Data Repository

Relevant Data from User-Partners and Relevant Projects

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ENCHANT Report
Data Repository from User-Partners and Relevant Projects
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ABSTRACT
This report is a deliverable for the ENCHANT EU H2020 Project, which outlines research based evidence of various previous projects: It summarizes the types of interventions applied on a wide variety of energy-related choices, sample characteristics, pilot locations, contextual moderators, intervention means, effects and conclusions, while also pointing at raw data sets, where available, in order to inform the realization of ENCHANT pilots (invested in WP4) and of a complex policy-making engine with real life evidence (invested in WP6). While pointing out the diversity of approaches, the current report also attempts to draw links between research procedures employed and the conclusions reached in various projects and to draw a number of inferences. It also hints at the main deficiencies and gaps identified.

The current report only reviews H2020 projects. It is closely related to a similar meta-analysis that will be performed at a later stage on a much larger set of projects outside the H2020 span, and it is closely interlinked with the outputs of other WPs, namely the WP2 literature review output and a description of data needs delivered by WP6.

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1. Introduction

The present report is part of the activity of WP3, which is invested with supportive tasks for the realization of the objectives of other WPs. More precisely, this output feeds into the design of ENCHANT pilots, but also into the work of WP6. The main goal of WP6 is to deliver a policy-recommendation engine that takes into account features and conclusions of various research projects, including ENCHANT pilots, in order to be able to produce informed outputs.

The evidence supply task of WP3 is split into two main steps. The first step is secured by the current report and it refers mainly to the investigation of previous projects, mainly H2020 projects implemented generally after the latest and most consistent energy efficiency legislation in the EU (2018), on which the current EU energy efficiency concept is based. The second step will be performed at a later stage, documented with deliverable D3.3, Report on Data-Review on Energy Behavioural Data. Baring the same general objective in mind, it will assess mainly academic articles with the scope of enlarging the repository with evidence coming from projects beyond the sphere of H2020 grants.

The methodology applied for this report is informed by three elements: The ENCHANT grant proposal, the WP2 literature review output and a description of data needs delivered by WP6. The WP3 team performed a rigorous reading of the grant proposal to identify all relevant elements that support the initial research design. This reading fed into an initial analytical table containing the projects assessment criteria. The table categories were extended or merged in the course of analysis to reflect the availability of data. A first table column was created to list the projects to be assessed. These were selected in a two-step process: the review of the CORDIS website, where topic-related projects have been selected on an implementation-year basis. In order to limit the number of projects under review and to secure for their conceptual relevance, we decided to admit into the analysis tool projects that were not older than 2018 (including in the process of implementation). A second step was a consultation process with the rest of the consortium, where partners were admitted into the working document and invited to add other relevant projects to the list, or to add to the analytical criteria. Based on this tool, the project review was performed. We assessed all major project deliverables, data sets and academic outputs in order to fill-in the assessment tool. The assessment criteria and list of projects was continuously revised in the process to exclude projects that, at a deeper analysis, proved not to fit the interest area of ENCHANT.

The current report summarizes the types of interventions applied in the projects on a wide variety of energy-related choices, sample characteristics, pilot locations, contextual moderators, intervention means, effects and conclusions, while also pointing at raw data sets or summaries, depending on availability. The report focuses mainly, but not

exclusively, on the seven intervention typologies that have been identified as relevant for the ENCHANT project, namely: feedback on consumer's own consumption, social norms, information including simplification, monetary incentives, commitment, competition, collective versus individual framing, and on the following behavioural effects: investment, maintenance, and behavioural adjustment. The present report also attempts to go beyond these straight-forward objectives and also look at emotional components where available, as these have been identified to be important factors of decision-making.

The report structure is straight-forward: while presenting each of the selected projects in a more or less inverted chronological order we try to present the general logic of each project in order to make better sense of their more targeted features - aspects that are meaningful for ENCHANT purposes and should be taken into consideration while designing the ENCHANT pilots and the decision-making tool. At the end of each project presentation we have displayed the relevant information in a synthetic box including the availability and form of the relevant data. An integrated analytical table is presented in the appendix. General conclusions will be formulated at the end.

2. Projects Overview

2.1. PEAKapp

PEAKapp developed an ICT-to-Human ecosystem with a number of set objectives: to trigger (lasting) energy savings through behavioural change and continuous engagement; to enable increased consumption of clean and low-priced electricity from the spot market for household customers; to connect them to social networks, to motivate them through serious gaming; to boost the efficacy of Smart Home building energy management systems by integrating their functionalities into the PEAKapp solution.

