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
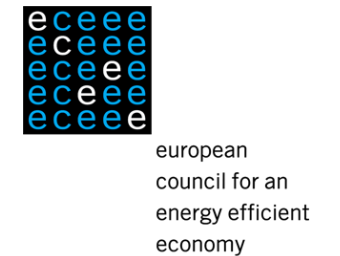
Tim Mandel

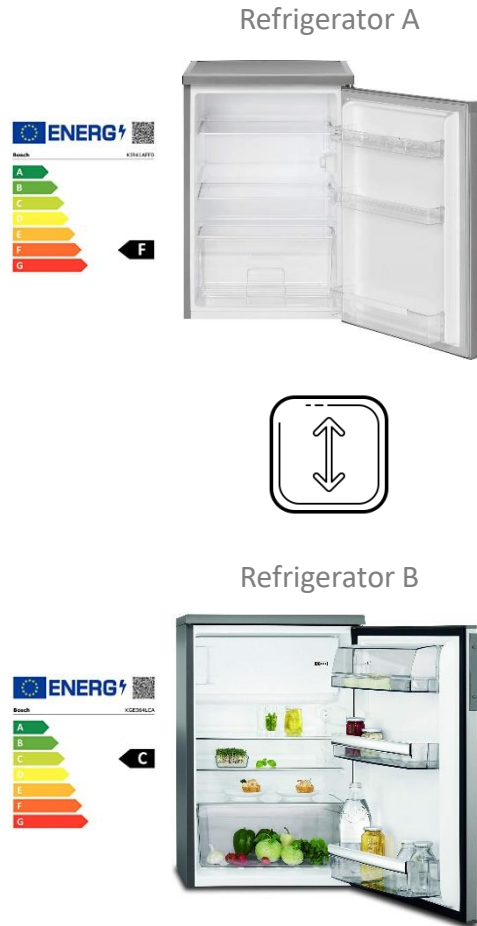Fraunhofer Institute for Systems and Innovation Research ISI

Background | CHEETAH project

- *Horizon 2020*
- Duration: 2016 – 2019
- www.briskee-cheetah.eu

Starting point | What drives households' adoption of energy efficiency technologies in theory & modelling practice?

Refrigerator A

Refrigerator B

Theory & empirical research | Determinants of technology adoption

Financial costs and benefits	Household characteristics	Technology characteristics	Policies
Upfront investment	Income	Features	Minimum standards
Energy expenditures	Household size	Brand	Labels
...	Attitudes, values, norms	Warranty & service	Rebates
	...	...	...

Modelling practice | Total cost of ownership (TCO)

$$TCO = f(investment, energy\ expenses, discount\ rate, lifetime)\qquad [EUR/a]$$

$$Market\ share = f(TCO)\qquad [\%_{sales}]$$

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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

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The core or 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, ...

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- **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.

Guetlein, M.-C., Tu, G., Faure, C., Schleich, J., 2019. Findings from Choice Experiments as Input for Energy-Economic Models Report on survey results relevant to WP 5: Milestone 3 of the CHEETAH Project (Changing energy efficiency technology adoption in households). Grenoble Ecole de Management (GEM), Grenoble.

03 | Model implementation in FORECAST

FORecasting Energy Consumption Analysis and Simulation Tool

Eq. 1. Utility and logit function in FORECAST.

