The Value of Lost Load in a decarbonised power sector

Mathilde Fajardy, David Reiner
Energy Policy Research Group, Judge Business School
University of Cambridge
What is VoLL?

• **Optimal level of security** required to supply peak electricity demand is based on **Value of Lost Load (VoLL)**

• Maintaining **traditional standards** for security of electricity supply might not be appropriate given the **increased costs of maintaining such standards** in a deeply-decarbonised system.
VoLL in Great Britain

- GB’s current VoLL for domestic and commercial consumers is an average annual value determined by a discrete choice experiment (DCE) in 2013 (Ofgem 2013) performed on both commercial and domestic consumers.

- Ovaere et al. (2019) shows that using a more segmented and time-varying VoLL could lower operational costs of the electricity system by 40%, which suggests that there is a need for time-varying and segmented VoLL studies at the country level.

- Currently no study assessing how domestic VoLL might be impacted by renewable share in the grid.
Two main approaches:
- Indirect: production functions
- Direct: contingent valuation and Discrete Choice Experiments (DCE)

Very few explicit VoLL studies using a DCE approach

Many willingness-to-pay studies (WTP) on the security of electricity supply, but few include the share of renewable or CO₂ emissions as an attribute
WTP for renewable integration

- Only one study on the WTP to avoid interruptions featuring emissions reduction as an attribute (Ofgem 2008): showed that WTP is the highest for the emissions reduction attribute.

- Among studies WTP for electricity services, respondents are WTP a premium for renewable integration in higher-income countries.

- This premium is typically lower than the actual cost of renewable integration.

- In lower-income countries, no significant WTP for renewable in India (Sagebiel 2014), and consumers care more about urban electrification than renewable integration in Indonesia (Siyaranamual 2020).

- Past studies show a non-linear relationship between WTP and renewable integration (slope decreases with increasing share) (Goett 2000): suggests that respondents care more about the “concept of renewables” than their environmental impact.
Study objectives and limits

1) Explore how **VoLL of GB households** might **have evolved** since the last time it was quantified in 2013 by the UK network operator (Ofgem) by emulating their method

2) Determine **how VoLL might be impacted by an increasing share of renewable electricity in the grid**

3) Provide insights into how VoLL **might vary across different population segments**

- The study does not pretend to provide the UK’s network operator with an updated VoLL, as it suffers from two limitations: 1) it only covers **domestic consumers**, and 2) **internet-based surveying methods** under-represent poorly connected areas
Methods

- Online survey on a UK representative sample of **3,016 respondents**
- 2 different DCE on each half of the sample: **1,500 with the ‘season’ version, 1,516 with the ‘renewable’ version**
- ‘Loss aversion’ bias (Beenstock 1998): half of the choice cards formulated as WTP, and half as WTA
- ‘Status-quo’ bias (Hartman 1991): respondents cannot choose to keep their current system, but can respond “I don’t know”
- **Mixed-logit** formulation to capture heterogeneity in respondent’s valuation (Train 2003), all variables are random
- **WTP space** to analyse the distribution of the WTP and VoLL (Richter 2018, Hole 2007)
- **Duration variable interacted** with frequency, time of year, time of day and share of renewable to evaluate VoLL for different time/share of renewable (Ofgem 2013)
- **Heterogeneity** explored with interactions between price and duration and key covariates (selected based on previous studies)
Methods – survey questions

1. **Housing characteristics**: dwelling type, dwelling age, dwelling floor area, number of rooms, energy performance certificate rating, heating technology

2. **Attitude towards energy**: knowledge about energy supply, energy consumption, smart metering ownership, time of peak energy demand, fuel consumption, heating patterns

3. **Environmental concern/knowledge**: climate change concern, share of renewables in electricity supplier, voting preference

4. **Socio-demographics**: age, income, gender, occupation, tenure type, financial situation, geographic location

5. **VoLL DCE specific attributes**: duration of interruption, frequency of interruption, season of interruption, time of day of interruption, share of renewables in electricity grid
## Discrete choice experiment – ‘season’

