NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Deliverable D1.1

Profiling of energy consumers: psychological and contextual factors of energy behavior

Authors: S. Van Hove, M. Karaliopoulos, L. Tsolas, P. Conradie, M. Amadori, I. Koutsopoulos, K. Ponnet

Project Coordinator: Filippos Anagnostopoulos

NUDGE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Understanding energy consumers' behaviour to design nudging interventions: first dive into the NUDGE project

Filippos Anagnostopoulos, NUDGE project Coordinator, IEECP
Peter Conradie, Senior Researcher, imec-mict-ugent
Merkouris Karaliopoulos, Senior Researcher, AUEB

9 November 2021

NUDGE

Nudging consumers towards energy efficiency through behavioural science

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

IEECP
INSTITUTE FOR EUROPEAN ENERGY AND CLIMATE POLICY

domX

Spring-Stof

imec

Zelena Energetska Zadruga

beegy
the energy manager

ACTIVE CITIZENSHIP NETWORK
CITTADINANZATTIVA

Fraunhofer ISI

inegi driving science & innovation

ΟΙΚΟΝΟΜΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

NUDGE

Nudging consumers towards energy efficiency through behavioural science

NUDGE aims to *systematically assess and unleash the potential of* ***behavioral interventions*** *towards achieving higher* ***energy efficiency****;*

and to pave the way *to the* ***generalized use of behavioural interventions*** *as a worthy addition to the* ***policy-making toolbox.***

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

What is nudging?

Nudging: is *any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any option or significantly changing their economic incentives*. R. Thaler, and C. Sunstein. *Nudge: Improving Decisions About Health, Wealth, and Happiness.* Penguin Books, 2009

Facilitating Nudges	Change the preset option; Personalized push notifications through the apps
Confront nudges	Provide information on consequences of actions between decision and action
Social Influence Nudges	Public commitment; Make actions of users visible to others; Comparison chart with social community
Reinforcement nudges	Point out desired behavior at a suitable time; Environmental impact highlighted through examples to create emotions of compassion
Fear nudges	Create perception of scarcity; Provide discount now instead of in the long run
Deceive nudges	Create optical illusions that alter people's perceptions and judgments

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

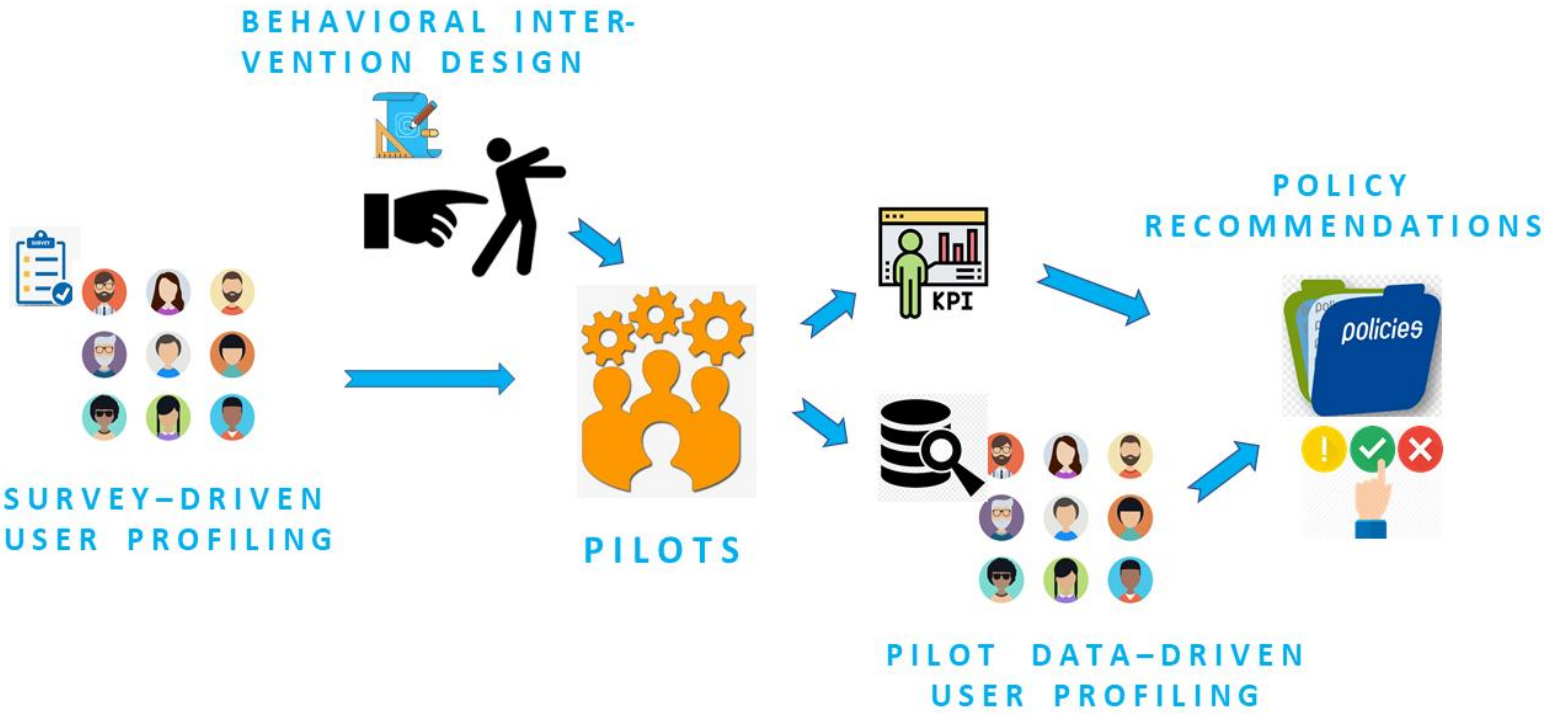
NUDGE Objectives

- Objective 1: Tailor the design of behavioral interventions to individual psychological and contextual variables by leveraging the data collection capabilities of digital mediation platforms and data analytics.
- Objective 2: Execute extensive field trials (pilots) that address multiple instances of consumer behavior, implementing different mixes of behavior-based and traditional interventions even across participants of the same pilot.
- Objective 3: Develop a systematic core and contextual research protocol to continuously measure the impact of the implemented behavioral interventions.
- Objective 4: Consolidate the findings of pilots into recommendations towards policy makers and relevant stakeholders.

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards ener through beha

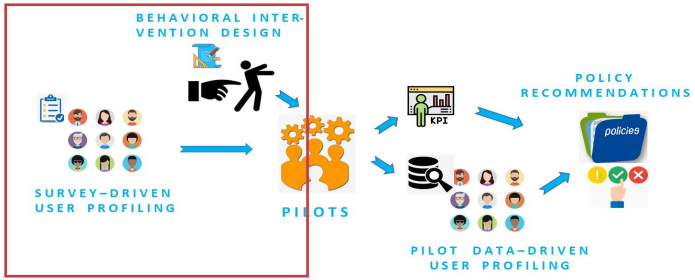


NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Methods and tools



Pre-pilot phase

- Survey-driven user profiling: profile consumers using a broad set of psychological and contextual variables
- Design of interventions (behavior-based and traditional interventions)
- Install energy monitoring and management tools (eg. smart meters, thermostats)
- Employ digital user interfaces (e.g., mobile applications, dashboards) to enable energy consumers to actively and efficiently monitor and manage energy flows
- Central pilot data platform to automate collection and monitoring of pilot data and the calculation of the relevant KPIs for performance comparison

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

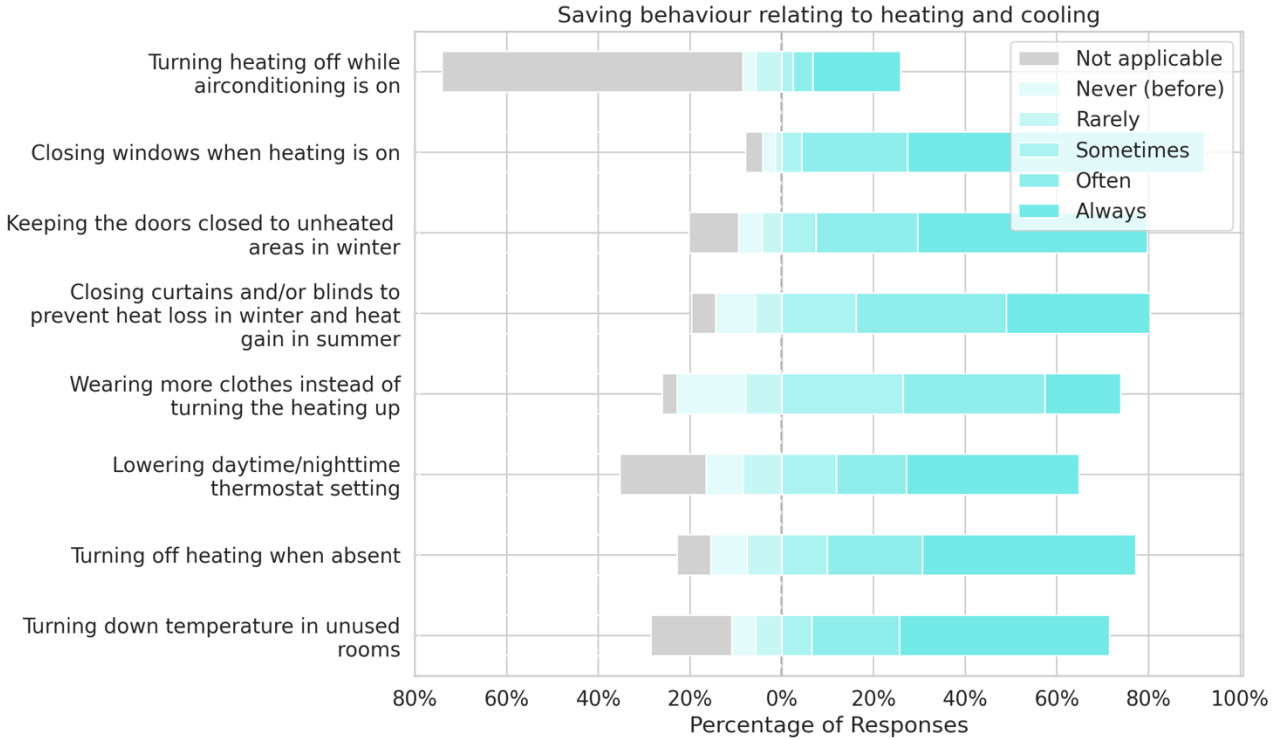
Nudging consumers towards energy efficiency through behavioural science

The NUDGE profiling survey

Based on:

- Theory of Planned Behaviour
- Value-Belief-Norm theory
- Prototype Willingness model

Control variables: Gender, Country of Residence, Income, Age and Level of Education



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Six profiles of energy consumers

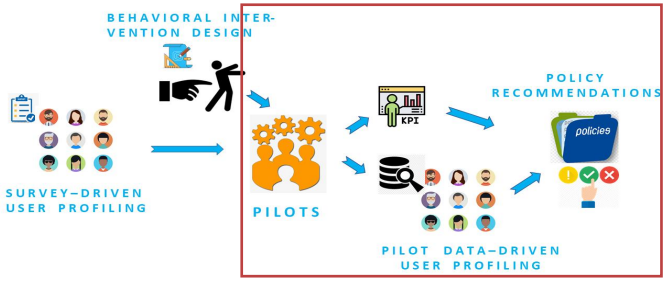
1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Methods and tools



Pilot phase

- Randomized controlled trials (RCTs) including control-treatment groups
- Time phasing of multiple interventions within and across pilots
- Automated monitoring of responses and adoption of tested interventions
- Mixed approach combining surveys and field trials to assess the effectiveness of interventions
- Evaluation of behaviour change across tested interventions and consumer profiles
- Comparison of findings within a pilot and across pilots

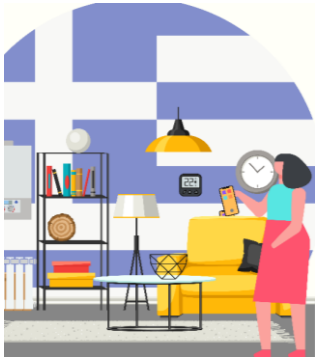
Post-pilot

- recommendations towards policy makers and relevant stakeholders.

