How French households value their electricity supply choices

Valuation of the hedonic attributes of electricity

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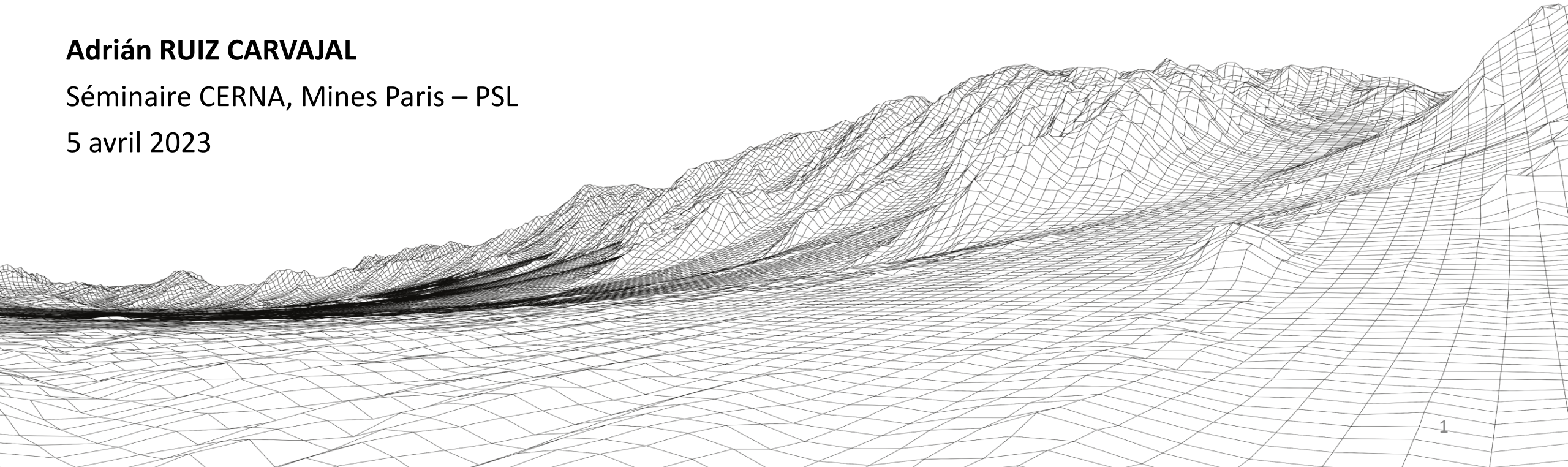

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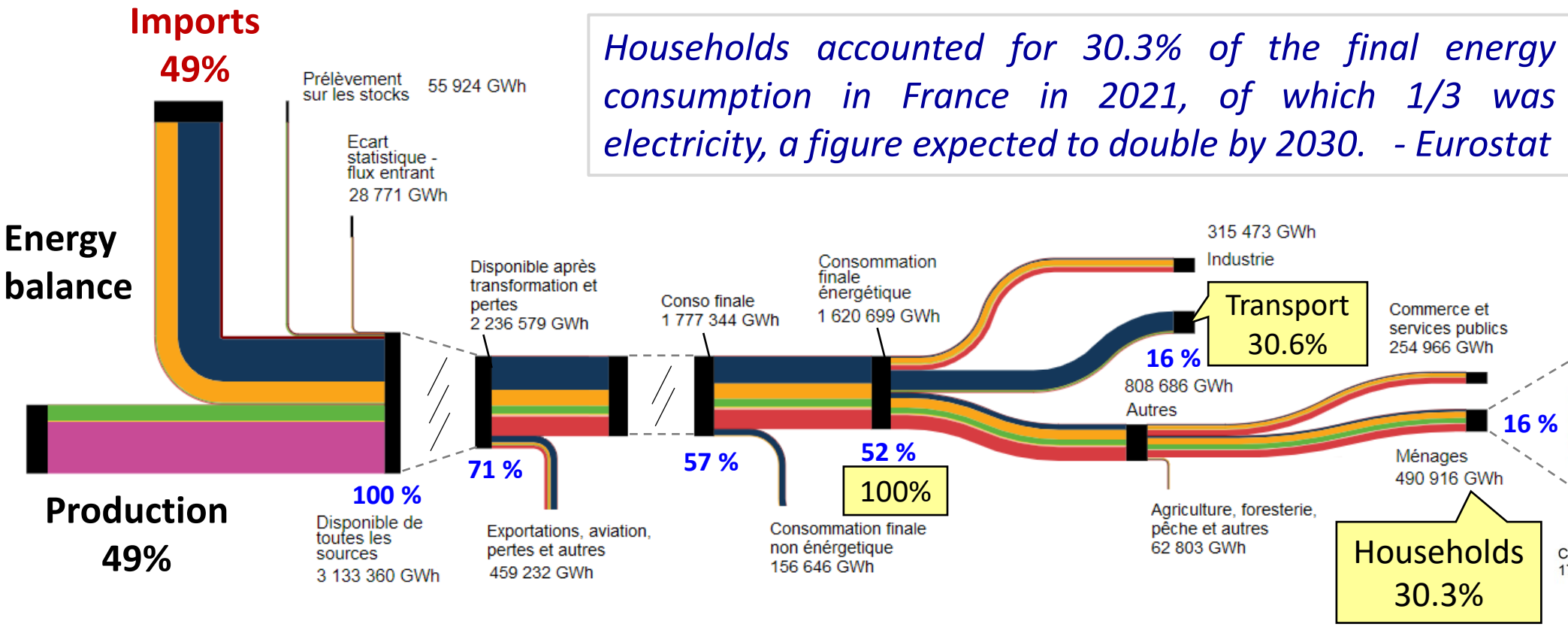
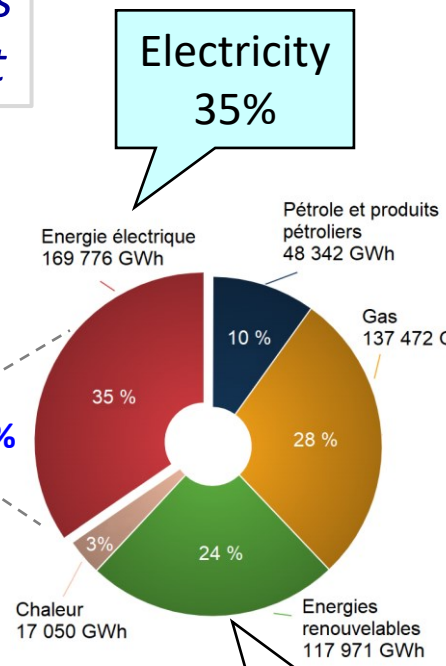
I. Introduction

