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The cost of electric power outages in the residential sector: A willingness to pay approach

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HIGHLIGHTS

- Heterogeneity in preferences for constant electricity supply in the residential sector is estimated.
- Households are willing to pay to avoid outages in winter, at peak times and at the weekend.
- Households with only electric heating have the highest willingness to pay.
- Differences in willingness to pay decrease across different groups as the length of power outages increase.

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ABSTRACT

Service providers and policymakers require data on the value of a service to consumers to justify investment. Due to the high reliability of electricity services in Europe, data on the value of constant electricity supply is not available. A choice experiment framework is used to estimate the welfare cost to households of power outages in northwest England. The willingness to pay (WTP) estimates obtained suggest that a household in northwest England is WTP; £5.29 to avoid having power outages in peak periods, £7.37 to have outages during the week rather than the weekend or bank holiday, and £31.37 to avoid power outages in winter. Households are also WTP between £1.17 (20 min) and £0.05 (480 min) to avoid a power outage depending on the length of the power outage. The use of a mixed logit model also demonstrated the impact of different socio-demographic and household characteristics on respondents WTP to avoid a power outage. From a policy perspective, the results provide data or a 'price' on the importance of constant electricity supply to domestic customers. Through engagement with policy makers and industry, these 'price signals' may be used to justify future investment and policy in the electricity sector.

1. Introduction

Customer interruption costs, the costs arising due to interruptions in customer electricity supply, are seen as a major component in providing the justification for infrastructure and energy system investment [1–3]. The estimation of customer interruption costs provides important information for current and future energy investment and policy. In Europe, the need to replace aging infrastructure, meet the demands of an increasing global population, and to connect an increasing share of energy from renewable sources to the grid requires major investments in electricity transmission and distribution networks in the coming decades [4–5]. At the same time, it is increasingly acknowledged that climate change may constrain future electricity generation capacity by (a) increasing the incidence of extreme heat and drought events [6–7] and (b) changing the temporal, spatial and operational patterns of energy supply and demand [8]. Together these factors mean that the high reliability of electricity supply currently enjoyed in Europe may be compromised in the future. As such new and adaptive energy policies are required that account for both the value of constant electricity supply across different sectors, such as residential versus industrial sectors, but also differing preferences within sectors.

A widespread approach to estimating the value of constant electricity supply has been to estimate ‘production functions’ for households and firms on the basis of aggregate electricity consumption and value added data by economic sector. In this way one can assess the value of lost load, i.e. the economic damage caused to that sector for each kilowatt-hour (kWh) not supplied to end users. Recent examples using a production function approach include de Nooij et al. [9–10]

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Table 1
A review of WTP estimates to avoid power outages in the residential sector.

Author(s) and year of publication, in reverse date order	Country	Method	Mean WTP value to avoid 1 h outage
Payment vehicle: Once off payment			
Developed countries			
Cohen et al. [24]	Europe (15/27 EU member countries)	Recursive binary choice	1 h outage (€): 3.994 Denmark; 3.991 Poland; 3.595 Ireland; 3.439 Romania; 3.279 Bulgaria; 3.194 Hungary; 3.158 Finland; 2.779 Slovenia; 2.501 Greece; 2.203 Spain; 2.096 Netherlands; 1.908 Sweden; 1.841 Estonia; 1.035 Germany; 0.364 France
London Economics [20]	UK	Conditional logistic regression	From zero (not winter, weekday) to £0.97 (Winter, weekend; both not peak and peak close to this value)
Carlsson and Martinsson [22]	Sweden	Mixed logit model	4 h outage: 8.53–28.40 SEK depending on day and time of year
Developing countries			
Abdullah and Mariel [19]	Kenya	Mixed logit model	3 h outage: 61.87Ksh, £0.48
Payment vehicle: Linked to electricity bill			
Developed countries			
Ozbafli and Jenkins [25]	North Cyprus	Mixed logit model	1 h outage: 0.28 YTL (£0.06) summer; 1.08 YTL (£0.28) for winter
Pepermans [18]	Belgium	Mixed logit model	1 h outage: High income €39.00, middle income €31.20, low income €26.40
Accent (for Ofgem) [21]	UK	Nested logit model	1 h outage: £4.20
Hensher et al. [26]	Australia	Mixed logit model	8 h outage: $AU60
Bliem [23]	Austria	Random effect binary Probit model	4 h outage: Bill reduction, 16%
Amador et al. [27]	Canary Isles	Mixed logit model	1 h outage: €1.99 per month (4.2% of rbill)
Developing countries			
Sagebiel and Rommel [29]	India	Latent class model	20% increase in costs require a 97 min of reduced scheduled power cuts
Blass et al. [28]	Israel	Mixed logit model	1 min reduction when outages have a duration of 60 min: US$0.42 (£0.33)