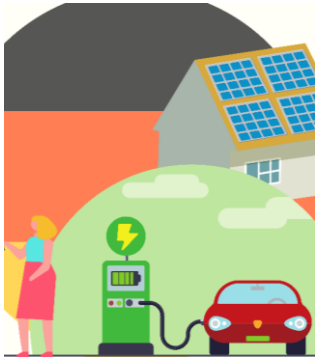
NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

The NUDGE Pilots

Croatia:
Promoting distributed self-production for local Energy communities



Greece:
Efficient control of heating and DHW preparation for Natural Gas boilers



Germany:
Optimization of EV charging with self-produced PV power

Belgium:
Interdisciplinary, project-based education on home energy consumption for children

Portugal:
Healthy homes for long-lasting energy efficiency behavior

Energy monitoring and management tools

Digital user interfaces

Long-term energy efficiency behavior change potential

NUDGE

Nudging consumers towards energy efficiency through behavioural science

imec-mict-UGent

Prof. dr. Koen Ponnet
Ghent University

Stephanie Van Hove
Researcher imec

dr. Peter Conradie
Senior Researcher

Fraunhofer

Sabine Pelka
Researcher Fraunhofer

dr. Katharina Wohlfarth
Researcher Fraunhofer

AUEB

Prof. dr. Iordanis Koutsopoulos
AUEB

Dr. Merkouris Karaliopoulos
Senior Researcher AUEB

Leonidas Tsolas
Researcher AUEB

Prof. dr. Maria Halkidi

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

MVV

Werner Neumeier

Dorina Rauth

ZEZ

Mislav Kirac

Lucija Nad

ACN

Bianca Ferraoilo

Manuela Amadori

Mariano Votta

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

NUDGE Survey

1.General information on the **physical characteristics** of people's main residence, its energy efficiency and or production of energy

2.The second module assessed the stated "actual" **energy-saving behaviour** of respondents

3.The third module had of a series (15) of **attitudinal, motivational** and **behavioural** constructs measuring the underlying theoretical model, with each construct comprising between 3 and 5 items.

4.Module four explored the **potential of energy platforms** that provide real-time energy monitoring but also control and automate energy flows.

5.A fifth and last module included **socio-demographic** indicators such as gender, age, household type, household composition, educational attainment, career status, and income.

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Method

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Sample

Survey sample sourced through several consumer organisations with the help of partner ACN (**n=2087**) and a Flemish panel (**n=1042**)

After data cleaning (i.e.: minors, persons not located in Europe) we arrive at a final sample of **n=3129**

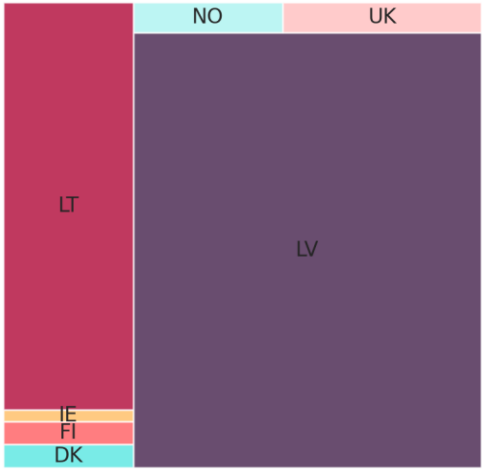
NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

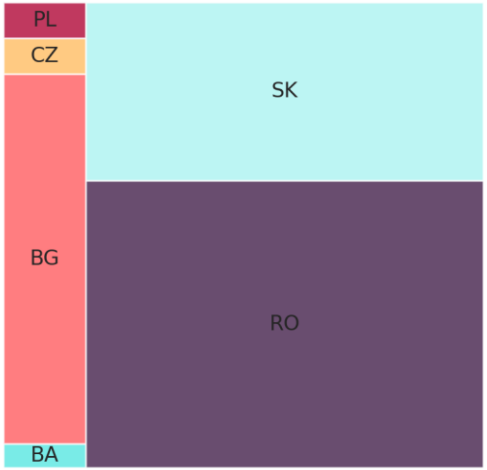
Nudging consumers towards energy efficiency through behavioural science

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

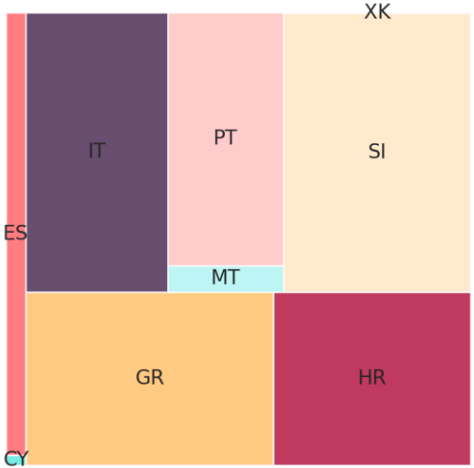
Northern Europe, n=148



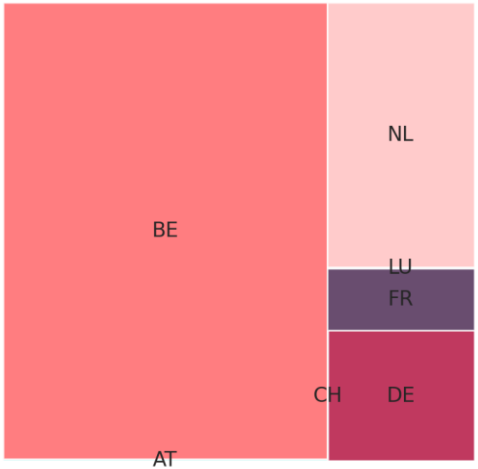
Eastern Europe, n=235



Southern Europe, n=1114



Western Europe, n-1665

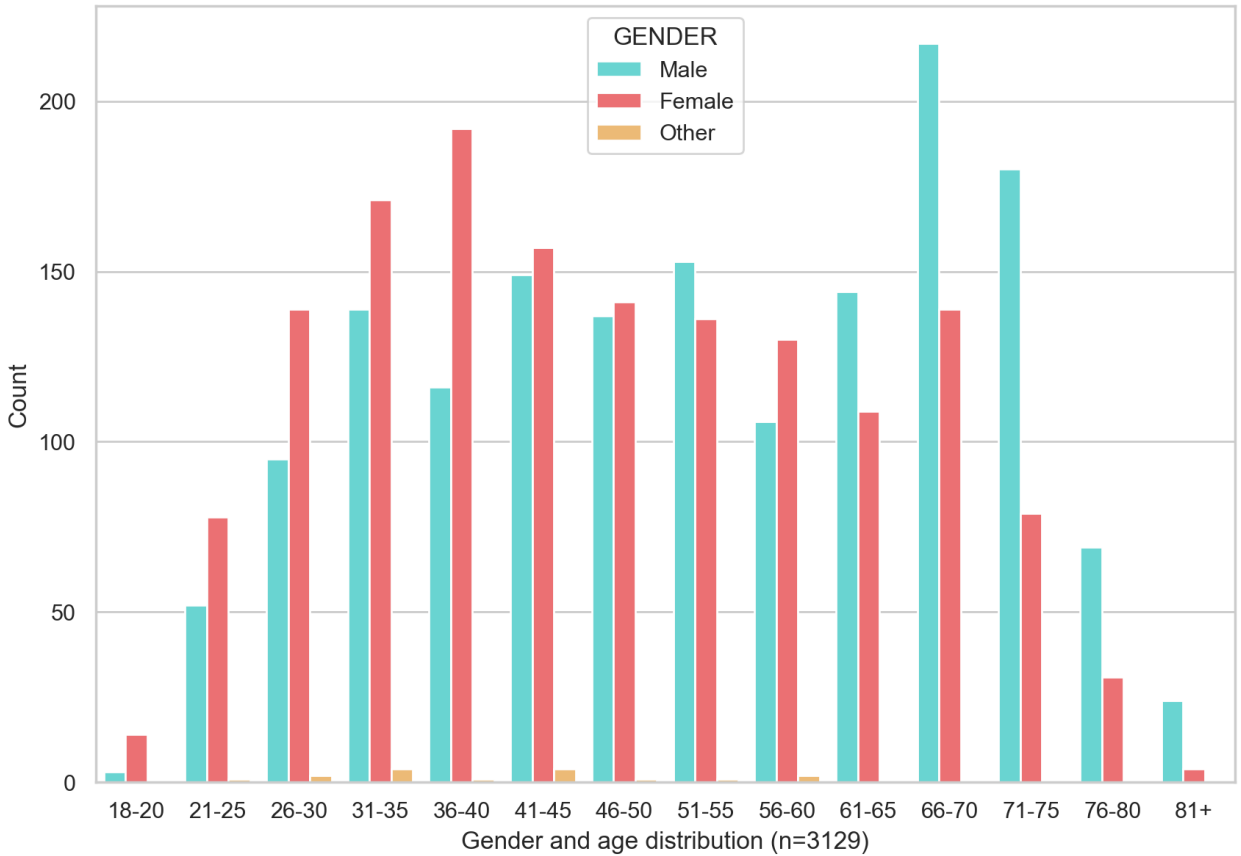


NUDGE

Nudging consumers towards energy efficiency through behavioural science

Sample

Male = 51%; Female = 48.5%; Other = 0.5%



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Saving behaviours in four use domains

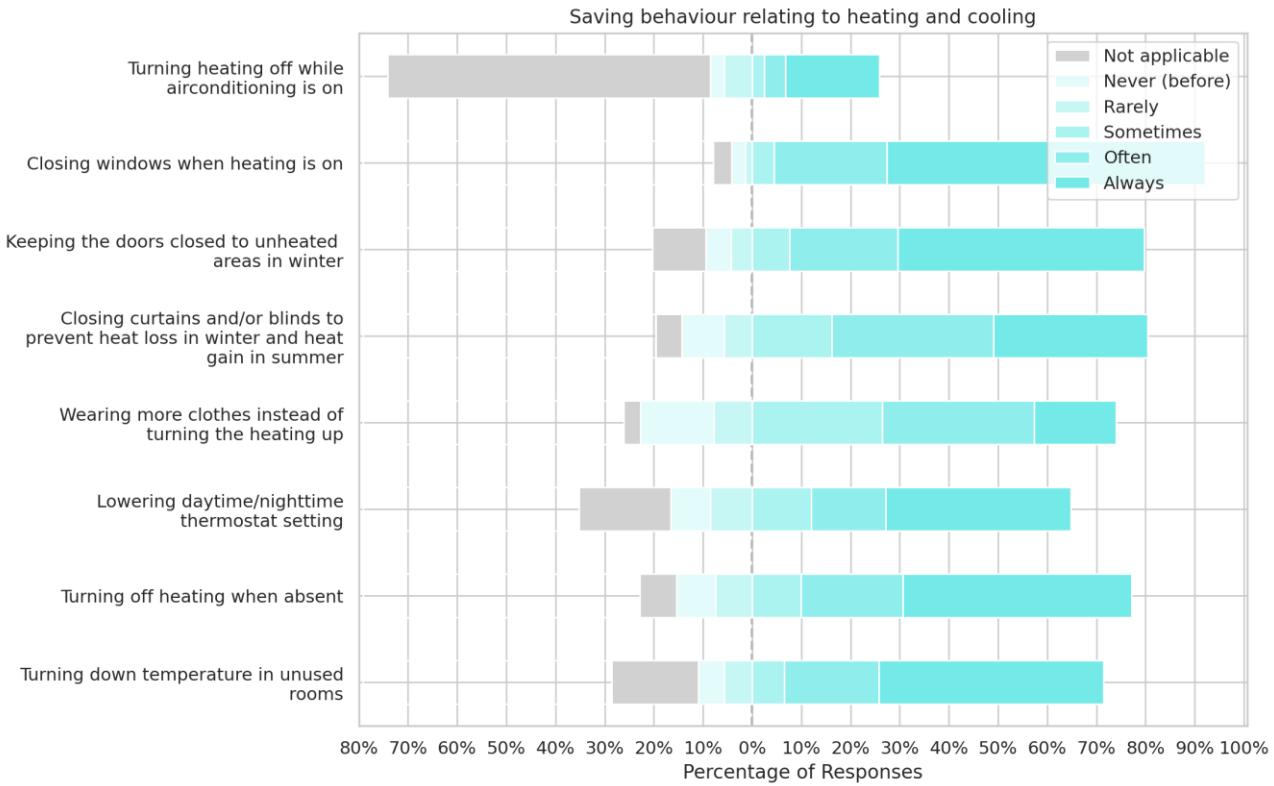
Heating and cooling, water, kitchen and general appliances

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Saving behaviour: heating and cooling