(1.1.) Utility function

$$U_{i,c,g,t} = \beta_{c,1} * price_{i,c,g,t}$$
$$+ (\beta_{c,2} + \beta_{c,3}bigfamily_g + \beta_{c,4}lowinc_g + \beta_{c,5}henvid_g) * A2_{i,c,g,t}$$
$$+ (\beta_{c,6} + \beta_{c,7}bigfamily_g + \beta_{c,8}lowinc_g + \beta_{ic,9}henvid_g) * A3_{0_{i,c,g,t}}$$
$$+ (\beta_{c,10} + \beta_{c,11}bigfamily_g + \beta_{c,12}lowinc_g + \beta_{c,13}henvid_g) * A3_{reb_{i,c,g,t}}$$
$$+ (\beta_{c,14} + \beta_{c,15}bigfamily_g + \beta_{c,16}lowinc_g + \beta_{c,17}henvid_g) * size_{i,c,g,t}$$
$$+ (\beta_{c,18} + \beta_{c,19}bigfamily_g + \beta_{c,20}lowinc_g + \beta_{c,21}henvid_g) * warranty_{i,c,g,t}$$
$$+ (\beta_{c,22} + \beta_{c,23}bigfamily_g + \beta_{c,24}lowinc_g + \beta_{c,25}henvid_g) * star4_{i,c,g,t}$$
$$+ (\beta_{c,26} + \beta_{c,27}bigfamily_g + \beta_{c,28}lowinc_g + \beta_{c,29}henvid_g) * star45_{i,c,g,t}$$
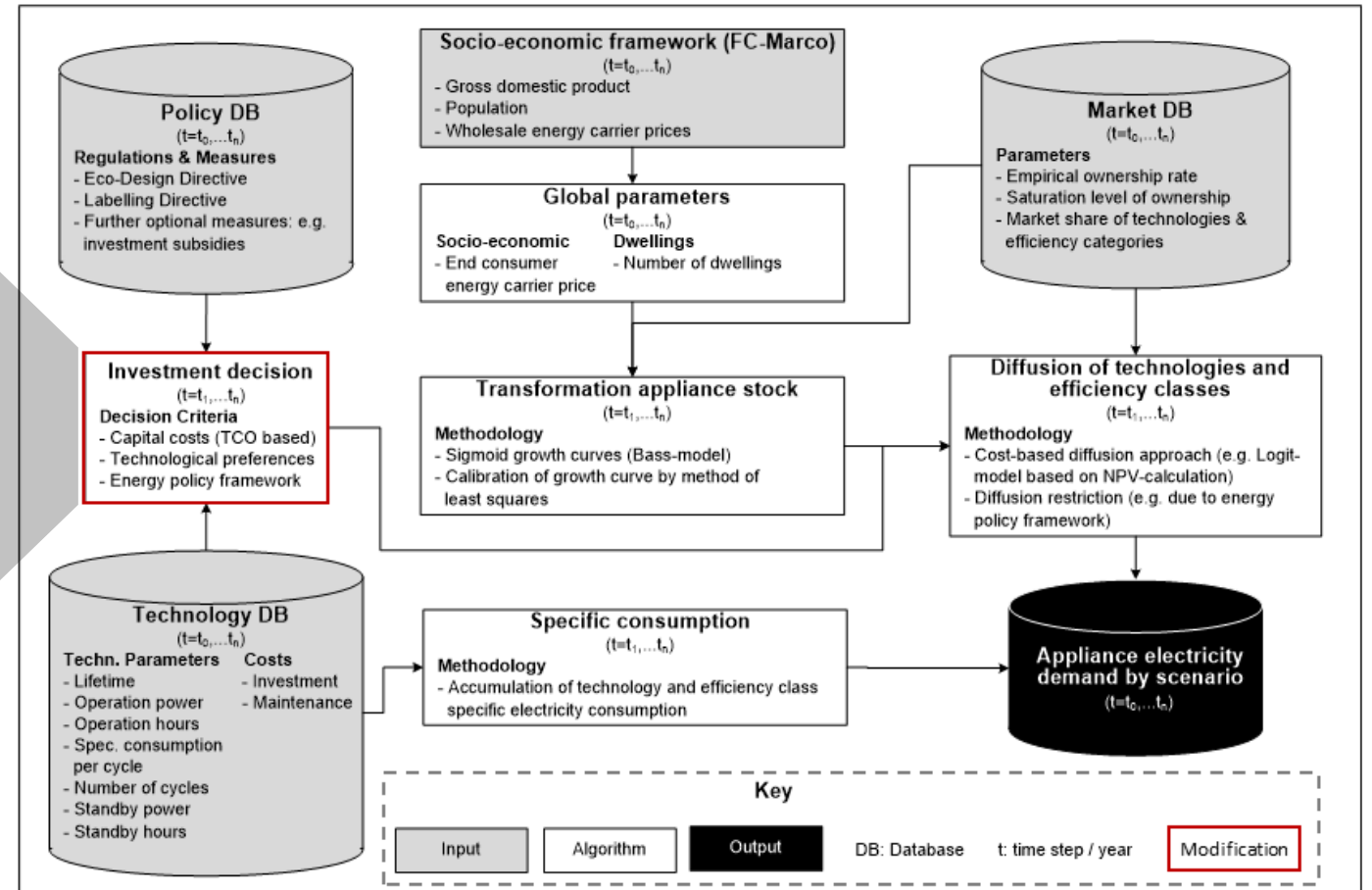
(1.2.) Logit function

