak demand an average of 10%, complementing savings from energy efficiency programs. http://aceee.org/blog/2017/02/demand-response-programs-can-reduce; 2017 (accessed 17 February 2020).

Nakai, M., Okubo, T., Kikuchi, Y., 2018. A socio-technical analysis of consumer preferences about energy systems applying a simulation-based approach: a case study of the Tokyo area. Energy Res Soc Sci, 46, 52–63.

Ndebele, T., Marsh, D., Scarpa, R., 2019. Consumer switching in retail electricity markets: Is price all that matters? Energy Econ 83, 88–103.

Nordic Council of Ministers, 2017. Flexible demand for electricity and power. Copenhagen: The Nordic Council of Ministers.

Official Journal of the European Union, 2018. DIRECTIVE (EU) 2018/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 amending Directive 2012/27/EU on energy efficiency. https://eur-lex.europa.eu/eli/dir/2018/2002/oj (accessed 7 February 2020).

Ozbafli, A., Jenkins, G., 2015. The willingness to pay by households for improved reliability of electricity service. Development Discussion Papers 2015-02. JDI Executive Programs.

Pepermans, G., 2011. The value of continuous power supply for Flemish households. Energy Policy, 39(12), 7853–64.

Pepermans, G., 2014. Valuing smart meters. Energy Economics 45, 280-294.

Richter, L.L, Pollitt, M.,G., 2018. Which smart electricity service contracts will consumers accept? The demand for compensation in a platform market. Energy Econ 72, 436–50.

Ruokamo, E., Kopsakangas-Savolainen, M., Meriläinen, T., Svento, R., 2019. Towards flexible energy demand—preferences for dynamic contracts, services and emissions reductions. Energy Econ 84, 104522. https://doi.org/10.1016/j.eneco.2019.104522 (accessed 4 February 2020).

Sagebiel, J., Rommel, K., 2014. Preferences for electricity supply attributes in emerging megacities—policy implications from a discrete choice experiment of private households in Hyderabad, India. Energy Sustain Dev 21, 89–99.

Schlereth, C., Skiera, B., Schulz, F., 2018. Why do consumers prefer static instead of dynamic pricing plans? An empirical study for a better understanding of the low preferences for time-variant pricing plans. Eur J Oper Res 269(3), 1165–79. https://doi.org/10.1016/j.ejor.2018.03.033 (accessed 12 November 2019).

Shim, D., Kim, S.,W., Altmann, J., 2018. Strategic management of residential electric services in the competitive market: demand-oriented perspective. Energy Environ 29(1), 49–66.

Shin, J., Woo, J., Huh, S-Y, Lee, J., Jeong, G., 2014. Analyzing public preferences and increasing acceptability for the renewable portfolio standard in Korea. Energy Econ 42, 17–26. https://doi.org/10.1016/j.eneco.2013.11.014 (accessed 10 October 2019).

Smart Energy Demand Coalition, 2016. Assessing the potential and market uptake of demand-side flexibility in the European energy system. Position paper.

Tanaka, M., Ida, T., 2013. Voluntary electricity conservation of households after the Great East Japan Earthquake: a stated preference analysis. Energy Econ 39, 296–304. https://doi.org/10.1016/j.eneco.2013.05.011 (accessed 12 June 2018).

Tomczykowski, J., 2014. Udział gospodarstw domowych w obciążeniu KSE. Energia Elektryczna.

Torriti, J., Hassana, M.G., Leach, M., 2010. Demand response experience in Europe: policies, programmes and implementation. Energy 35, 1575–83.

Tversky, Y., Kahneman, D., 1991. Loss aversion in riskless choice—a reference-dependent model. Q J Econ 106:1039–61.

Warren, P., 2015. A review of demand-side management policy in the UK [PhD thesis]. London: University College London.

World Bank, 2018. Tracking SDG7: the energy progress report 2018. https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg7-the_energy_progress_report_full_report.pdf (accessed 18 October 2019).

Yoshida, Y., Tanaka, K., Managi, S., 2017. Which dynamic pricing rule is most preferred by consumers? Application of choice experiment. J Econ Structures 6(1), 4.