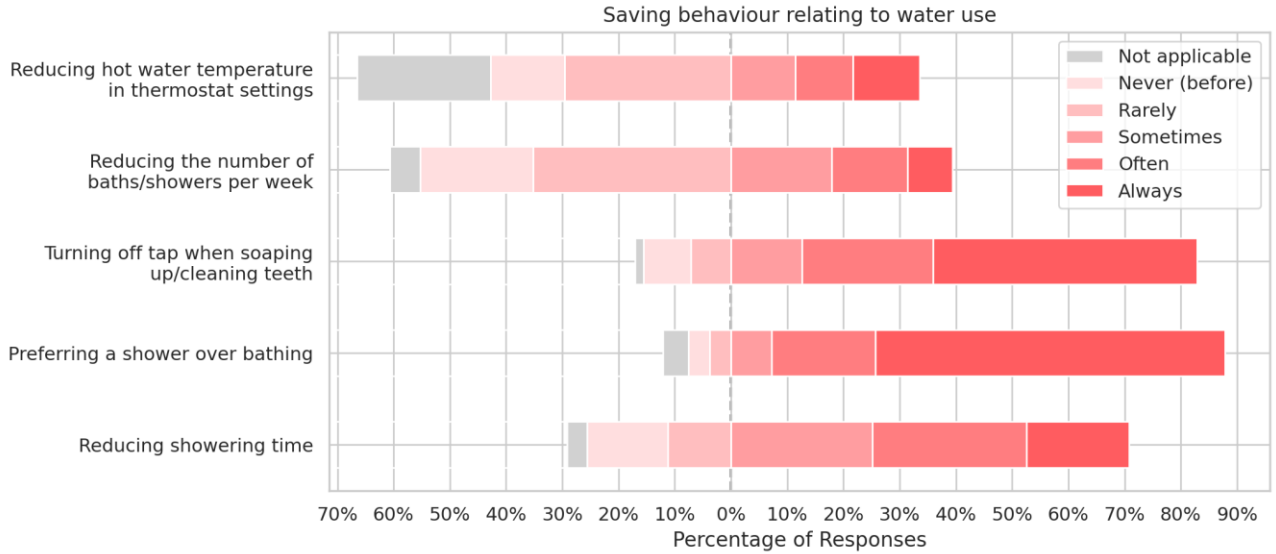


NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Saving behaviour: Water use

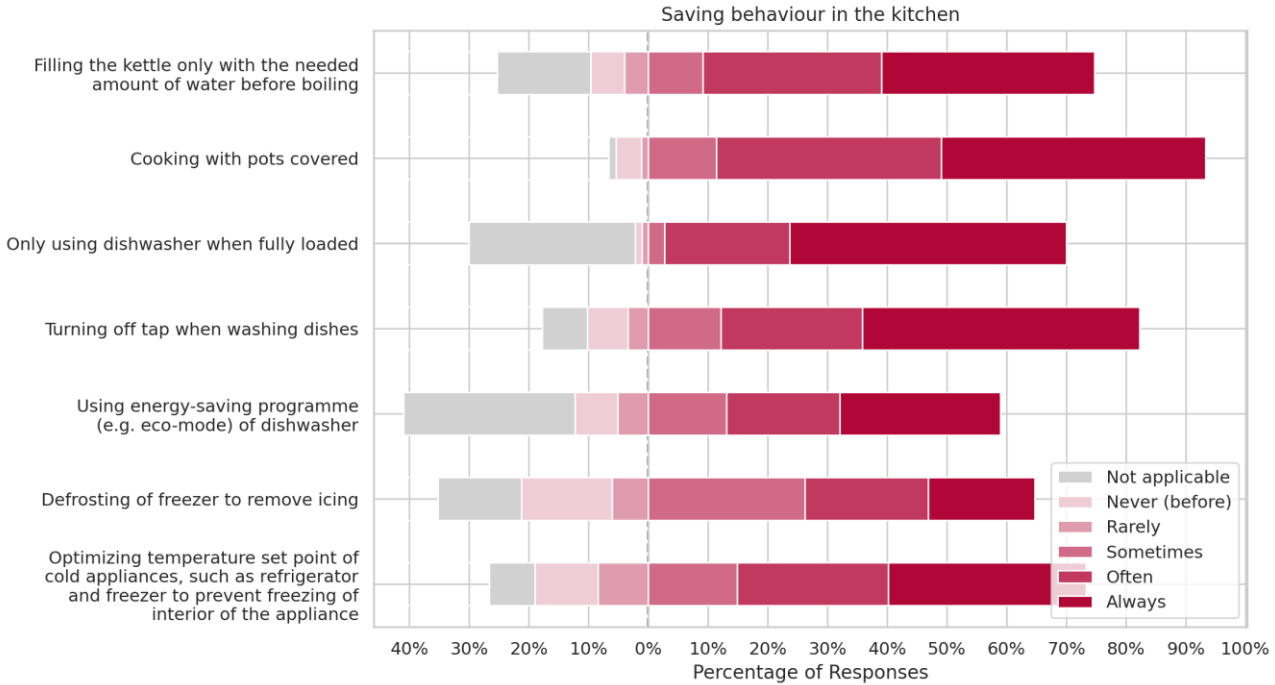


NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Saving behaviour: Kitchen

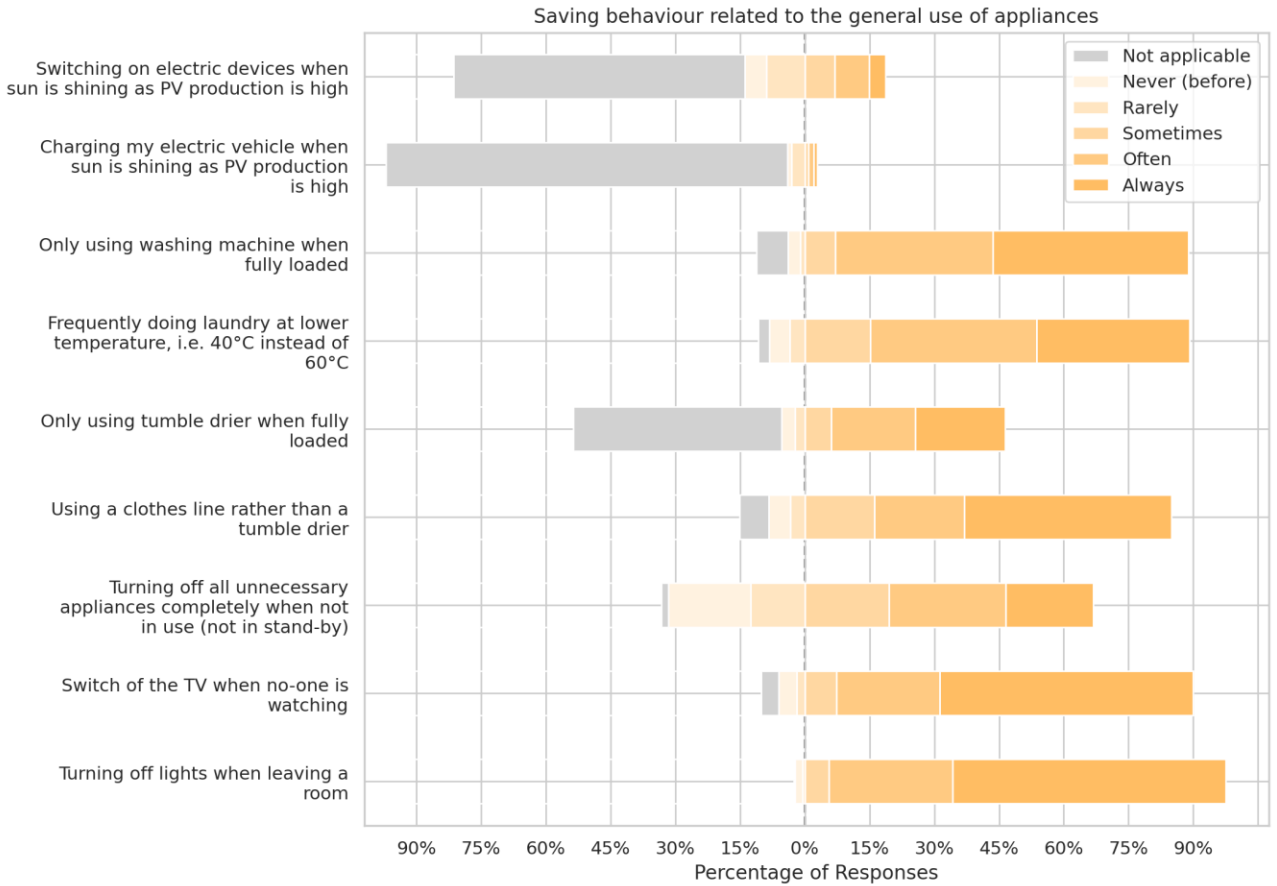


NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Saving behaviour: General appliances

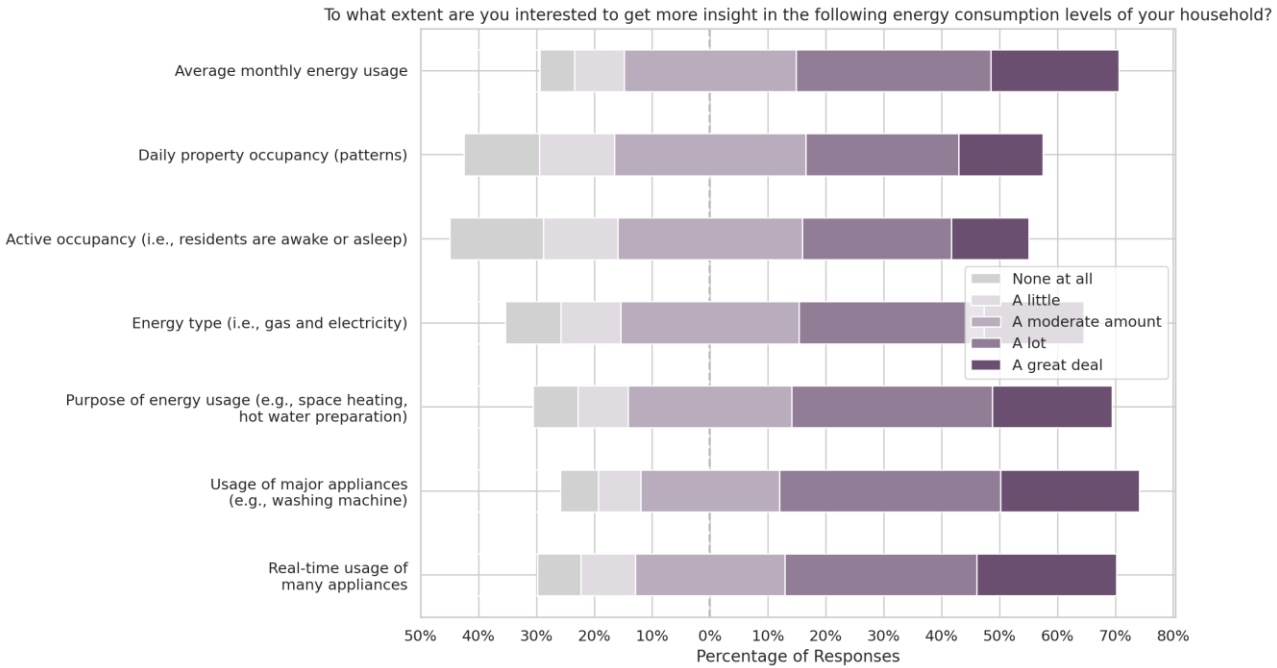


NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Interest in consumption levels