French energy sources and uses 2020-2021

Households accounted for 30.3% of the final energy consumption in France in 2021, of which 1/3 was electricity, a figure expected to double by 2030. - Eurostat





- Primary solid biofuels (wood) 16.0 %
- Heat pumps 7.6 %
- Solar thermal 0.4 %

Household electricity end uses

Source: Eurostat database

Progress toward an energy transition

There is a European drive to promote renewable energy as a means to achieve a large number of environmental, social and development goals, e.g. EU Directives 2018/2001 & 2019/944; RE 32% → 42.5% @ 2030

France continues to adopt legal and fiscal frameworks[1] to accomodate higher shares of renewables at the individual and collective levels

☞ *More end uses still need to be electrified!*

Consumers are driving the adoption of renewable and local electricity, with implications for future investments and technology choices.

[1] *Code de l'énergie, Arrêté du 24 avril 2016, Ordonnance 2016-1059, Décret 2019-557, LOI n° 2023-175, etc.*

Consumers are already driving renewable adoption

More and more French households are willing to switch to alternative sources of supply

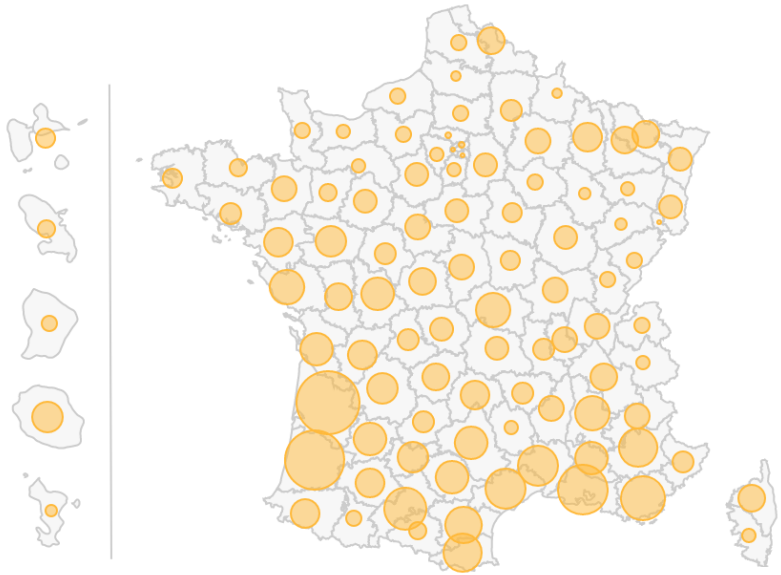
Can their behavior be explained by financial incentives alone, or do they value something else? If so, what and how much?

4 000 000+

Residential consumers subscribed to a 100% “green” electricity offer in 2020, a 152% increase since 2017

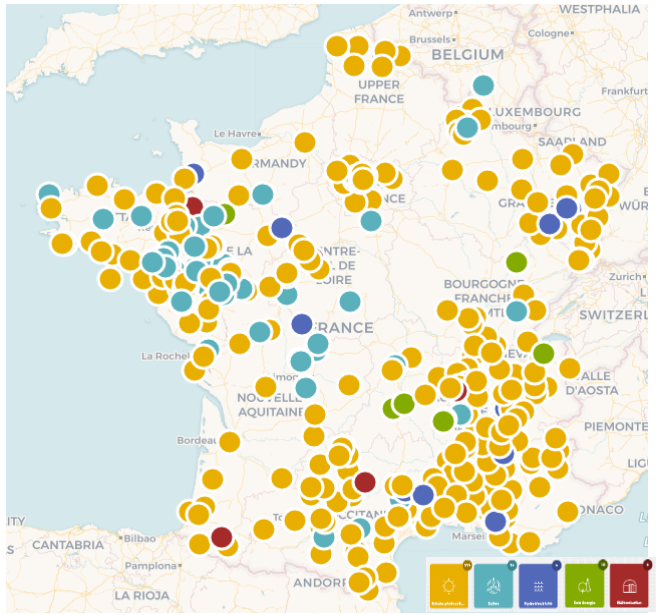
144 000+

Self-consumption installations < 9 kW (2022)



