[*UPDATING THE VALUE OF LOST LOAD FOR THE OPTIMAL DECARBONISATION OF HEAT AND POWER SYSTEMS IN THE UK*]

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Overview

In line with the Paris Agreement commitment to return net greenhouse gas emissions to zero by the second half of the 21st century, many countries have begun to debate and adopt net zero targets. The UK was the first major industrialised country to set an economy-wide net zero emissions target by mid-century (CCC 2019). With an increasingly decarbonised electricity grid, electrification of hard-to-decarbonise sectors – such as heating, transport and parts of industry – offers one potential decarbonisation pathway (Charitopoulos *et al*., *in review*; Heinen *et al*. 2018). In the case of heating, in particular, the high penetration of intermittent renewables, and the high seasonality and hourly variability of heat demand, could pose significant challenges for both hourly system operation and for long term investment decision planning of electricity systems. Governments and regulators will need to determine whether maintaining traditional standards for security of supply are appropriate given the increased costs of maintaining such standards in a deeply-decarbonised system, but first there is a need to assess if there has been any evolution in how consumers assess security of supply.

Designing a future electricity system with a high level of security typically involves adding power generation capacity and lowering the overall capacity factor of the system, which is equally costly to the economy. The cost incurred from this transition within the electricity sector is therefore highly related to the security criteria adopted for the electricity grid (Ovaere *et al*. 2019). The optimal level of security which is required to supply the electricity peak demand is established based on Value of Lost Load (VoLL), which measures the cost of disrupting power supply for consumers, and is often incorporated into standards established by sector regulators (Röpke 2013; Schröder and Kuckshinrichs 2015). The extent to which electrification of heating will interact with the VoLL in the residential sector therefore remains very uncertain. Consumer flexibility, encouraged by an increased knowledge of consumption provided by smart-metering devices and greater concern over climate change might lead to an appreciation that reduced security of supply might be a necessary part of deep decarbonisation, both of which could lower the VoLL. The current state of flux offers an opportune time to explore the potential for changing views of security of supply.

Schröder and Kuckshinrichs (2015) categorise the different methods to measure the VoLL into survey-based (or *direct*) and analytical (or *indirect*) approaches. The most common indirect method involves the use of production functions to assess the economic cost of interrupted power supply, which translates, for domestic consumers, into an income-based valuation of leisure time. A recent study by Cambridge Economic Policy Associates (2018) for the Agency for the Cooperation of Energy Regulators (ACER) used this methodology to determine the VoLL of domestic consumers in European countries, including the UK. However, direct approaches such as *contingent valuation* (CV) or *discrete choice experiments* (DCE), are usually preferred over indirect methods, owing to the risk associated with simplified assumptions used in analytical methods. In 2013, London Economics (2013) assessed the VoLL of UK domestic consumers, using both the CV and DCE methods on behalf of the UK energy regulator Ofgem. The study assessed consumers' willingness to pay (WTP) for a secure supply, or the willingness to accept (WTA) interruptions in their power supply, by presenting respondents with a range of interruptions scenarios. This study did not capture, however, how the transition to a diversified and decarbonised grid might affect the VoLL in the domestic sector.

Our study to assess VoLL in a changing context will contribute to our broader objective of determining optimal energy system investment and operational decisions to decarbonise electricity and residential heat demand, and can be incorporated into our ongoing systems modelling of heat decarbonisation (Charitopoulos *et al., in review*). This contribution presents the surveying methodology used to update the VoLL for domestic consumers in the UK.

Methods

We employ a DCE approach to measure the VoLL of domestic consumers in the UK. We conducted a representative sample of 3,000 respondents across Great Britain. The survey questions are divided into five sections:

- Housing characteristics: dwelling type, dwelling age, dwelling floor area, number of rooms, energy performance certificate rating;
- Attitude towards energy: knowledge about energy supply, energy consumption, smart metering ownership, time of peak energy demand;
- Environmental concern/knowledge: climate change concern, share of renewables in electricity supplier, voting preference;

- Socio-demographics: age, income, gender, occupation, tenure type, financial situation, geographic location;
- DCE specific attributes: duration of interruption, frequency of interruption, season of interruption, time of day of interruption, share of renewables in electricity grid.