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

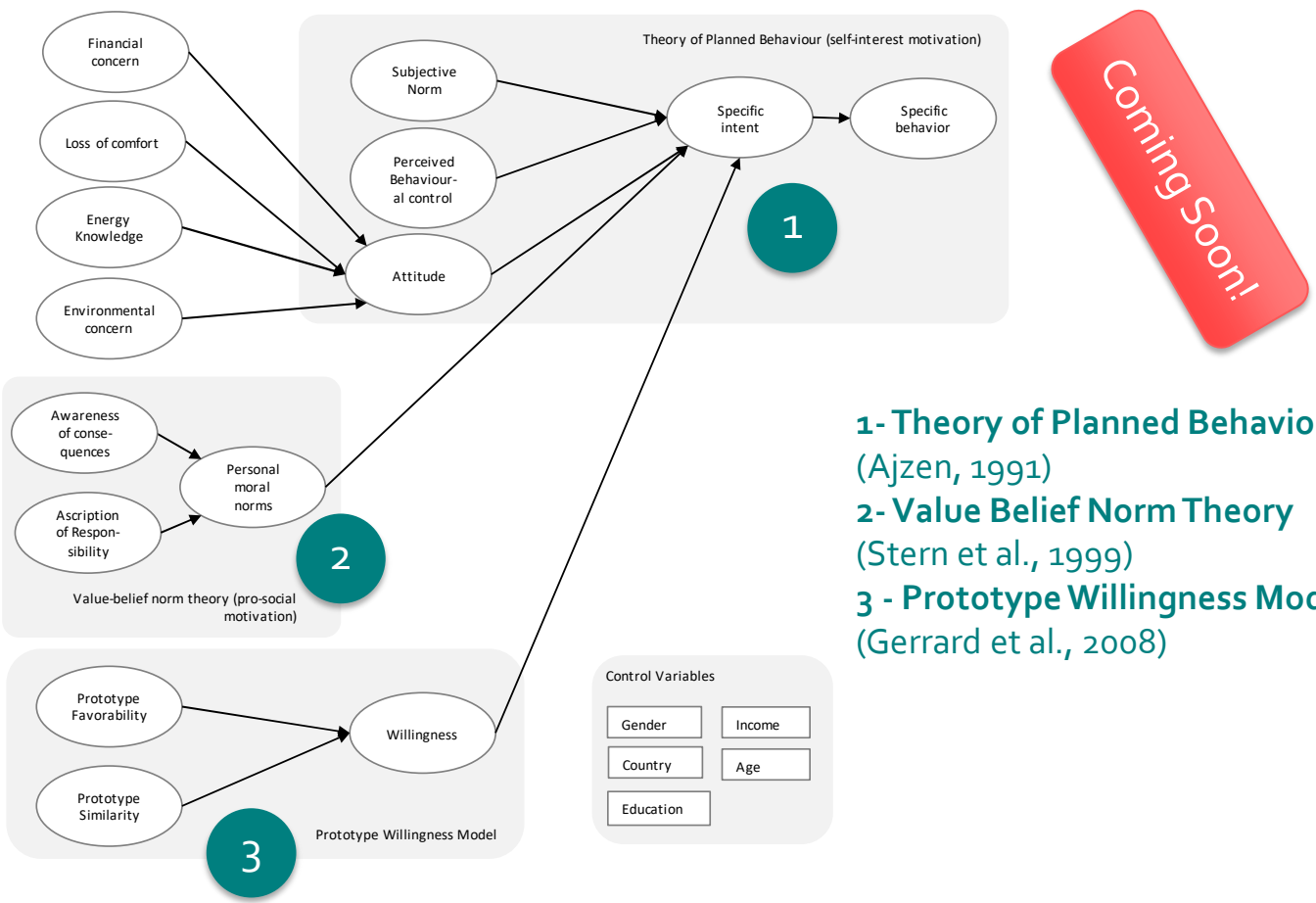
Nudging consumers
towards energy efficiency
through behavioural science

Predicting intent to reduce heating related consumption

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science



Coming Soon!

1- Theory of Planned Behaviour (Ajzen, 1991)

2- Value Belief Norm Theory (Stern et al., 1999)

3 - Prototype Willingness Model (Gerrard et al., 2008)

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Relation to Nudging

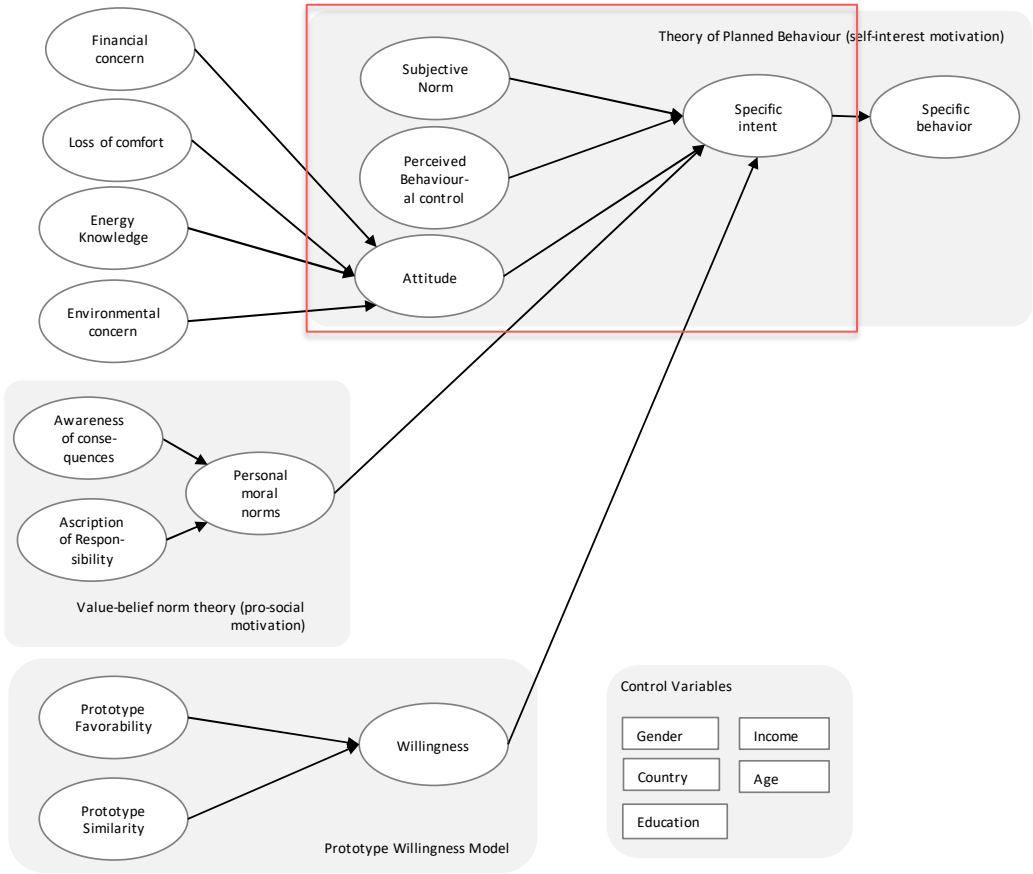
Our survey as a whole does not specifically ask questions about particular nudges or nudge techniques. This is a deliberate decision since nudges are typically evaluated experimentally, as opposed to through a survey. However, despite the lack of explicit nudging assessment, the different theoretical behaviour models presented in our survey do capture and align with several types of nudges.

I.e.:, loss aversion has practical links with 'financial concern' and 'awareness of consequences'

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Theory of Planned Behaviour

Subjective Norm

*People who are important to me expect that I save energy by lowering the temperature setting in winter (**Cronbach α** 0.83)*

Perceived Behavioural Control

*I have the capabilities to save energy by lowering the temperature setting in winter (**Cronbach α** 0.82)*

Attitude

For me, saving energy by lowering the temperature setting in winter is useless/useful (**Cronbach α** 0.91)

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Predicting intent to reduce consumption

	Specific intent to reduce consumption
	Model 1
Age	
Age	-0.004**
Region	
Northern Europe	-0.37***
Southern Europe	0.34***
Western Europe	0.04
Degree	
Upper secondary	-0.03
Bachelor	0.03
Master	0.06
Doctor	0.07
Theory of Planned Behaviour	
Attitude	
Perceived Behavioural Control	
Subjective Norms	
Constant	3.42***
Observations	3,098
R^2	0.04
Adjusted R^2	0.04
F Statistic	16.69*** (df = 8; 3089)

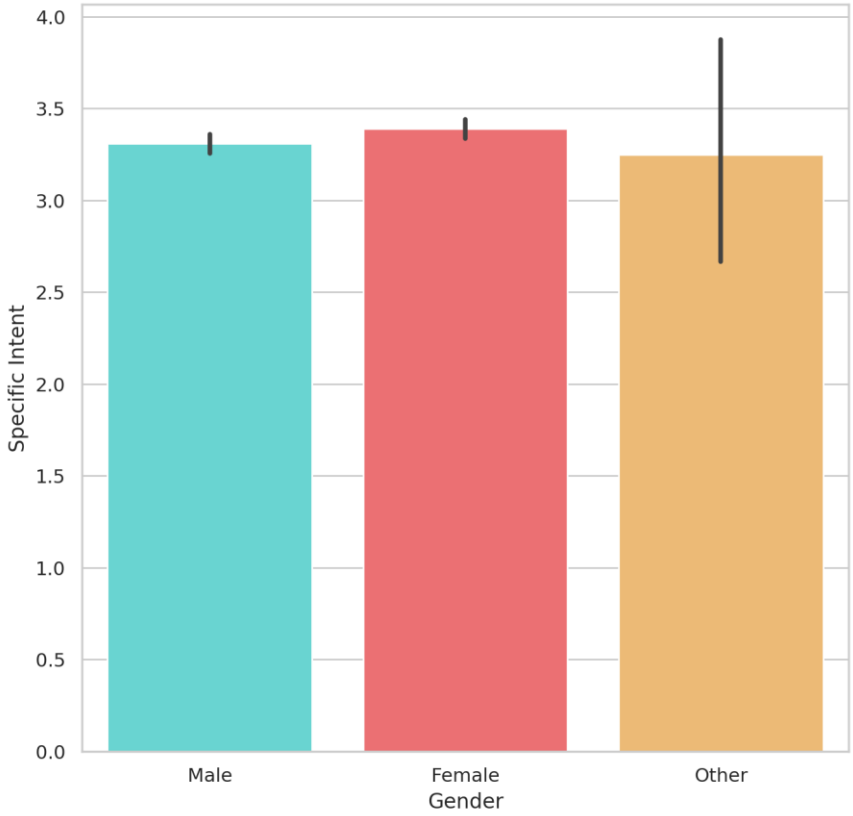
Notes:
*p**p***p<0.001
1 - Reference Category = Eastern Europe
2 - Reference Category = Lower Education

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Gender and Intent



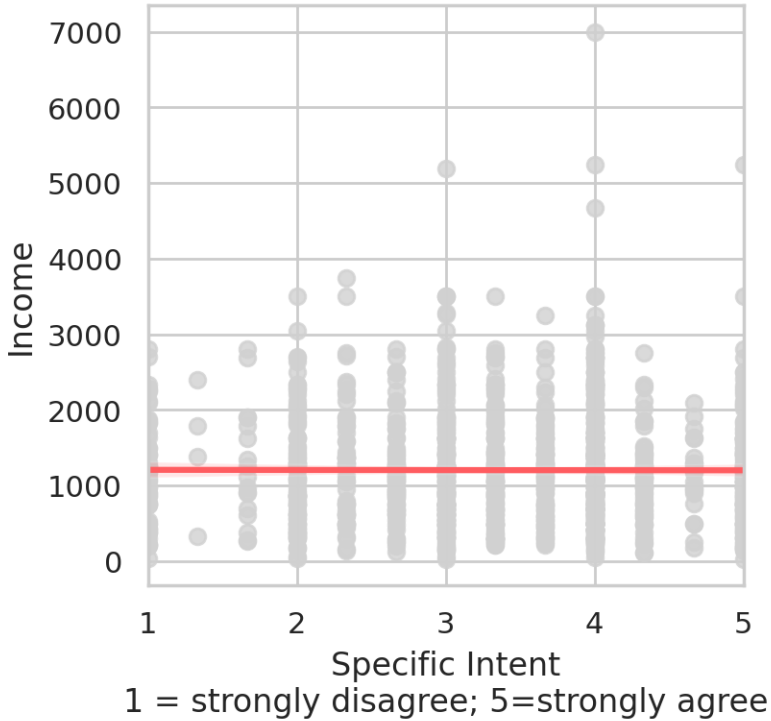
No significant association between gender and intent (p=0.08)

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Income and Intent



No significant association between income and intent (p=0.94)

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Predicting intent to reduce consumption

	Specific intent to reduce consumption
	Model 2
Age	
Age	
Region	
Northern Europe	
Southern Europe	
Western Europe	
Degree	
Upper secondary	
Bachelor	
Master	
Doctor	
Theory of Planned Behaviour	
Attitude	0.17^{***}
Perceived Behavioural Control	0.49^{***}
Subjective Norms	0.33^{***}
Constant	-0.35^{***}
Observations	3,098
R^2	0.57
Adjusted R^2	0.57
F Statistic	$1,368.19^{***}$ (df = 3; 3094)