Zarnikau, J., 2010. Demand participation in the restructured electric Reliability Council of Texas market. Energy 35, 1536–43.

Zemo, K.,H., Kassahun, H.,T., Olsen, S.,B., 2019. Determinants of willingness-to-pay for attributes of power outage - An empirical discrete choice experiment addressing implications for fuel switching in developing countries. Energy 174, 206–15. https://doi.org/10.1016/j.energy.2019.02.129 (accessed 18 December 2019).

Zhao, J., Kling, C.,L., 2001. A new explanation for the WTP/WTA disparity. Econ Lett 73, 293–300.

Appendix:

Table 5. Attributes analyzed in CE studies related to electric power

Authors	Analyzed attributes
Abdullah, Mariel (2010)	duration of outages***, number of planned outages***, type of distribution provider
Abrate, Bruno, Erbetta, Fraquelli, Lorite-Espejo, (2016)	duration of power outages***
Accent (2007)	the number of power cuts*, the average duration of power cuts*, number of short power interruptions*, provision of information*, restoration of supply*, notice for planned interruptions*, undergrounding of overhead lines for amenity reasons*, network

	resilience to flooding*, resilience of the network to storms*, reduction in carbon emissions*
Albani, Domigall, Winter, (2017)	tariff model*, electricity savings support*, electricity monitor*, communication channel*
Amador, González, Ramos-Rea (2010)	supply reliability*** (number of nonscheduled outages, the average length of outages), the share of renewable energies*** and availability of a complimentary energy audit service***
Blass, Lach, Manski, (2010)	duration and frequency of outage
Bliem (2009)	duration (4 hours**, 10 hours**), frequency of outages**, time of day (night), day of the week (sunday)**, notification (yes),
Breit, Komatsu, Kaneko, Ghosh, (2016)	frequency of outages**, duration of outages**, one-day prior notification**
Broberg, Persson (2016)	accepting external control of the heating system during the morning peak hours, accepting external control of the heating system during the evening peak hours***, the control of household electricity during the evening peak hours***, the control of household electricity during the morning peak hours***, accepting external control during extreme occasions***, sharing information about electricity consumption**
Buryk, Mead, Mourato, Torriti, (2015)	dynamic tariffs: Time-Of-Use***, Critical-Peak-Pricing***
Carlsson, Martinsson (2008)	the number of outages with 4-hour***/8-hour***/24-hour*** duration; working days***/weekends***
Daniel, Persson, Sandorf (2018)	control of heating morning/evening***, control of domestic electricity morning/evening***, control in extreme conditions per year***, distribution of information***

Dütschke, Paetz, (2013).	(1) dynamics (static, dynamic, variable), (2) rates defining the price spread (low, high), and (3) demand response (manual, automated)
Goett, Hudson, Train (2000)	(a) pricing and contract terms, including time-of-day, seasonal, and hourly rates, contract length, and sign-up bonuses, (b) green energy attributes, namely, the amount and type of renewables, (c) customer services, including billing options, web-based information sources, and availability of service representatives, (d) value-added services, such as energy audits, financing for equipment purchases, warranties on new equipment, and reliability, (e) community presence, including donations to schools, nonprofits, or children's programs, and the presence of local offices.
Graber, Narayanan, Alfaro, Palit, (2018).	reliability***, power, price***, availability***
Gunatilake, Patil, Yang, (2012).	hours of supply (24 hours**, 18 hour, 12 hours**); quality of supply** (voltage fluctuations, dimming of lights, burning of small electronic equipment); customer service**; and billing**
Huh, Woo, Lim, Lee, Kim, (2015)	electricity mix - increasing the share of renewable energy ***, installation of smart meter***, number of blackouts/year***, duration of blackouts (min)***, social contribution of the electric power company***
Ida, Murakami, Tanaka, (2014)	HEMS (home energy management systems): visualization of electricity consumption***, off-peak discount***, peak surcharge***, remote control of air-conditioning during a power shortage***, reduction in greenhouse gas emission***
Kaenzig, Heinzle, Wüstenhagen (2013)	power provider, location of electricity generation, certification, price guarantee, cancellation period, electricity mix
Kaufmann, Künzel, Loock, (2013)	tariff, remote meter reading, with accurate monthly billing, real-time consumption feedback, programming and steering services, home security and surveillance services with alert functions