Based on PEAKapp reviews, ICT-based solutions can produce effects on consumer behaviour of up to 5% reduction in household final electricity consumption (Bastida, Cohen, Kollmann, Moya, & Reichl, 2019). As such, PEAKapp aimed to show the high effectiveness of automation technology that optimizes demand response to variable electricity prices and requires only limited engagement from household members.

The theoretical background for some of the project interventions (i.e. informational feedback) is also linked to the high search and processing costs that households face when exposed to variable prices (Faruqui & Sergici, 2010), or the fact that people do not react very quickly to price signals, as a meta-analysis of short-term residential price elasticity estimations that finds a mean value of -0.228 across 175 published studies (Zhu, Li, Zhou, Zhang, & Yang, 2018).

PEAKapp selected a sample of 2,500 European households over a 1-year timeframe, and 50 households for testing the PEAKapp ecosystem interconnected to a smart home (building energy management) system. The main method of investigation is a field experiment. The PEAKapp project primarily investigated the effect of information on households' demand flexibility. Next to a control group, the design of the PEAKapp field experiment investigated the importance of variable prices through temporary price rebates, the effect of frequent and easily accessible price information, and the impact of easily accessible, frequent, and, particularly, salient consumption feedback.

The recruitment strategy of the PEAKapp project was based on the development of a mobile application to sensitize consumers to their energy consumption and to motivate households to adopt and sustain behavioural changes through difference incentives including dynamic prices, social comparison, and serious gaming (Reichl et al, 2019). The main features of the app were dynamic prices; electricity consumption analysis, implemented also in a graphical user-friendly and easy-to-understand way; a benchmark system which enables users to compare their energy consumption with comparable

households; a serious game, providing insights on the household's electricity consumption and the electricity consumption of specific household appliances.

The PEAKapp sample covered four countries: Austria, Latvia, Estonia, and Sweden. Approximately a third of the households chose to either never download the PEAKapp or renounced usage after an initial download. Interventions were based on information—notifications, commitment—set targets, gamification, and peer comparison. These were reflected in the three app functionalities: analysis, benchmarking, and gaming functionality. Looking at control samples, PEAKapp project found that app users have lower average consumption at all times of the day than non-app users. Two explanations were awarded: app users may have been overall more energy efficient, in terms of daily behaviour (e.g., energy saving room temperature settings) and appliance and building purchases (e.g., energy efficient appliances, improved insulation, etc.), or sample composition, with treatment households were systematically smaller, with fewer members and fewer appliances (Reichl et al, 2019).

One of the notable recorded effects of the information interventions via the mobile app developed through the PEAKapp project was that the less energy efficient households ("heavy users") monitored in the project decreased their energy consumption by 7.1%. On average, discount messages elicited an increase in consumption of 0.96-1.15% on weekdays and 0.8-2% on weekends during the periods of discounted electricity prices.

Selected project results
PEAKapp applied the following interventions: Mobile app tracking, Engagement and Set targets, Gamification, Information, Peer Comparison, Self-reporting. In terms of results, the information interventions via the mobile app had the largest effect on less energy efficient households ("heavy users"), which decreased their energy consumption by 7.1%. Discount messages elicited an increase in consumption of 0.96-1.15% on weekdays and 0.8-2% on weekends during the periods of discounted electricity prices. Datasets are not publicly available, but relevant datasets forming the basis of peer-reviewed publications can be supplied to journal editors upon request (Reichl, 2016). Descriptive statistics and results are available in Deliverable 4.1 (Reichl et al, 2019).

2.2. ENCOMPASS

EnCOMPASS has implemented three pilots to test socio-psychological factors determining energy consumption behaviour, across different building types (i.e. residential, schools, and office buildings), across different age groups, and in different countries (i.e. Germany, Greece, Switzerland). Additionally, the EnCOMPASS project developed an ICT-based solution targeting energy behaviour through such interventions such as gamification, information, or engagement.

The literature review that informed EnCOMPASS, included a variety of 859 studies on: Theory of Planned Behaviour, Value-Belief-Norm Theory, Process Model, Theory of Reasoned Action, Goal-gaming Theory, Goal Setting Theory, Social Identity Theory, Influential Theory of Persuasion, The Theory of Interpersonal Behaviour, Rational Choice Models, Norm Activation Models and Norm Activation Theory (KTU, 2017).

In its three pilots comprising of household and public buildings in Germany, Switzerland and Greece, the EnCOMPASS project was deployed with the following sequencing: (1) a preliminary baseline questionnaire meant to evaluated personal norms, ascription of responsibility, perceived behavioural control, behavioural intention to save energy and self-reported knowledge of energy saving actions of the participants in the three pilots, (2) recruited the intervention and the control groups, (3) installed the sensing equipment and smart meters, and then (4) the EnCOMPASS App was launched (SHF, 2018). It then included a deployment of interventions via the EnCOMPASS app and a FUNERGY game for schools. The results of the interventions in the treatment period between June 2018 and February 2019 were compared to the behavioural data from the baseline period (June 2017 – February 2018) (Koroleva K. M., 2019).