Notes:
*p**p***p<0.001
1 - Reference Category = Eastern Europe
2 - Reference Category = Lower Education

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Predicting intent to reduce consumption

	Specific intent to reduce consumption		
	Model 1	Model 2	Model 3
Age			
Age	-0.004**		-0.005***
Region			
Northern Europe	-0.37***		-0.09
Southern Europe	0.34***		0.13**
Western Europe	0.04		-0.13**
Degree			
Upper secondary	-0.03		-0.06
Bachelor	0.03		-0.06
Master	0.06		-0.08
Doctor	0.07		-0.13*
Theory of Planned Behaviour			
Attitude		0.17***	0.18***
Perceived Behavioural Control		0.49***	0.48***
Subjective Norms		0.33***	0.31***
Constant	3.42***	-0.35***	-0.07
Observations	3,098	3,098	3,098
R^2	0.04	0.57	0.59
Adjusted R^2	0.04	0.57	0.59
F Statistic	16.69*** (df = 8; 3089)	1,368.19*** (df = 3; 3094)	407.78*** (df = 11; 3086)

Notes:
*p**p***p<0.001
1 - Reference Category = Eastern Europe
2 - Reference Category = Lower Education

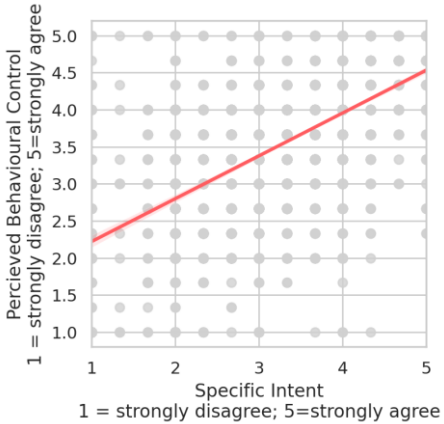
NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

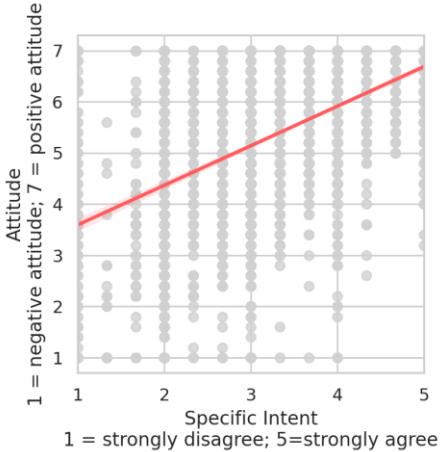
NUDGE

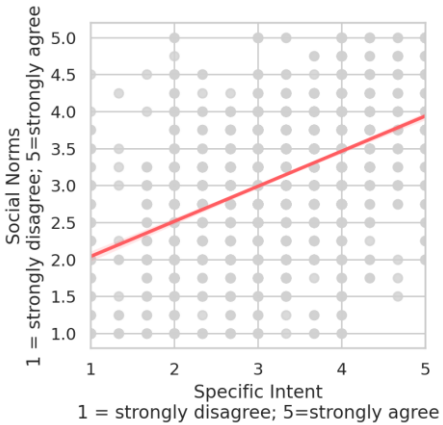
Nudging consumers towards energy efficiency through behavioural science

Predicting intent to reduce consumption

I intend to save energy by lowering the temperature setting in winter







NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Noteworthy take aways

Sociodemographic effects present but minimal (R^2 = 0.04)

Attitude remains a predictor of intent (B=0.18), but both **Perceived Behavioral Control** (B=0.48) and **Subjective Norms** (B=0.31) shows stronger associations with intent.

Especially for **Perceived Behavioral Control** this point to the value of providing people with the practical means to enact change, i.e.: supporting their ability to reduce consumption.

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Segmentation of energy consumers into behavioural profiles

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Identifying consumer profiles

Recall NUDGE Objective 1:

Tailor the design of behavioral interventions to individual psychological and contextual variables by leveraging the data collection capabilities of digital mediation platforms and data analytics.

SURVEY–DRIVEN USER PROFILING

The "big" question:

Can we identify distinct energy consumer profiles out of the survey data *that can be readily addressed with nudging interventions ?*

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

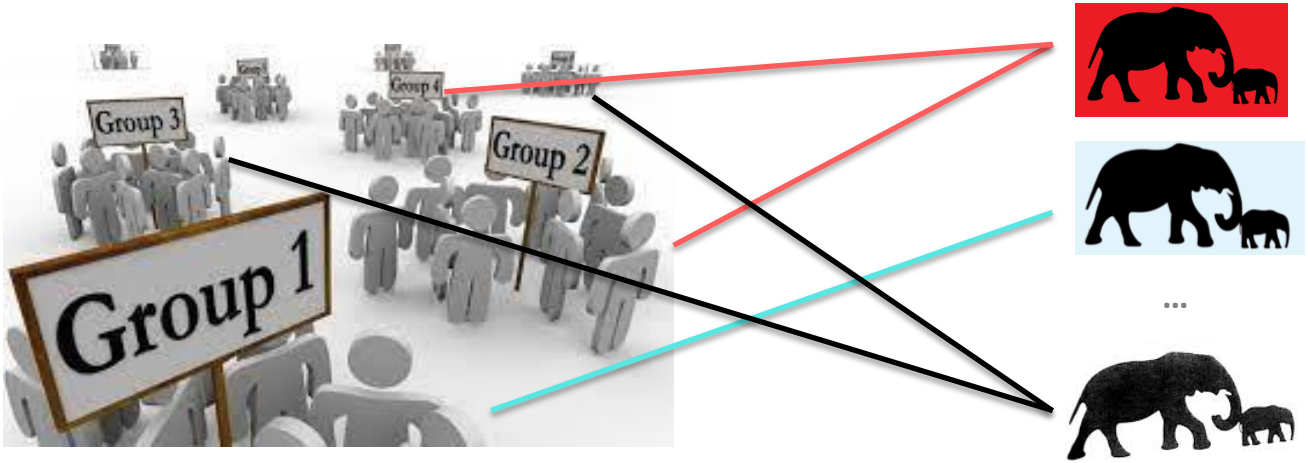
Nudging consumers towards energy efficiency through behavioural science

The problem more tangibly

INPUT : a 3129 x 15 matrix of the users' scores in the 15 constructs/variables*

- Scores are averages over all items measuring the construct
- Real numbers between 1 and 5
  - averages of multiple item scores, each in {1..5} LIKERT scale

OUTPUT : consumer segmentation into "intervention-ready" groups/classes



* assumption : socio-demographic variables (Age, Gender, Education) are used in a second step, to describe the identified profiles.

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Clustering : the de facto tool for the segmentation task

- Separate the set of objects into groups (clusters) so that objects in the same cluster are more similar to each other, according to some criteria, than to objects in other clusters.
    - objects are defined by a common set of features (e.g., the scores in the 15 constructs in our case)

- Highly automated process but also highly differentiated and unpredictable:
    - how many and which features to consider in clustering (feature selection and feature transformation techniques)
    - algorithm to use for clustering (k-means, hierarchical, spectral clustering)
    - measure of similarity between two (or more) objects (Euclidean, Manhattan/taxi, cosine similarity)
    - number of clusters (fixed input to or dynamically determined by the algorithm)

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Clustering results

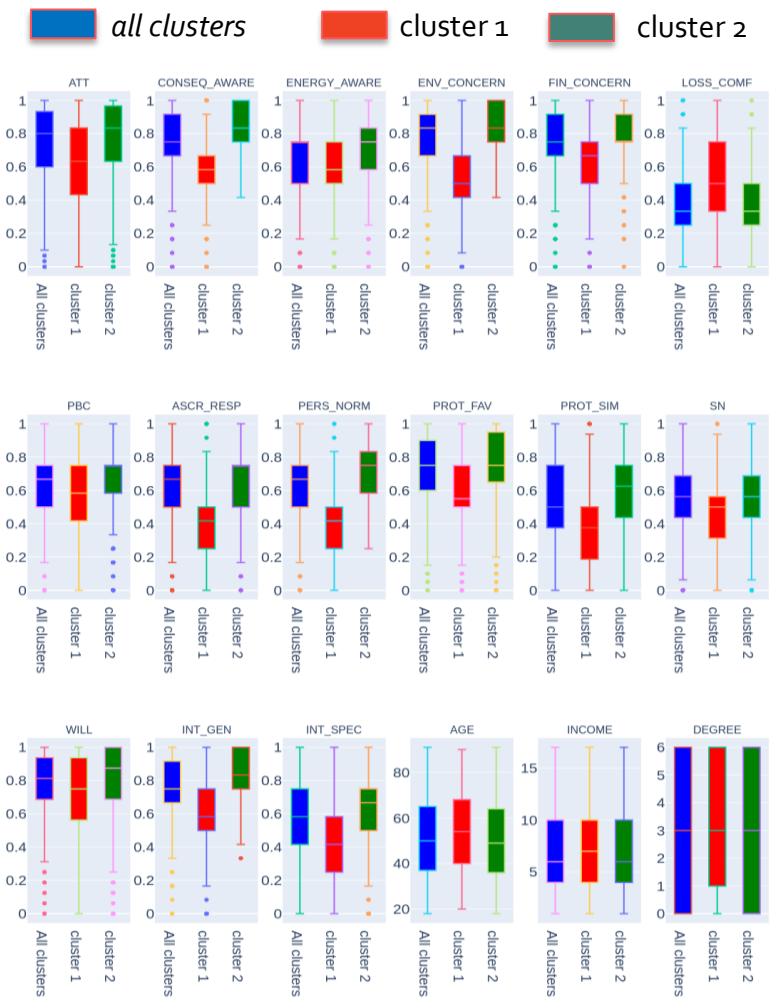
algorithm: **k-means**

similarity measure: **Euclidean distance**

number of clusters: **2**

feature selection: **on**

- Hopkins-measure driven
- resulting feature set {CONSEQ_AWARE, ENV_CONCERN, ASCR_RESP, PERS_NORM}



Cluster 2 (2502) consumers consistently score better, on average, than Cluster 1 consumers (627) in *all* 15 constructs

notation ≡ Cluster 2 ≥ Cluster 1

Age, Gender, Education degree distributions are almost identical across clusters

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Clustering results

algorithm: **k-means**

similarity measure: **Euclidean distance**

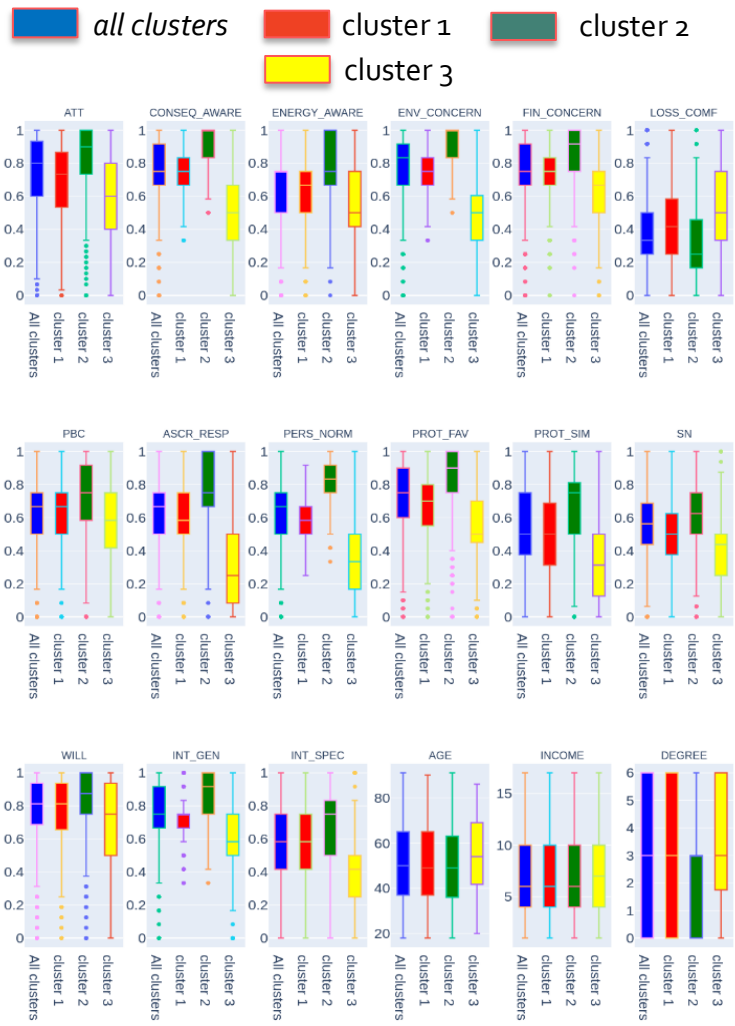
number of clusters: **3**

feature selection: **on**

- Hopkins-measure driven
- resulting feature set {CONSEQ_AWARE, ENV_CONCERN, ASCR_RESP, PERS_NORM}