Knoefel, Sagebiel, Yildiz, Müller, Rommel, (2018)	co-determination rights***, transparent pricing policies***, and an electric utility's profit distribution***
Layton, Moeltner (2005)	power outages
Longo, Markandya, Petrucci (2008)	annual reduction in greenhouse gas emission***, change in the number of employees in the power sector***, annual length of electricity shortages in minutes***
Mahmoodi, Prasanna, Hille, Patel, Brosch (2018)	electricity tariffs that apply a combination of rewards and/or penalties for electricity consumption***, electricity mix***, location of generation***
Mengelkamp, Schönland, Huber, Weinhardt, (2019)	choice of supplier, input frequency (degree of interaction), electricity source, data usage, investment (initial investment a customer is willing to take when changing electricity procurement)
Morrissey, Plater, Dean (2018)	duration of the power outage***, the day of the week that the outage occurs (weekend, holiday**), season (summer***), timing of the outage (non-peak)
Nakai, Okubo, Kikuchi, (2018)	power provider***, energy mix***, the stability of energy supply***, price volatility***
Ndebele, Marsh, Scarpa (2019)	call waiting time***, length of the fixed-rate contract**, renewable energy***, loyalty rewards***, supplier ownership***, and supplier type***
Osbafli, Jenkins (2016)	frequency of outages**, duration of outages***, time of outages*, prior notification of outages***
Pepermans (2010)	outages: annual frequency***, duration***, peak or off-peak***, announced or unannounced***, winter or summer*** and invoice impact***
Pepermans (2014)	smart meters described by: comfort (reduced comfort***, load shifting, little impact) and privacy level (load profile communicated, load profile communicated and intervention possible***),

	functionality (monitoring**, dynamic management), visibility (on the wall, in appliance), investment cost
Richter, Pollitt (2018)	electricity usage smart monitoring, remote monitoring***, control of electrical devices***, technical support***, data privacy***, expected electricity bill savings***
Ruokamo, Kopsakangas-Savolainen, Meriläinen, Svento (2019)	electricity distribution contract: two-rate tariff**, power-based tariff, electricity sales contract: real time pricing***, remote control of heating***, remote control of electricity system-level***, emissions reduction (−10%, −30%***)
Sagebiel, Rommel (2014)	duration of scheduled power cuts**, duration of unscheduled power cuts, renewable energy in energy mix, institutional setup (private supplier**, cooperative society supplier**)
Schlereth, Skiera, Schulz (2018)	dynamic pricing plans*** (constant, time-of-use, fuse size, critical peak, real-time), expected increase/decrease of billing rate***, cost insurance***
Shim, Kim, Altmann, (2018)	type of service-providing company**, installation of smart meter devices**, the introduction of prosumer groups**, relaxation of progressive electricity billing system**, and share of renewable energy in the generation mix**
Shin, Woo, Huh, Lee, Jeong, (2014)	attributes of renewable portfolio standard: the increase in the prices***, reduction of CO_2 emissions***, employment creation***, annual power outage time***, forest damage***
Tanaka, Ida, (2013)	settings of air conditioning, refrigerators and standby power of electrical appliances: setting air conditioning to higher temperature***, reducing the cooling level of refrigerators, suppressing the standby power of electric appliances***
Yoshida, Tanaka, Managi, (2017)	direct load control (DLC), dynamic pricing scheme: time-of-use (TOU), critical peak pricing (CPP), real-time pricing (RTP)
Zemo, Kassahun, Olsen, S. B. (2019)	frequency of outages***, Duration of outages***, Time of outages (weekday, weekend*), Prior notification of outages (three

	days***, one week**, two weeks***), method of notification of power outage**

***, **, * indicate 1%, 5%, 10% significance level, respectively

Table 6. WTP for the change in electricity supply.