Summary of Pilot ENCOMPASS app Household Usage

Households	Active users	Activity level – log ins (average)	Most popular pages	Awarded badges (average)	Tips read (average)
German pilot (four months)	93	45,2	Saving goal (43) Comfort (34)	4,9	63
Swiss pilot (four months)	66	44,2	Saving goal (54) Comfort (53)	5,4	47
Greek pilot (one month)	64	2,06	Comfort (5,3) Saving Goal (4,2)	1,3	20,1

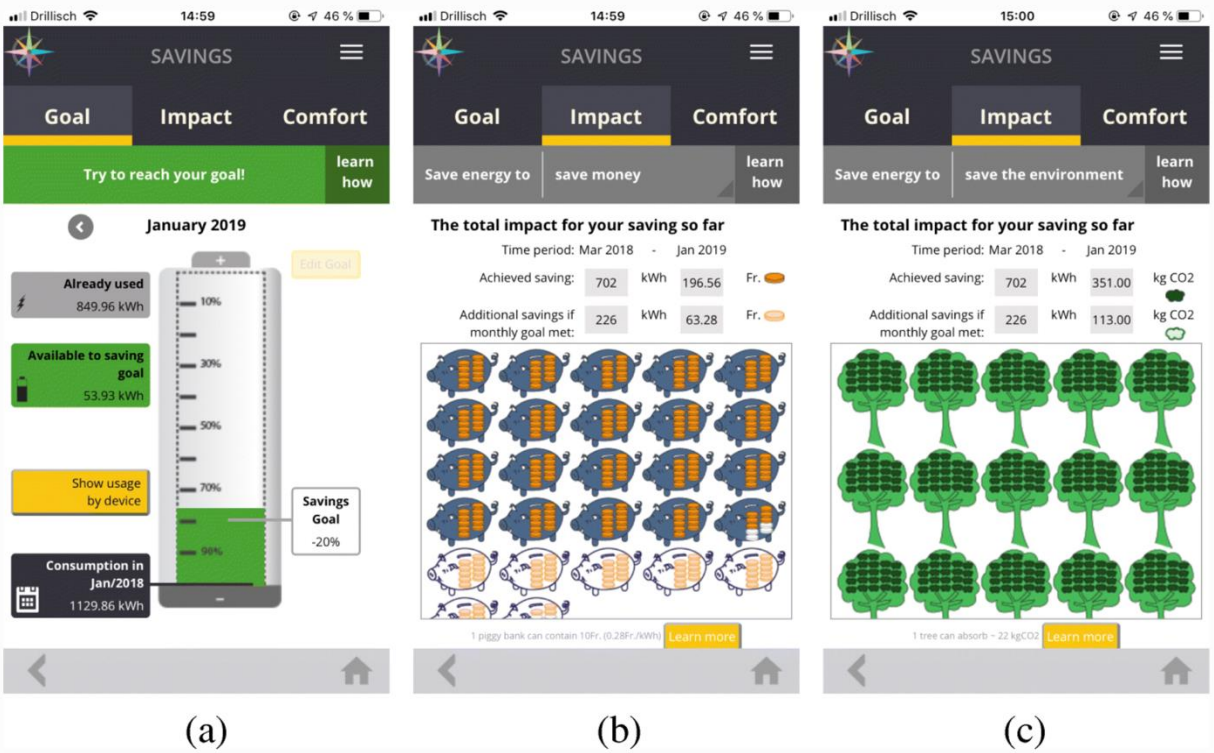
Source: (SHF, 2018).

Means, deviations, and statistical test results for the change in attitudes, intention and knowledge of the ENCOMPASS app intervention

Construct	Group	N	Mean	St. Dv.	Shapiro Wilk	Levene's Test
Perceived Behavioural Control	Intervention	40	0.04	0.92	D(40)=0.95, n.s.	F=0.23, n.s.
	Control	26	-0.22	0.78	D(26)=0.94, n.s.	
Behavioural Intention	Intervention	40	-0.06	1.11	D(40)=0.96, n.s.	F=0.17, n.s.
	Control	26	0.33	1.29	D(26)=0.95, n.s.	
Energy Knowledge	Intervention	40	2.17	6.30	D(40)=0.95, p <0.05	F=0.37, n.s.
	Control	26	-1.73	4.9	D(26)=0.94, n.s.	

Source: (Koroleva K. M., 2019).