Cluster 2 (1268) ≻ Cluster 1 (1480) ≻ Cluster 3 (381)

consistent ranking in all 15 constructs



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Clustering results

algorithm: **k-means**

similarity measure: **Euclidean distance**

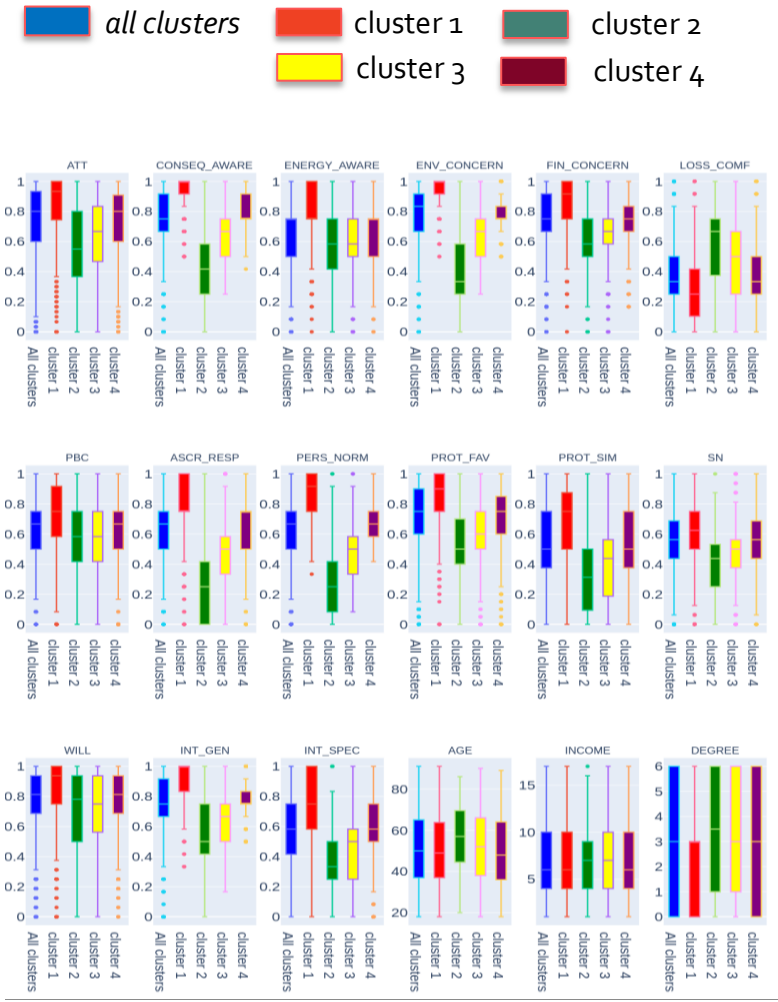
number of clusters: **4**

feature selection: **on**

- Hopkins-measure driven
- resulting feature set {CONSEQ_AWARE, ENV_CONCERN, ASCR_RESP, PERS_NORM}

Cluster 1 (931) ≥ Cluster 4 (1405) ≥ Cluster 3 (693) ≥ Cluster 2 (200)

consistent ranking in all 15 constructs



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Clustering results

algorithm: **k-means**

similarity measure: **Euclidean distance**

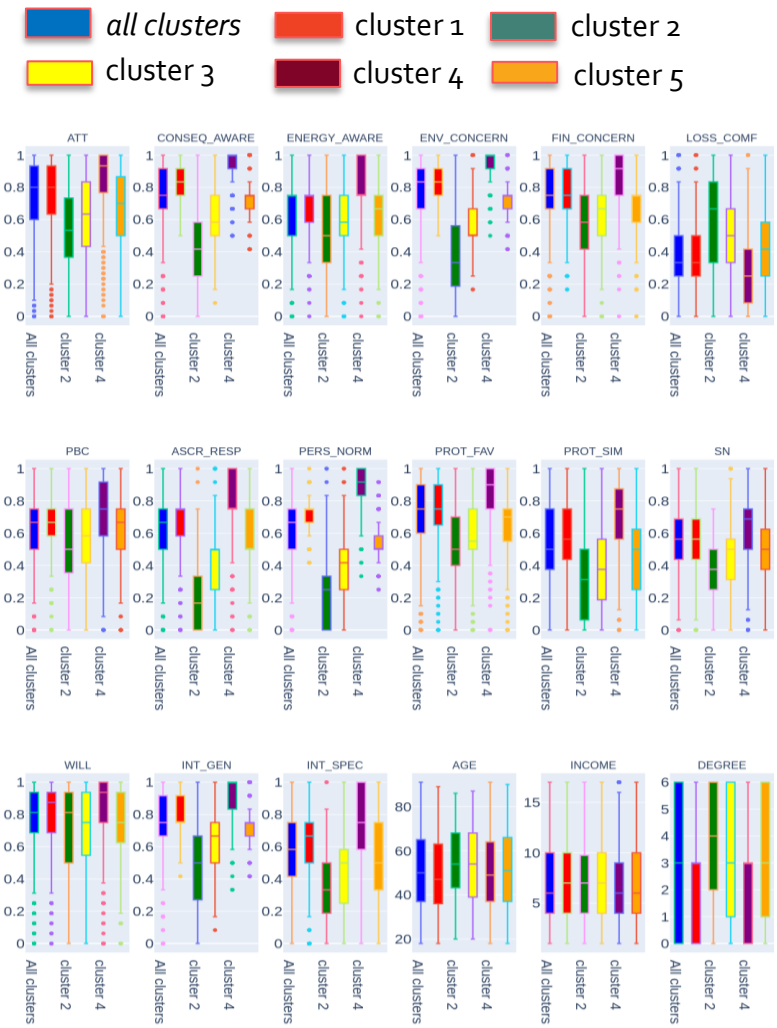
number of clusters: **5**

feature selection: **on**

- Hopkins-measure driven
- resulting feature set {CONSEQ_AWARE, ENV_CONCERN, ASCR_RESP, PERS_NORM}

Cluster 4 (803) ≥ Cluster 1 (1071) ≥ Cluster 5 (729) ≥ Cluster 3 (393) ≥ Cluster 2 (143)

consistent ranking in all 15 constructs



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Summarizing clustering results

- Clustering yields energy consumer groups with identical score rankings in all constructs
  - *i.e.*, clusters *1-k* can be indexed so that energy consumers in cluster *m*, $1 \leq m \leq k$ exhibit, on average, the m^{th} best score in *all* constructs

- This clustering structure is persistent under
  - different clustering algorithms (hierarchical agglomerative clustering, spectral clustering)
  - different measures of similarity ("distance" variations) : Euclidean, Manhattan, cosine similarity)
  - different subsets of the full feature set, with application of feature selection and feature space transformation techniques (PCA)

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

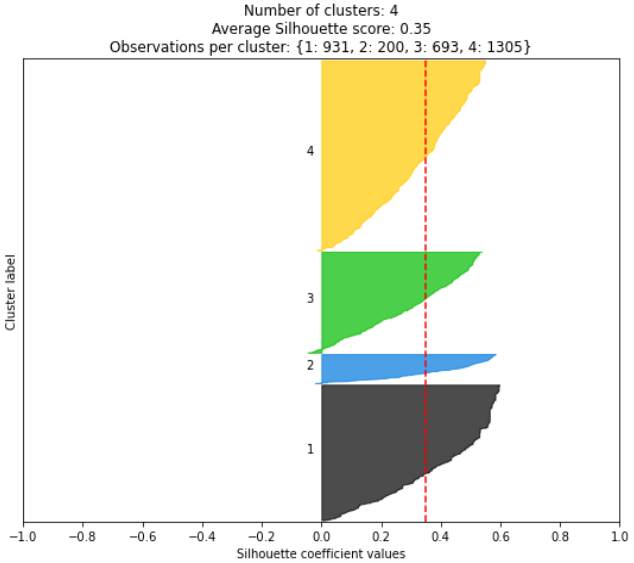
NUDGE

Nudging consumers towards energy efficiency through behavioural science

Is this a "good" clustering?

It "depends"…

- Good clustering fitness
  - silhouette scores in the order of 0.35-0.4
- Clustering balance
  - cluster sizes are reasonably spread, no cluster is smaller than 5% of the sample



- …but not many hints for targeting nudging interventions

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

Intervention-aware classification

Go the other way round and start from the available set of interventions

- We know the set of possible interventions
  - with a rough idea of how to deliver them through mobile apps, dashboards and other means

- We anticipate which profiles of consumers are amenable to each intervention
  - for instance, consumers with primarily financial concerns should be approached with tips/pop up messages reminding them the financial consequence of an action (e.g., increase of the thermostat's target temperature)

- Why not searching specifically for such profiles in the data?

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Specifying energy consumer profiles/classes

First, descriptively with reference to the constructs measured in the survey

One example – class 1

Environmentally conscious and well-informed energy consumers combine:

- high concern about the environment
- good knowledge about the energy matters and consequences of energy waste
- strong sense of personal responsibility for energy-saving action
- strong intentions to engage into energy-saving activities, with respect to heating but also overall

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Specifying energy consumer profiles/classes

First, descriptively with reference to the constructs measured in the survey

Another example – class 3:

Concerned but lacking awareness energy consumers combine:

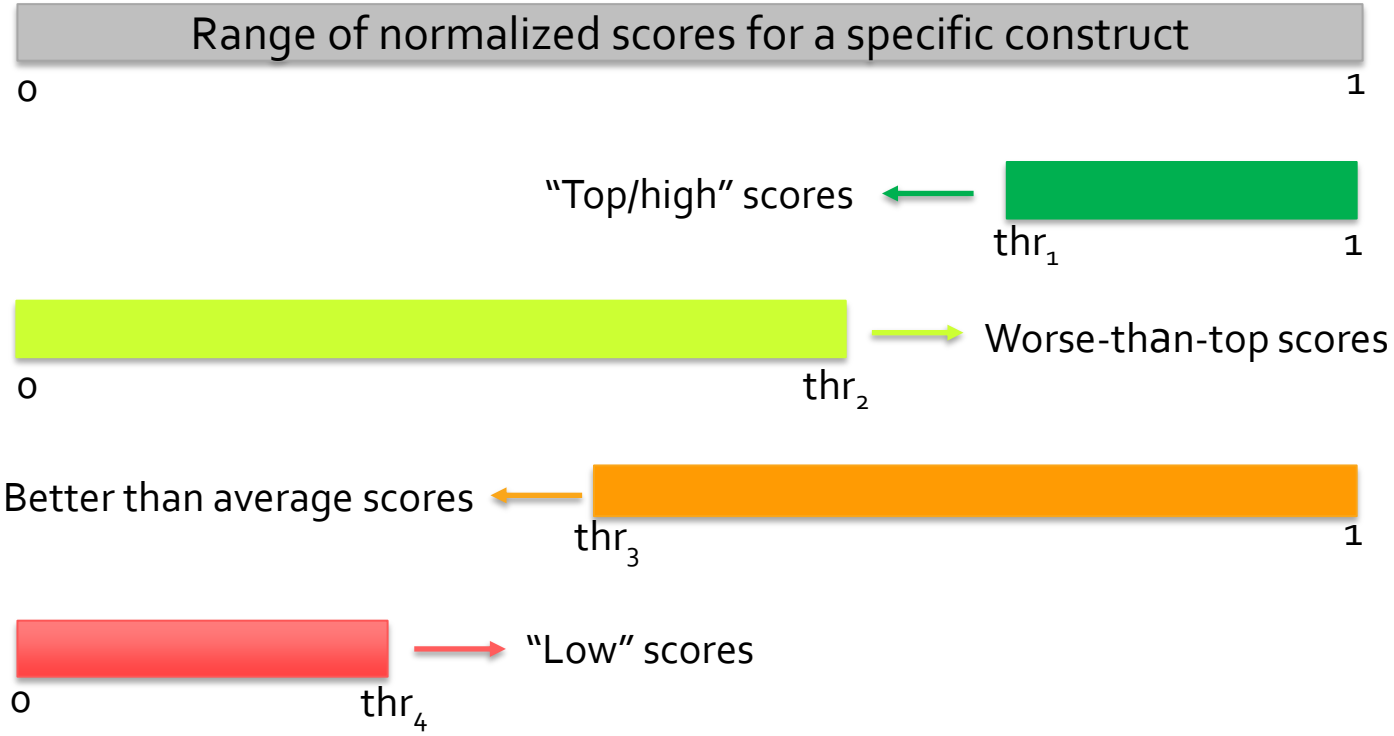
- high concern about the environment
- good understanding of the consequences of non-energy-saving behavior
- lack the practical knowledge that would strengthen their intention to adopt ideal energy-saving behavior