<table>
<thead>
<tr>
<th>Choice card (example)</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of interruption</td>
<td>20 minutes</td>
<td>4 hour</td>
</tr>
<tr>
<td>Time of day</td>
<td>Peak (3pm-9pm)</td>
<td>Off-Peak (10pm-2pm)</td>
</tr>
<tr>
<td>Frequency of interruption</td>
<td>Once every 2 years (“1-in-2”)</td>
<td>Once every 4 years (“1-in-4”)</td>
</tr>
<tr>
<td>Season of interruption</td>
<td>Off-winter</td>
<td>Winter</td>
</tr>
<tr>
<td>Price to pay to avoid interruption (4 cards out of 8)</td>
<td>£1 one-off payment</td>
<td>£10 one-off payment</td>
</tr>
<tr>
<td>Which option do you prefer?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

☐ I Don’t know
Discrete choice experiment – ‘renewable’

<table>
<thead>
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<th>Choice card (example)</th>
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</tr>
<tr>
<td>Frequency of interruption</td>
<td>Once every 2 years (“1-in-2”)</td>
<td>Once every 4 years (“1-in-4”)</td>
</tr>
<tr>
<td>Share of renewables in the grid (50% of the sample)</td>
<td>99%</td>
<td>50%</td>
</tr>
<tr>
<td>Price to pay to avoid interruption (4 cards out of 8)</td>
<td>£1 one-off payment</td>
<td>£10 one-off payment</td>
</tr>
<tr>
<td>Which option do you prefer?</td>
<td>[                  ]</td>
<td>[                  ]</td>
</tr>
</tbody>
</table>
1. VOLL today vs. Ofgem 2013

- Results in line with the Ofgem 2013 study
- VOLL is within the confidence interval
- VOLL increases linearly with frequency
2. WTP vs. WTA

- The WTA version is also consistent with the Ofgem study.
- As in the Ofgem study, we find a large difference between WTP and WTA values.
3. The impact of renewable integration

• Respondents do value the share of renewable electricity in the grid, and are ready to lower the current standard of electricity supply to increase this share.

• WTP to avoid an interruption occurring during peak time every 4 years but with a 90% renewable grid is found lower than for one occurring every 12 years but with a 50% renewable grid.
VoLL and renewables

- VoLL decreases roughly linearly with the increasing share of renewables in the grid
- Clear change in perception of renewable from past studies (Goett 2000)
4. Drivers of heterogeneity – ‘season’

- Age and income effects in both versions of the DCE:
  - Younger respondents are WTP less, while older respondents are willing to pay more
  - Higher income respondents are WTP more

- Producing own electricity has an important impact of the VoLL in spite of representing small fraction of the population
4. Drivers of heterogeneity – ‘season’

- Similar trends in DCE ‘renewable’
- Environmental concern which was not a driver of heterogeneity in DCE ‘season’ has an impact on VoLL in DCE ‘renewable’
- Environmental concern could further decrease VoLL
Conclusions 1/2

- VoLL within the 95% confidence interval of Ofgem (2013) which confirms the robustness of DCE to assess GB domestic VoLL

- **Frequency is a key driver of VoLL**, with a linear relationship between VoLL and frequency
  - Suggests a potentially high increase in VoLL should the transition to a low carbon grid cause an increase in blackout frequency
  - Highlights the need to explore VoLL response to higher frequencies (infra year)

- Domestic VoLL decreases linearly with renewable integration (from 50% to 99%):
  - **important paradigm shift** compared to existing studies pointing out to the fact that respondents only value how green the electricity grid is to a certain point (Goett 2000)
Conclusions 2/2

- WTP to avoid more frequent interruptions (1-in-4) but occurring on a cleaner grid (90%) is found lower than WTP to avoid less frequent interruptions (current frequency standard 1-in-12) occurring on a grid with less renewable (50%)

- Renewable integration could compensate the effect of higher blackout frequency on domestic VoLL

- Heterogeneity driven by the same effects across both DCEs, mainly income and age: overall, older and higher income respondents are willing to pay more to avoid blackouts, while younger respondents are willing to pay less

- Environmental concern was only found statistically significant in DCE ‘renewable’ which confirms that renewable integration could further decrease VoLL
Quality control

- Compute versions 1 and versions 2 separately (different sets of respondents)
- Compute WTP and WTA choice cards separately (compare WTP and WTA)
- Take out respondents with random answering behaviour among the 8 choice cards
- In each WTP/WTA subgroup, take out respondents who show non-engagement (4 “I don’t know” out of 4