Authors	Analyzed attributes	WTP - € per month
Abdullah, Mariel (2010)	frequency of outage duration of outage community provider private provider	0.46 0.54 0.51 0.50
Accent (2007)	the number of power cuts, the average duration of power cuts, number of short power interruptions and resilience of the network to storms	values depending on the characteristics of supply; for maximum improvements: 1.56 (London) 2.62 (non-London)
Amador, González, Ramos-Rea (2010)	number of nonscheduled outages,	(-2.47,-1.25)
	the average length of outages	(-0.23,-0.12)
	the share of renewable energies	0.20-0.39 (non-graduate) 0.30-0.59 (graduate)
	availability of a complimentary energy audit service	0.96-1.90
Blass, Lach, Manski, (2010))	reduction in duration of outages (1 min); weekday, peak	0.80
	reduction in frequency of outages (30min length); weekday, peak	0.11
Bliem (2009)	duration of outages, frequency, time of day, day of the week, advance notification of an outage	

Breit, Komatsu, Kaneko, Ghosh, (2016)	frequency of outages duration of outages one-day prior notification	0.01–0.03 (reducing power outage per one time) 0–0.01 (shortening power outage per 1 min)
Carlsson, Martinsson (2008)	avoiding outages (November–March), 4 hours weekdays	0.7
	avoiding outages (November–March), 8 hours weekdays	1.98
	avoiding outages (November–March), 24 hours weekdays	8.95
	avoiding outages (November–March), 4 hours weekend	2.72
	avoiding outages (November–March), 8 hours weekend	3.58
	avoiding outages (November–March), 24 hours weekend	11.81
Goett, Hudson, Train, (2000)	price, supplier type, sign-up bonuses, contracts, variable rates, renewables, personal service, billing options, websites, bundled services, power fluctuations, reliability, contributions	WTP calculated for clusters of consumers
	no fluctuations in voltage	1 cent/kWh
	reducing outages from four to two (duration 30 min)	1.21 cent/kWh
	customized billing	0.38 cent/kWh
	energy usage and information site	0.43 cent/kWh
Graber, Narayanan, Alfaro, Palit, (2018).	reliability, power, price, availability	0.34–0.68

		average 0.52 for an additional hour of electricity in the evening
Gunatilake, Patil, Yang, (2012).	hours of supply (24 hours)	1.33
	quality of supply	0.68
	customer service	0.48
	and billing	0.57
Huh, Woo, Lim, Lee, Kim, (2015)	electricity mix, smart meter, number of the blackout, duration of the blackout, social contribution of the electric power company	2.1 (installation of the smart meter)
		5.20 (4 458.31) number of blackouts/year)
		6.62 (active social contribution)
		0.05 (42.8684) duration of blackout - minutes)
		0.01 (increasing the share of renewable energy)
Ida, Murakami, Tanaka, (2014)		
	visualization of electricity consumption,	0.63
	Energy-saving advice	1
	off-peak discount,	0.18
	peak surcharge	−0.64
	remote control of air-conditioning during a power shortage	−0.36
	reduction in greenhouse gas emission	0.09
Kaenzig, Heinzle, Wüstenhagen (2013)	power provider location of electricity generation monthly	WTP calculated for different scenarios

	electricity cost certification price guarantee cancellation period electricity mix	
Kalkbrenner, Yonezawa, Roosen, (2017)	shares of regional generation 100%	0.25
	66%	0.3
	0%	-0.71
	local cooperation	1.24
	regional provider	3.50
	foreign provider	-5.55
	solar and hydro mix	3.55
	renewable mix	2.70
	German default mix	−3.62
Kaufmann, Künzel, Loock, (2013)	Tariff (11/17 RP/kWh),	2.76
	remote meter reading, with accurate monthly billing	2.16
	real-time consumption feedback	1.41
	programming and steering services	1.18
	home security and surveillance services with alert functions	0.84
Knoefel, Sagebiel, Yildiz, Müller, Rommel, (2018)	co-determination rights	2.05 cent/kWh
	transparent pricing policies, an electric utility's profit	2.90 cent/kWh