ENCOMPASS App - Designing an integrated socio-technical behaviour change system for energy saving



Metaphorical feedback visualizations. **a** battery metaphor to set and monitor an energy saving goal. **b** monetary impact visualization. **c** environmental impact visualization

Source: (Koroleva K. M., 2019)

Selected project results
EnCOMPASS applied the following interventions: Survey, Gamification, Social Norms, Information including simplification. Early results indicate that the platform is successful in reducing household user energy consumption on average by 5.81% as opposed to the control group which increased the consumption by 1.33% (Launonen H. T., 2019). User Data and Baseline Questionnaire results are available. Information interventions via ENCOMPASS app can also be accessed (SHF, 2018).

2.3. ENERGISE

ENERGISE focused its interventions on social norms, and ways to change them to achieve sustainability in the field of energy consumption. Based on several living labs spread across 8 countries (Denmark, Finland, Germany, Hungary, Ireland, Netherlands, Switzerland, UK), it covered 306 households. ENERGISE adopted a Living Labs approach to directly observe existing energy cultures in a real-world setting and to test both household and community-level initiatives to reduce energy consumption. A comprehensive review and classification of household and community energy initiatives from 30 European countries provided the foundation for the development of two prototype 'ENERGISE Living Labs' designed to capture influences on individual and collective energy consumption. This mapping overview resulted in a database of sustainable energy consumption initiatives (SECIs).

ENERGISE challenged the idea that it is just individual behaviour that needs to be targeted in energy efficiency interventions. ENERGISE looked at unintended consequences of individual interventions, such as rebound effects or other (positive or negative) shifts in consumption patterns (Sahakian, 2011) (Jensen, 2017). To better avoid (negative) unintended consequences, it was concluded that problem framings and related representations of change may, to a larger extent, recognise the social embeddedness of practices across systems and domains (Jensen, 2017).

The ENERGISE 'Living Lab' (ELL) approach was informed by social practice theory. Two challenges were introduced to 306 households in eight countries: to lower indoor temperatures and to reduce laundry cycles. Weekly surveys recorded the effects on the sample. Interventions consisted of engagement from participants.
The results of the project included: (1) for reducing the laundry cycles, the largest effect was registered in the households with "heavy" usage (i.e., 5 or more cycles) with a 30% reduction, and (2) for the temperature challenge, the largest effect was in the case of single person households with a temperature reduction of 1.42 Celsius (see the table below).

Effect of Interventions in ENERGISE

Change in temperatures		Change in weekly wash cycles
Living room	**Bedroom**	**All**
From 21.2 °C to 20.1 °C	From 20 °C to 18.5 °C	From 4.1 cycles to 3.1 cycles
1°less	*1.5°less*	*1 cycle less*
Follow-up:19.8 °C	Follow-up:17.7 °C	Follow-up: 2.9 cycles

Source: Sahakian et al 2021.

Selected project results
ENERGISE applied the following interventions: Survey, Engagement, Self-reporting. For reducing the laundry cycles, the largest effect was registered in the households with "heavy" usage (i.e., 5 or more cycles) with a 30% reduction. For the temperature challenge, the largest effect was in the case of single person households with a temperature reduction of 1.42 degrees Celsius. The Online Database maps 1,067 Sustainable Energy Consumption Initiatives across 30 European countries, on four areas: (1) Changes in Technology, (2) Changes in Individual Behaviour, (3) Changes in Everyday Life Situations and (4) Changes in Complex Interactions (ENERGISE, 2021). Survey data results from ENERGISE 'Living Lab' (ELL) available only in country reports: Denmark, Finland, Germany, Hungary, Ireland, the Netherlands, Switzerland, UK

2.4. eTEACHER

The eTeacher project performed and combined measurements on energy consumption, indoor conditions, outdoor conditions, and other parameters such as occupancy or windows opening, which were collected in the 10 buildings to estimate the energy saving potential, with actions on energy saving behaviours related to the use of HVAC systems, appliances, and lightings. This project was anchored in socio-psychological research methods.

This research project aimed at developing interventions based mainly on social norms (Dotti, N/A), and references studies on targeted communication with social comparison nudges (i.e., others are producing more) or loss aversion nudges (i.e., loss of money from poor energy efficiency) resulting in as much as 45% engagement of people[1]. It also references social stimuli projects, that use such social mechanisms as comparative feedback and injunctive norm.