<table>
<thead>
<tr>
<th></th>
<th>Number of respondents</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>3016</td>
<td>72784</td>
</tr>
<tr>
<td><strong>Version 1</strong></td>
<td>1500</td>
<td>36000</td>
</tr>
<tr>
<td><strong>Version 2</strong></td>
<td>1516</td>
<td>36384</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th><strong>WTP</strong></th>
<th><strong>WTA</strong></th>
<th><strong>WTP</strong></th>
<th><strong>WTA</strong></th>
<th><strong>WTP</strong></th>
<th><strong>WTA</strong></th>
<th><strong>WTP</strong></th>
<th><strong>WTA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. WTP/WTA differentiations</td>
<td>1331</td>
<td>1331</td>
<td>1346</td>
<td>1346</td>
<td>15972</td>
<td>15972</td>
<td>16152</td>
<td>16152</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th><strong>WTP</strong></th>
<th><strong>WTA</strong></th>
<th><strong>WTP</strong></th>
<th><strong>WTA</strong></th>
<th><strong>WTP</strong></th>
<th><strong>WTA</strong></th>
<th><strong>WTP</strong></th>
<th><strong>WTA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Take out respondents who showed non-engagement (more than 3/4 I don’t knows)</td>
<td>1287</td>
<td>1309</td>
<td>1303</td>
<td>1312</td>
<td>15444</td>
<td>15708</td>
<td>15636</td>
<td>15744</td>
</tr>
</tbody>
</table>
Potential drivers of heterogeneity

General statistics

- A priori identification of potential heterogeneity among population:
  - **General statistics**: age, whether there are children in the household, education, dwelling environment
  - **Reliance on electricity**: whether produces own elec, whether is electrically heated or cooled
  - **Occupation and income**
  - **Attitudes towards the environment**: green energy plan subscription, concern about climate change
  - **Peak electricity demand time** (attribute in DCE)

<table>
<thead>
<tr>
<th></th>
<th>V1 (season)</th>
<th>V2 (renewables)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>1331</td>
<td>1346</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-24</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>25-34</td>
<td>16%</td>
<td>17%</td>
</tr>
<tr>
<td>35-44</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>45-64</td>
<td>33%</td>
<td>34%</td>
</tr>
<tr>
<td>65-</td>
<td>23%</td>
<td>23%</td>
</tr>
<tr>
<td>Children</td>
<td>33%</td>
<td>35%</td>
</tr>
<tr>
<td>High education</td>
<td>43%</td>
<td>42%</td>
</tr>
<tr>
<td>Setting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>21%</td>
<td>22%</td>
</tr>
<tr>
<td>Urban</td>
<td>79%</td>
<td>78%</td>
</tr>
<tr>
<td>Elec heating</td>
<td>10%</td>
<td>9%</td>
</tr>
<tr>
<td>Own elec</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>AC owner</td>
<td>8%</td>
<td>8%</td>
</tr>
</tbody>
</table>
Potential drivers of heterogeneity
*Occupation and income*

What is your occupation status?

- Employed:
- Retired:
- Unemployed:
- Student:

Income range

- Rather not say:
- >50k:
- 35-50k:
- 25-35k:
- 15-25k:
- <15k:
**Potential drivers of heterogeneity**

**Attitudes towards the environment (V2)**

- Only 10% correlation between environmental concern and subscribers to a green energy plan.
- Higher income respondents, the share of green energy plan subscribers increase to 28%, and the share of respondents not on a plan and willing to pay more increases to 9%.
- Among higher education respondents, these values increased to 30% for green plan subscribers, and decreased to 5% for non-subscribers willing to pay more.
Potential drivers of heterogeneity

Peak demand information

- A large majority of the population (90-92%) have a peak electricity demand in the evening, with 43-45% between 5 and 7pm, 39-41% between 7 and 9pm and 7% between 9 and 11pm.

- Only 6-7% of people claim to have their peak demand in the morning (6-8am), while a marginal amount claim their peak occur during the day (0-1%), or do not know when their peak is (2%).

- This confirms our choice of indicating that peak time occurred between 3 to 9pm in the survey.