	distribution	5.68 cent/kWh
Layton, Moeltner (2005)	power outage (1-hour shortage)	1.22
Longo, Markandya, Petrucci (2008), England	reduction in CO_2 (ton)	11.47
	change in the number of employees in the power sector	0.01
	annual length of electricity shortages in minutes	−0.14
Mahmoodi, Prasanna, Hille, Patel, Brosch (2018)	electricity tariffs that apply a combination of rewards and/or penalties for electricity consumption	6.36–16.35 (to receive a bonus tariff)
Mengelkamp, Schönland, Huber, Weinhardt, (2019)	change of supplier	−10 (30 in Allgäu)
	input frequency	5
	electricity source, and data usage, investment	
Morrissey, Plater, Dean (2018), England	avoiding power outages in peak periods	6.11
	having outages during the week rather than the weekend or bank holiday,	8.52 36.25
	avoiding power outages in winter	
Nakai, Okubo, Kikuchi, (2018)	power provider (regional),	2.45
	energy mix (fossil fuels 80%, nuclear 20%),	2.58
	stability of energy supply (possible blackouts caused by the weather)	−3.23
	price volatility (100 JPY variation),	−3.14

Osbafli, Jenkins (2016)	frequency of outages	0.07 (summer) 0.04 (winter)
	duration of outages (1 hour)	0.07 for summer; 0.32 for winter
	time of outages	−0.05 (winter)
		−0.08 (summer)
	prior notification of outages	0.15 (summer) 0.11 (winter)
Pepermans (2010), Belgium	avoiding power outages in peak periods	1.68
	having power outages in summer rather than in winter	2.31
	having power outages announced rather than unannounced	1.29
	avoiding a one-unit increase in the frequency of power outages per year	1.47
	avoiding an increase in the average duration of a power outage with one minute	0,03
Pepermans (2014)		
	reduced comfort,	−12.75
	load shifting (little impact)	−3.67
	dynamic management	−0.42
	only monitoring	−3.58
	profile communicated, intervention possible	−12.92
	load profile communicated	−0.58

	in the wall	13.42
	on the wall	−5.92
	in appliances	−0.58
	cost savings	1.17
Richter, Pollitt (2018), Great Britain	usage data sharing	−3.69
	usage and personally identifying data sharing	−6.13
	ongoing support	2.01
	premium support	1.98
Shim, Kim, Altmann, (2018)	type of service-providing company (telecommunication)	0.37
	installation of smart meter devices	0.64
	introduction of e-prosumer groups	0.33
	relaxation of progressive electricity billing system	−0.39
	share of renewable energy in the generation mix	0.02
Yoshida, Tanaka, Managi, (2017), Japan	time-of-use	25.61
	critical peak pricing	11.07
	real-time pricing	22.54
	direct load control	22.81
	direct load control and critical peak pricing	15.71
Zemo, Kassahun, Olsen, S. B. (2019)	frequency of outages	−18.571 (1 time)
	duration of outages	−11.155 (1 hour)
	time of outages	−5.797 (weekday)

	−5.262 (weekend)
prior notification of outages	6.084 (1 week)
method of notification of power outage	−7.08 (text message)

Table 7. WTA for the change in electricity supply

Authors	Analyzed attributes	WTA - € per month
Abrate, Bruno, Erbetta, Fraquelli, Lorite-Espejo, (2016)	power outages (different interruption scenarios)	17.12/kWh for 2 hours
Broberg, Persson (2016), Sweden	accepting external control of the heating system during the evening peak hours	5.14
	the control of household electricity during the evening peak hours	11.22
	the control of household electricity during the morning peak hours	6.63
	accepting external control during extreme occasions	0.35
	sharing information about electricity consumption	1.93
Buryk, Mead, Mourato, Torriti, (2015)		
	TOU	12.22% discount on electricity bill
	CPP	18.45% discount
Daniel, Persson, Sandorf (2018)	control of heating, control of domestic electricity:	
	morning	-13.92
	evening	0.74
	control in extreme conditions	1.62
	distribution of information	1.84
Frondel, Sommer, Tomberg, (2019)	avoiding outage, 1/year, max 4h	7.46
	the real-time pricing contract	6.25

Ruokamo, Kopsakangas-Savolainen, Meriläinen, Svento (2018), Finland	direct load control in heating	5.17 and 3.5
	load control in electricity usage	12.83 and 3.83
	power system level emissions reductions	11.08

University of Warsaw
Faculty of Economic Sciences
44/50 Długa St.
00-241 Warsaw
www.wne.uw.edu.pl