study in the Netherlands and Leahy and Tol [11] study for Ireland. These methods can provide reasonable approximations of electricity interruption costs, particularly when coupled with sensitivity analyses to account for the uncertainty associated with them [12]. However, while a production function approach may be an appropriate approach to estimating the value of lost load for the industrial sector, in reality the costs arising from interruptions in the residential electricity supply market are a blackbox [9,13–14]. In contrast to businesses where lost turnover can be used as a proxy for the value of constant electricity supply [9], the costs accrued to households during a power outage are more complex. Non-material losses such as inconvenience or fear, as well as material losses such as spoiled food, occur side-by-side in the case of power outages. Both non-material and material losses are relevant for the analysis of households' perception of access to constant electricity [15]. Representing 27% of overall electricity consumption in the UK [16], the cost to the residential market for these losses, particularly non-material costs, are not represented in the market place [9,17].

Within a policy context, this lack of information may lead to misinterpretation of the benefits of reliability improvements to domestic consumers and result in the postponement of infrastructure investments [13–14] or delay policy changes. It should also be recognized that the optimal reliability of electricity supply could be customer specific [18]. The burden or 'cost' of an electricity outage may be assumed to vary based on the demographic and socio-economic characteristics of a household. For example, larger households with may experience higher objective and subjective costs as more people experience the power outage. A lack of information on how different households value electricity may lead to further sub-optimal investment decisions that impact disproportionally on certain sub groups of the population (i.e. larger households, older households). In the face of changing demand and supply of electricity, the efficiency of the electricity system for the residential sector could be maximised by understanding differing patterns of electricity demand across different household groups. Understanding electricity demand across different household groups would mean that potentially limited generation, transportation and distribution capacities could be allocated to their most valuable use [18]. With the recent development of smart grids, and commercial growth of smart homes and smart metering this also becomes technically feasible. For the purpose of investment decisions, a method that accounts for different electricity needs or 'preferences' across different households is required to obtain the value of constant electricity supply to residential consumers.

In the face of changing demand and supply of electricity, this paper outlines a choice experiments (CE) and mixed logit framework to understand the value of continuous electricity supply in northwest England. The willingness to pay (WTP) estimates obtained from the CE and mixed logit framework may be used as the value of continuous electricity supply in northwest England within future decision-making on investment in the electricity system. Given recent developments in smart technology and the capacity to deliver bespoke electricity options depending on household preferences, one of the main aims of this paper is to capture and begin to understand if different electricity needs or 'preferences' for constant electricity exists across the residential sector. Previous research by Abdullah and Mariel [19] and Pepermans [18] demonstrate the usefulness of choice experiments, when incorporated within a mixed logit model as a method to account for the heterogeneity of preferences for constant electricity across different household types. Finally, whilst most energy policy originates at the national level, another key aim of this paper is to demonstrate that households even within relatively small regions such as the northwest of England have heterogeneous preferences for constant electricity supply, and that future energy policy should consider sub-regional circumstances.

The paper is structured as follows. Section 2 provides an overview of previous research that has using Choice Experiments to elicit the value of constant electricity supply in the residential sector. Section 3 continues by describing the data and the data collection process. Section 4 presents the choice experiment methodology and the development of the choice sets. Section 5 provides the theoretical framework. Section 6 provides the model results and continues by presenting WTP estimates for changes in power outage attribute levels and their distribution sample. Finally, Section 7 concludes and emphasizes the significance of the findings.