296+

Energy communities in 2023

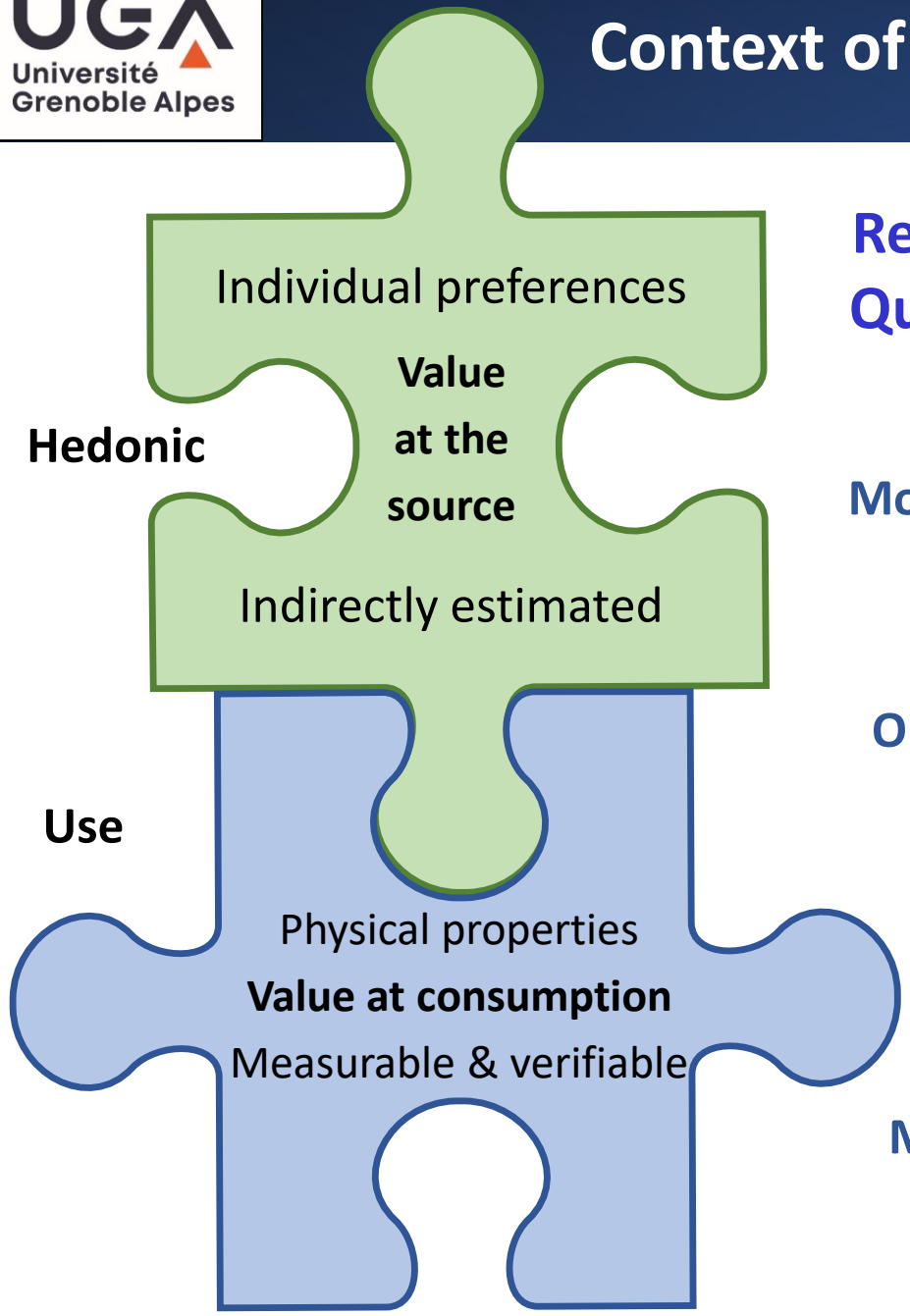


https://www.cre.fr/Documents/Publications/Rapports-thematiques/le-fonctionnement-des-marches-de-detail-francais-de-l-electricite-et-du-gaz-naturel-rapport-2018-2019

https://www.statistiques.developpement-durable.gouv.fr/publicationweb/527

https://energie-partagee.org/

Context of the study



Research Question *What motivates households to pay a premium for electricity that appears identical?*

Motivation ***WHY***

The energy transition can be accelerated by understanding the motivations and preferences behind consumer choices.

There is limited research on French households' willingness to pay (WTP) for the hedonic attributes of electricity.

Objective ***WHAT***

To reveal the WTP of French households for the hedonic attributes of electricity and their sources.

Premise: Individuals are (constrained) rational utility maximizers.

Hypotheses: Electricity perceived as differentiated based on hedonics.

Method ***HOW***

Using a ***Discrete Choice Experiment (DCE)*** to elicit preferences towards (hypothetical) products and services that contain hedonic attributes.

Electricity as a differenciated good

TYPE	CATEGORY	ATTRIBUTE	EXAMPLE	REFERENCE
Use	Economic	**Price**	Selling price, LCOE	Yang et al., 2015 ; Hirsch et al., 2018
			Opportunity cost	Kirchhoff and Strunz, 2019 ; da Silva et al., 2020
		Quality	kWh, customer service	Torsten and Mahmudova, 2010 ; Kirchhoff and Strunz, 2019
Hedonic	Environment	**Green**	Air pollution, GHG emissions, biodiversity, landscape	Yang et al., 2015 ; Morstyn and McCulloch, 2019 ; Hirsch et al., 2018 ; da Silva et al., 2020 ; Balcombe et al., 2013 ; Groh and Möllendorff, 2019
	Sociale	**Local**	Local solidarity, P2P, belonging, short circuits	Morstyn and McCulloch, 2019 ; Tröndle et al., 2019 ; Palm, 2017
	Psychological	**Autonomy**	Autarky, independence, self-sufficiency	Ecker et al., 2018 ; Müller et al., 2011 ; Rae and Bradley, 2012 ; Pienkowski & Zbaraszewski, 2019
		Control	Security, flexibility, data privacy	Ecker et al., 2018 ; Hirsch et al., 2018 ; Cuijpers and Koops, 2012
		Altruism	Philanthropy, moral obligation, “warm glow”	Morstyn and McCulloch, 2019 ; Groh and Möllendorff, 2019 ; Ito et al., 2010 ; Wolske et al., 2017
		Status	Reputation, conspicuous consumption	Satsiou et al., 2013 ; Krovvidi, 2010 ; Dastrup et al., 2011 ; Hoen et al., 2015 ; Menges et al., 2005