eTEACHER has defined a methodology that uses measured and self-reported evidence and is based on three methods: (a) monitoring to collect data on energy consumption, outdoor and indoor conditions; (b) eTEACHER app to collect information related to users' interaction (number of users registered, number of active users, etc.) and (c) feedback forum and surveys to gather the opinion of the building users (Hoffrichter, et al., 2020).
The project covered a sample of 5000 people, from 3 EU countries (Spain, UK, and Romania). The experimental design consisted of intensively monitoring 10 European buildings at building and room/apartment level during 8 months from February until September 2019. The 10 pilot buildings are real buildings and include a kindergarten (1976, 905 m^2, 1 floor, 20 users), a high school (1965, 5,307 m^2, 3 floors, 120 users), an office building (2011, 3,211 m^2, 3 floors, 130 users), a residential building (1984, 4,540 m^2, 5 floors, 95 users) and two healthcare centers (2000/2002, 1,270/2,180 m^2, 2/2 floors, 577/915 users) in Spain as well as four residential buildings (2009, 67,900 m^2, 4 buildings, 1,500 users) in Romania (Calleja-Rodríguez, Peralta-Escalante, Jiménez-Redondo, Márquez-Pocostales, & Anghelita, 2020).
For all pilots, in total, nine energy-related target behaviours were defined:

- Lighting use behaviour: (TB1) Turn off lights when leaving a room or at the end of the day; (TB2) reduce the use of unneeded lights, check lighting levels and needs during the day.
- Appliance use behaviour: (TB3) Turn off appliances (computers, TVs, medical equipment, etc.) at the end of the day; (TB4) turn off appliances when away.

[1] PV EAST, which stands for Photovoltaic (plants) Easy (language) Attractive (message) Social (comparison) Timely (encouraging people when they are more reactive), https://ecoraf.weebly.com/progetto-eco-raf.html

- HVAC use behaviour: (TB5) Reduce thermostat temperature for heating when overheating; (TB6) increase thermostat temperature for cooling when undercooling; (TB7) ensure that windows and doors are kept closed if heating/cooling is on; (TB8) turn off HVAC system if room/building is not in use for more than one hour; (TB9) ensure that air-conditioning and heating are not working at the same time.

The results also show that the office building could have saved up to EUR 2,500 in energy during the study period (i.e., 8 months from February to September 2019), while the healthcare centres could have saved more than EUR 1,000. The most promising target behaviours in terms of energy saving potential are those related to the use of the cooling system: (TB6) Increasing thermostat if undercooling, (TB7) Close windows if HVAC is on, (TB8) Turn off HVAC if no one is present. It should be noted that the target behaviours focused on heating were not analysed due to the weather conditions during the monitoring months. The highest energy saving potential is related to the use of the Heating, Ventilation and Air-Conditioning (HVAC) system. It has also been found out that there is a potential to improve comfort conditions in all the pilot buildings. The highest potential on comfort is identified in the improvement of the luminance conditions.

Table 1. Description of target behaviors' characterization.

Target Behavior	Description
TB1: Turning off lights when leaving a room or at the end of the day	Count number of hours in every monitoring room where there is no one present and the lights are on (presence = 0 and C_lighting > 0 kWh) Lighting energy consumed during those hours: (∑C_Lighting (kWh)) Cost of that energy: (e.g ∑C_Lighting kWh × 0.129893 EUR/kWh)
TB4: Appliances off when away from room for 1 h or more.	Count number of hours in every monitoring room that appliances are on, there is no one (C_appliances > 0 kWh and presence = 0) Appliances energy consumed during those hours: ($\sum C\_Appliances$ (kWh)) Cost of that energy (e.g. $\sum C\_Appliances$ kWh × 0.129893 EUR/kWh)
TB6: Increasing thermostat temperature for cooling when undercooling	Count number of hours in every monitoring room that temperature inside is high and heating is on (temp_i > 21 °C & C_cooling > 0 kWh) Cooling energy consumed during those hours ($\sum C\_cooling$ (kWh)) and cost of that energy (e.g., $\sum C\_cooling$ kWh × 0.129893 EUR/kWh)