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Towards formally specifying energy consumer classes



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Energy consumer classes as conjunctions of conditions

Environmentally conscious and well-informed energy consumers

CONSEQ_AWARE ≥ thr_1 AND **ENV_CONCERN≥ thr_1** AND **ASCR_RESP ≥ thr_1**

AND **PROT_FAV ≥ thr_1** AND **INT_SPEC ≥ thr_1** AND **INT_GEN ≥ thr_1**

Concerned but lacking awareness energy consumers

CONSEQ_AWARE ≥ thr_3 AND **ENERGY_AWARE ≤ thr_4** AND

ENV_CONCERN≥ thr_3 AND **INT_GEN ≤ thr_2**

Concerned but comfort-oriented energy consumers

…

Materialistic energy consumers escaping their personal responsibility

…

Prone to social influence energy consumers

…

Indifferent energy consumers

…

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

Formal specification of all 6 energy consumer classes

Class 1	**CONSEQ_AWARE** ≥ thr_1 AND **ENV_CONCERN**≥ thr_1 AND **ASCR_RESP** ≥ thr_1 AND **PROT_FAV** ≥ thr_1 AND **INT_SPEC** ≥ thr_1 AND **INT_GEN** ≥ thr_1
Class 2	**LOSS_COMF** ≥ thr_3 AND **FIN_CONCERN** ≥ thr_1 AND **INT_SPEC** ≤ thr_2 AND **INT_GEN** ≥ thr_1
Class 3	**CONSEQ_AWARE** ≥ thr_3 AND **ENERGY_AWARE** ≤ thr_4 AND **ENV_CONCERN**≥ thr_3 AND **INT_GEN** ≤ thr_2
Class 4	**ASCR_RESP** ≤ thr_4 AND **FIN_CONCERN** ≥ thr_1 AND **INT_GEN** ≤ thr_2
Class 5	**SN** ≥ thr_3 AND **INT_SPEC** ≤ thr_2 AND **INT_GEN** ≤ thr_2
Class 6	**PBC** ≤ thr_4 AND **PROT_SIM** ≤ thr_4 AND **INT_SPEC** ≤ thr_2 AND **INT_GEN** ≤ thr_2

The specification of all 6 classes involves 12 constructs and four parameters thr_1, thr_2, thr_3, thr_4

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Optimizing for the threshold values

Values of thr_1, thr_2, thr_3, thr_4 need to be determined → optimization problem

Constraints

- $thr_1 \geq thr_2 \geq thr_3 \geq thr_4$
- classes should contain at least 5% of the totally assigned users and no more than 50% of those

Objective

- Maximize the number of participants that can be assigned to one or more classes

Outcome

thr_1	thr_2	thr_3	thr_4	Users classified in at least one class	class 1	class 2	class 3	class 4	class 5	class 6
0.75	**0.75**	**0.5**	**0.5**	**2132**	529	477	507	425	1041	112

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

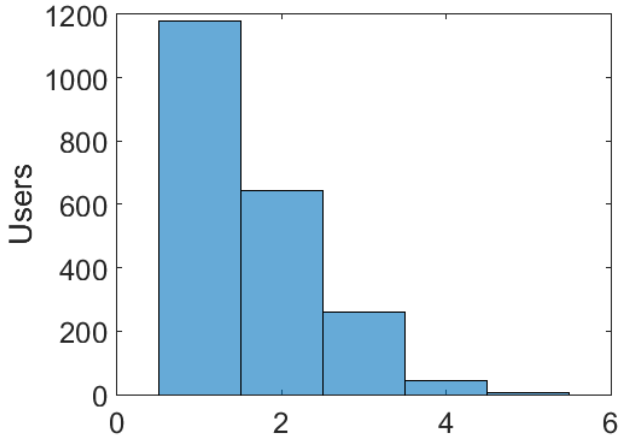
Nudging consumers towards energy efficiency through behavioural science

Multihomed and non-assigned energy consumers

Note 1:

Users are not assigned to a single class

- 1180 (55.27%) of the users can be assigned to one class, the rest are "multihomed"



Note 2:

What about the remaining 997 energy consumers who do not satisfy the specification of any class?

- They are assigned to the "closest" class
  - We compute the centroids of the six classes (average scores of its members in the constructs that specify the class)
  - For each of the 997 consumers we compute its distance from the 6 class centroids

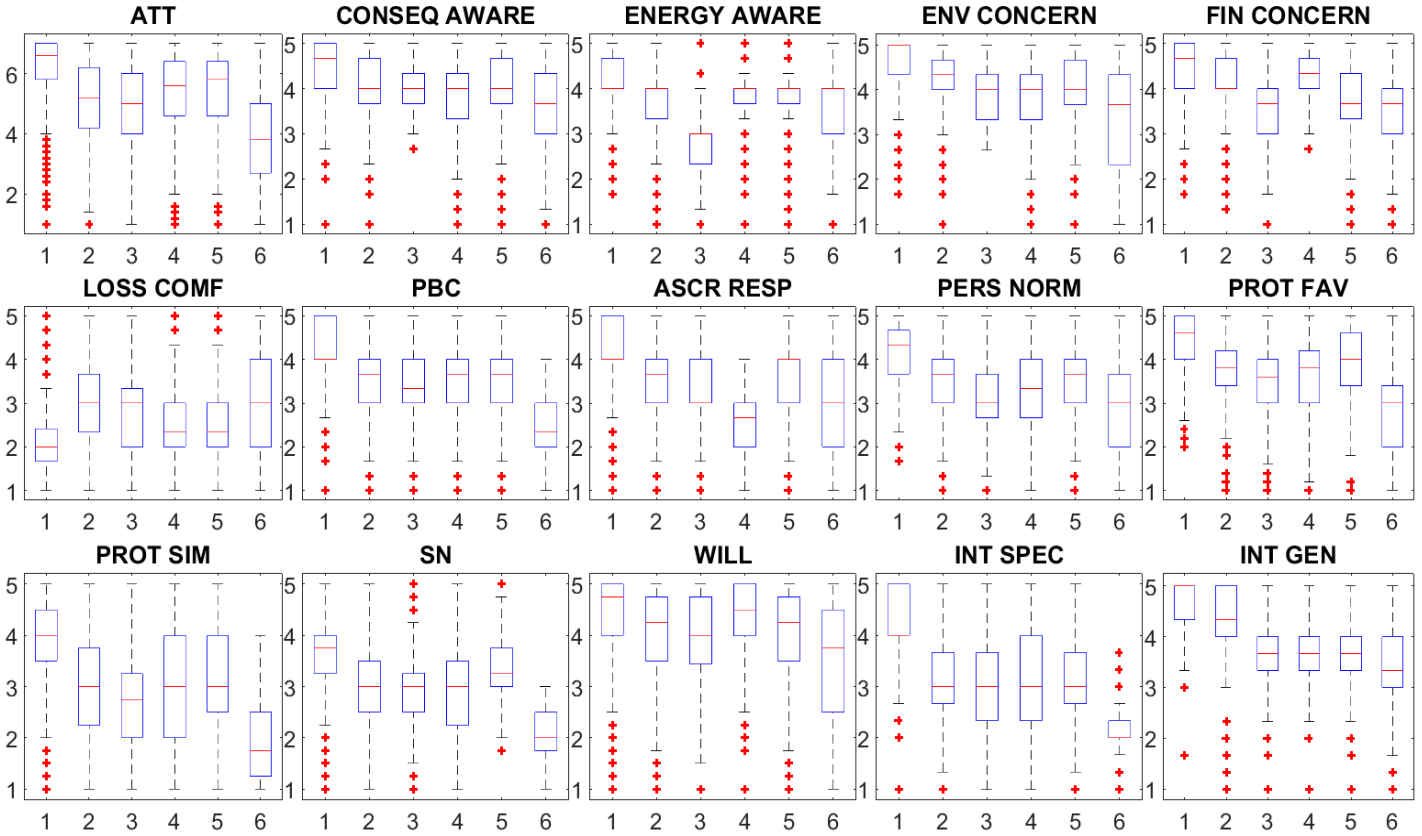
NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

Eventual consumer segmentation



NUDGE

Nudging consumers towards energy efficiency through behavioural science

1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

Mapping of intervention types

Key points	(Nudge) intervention type	Description
High scores in all features	**Reinforcement**	**Feedback & awareness**: keep the interest warm through regular information about energy-saving (selected notifications, regular marketing campaigns)

NUDGE

Nudging consumers towards energy efficiency through behavioural science

1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

Mapping of intervention types

Key points	(Nudge) intervention type	Description
Strong concern about comfort & financial implication of energy-saving	**Confronting**	**Reminding of consequences**: prompt the user to consider the consequences of an action e.g., increasing the target temperature of the thermostat or the air-conditioning, insisting on the extra cost it incurs: net increase of the energy bill at monthly/annual level.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

Mapping of intervention types

Key points	(Nudge) intervention type	Description
High environmental concern, awareness of consequences but lack of practical know-how to save energy	**Facilitating**	**Default:** Turn energy-friendly operational settings of devices (thermostat, air conditioning equipment) into defaults, to save the user from the "burden" of learning what is appropriate and what is not.
	Reinforcement	**Just-in-time prompts and tips:** Provide the user with tips and recommendations exactly upon the time she mingles with devices' settings that have an impact on energy consumption.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Summary

Experiments with two different ways to group energy consumers

- First group, then check for interventions → clustering
- First define classes accounting for interventions, then form groups → intervention-aware classification

In the second case, we could get informative groupings that facilitated the mapping of interventions to classes

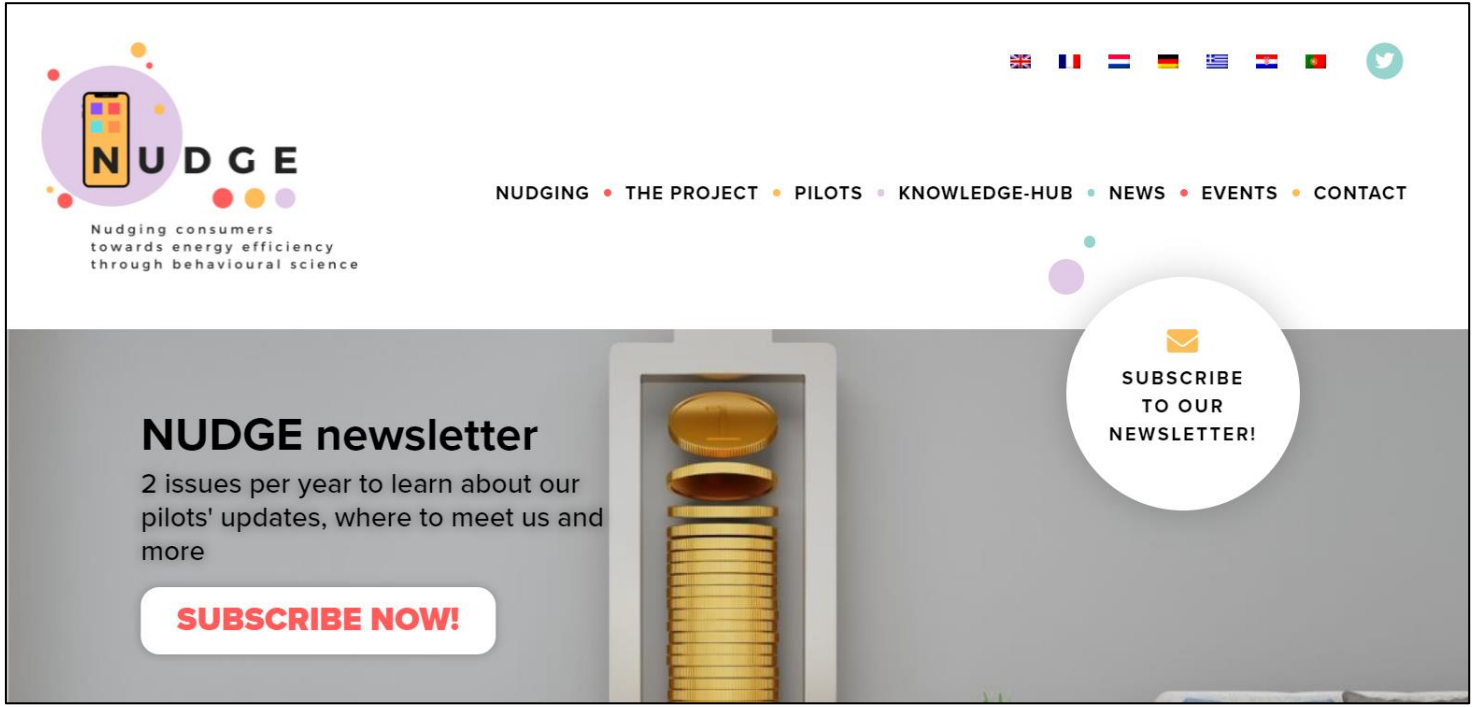
- six energy consumer classes, each marked by barriers/facilitators towards energy-saving
- whether these classes generalize will also be tested in the pilots