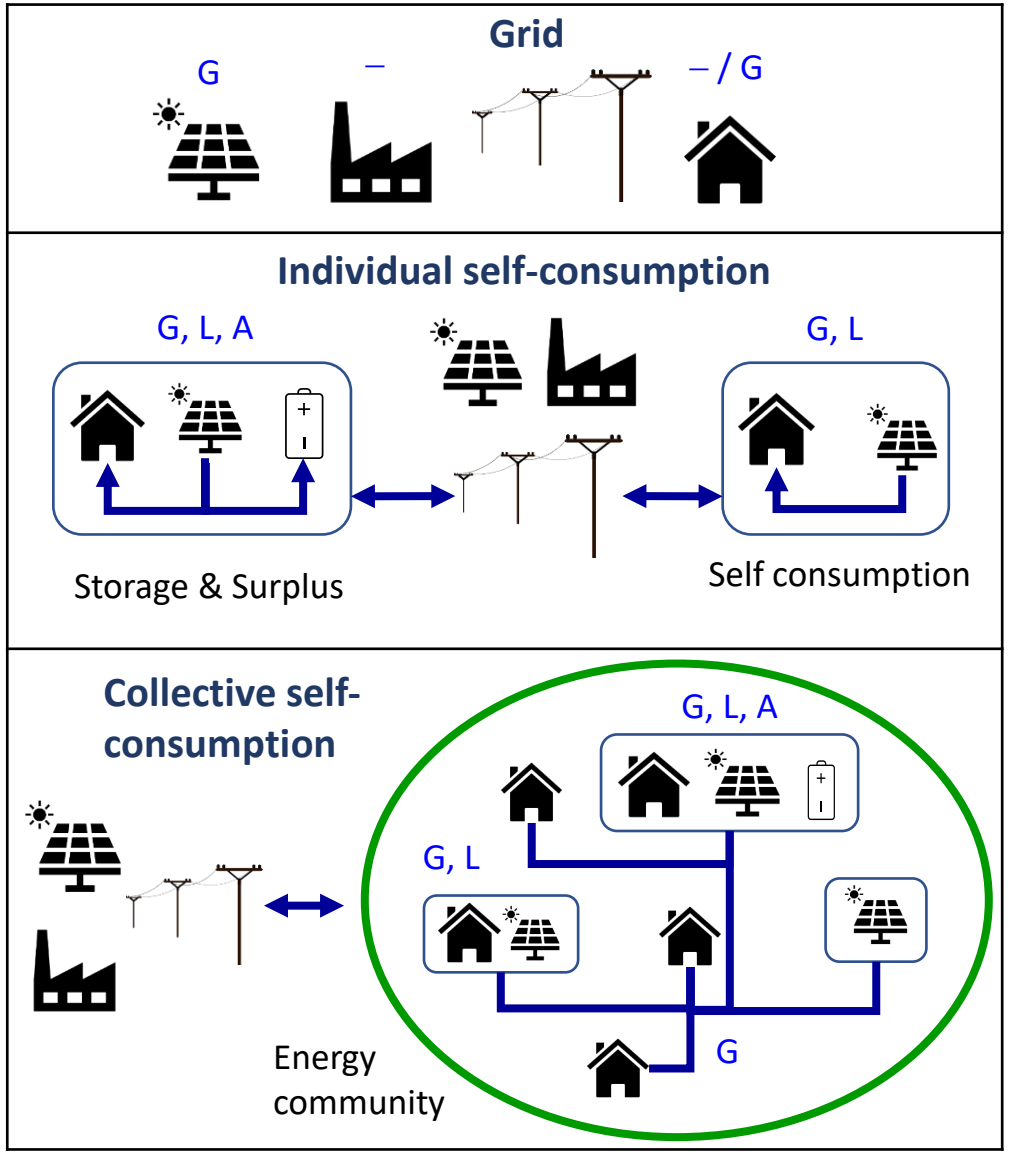
II. The Research

Hedonic attribute selection

Price	Monthly premium assumed positive for attributes and zero by default. Percentage (0 – 30%) and €/m.
Green	Percentage (0 – 100%) of renewable electricity supplied from any technology (excluding nuclear).
Local	Percentage (0 – 50%) of electricity produced at a distance of up to 40 km.
Autonomy	Percentage (0 – 50%) of total consumption that is self-produced (only generation ± storage).

Attributes and levels

ATTRIBUTE	CODE	LEVEL	VALUE	SOURCE		
				Grid	Individual	Collective
Green	G1	*status quo*	25%	•	-	-
	G2	Low	50%	•	•	•
	G3	Medium	75%	•	•	•
	G4	High	100%	•	•	•
Local	L1	*status quo*	0 %	•	-	-
	L2	Low	25%	-	•	•
	L3	Medium	50%	-	•	•
Autonomy	A1	*status quo*	0%	•	-	•
	A2	Low	25%	-	•	-
	A3	Medium	50%	-	•	-
Price premium	P1	*status quo*	+ 0 €/m	•	•	•
	P2	+ 0-5%	+ 0-3 €/m	•	•	•
	P3	+ 5-15%	+ 3.1-10 €/m	•	•	•
	P4	+ 15-30%	+ 10.1-20 €/m	•	•	•
	P5	> 30%	> 20 €/m	•	•	•