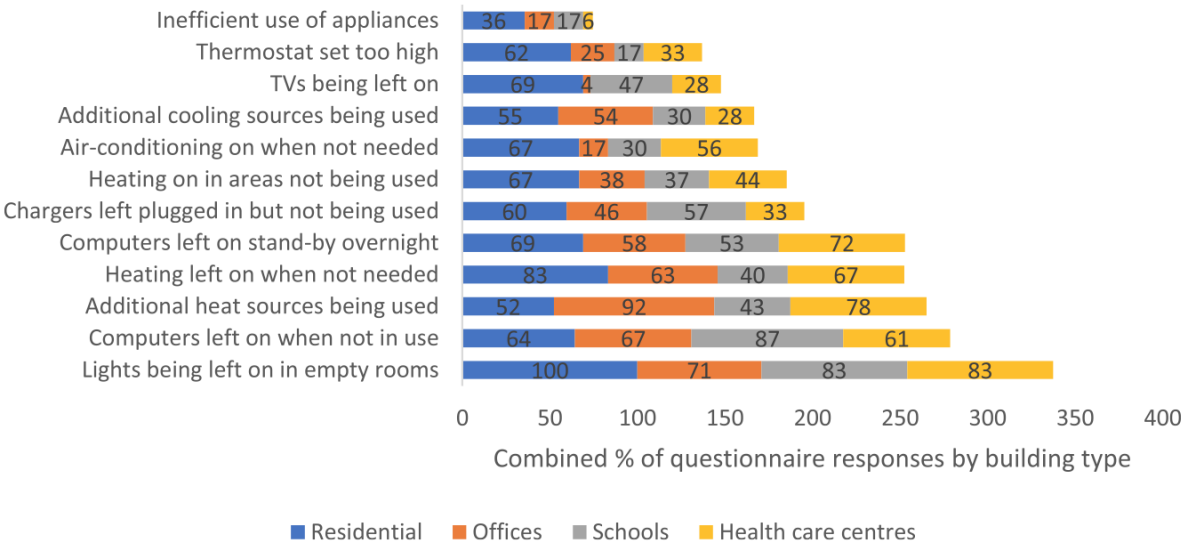
Source: Calleja-Rodríguez et al, 2020

The interventions will subsequently be deployed within the project, by deploying ICT solutions to change energy behaviour of these buildings' users. The building users of these pilots will be provided with an app to encourage energy behaviour change during the demonstration phase of the eTEACHER project (Calleja-Rodríguez, Peralta-Escalante, Jiménez-Redondo, Márquez-Pocostales, & Anghelita, 2020, p. 6).

eTEACHER sees energy end-user engagement as a key feature, designing its ICT interventions through the pilots described above. It sought to develop and tailor effective behaviour change intervention, based upon research evidence, consultation with energy

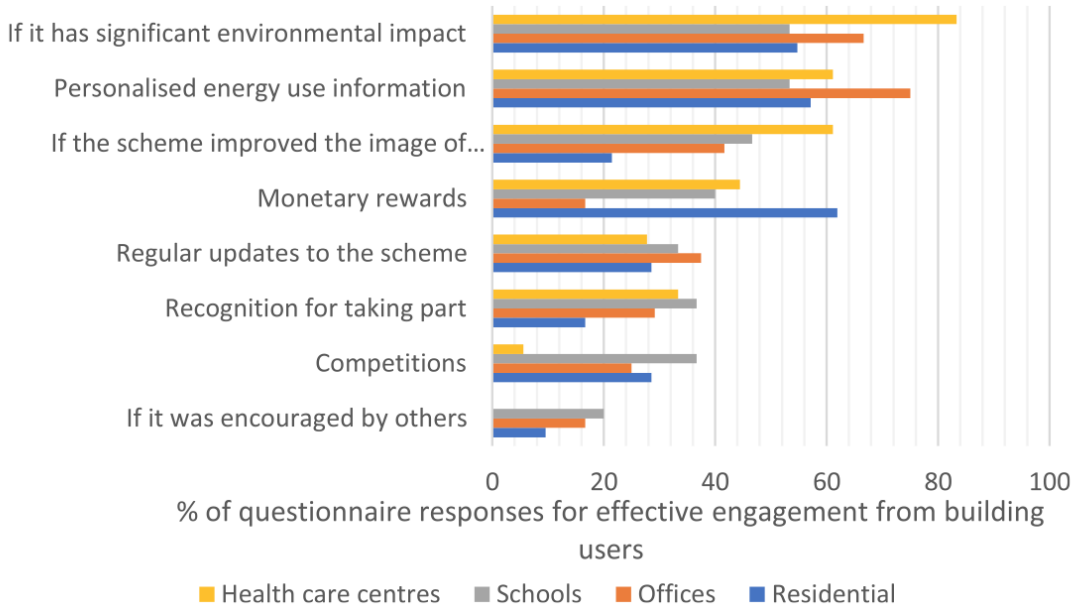
end-users, and a pre-chosen structured framework for designing behavioural change initiatives, through the „Enabling Change" framework which is an evidence-based approach advocating for a participatory approach to project development, at both whole-programme level and with relation to specific interventions on the ground (Robinson, 2011). As part of this approach, Feedback Forums, a group of key building stakeholders and actors who could provide feedback on key ideas and concepts for the development of the eTEACHER tool, were formed in each of the 12 pilot buildings that eTEACHER is being trialled in. The Feedback Forums acted as a means of co-creation during the tool planning and development phase and allowed for user experience feedback during the implementation and demonstration phase of the project (Hoffrichter, et al., 2020).
eTEACHER has incorporated end-user engagement across all phases of the project duration, allowing for end-user feedback to not only help steer the tool design but also tailor the intervention roll-out and subsequent engagement activities throughout the demonstration phase. This approach, we believe, will maximize the end-user acceptance of our eTEACHER tool and optimize its impact on improving energy efficiency across a wide range of building types and building user groups.