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

www.nudgeproject.eu



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Backup slides

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

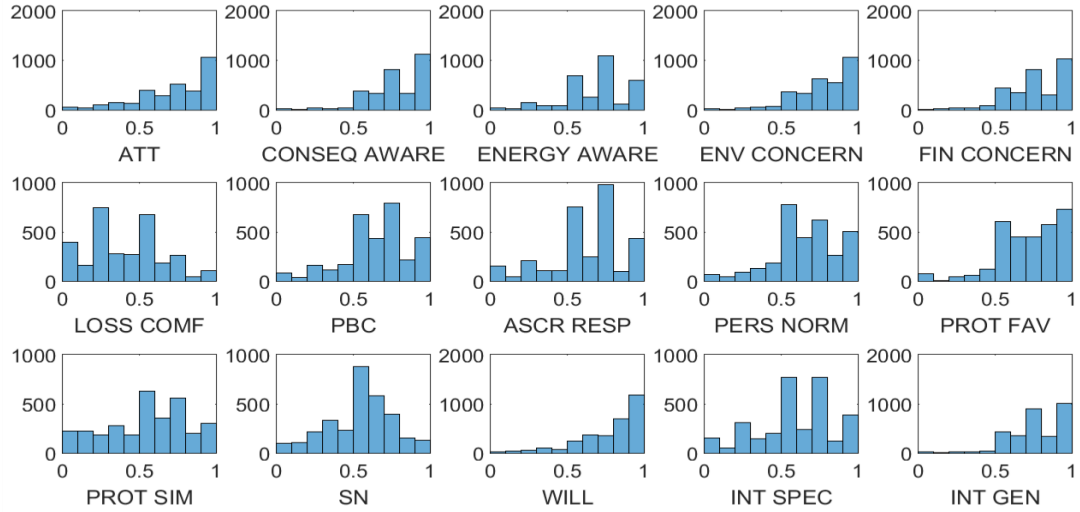
NUDGE

Nudging consumers towards energy efficiency through behavioural science

Clustering tendency test : positive

- Positive visual evidence of variance in construct scores across users

Distributions of normalized users' scores in the 15 variables



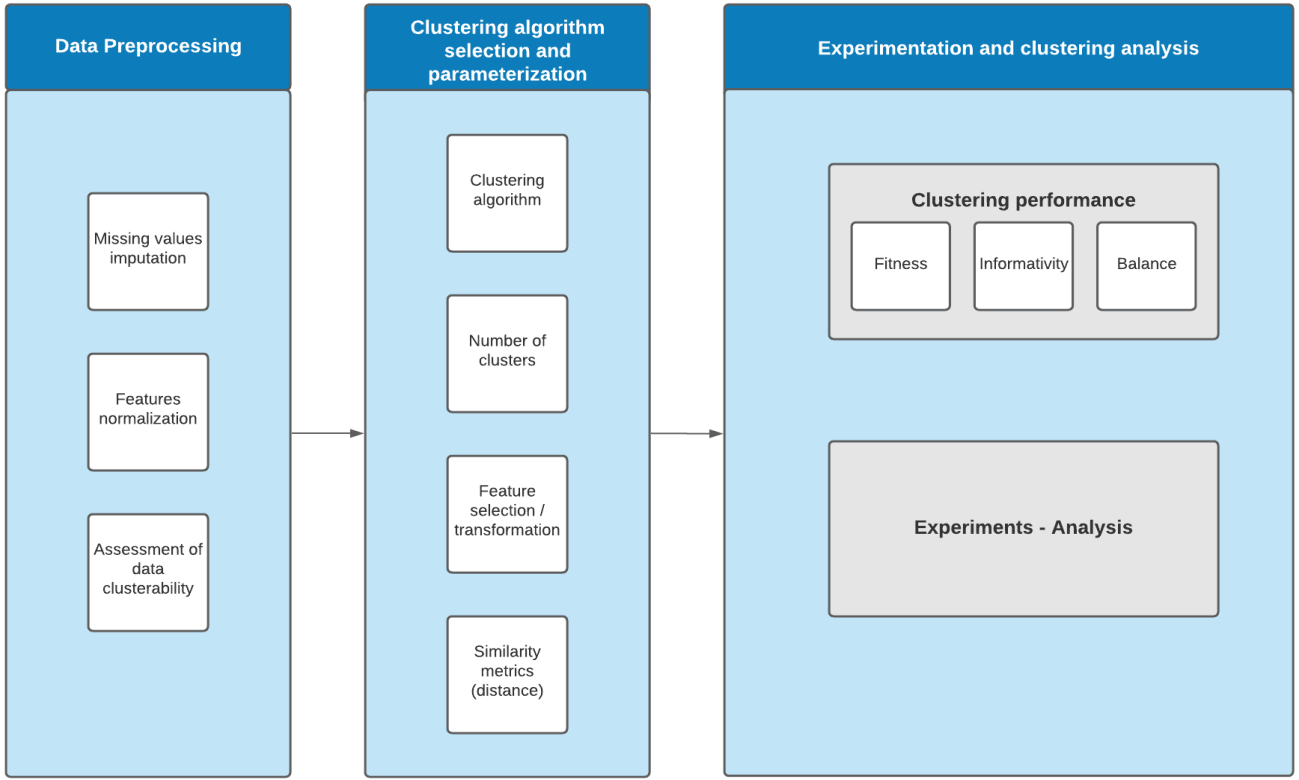
- More importantly, Hopkins test values in the order of 0.8-0.94 for subsets of 3-5 features

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Clustering



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Specifying consumer classes

First, descriptively with reference to the constructs measured in the survey

Another example – class 2:

Concerned but comfort-oriented energy consumers combine:

- clear overall intentions to act in energy-saving manner.
- Much weaker intentions for energy-saving behavior with respect to heating, in particular, since this implies comfort loss (e.g., setting the thermostat at lower temperature and wearing more clothes to make up for it) that appear not to be acceptable for them
- high concern about the monetary cost involved in higher energy consumption

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Specifying consumer classes

First, descriptively with reference to the constructs measured in the survey

Another example – class 4:

Materialistic energy consumers escaping their personal responsibility

combine:

- low anticipation of personal responsibility to act
- lower than average energy-saving intentions and
- high concern for the financial implications of energy-saving activities on the monthly bills.

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Specifying consumer classes

First, descriptively with reference to the constructs measured in the survey

Another example – class 5:

Prone to social influence energy consumers combine:

- lower than average energy-saving intentions with respect to heating
- distinctly higher than average scores in the Subjective Norm variable

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Specifying consumer classes

First, descriptively with reference to the constructs measured in the survey

Another example – class 6:

Indifferent energy consumers combine:

- low perception of behavioral control, more related to perceived self-efficacy
- no identification with the prototype of energy-saver
- moderate energy-saving intentions, both overall and specifically with respect to heating

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Formal specification of all 6 energy consumer classes

Class 1	**CONSEQ_AWARE** ≥ thr_1 AND **ENV_CONCERN**≥ thr_1 AND **ASCR_RESP** ≥ thr_1 AND **PROT_FAV** ≥ thr_1 AND **INT_SPEC** ≥ thr_1 AND **INT_GEN** ≥ thr_1
Class 2	**LOSS_COMF** ≥ thr_3 AND **FIN_CONCERN** ≥ thr_1 AND **INT_SPEC** ≤ thr_2 AND **INT_GEN** ≥ thr_1
Class 3	**CONSEQ_AWARE** ≥ thr_3 AND **ENERGY_AWARE** ≤ thr_4 AND **ENV_CONCERN**≥ thr_3 AND **INT_GEN** ≤ thr_2
Class 4	**ASCR_RESP** ≤ thr_4 AND **FIN_CONCERN** ≥ thr_1 AND **INT_GEN** ≤ thr_2
Class 5	**SN** ≥ thr_3 AND **INT_SPEC** ≤ thr_2 AND **INT_GEN** ≤ thr_2
Class 6	**PBC** ≤ thr_4 AND **PROT_SIM** ≤ thr_4 AND **INT_SPEC** ≤ thr_2 AND **INT_GEN** ≤ thr_2

The specification of all 6 classes involves 12 constructs and the four parameters

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Class size evolution through the process	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Sum
After identifying which users are eligible for which class	529	477	507	425	1041	465	-
After all 2132 users are assigned to a single class	529	400	440	259	392	112	2132
After the remaining 1071 users are assigned to the "closest" class	917	733	497	311	499	172	3129

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

Mapping of intervention types

Key points	(Nudge) intervention type	Description
High scores in all features	**Reinforcement**	**Feedback & awareness**: keep the interest warm through regular information about energy-saving (selected notifications, regular marketing campaigns)

Key points	(Nudge) intervention type	Description
Strong concern about comfort & financial implication of energy-saving	**Confronting**	**Reminding of consequences**: prompt the user to consider the consequences of an action e.g., increasing the target temperature of the thermostat or the air-conditioning, insisting on the extra cost it incurs: net increase of the energy bill at monthly/annual level.

Key points	(Nudge) intervention type	Description
High environmental concern, awareness of consequences but lack of practical know-how to save energy	**Facilitating**	**Default:** Turn energy-friendly operational settings of devices (thermostat, air conditioning equipment) into defaults, to save the user from the "burden" of learning what is appropriate and what is not.
	Reinforcement	**Just-in-time prompts and tips:** Provide the user with tips and recommendations exactly upon the time she mingles with devices' settings that have an impact on energy consumption.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

Mapping of intervention types

Key points	(Nudge) intervention type	Description
Concern about the environment, awareness of consequences but lack of know-how to practically save energy	**Confronting**	**Reminding of consequences:** prompt the user to consider the consequences of an action e.g., increasing the target temperature of the thermostat or the air-conditioning, insisting on the extra cost it incurs: net increase of the energy bill at monthly/annual level.

Key points	(Nudge) intervention type	Description
Strong sense of subjective norms, average scores-no distinct differentiation in other features	**Social influence**	**Enabling social comparison**: leverage different means (from written text and diagrams printed on a paper to online social platforms and dynamic query response systems) to facilitate the comparison with other peers (friends, neighbours, consumers of similar demographic characteristics).
	Social influence	**Goal setting & commitment**: get the consumers to sign a formal commitment to reduce the energy they consume, many times in return of some (non-monetary) reward.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

1. Environmentally conscious and well-informed energy consumers
2. Concerned but comfort-oriented energy consumers
3. Concerned but lacking awareness energy consumers
4. Materialistic energy consumers escaping their personal responsibility
5. Prone to social influence energy consumers
6. Indifferent energy consumers

Mapping of intervention types

Key points	(Nudge) intervention type	Description
Low perception of self-efficacy and possible impact of personal action, low concern and awareness about environmental matters.	**Facilitating**	**Default**: Turn energy-friendly operational settings of devices (thermostat, air conditioning equipment) into defaults, to save the user from the "burden" of learning what is appropriate and what is not.
	Reinforcement	**Feedback & awareness**: use tips, notifications, marketing campaigns, to sensivitize this group of users and overcome their reservations about the efficacy of their behavior.
	Reinforcement	**Hedonic goal** : stress the big picture and the impact on big things, possibly with some exaggeration, to render energy-saving a goal.