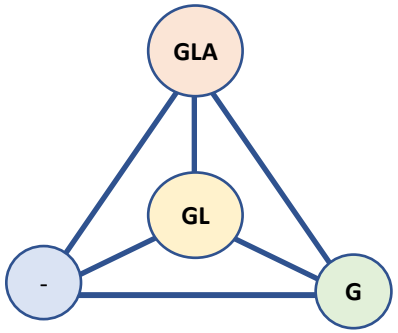


From 180 choice cards to 10 scenarios

- Full factorial:

$$4^{1\,\{\text{green}\}} \cdot 3^{\,2\,\{\text{local+auto}\}} \cdot 5^{1\,\{\text{price}\}} = 180$$

- Initially 30 choice cards (scenarios) were produced:
  - ✓ **15** ***D-error efficient*** to minimize the correlation between parameters and the standard error[1]. Ideal for mixed logit
  - ✓ **15** ***C-error efficient*** to minimize the variance of the ratio between 2 parameters. Ideal for estimating WTP
- We reduced from **30** to **10** scenarios using simplifying assumptions on household consumption, quality of supply, transaction costs and local procurement.



Final 10 choice cards (scenarios)

CARD (scenario)	GRID		COLLECTIVE			INDIVIDUAL			
	G	P	G	L	P	G	L	A	P
1	50 %	0 %	50 %	50 %	15 %				
2	75 %	5 %	75 %	25 %	10 %				
3	25 %	0 %				25 %	25 %	25 %	5 %
4	50 %	5 %				75 %	50 %	50 %	15 %
5	75 %	10 %				75 %	50 %	50 %	20 %
6			25 %	25 %	5 %	75 %	25 %	0 %	10 %
7			75 %	50 %	10 %	75 %	50 %	50 %	15 %
8			25 %	25 %	0 %	75 %	25 %	25 %	15 %
9			75 %	25 %	5 %	50 %	50 %	0 %	10 %
10			50 %	50 %	10 %	75 %	50 %	50 %	20 %

[1] This corresponds to the diagonal of the variance-covariance matrix.

Simplifying Assumptions

Household consumption

1. The average household electricity consumption remains fixed.
2. No household is isolated from the grid (no 100% self-consumption).
3. Households with WTP > €30/month are negligible (Shi et al., 2013).
4. Self-consumption cannot exceed self-production.
5. The default supply (EdF *tarif bleu*) has 25% green, 0% local and 0% autonomy.

Quality of supply

6. The quality of supply from all sources is identical.
7. Only individual production with storage has all 3 hedonic attributes.

Transaction costs

8. Negligible costs to switch supply (*in practice switch rate > 10%, CRE 2019*).

Local procurement

9. Local electricity can be green or fossil.
10. Collective self-consumption provides no autonomy to strict consumers, as they are still reliant on third party generators (producers in the community).

Example: Scenario 8

Participants were informed of the definitions and characteristics of each attribute and source in advance.

CARD (scenario)	GRID		COLLECTIVE			INDIVIDUAL			
	G	P	G	L	P	G	L	A	P
1	50 %	0 %	50 %	50 %	15 %				
2	75 %	5 %	75 %	25 %	10 %				
3	25 %	0 %				25 %	25 %	25 %	5 %
4	50 %	5 %				75 %	50 %	50 %	15 %
5	75 %	10 %				75 %	50 %	50 %	20 %
6			25 %	25 %	5 %	75 %	25 %	0 %	10 %
7			75 %	50 %	10 %	75 %	50 %	50 %	15 %
8			**25 %**	**25 %**	**0 %**	**75 %**	**25 %**	**25 %**	**15 %**
9			75 %	25 %	5 %	50 %	50 %	0 %	10 %
10			50 %	50 %	10 %	75 %	50 %	50 %	20 %

Offer type	**Offer A**	**Offer B**	**PRESENT**
Supply type	Collective self-consumption	Individual self-consumption	Supplier (national grid)
Green	25 %	75 %	25 %
Local	25 %	25 %	0 %
Autonomy	0 %	25 %	0 %
Price premium	+0 % (0 €/m)	+15 % (10.2 €/m)	+ 0 % (0 €/m)

Survey development

Beta
215 invitations
130 accepted
116 responded

Main
886 invitations
539 accepted
503 responded

- ✓ Grenoble-Alpes Métropole
- ✓ 29 - 31 March, 2022
- ✓ 2/3 live in apartments, 2/3 owners
- ✓ Average bill: 71 €/m declared; 83 €/m estimated

RGPD | Oath

w_{ij}

Part 1
ENERGY CONSUMPTION

- Housing type
- Occupation
- Area
- Space heating
- Water heating
- Ownership

Bill ?
- YES : kWh, €/m
- NO : estimate kWh, €/m

Individual-specific €/m

Part 2 x_{ij}
PREFERENCES

Context and information
- Electricity attributes
- Individual & collective self-consumption
- Context, instructions and constraints

DCE : 10 scenarios x 3 offers

Part 3 w_{ij}
SOCIO-DEMOGRAPHIC

- Preferences, beliefs, attitudes
- Knowledge of the sector
- Demographics

End, payment

Descriptive statistics

HOUSEHOLD	Value	No.	%	Reference
Type of dwelling (TYPE)	House	157	31.2	49.9 %
	Apartment	346	68.8	49.1 %
Tenure (PROP)	Owner	309	61.4	58.8 %
	Tenant	185	36.8	39.1 %
	Shared	9	1.8	*N/A*
Occupancy (OCCUP)	Mean no. of residents	503	2.6	2.19
Electricity bill (BILL)	€/month, stated	455	70.5	184 (200)
Electricity bill (EST_BILL)	€/month, estimated	503	82.7	184 (200)
Power consumption (EST_CONS)	kWh/month, estimated	503	321.8	451.4
Current contract (CONT)	Regular supplier	421	83.7	*N/A*
	Green supplier	45	8.9	*N/A*
	Self-production	3	0.6	*N/A*
	Other	34	6.8	*N/A*
Main heating (HEAT)	Percentage electric heating	131	26.0	26.2 - 32.4 %
Water heating (WHEAT)	Percentage electric water heating	193	38.4	46.5 %