Reported inefficient energy behaviours by building user questionnaire responses (eTEACHER)



Source: Morton, Reeves, Bull, & Preston, 2020, p. 6

Motivation towards engagement with ICT-based intervention within buildings (eTEACHER)



Source: Morton, Reeves, Bull, & Preston, 2020, p. 6

Due to the COVID- 19 pandemic, preliminary results of the ICT interventions were not yet available (Hoffrichter, et al., 2020).

Selected project results
eTEACHER applied the following interventions: Survey, Engagement, Self-reporting, Gamification through App. The results also show that the office building could have saved up to EUR 2,500 in energy during the study period (i.e., 8 months from February to September 2019), while the healthcare centres could have saved more than EUR 1,000. The most promising target behaviours in terms of energy saving potential are those related to the use of the cooling system: (TB6) Increasing thermostat if undercooling, (TB7) Close windows if HVAC is on, (TB8) Turn off HVAC if no one is present. It should be noted that the target behaviours focused on heating were not analysed due to the weather conditions during the monitoring months. The highest energy saving potential is related to the use of the Heating, Ventilation and Air-Conditioning (HVAC) system. The results from pilots are only available in resulting academic publications: (Calleja-Rodríguez, Peralta-Escalante, Jiménez-Redondo, Márquez-Pocostales, & Anghelita, 2020) (Hoffrichter, et al., 2020). Due to the COVID-19 pandemic, preliminary results of the ICT interventions were not yet available (Hoffrichter, et al., 2020).

2.5. FEEdBAck

FEEdBACk project addressed energy efficiency through behavioural change. Its gamification engine and corresponding platform were designed and developed with the objective of motivating permanent behavioural change by increasing the consumer awareness and engagement through targeted messages and gamified peer competition schemes.

FEEdBACk developed an interactive app platform that combined gamification with real-time data feedback and personalized messages based on sensor data and in-game activity. The gamification content was developed using feedback from users in early-stage engagement events and activities including workshops, interviews, and a comprehensive user profiling survey. The app collected users' gameplay data, monitors logins, and level of progression. Players gained badges for interaction and receive reminders in the form of video or text messages. The project combined user profiles and player feedback with social cognitive theory and spaced learning methodologies, to develop TV Novella style drama and character-based games, which showed players their own behaviours through relatable characters (Hoffrichter, et al., 2020).

The Behaviour Predictor application aimed at evaluating users' reactions to the stimuli sent by the gamification platform. With the continuous operation of the gamification platform and the increasing amount of data available, the Behaviour Predictor was expected to provide increasingly accurate forecasts of the users' behaviour when a stimulus are sent. This would allow targeting of messaging that maximise relevance and build continued commitment to goal achievement.
The datasets resulting from this project covered the following categories: Behavioural, Environment Envelope / Site characterization, User Gaming Profile / Segmentation, Indoor Air Quality (Temperature, Humidity, CO_2), Load Disaggregation, Occupancy, Automation management, Energy Saving, Consumption (Water, Gas, Electricity) (Desport Coelho, 2018).

Behavioural data was collected through the pervasive app. The gamification ECOplay app reached 1041 users and helped some of them become more sustainable. But, due to the COVID-19 pandemic, preliminary results are not yet made available (Hoffrichter, et al., 2020).

Selected project results
FEEdBACk applied the following interventions: User profile survey, Engagement, Social Norms, Feedback Information and Gamification through App. The gamification ECOplay app reached 1,041 users and helped some of them become more sustainable, but due to the COVID- 19 pandemic, preliminary results are not yet made available (Hoffrichter, et al., 2020).

2.6. NUDGE

The NUDGE project was launched in 2020 to analyse people's behaviour, and design and test nudging interventions. This project is anchored in socio-psychological research (much like eTEACHER). The project plans out the implementation of field experiments in 5 national pilots around the EU (Greece, Belgium, Germany, Portugal and Croatia) (as displayed in the table below), in different environments (i.e. residential, energy communities, schools), belonging to different age groups (including young children) or different income classes. It targets both electricity and natural gas energy carriers, as well as prosumers and Electric Vehicle drivers.

Methodologies and tools used include field experiments and surveys to assess the impact of an intervention, coupled with randomized control trials to assess the effectiveness of the interventions. The questionnaire uses Theory of Planned Behaviour, Prototype Willingness Model, Value Belief Norm Theory, Environmental Concern, Financial Concern, Energy Awareness, and Loss of Comfort.