$$m_{i,c,g,t} = exp^{-\lambda_{i,c,t} * \frac{U_{i,c,gt}}{\frac{1}{z}\sum_{i=1}^{z} U_{i,c,g,t}}}$$

Key:

Variables		Unit	Indices	
U	= Utility of decision-maker	[€]	i	= Technology option
β	= Weighting coefficient	[none]	c	= Country
$price$	= net price of technology	[€]	g	= Household group
$A2$	= A++ label binary	[litre]	z	= No. of alternatives
$A3\_0$	= A+++ label binary without rebate	[years]	t	= Year
$A3\_reb$	= A+++ label binary with rebate	[none]		
$size$	= Appliance size binary	[none]		
$warranty$	= Warranty binary	[none]		
$star4$	= 4 star rating binary	[none]		
$star45$	= 4.5 star rating binary	[none]		
$bigfamily$	= Family size binary	[none]		
$lowinc$	= Household income binary	[none]		
$henvid$	= Environmental behaviour binary	[none]		
λ	= Heterogeneity of market	[none]		

Fig. 2. Overview of the FORECAST modelling approach.

https://www.forecast-model.eu/

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| Scenario	Description
Current-policy scenario (**CPS**)	Baseline against which the other scenarios can be compared
Rebates for low-income households (**REB-LIG**)	Rebates disbursed only to low-income households for best-available efficiency class
Rebates for all household groups (**REB-AIG**)	Rebate disbursed to all income groups, regardless of income level
Tightened minimum energy performance standards (**MEPS+**)	(MEPS) are tightened in a way that only the two highest efficiency classes available in the market are allowed for sale
Best-available technology (**BAT**)	Only best available technology for sale in market