DEMOGRAPHIC	Value	No.	%	Reference
Age (AGE)	Mean (2022 – year of birth)	503	43.5 y	*N/A*
Gender (GEN)[30]	Male	144	29.1	48.6 %
	Female	351	70.9	51.4 %
Education (EDU)[31]	High school or below	113	22.5	47.9 %
	Advanced degree	390	77.5	31.8 %
Employment (JOB)[32]	Self-employed	29	5.8	4.7 %
	Mid-level professionals	173	34.4	24.6 %
	Employees	175	34.8	15.6 %
	Blue collar worker	4	0.8	12.4 %
	Intermediate occupation	63	12.5	15.2 %
	Retired	35	7.0	27 %
	Unemployed	24	4.8	15.7% (2020)
Household income *(INC)*	Mean (€/m)	503	3,346	1,884 (2019)

Houses 31% ◆ 50% region

Water heating 38% ◆ 46.5% region

Bill 70-83 €/m ◆ 184 €/m region

Female 71% ◆ 51% region

Advanced degree 77% ◆ 32% region

Income 3,346 €/m ◆ 1,884 €/m region

Sources: INSEE, 2018-2021; ADEME 2016; MonExpert, 2021

III. Results

Econometric model: Logit

« Random utility models »

Observed & random elements

$$\boldsymbol{U_{ij} = \theta z_{ij} + \varepsilon_{ij}} \;;\; \boldsymbol{\theta \rightarrow [\beta_i, \gamma_j]} \;;\; \boldsymbol{z_{ij} \rightarrow [x_{ij}, w_{ij}]}$$

$$\boldsymbol{U_{ij} = \alpha_j + \beta_i x_{ij} + \gamma_j w_{ij} + \varepsilon_{ij}}$$

where:

U_{ijk}	utility derived by individual i from choosing option j under distribution k
z_{ij}	Observed characteristics of individual i and option j
θ	vector of unobserved coefficients
α_j	nominal fixed factor (intercept) associated to the base scenario
β_i	Unobserved generic coefficients for individual i
γ_j	Unobserved alternative j-specific coefficients
x_{ij}	Observed attributes of choice j evaluated by individual i
w_{ij}	Observed characteristics of individual i making choice j
σ_k	standard deviation of distribution k
ε_{ij}	Unobserved i.i.d random error component

« Multinomial logit»

Individual-specific characteristics

$$\boldsymbol{U_{ij} = \gamma_j w_{ij} + \varepsilon_{ij}}$$

« Conditional logit»

Choice-specific attributes

$$\boldsymbol{U_{ij} = \beta_i x_{ij} + \varepsilon_{ij}}$$

« Mixed logit »

Individual and choice-specific coefficients as random distributions

Random coefficients

Emphasis on preference variations

$$\boldsymbol{U_{ijk} = \beta_{ik} x_{ij} + \varepsilon_{ij}}$$

random $\boldsymbol{\beta_{ik}} \sim N(mean_k, cov_k)$

Error components

Emphasis on attribute correlations

$$\boldsymbol{U_{ijk} = \beta_i x_{ij} + \gamma_j w_{ij} + \varepsilon_{ij}}$$

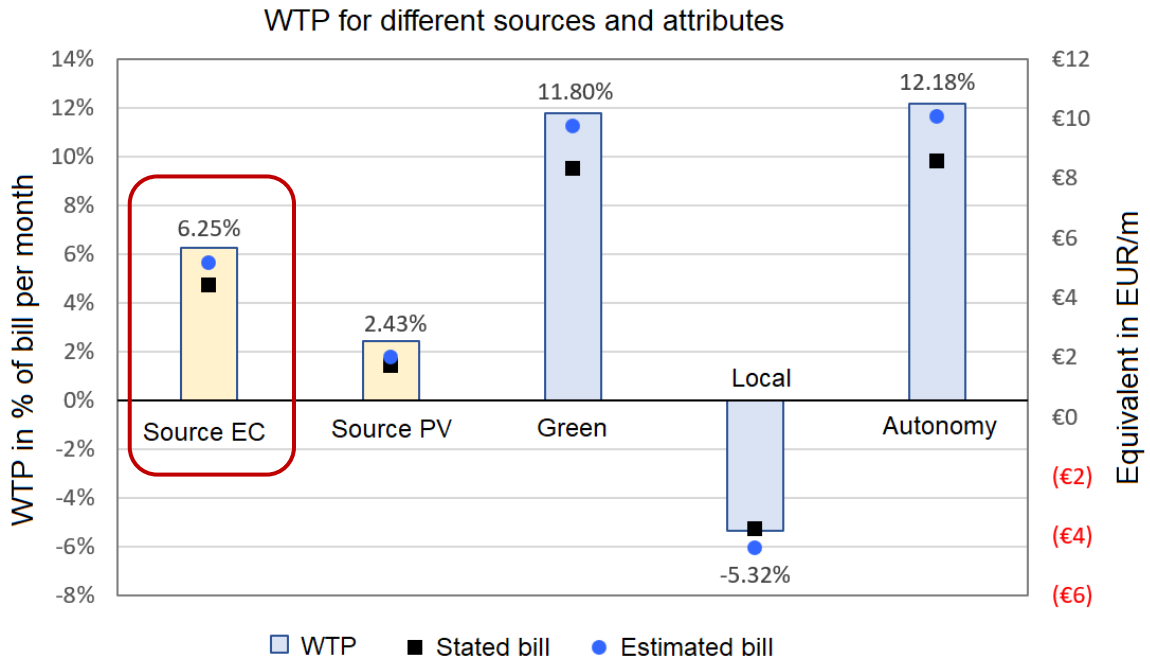
random $\boldsymbol{\gamma_j = \gamma} \sim N(0, \sigma_k)$