The DCE is presented as a series of 8 choice cards between two electricity supplier contracts. The five attributes and levels used for this DCE are summarised in Table 1. The DCE is divided into two versions: version A which emulates the DCE used by the London Economics (2013) study, to assess potential changes since 2013, and version B which replaces the season of interruption by the share of renewables in the grid, to determine whether this might impact domestic consumers' valuation of the security of their electricity supply. Half of the respondents sample is presented with each version of the DCE. In order to appraise potential differences in WTP/WTA, half of the cards formulate attribute 5 as a compensation for the interruption, while four cards formulate attribute 5 as the price to pay to avoid the interruption. A multinomial logit model approach is used to process the survey results.

Table 1: Attributes and levels for the discrete choice experiment.

Attributes		**Levels**
Attribute 1: Duration of interruption		20 minutes/1 hour/4 hours
Attribute 2: Time of day		Peak (3pm-9pm)/ Non-Peak (10pm-2pm)
Attribute 3: Frequency of interruption		Once every 2/4/12 years
Attribute 4: Split sample (50% version A/50% version B)	A. Season of interruption (50% of respondents)	Winter/summer
	B. Share of renewables in the grid (50% of respondents)	50%/90%/99%
Attribute 5: 4 experiments for each	Compensation for interruption	£1, £5, £10, £15 one-off payment
	Price to pay to avoid interruption	

Results

The survey is currently in the field and results will be available from late January 2020. They will be analysed to assess the VoLL for a range of household segments in the UK, determine the key variables driving the VoLL, and discuss potential differences between consumer WTP and WTA. Results will be compared against those from the London Economics (2013) survey to assess the potential impact of electricity decarbonisation on consumers' perception of the security of their electrcitiy supply.

Conclusions

Despite the dramatic changes in the electricity mix in the UK over the past five years and increasing the legally-driven commitment to cut overall net emissions to zero, no other study has quantified the VoLL for UK domestic consumers to account for this changing context. A first outcome of this study is to identify key factors impacting the VoLL, and the quantification of the VoLL for different household segments. These results can be used to introduce household heterogeneity according to these identified variables in energy systems optimisation models, to calibrate the VoLL for different segements, and determine the optimal design and operation of the electricity system to meet decarbonisation targets by mid-century.

References

Cambridge Economic Policy Associates. 2018. "Study on the Estimation of the Value of Lost Load of Electricity Supply in Europe .06 July 2018." https://www.acer.europa.eu/en/Electricity/Infrastructure_and_network development/Infrastructure/Documents/CEPA study on the Value of Lost Load in the electricity supply.pdf.

CCC. 2019. "Net Zero - The UK' s Contribution to Stopping Global Warming." https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/.

Charitopoulos, V., C. K. Chyong, and D. M. Reiner. (in review). "The Prospect of Electrification for the Decarbonisation of Heat in the UK." *EPRG Working Paper*.

Heinen, S., P. Mancarella, C. O'Dwyer, and M. O'Malley. 2018. "Heat Electrification: The Latest Research in Europe." *IEEE Power and Energy Magazine* 16 (4): 69–78. https://doi.org/10.1109/MPE.2018.2822867.

London Economics. 2013. "The Value of Lost Load (VoLL) for Electricity in Great Britain: Final Report for OFGEM and DECC." *OFGEM and DECC*, no. July: 1–225. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224028/value_lost_load_electricty_gb.pdf.

Ovaere, M., E. Heylen, S. Proost, G. Deconinck, and D. Van Hertem. 2019. "How Detailed Value of Lost Load Data Impact Power System Reliability Decisions." *Energy Policy* 132: 1064–75.

Röpke, L. 2013. "The Development of Renewable Energies and Supply Security: A Trade-off Analysis." *Energy Policy* 61: 1011–21.

Schröder, T., and W. Kuckshinrichs. 2015. "Value of Lost Load: An Efficient Economic Indicator for Power Supply Security? A Literature Review." *Frontiers in Energy Research* 3 (DEC): 1–12.

White, P. R., and J. D. Rhodes. 2019. "Electrification of Heating in the Texas Residential Sector." https://www.pecanstreet.org/electrictexas/.