INTEGRATING DISCRETE CHOICE EXPERIMENTS AND BOTTOM-UP ENERGY DEMAND MODELS TO INVESTIGATE THE LONG-TERM ADOPTION OF ELECTRICAL APPLIANCES IN RESPONSE TO ENERGY EFFICIENCY POLICIES

Tim Mandel
Fraunhofer Institute for Systems and Innovation Research ISI
Background | CHEETAH project

- Horizon 2020
- Duration: 2016 – 2019
- www.briskee-heetah.eu
**Starting point** | What drives households’ adoption of energy efficiency technologies in theory & modelling practice?

---

**Theory & empirical research** | Determinants of technology adoption

- **Financial costs and benefits**
  - Upfront investment
  - Energy expenditures

- **Household characteristics**
  - Income
  - Household size
  - Attitudes, values, norms

- **Technology characteristics**
  - Features
  - Brand
  - Warranty & service

- **Policies**
  - Minimum standards
  - Labels
  - Rebates

---

**Modelling practice** | Total cost of ownership (TCO)

\[ TCO = f(\text{investment, energy expenses, discount rate, lifetime}) \] [EUR/a]

Market share = f(TCO) [\%sales]
Methodology | Integrating discrete choice experiments and bottom-up energy demand modelling

**Objective:** Integrate empirical findings on technology adoption behaviour into a bottom-up model to simulate long-term effects of major EU energy efficiency policies on the adoption of energy-efficient technologies

---

**01 Literature review**
- Empirical findings on energy efficiency adoption and its determinants
- Choice experiment studies on technology adoption

---

**02 Survey**
- Empirically analyse determining factors for technology adoption
- 8 EU Member States
- Discrete choice experiments

---

**03 Model implementation**
- Bottom-up energy demand model FORECAST
- Use survey data to parametrize investment decision-making

---

**04 Scenario analysis**
- Simulate adoption of white appliances in EU-28 in response to policy instruments
- Timeframe 2015 – 2030

© Fraunhofer

Page 4
The core of our empirical research: large representative household surveys

- Demographically representative online survey in 7 EU countries + UK
- Total sample size $n = 4,557$ households
- Data collection 7/2018-8/2018
- Stated Preferences Discrete Choice Experiments (DCEs)
- Wide range of household, individual and dwelling/appliance characteristics, attitudes, energy literacy, ...
Willingness-to-pay for higher energy classes is positive in all countries, though there is substantial heterogeneity within and across countries.

Subsidies increase WTP for A+++ refrigerators in all countries except the UK, though there is again substantial heterogeneity within and across countries.

Households size, income and environmental behaviours have an effect on the valuation of some attributes, but not on WTP for A+++ refrigerators.

Respondents who are more energy literate have a higher WTP for A++ or A+++ refrigerators in 5 out of 8 countries.
Eq. 1. Utility and logit function in FORECAST.

\[ U_{\text{FORECAST}} = \beta_0 + \sum \beta_i X_i \]

(1.1) Utility function

- \( \beta_0 \)
- \( \beta_{\text{bigfamily}} \)
- \( \beta_{\text{lowinc}} \)
- \( \beta_{\text{trash aware}} \)
- \( \beta_{\text{investment}} \)
- \( \beta_{\text{technology option}} \)
- \( \beta_{\text{country}} \)
- \( \beta_{\text{household group}} \)
- \( \beta_{\text{years}} \)
- \( \beta_{\text{no of alternatives}} \)
- \( \beta_{\text{year}} \)

(1.2) Logit function

\[ m_{\text{FORECAST}} = \exp \left( \frac{U_{\text{FORECAST}}}{X} \right) \]

Fig. 2. Overview of the FORECAST modelling approach.

- **Socio-economic framework (FC. Marco)**
  - Gross domestic product
  - Population
  - Wholesale energy carrier prices
- **Dwellings**
  - End consumer energy carrier price
- **Global parameters**
  - Empirical ownership rate
  - Satisfication level of ownership
- **Market DB**
  - Share of technologies & efficiency categories
- **Technology DB**
  - Costs
  - Investment
  - Maintenance
- **Transformation appliance stock**
  - Methodology
  - Simulation growth curve (isre-model)
  - Calibration of growth curve by method of least squares
- **Diffusion of technologies and efficiency classes**
  - Methodology
  - Cost-based diffusion approach (isre-logit model based on NPV calculation)
  - Diffusion restriction (e.g. due to energy policy framework)
- **Applicance electricity demand by scenario**
  - Methodology
  - Accumulation of technology and efficiency class specific electricity consumption

Input  Algorithm  Output  DB Database  t: time step/year  Modification

https://www.forecast-model.eu/
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current-policy scenario (CPS)</td>
<td>Baseline against which the other scenarios can be compared</td>
</tr>
<tr>
<td>Rebates for low-income households (REB-LIG)</td>
<td>Rebates disbursed only to low-income households for best-available efficiency class</td>
</tr>
<tr>
<td>Rebates for all household groups (REB-AIG)</td>
<td>Rebate disbursed to all income groups, regardless of income level</td>
</tr>
<tr>
<td>Tightened minimum energy performance standards (MEPS+)</td>
<td>(MEPS) are tightened in a way that only the two highest efficiency classes available in the market are allowed for sale</td>
</tr>
<tr>
<td>Best-available technology (BAT)</td>
<td>Only best available technology for sale in market</td>
</tr>
</tbody>
</table>
**Fig. 3.** Final energy demand of refrigerators in the eight survey countries, 2008–2030.

**Fig. 4.** Policy effectiveness relative to BAT in target year 2030 for the eight survey countries.
Conclusion | Integrating discrete choice experiments and bottom-up energy demand modelling

Benefits of the approach

- Empirical substantiation of scenario projections
- Representation of diverse consumer groups
- Allows for detailed policy analysis

Limitations of the approach

- Coverage of survey data (EU countries)
- Projection of cross-sectional survey data to future years
- Incomplete implementation of survey data in model
Thank you!

Tim Mandel
Fraunhofer ISI
tim.mandel@isi.fraunhofer.de

Heike Brugger
Fraunhofer ISI
heike.brugger@isi.fraunhofer.de

Marie-Charlotte Guetlein
Grenoble École de Management
marie-charlotte.guetlein@grenoble-em.com

Joachim Schleich
Grenoble École de Management / Fraunhofer ISI
Joachim.schleich@isi.fraunhofer.de