Willingness to Pay

- WTP is estimated as the marginal rate of substitution (MRS) between a coefficient β_{ij} and the price coefficient β_P.
- 51.5% of respondents had a WTP = 0 and the average WTP for the rest was +8.9%.
- To obtain the WTP in €/month multiply the MRS by the bill.

Example: the average premium to increase by 25% the supply from an EC is +6.25% (4.41 - 12.50 €/m)

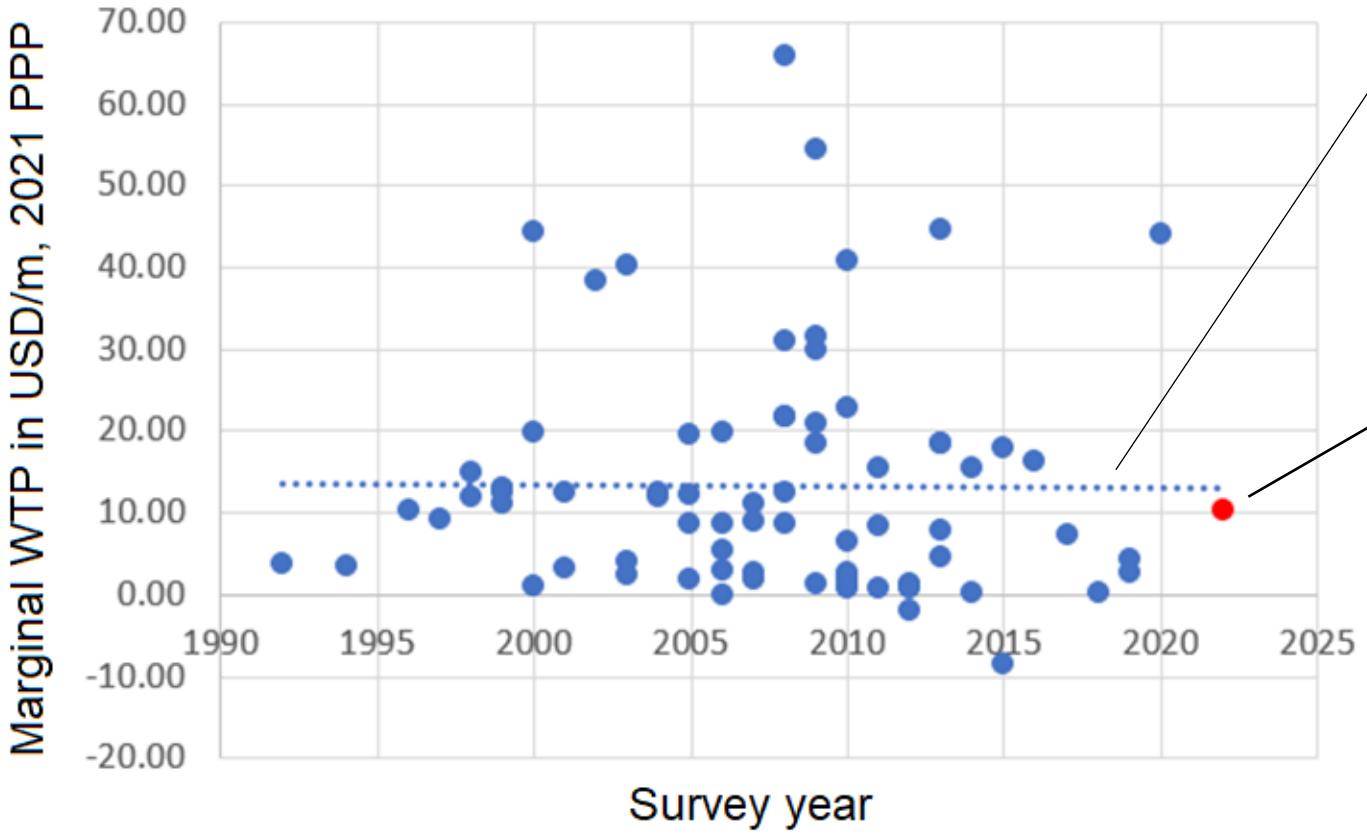
$$CaP_{ij} = -\frac{\beta_{ij}}{\beta_P} = -\frac{1{,}100}{(-0{,}176)} = 6.25$$



	Attribute	WTP +%/m	Stated bill (70.5 €/m)	Est. bill (82.7 €/m)
β_1	Collective	**6.25%**	4.41	5.17
β_2	Individual	**2.43%**	1.71	2.01
β_3	Green	**11.80%**	8.32	9.75
β_4	Local	**-5.32%**	-3.75	-4.40
β_5	Autonomy	**12.18%**	8.59	10.07

WTP for green electricity in the literature

Average WTP for green electricity in 80 studies identified in the literature: **12.89 USD/m** PPP



WTP in this study:

9.04 €/m (8.32 - 9.75)

10.26 USD/m PPP

Source: Compiled by the author

Individual & household-specific characteristics

- ✓ Mixed logit takes into account the characteristics of choices and individuals.
- ✓ A total of 40 questions with 146 choices were included in the survey.
- ✓ **Zero-inflated models*** make it possible to identify statistically significant variables within a large set of variables whose coefficients are close to zero.