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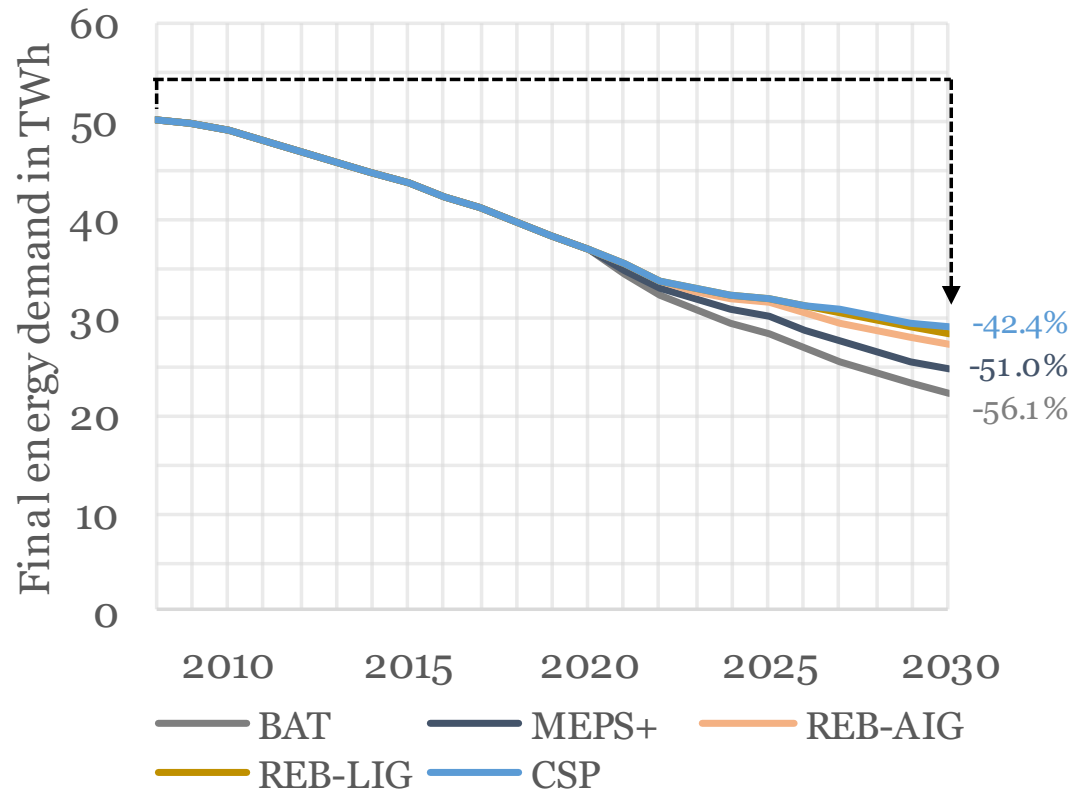
Fig. 3. Final energy demand of refrigerators in the eight survey countries, 2008–2030.
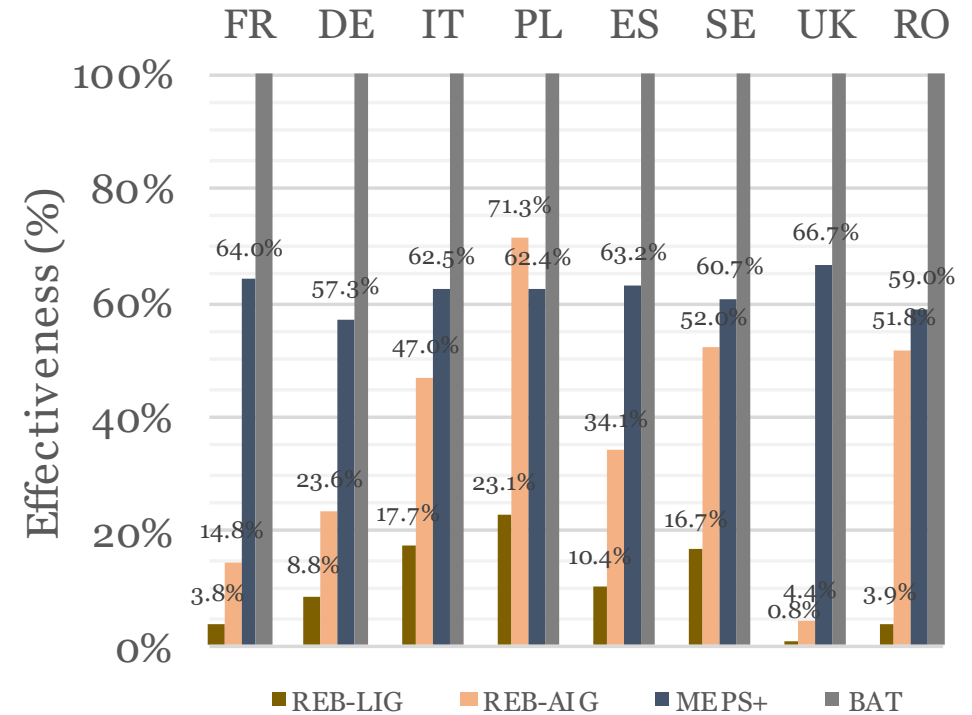

Fig. 4. Policy effectiveness relative to BAT in target year 2030 for the eight survey countries.

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

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Thank you!

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