$$U_{ij} = \alpha_j + \boldsymbol{\beta}_i \boldsymbol{x}_{ij} + \boldsymbol{\gamma}_j \boldsymbol{w}_{ij} + \varepsilon_{ij}$$

$$U_{ij} = \alpha_j + \boldsymbol{\beta}_i CHOICE_{ij} + \boldsymbol{\gamma}_j INDIV_{ij} + \varepsilon_{ij}$$

$$\alpha_j = SOURCE_{GRID}\{P_{0\%} + G_{25\%} + L_{0\%} + A_{0\%}\}$$

$$\boldsymbol{\beta}_i CHOICE_{ij} = \beta_i\{P_{ij} + G_{ij} + L_{ij} + A_{ij}\}$$

$$\boldsymbol{\gamma}_j INDIV_{ij} = HH_i\{\gamma_{1j} \dots \gamma_{9j}\} + PSY_i\{\gamma_{10j} \dots \gamma_{13j}\} + DEM_i\{\gamma_{14j} \dots \gamma_{18j}\}$$

Stat. Significant	Not Significant
Household	**Household**
Own_share ***/***	Bill, €/m **UR**
Supply_PV ***/**	Type (house/apt) **UR**
	Occupancy
	Area
	Heating
	Water heating **UR**
Psychological	**Psychological**
Influence_Price ***/***	Influence_belong
Influence_Green ***/**	Affinity_storage
Influence_Local ***/**	Affinity_neighbor
Influence_Auto ***/*	Identity_enviro
Affinity_PV ***/*	Familiarity_green_other
Opinion_green_exp **/*	Know_other
Know_coop ***/*	
Demographic	**Demographic**
Gender ***/* **OR**	Age
	Educational attainment **OR**
	Occupation
	Revenue **OR**

OR/UR: Over/Under-represented in sample

* In this study Zero-Inflated Poisson (ZIP) and Negative Binomial (NB) models were used.

Main Results I

What did we learn?

We tested the hypothesis of whether (and how much) French households are WTP for 3 hedonic attributes of electricity and their sources.

We conducted a DCE on 503 households from the ARA region and processed the data using various models.

We found statistically significant WTP values for all hedonic attributes and sources.

Main Results II

Green electricity

- Refers to electricity produced from renewable sources such as hydro, wind, solar or biomass.
- **Households are WTP +11.8 % (~ 9 €/m)** for a 25% increase in the green attribute.

Local electricity

- Refers to electricity produced near its place of consumption (ca. 40 km) with any technology.
- With a negative value, **households need a discount of -5.3% (~ 4 €/m)** to accept 25% more of it.

Autonomy

- Refers to the degree of self-sufficiency a household enjoys due to its self-production and storage.
- **It is the most highly valued with a WTP of +12.2 % (~ 9.3 €/m)** for a 25% increase.

Main Results III

And irrespective of their attributes…

Individual self-consumption

- Limited to residential solar PV systems +/- storage
- **WTP of +2.4 % (~ 1.8 €/m)** for a 25% increase in self-produced electricity

☞ *Probably not enough to finance a PV system, but may signal support for the technology (Dastrup S. et al., 2012).*

Collective self-consumption

- Joining a nearby energy community as consumer or prosumer.
- **WTP of +6.3 % (~ 4.8 €/m)** for a 25% increase in energy from an energy community

☞ *Raises the possibility that additional underlying factors may be at play.*

IV. Conclusions and future work

General Conclusions

- **Price is not the main barrier** preventing households from investing in alternative energy sources, **but it sets a boundary** on their WTP for specific attributes.
- Communications strategies should **emphasize autonomy & green** attributes to raise the odds of persuading households to switch.
- **Psychological characteristics appear to dominate** household and demographic characteristics in explaining individual preferences – thus expanding the size of the potential market.
- **The maximization of value** (rather than the minimization of cost) can be a legitimate optimization goal if electricity is a differentiated good and the market is segmented (e.g., an energy community).

➲ General

- ✓ **Expand the research boundaries** to assess households' energy consumption preferences:
  - In different French regions and fuel types (thermal)
  - Explore the robustness of WTP under rising electricity costs
  - Assess the impact of 2022 w.r.t. weaknesses in the electricity generation capacity
- ✓ **Explore the WTP** for:
  - Additional attributes, e.g., energy security
  - Specific technologies, e.g., wind, hydro, bio, storage
  - Alternative applications, e.g., energy efficiency, emissions reductions, e-waste
- ✓ **Assess the value of attributes using securities** (certificates) independent of tech or source.
- ✓ Cross-validate results with data from **revealed preference studies**.
- ✓ Assess the **cost implications to the grid** of the attribute choices presented in this study.

Additional lines of research II

For suppliers

- ✓ Explore the effect of **price discrimination** to maximize value or profits by region/department, e.g., EDF *tarif vert*, *vert régional*.

For individual PV

- ✓ Reassess the 'autonomy' attribute from a **distributed storage (+ EV) perspective**
- ✓ Assess the value assigned by households to the **'democratizing potential' of DERs**
- ✓ Research the **public acceptance** of autonomy-related investments[1]

For communities

- ✓ Explore options to **incentivize household aggregation** into Renewable Energy Communities (*EU Directive 2018/2001*) vs. Citizen Energy Communities (*EU Directive 2019/944*)
- ✓ Explore energy communities as means to **signal "solidarity"** and advance the ideal of a **Social and Solidarity Economy**[2]

[1] Rijnsoever and Mossel (2015) [2] Economie Sociale et Solidaire

THANK YOU

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