Intended Nudging Interventions in NUDGE

	Pilot Description	Intended Nudging Interventions
1.	**Efficient heating** and DHW preparation for Natural Gas consuming boilers in Greece	**Facilitating:** Change the default temperature setting of available heating schedules **Deceive:** Visualize the environmental consequences of non-efficient actions (e.g., overheating) **Social Influence:** Comparison with similar households in the same neighbourhood, city, etc.
2.	Interdisciplinary project-based **education on home energy consumption** for children in Belgium	**Facilitating**: Change the default temperature setting of available heating schedules **Deceive**: Visualize the environmental consequences of non-efficient actions (e.g., overheating) **Social Influence**: Comparison with similar households in the same neighbourhood, city, etc.
3.	**Optimization of EV charging with self-produced PV power** in Germany	**Facilitating**: Suggest alternative periods for EV charging **Reinforcement**: Point out that EV charging is advised during periods of high PV production **Reinforcement**: Provoke feelings of environmental responsibility to drive efficient EV charging

4.	Promoting **distributed self-production for local Energy communities** in Croatia	**Social Influence**: Social comparison with members of the cooperative **Social Influence**: Leverage commitment of individuals to common goals of the cooperative **Social Influence:** Invoke feelings of reciprocity by advising members to consume when PV energy is available
5.	Healthy homes for long-lasting **energy efficiency behaviour** in Portugal	**Social Influence:** Prompt users to follow individual targets towards improving health conditions for their family **Facilitating:** Suggest alternative means for improving indoor environment conditions that take into account the impact on overall energy use (e.g., ventilation to reduce indoor pollutant concentrations when outdoor temperature/humidity conditions permit) **Fear:** Inform parents that prevailing outdoor air quality is not optimal for energy-efficient house ventilation

Source: (Nudge, 2021)

Selected project results
NUDGE is set out to apply multiple Nudging Interventions in different pilots: Engagement, Self-reporting, Information, Social Norms. Results and data are not available yet, as project was launched in 2020.

2.7. SCOoPE

SCOoPE did not focus on households, yet its approach proved interesting due to a number of features: the cross-learning concept applied, the interventions employed, their interlinkage through the employment of a collaborative management system that generated on-the-spot solutions coming from synergies, and due the overall impact in terms of consumption. The results registered may furthermore generate questions with regards to the potential replicability of methods and outcomes in the residential sector. The project specifically aimed to reduce energy consumption in energy-intensive agro-food industries by 10%-15% over the medium term. This was to be achieved without a decrease in production capacity, but rather through higher efficiency generated through the implementation of various techniques and technologies that had proven to be effective in other industries. Corrections would be applied on a baseline value stream map that would highlight the most energy consuming processes. In addition to that, the project implemented a collaborative energy management system that enabled common evaluation of data, exchange of best practices, identification of common bottlenecks, common solutions based on real-time data coming from the complementarities and similarities of the industrial sites analyzed (as described in (SCDF - Services Coop de France, 2017). Also, the system allowed for the active involvement in the solution-finding process of two additional categories of stakeholders: the technology providers and financial institutions – a novelty in terms of solution-finding.

The project consisted of the application of a number of interventions during one year on 6 industry clusters, consisting of 81 cooperatives functioning in industry subsectors such as arable crops drying and storage, meat and poultry, dairy, transformation of fruit and vegetables. These businesses have been selected from 5 different countries (France, Italy, Greece, Portugal, and Spain). The cluster members were selected from a list of members of the Association of Producers and other interesting parties, on a project invitation and a voluntary decision based on a number of costs and advantages presented to them. As for some of the participants some of the costs were excessively high, such as the acquisition of the energy monitoring systems, they only participated after receiving third party (private/public) financial support. Participation was commitment-based, as the parties involved needed to sign a participation contract based on a standard action plan (ENEA, 2018).

Interventions can be reduced to two main approaches: investments (21% on renewable energy systems and 79% energy efficiency measures and integrative processes with a total value of 31,47 M EUR) and reporting on consumption (this has been performed through an auditing process through specialized project experts). These interventions have led to important total energy savings (83.07 GWh) (Spanish Agrifood Cooperatives, 2019). These have been recorded in almost real time over a dashboard tool (accessible in

description here) connected to measurement tools and sensors that enabled, beyond data collection, comparison between nominal and real consumption, cost and consumption visualization per process, a graphic visualization of consumption and monthly reports. Information on the dashboard could be accessed by a number of entities: The Country Cluster Coordinator, the company manager, the Dashboard coordinator for technical assistance, the Scoops project coordinator and ENEA, the WP leader who was in charge of the pilots, who took part in the analysis and decision-making process via periodical teleconferences.

The project concluded that the largest part of savings registered during the lifetime of the project (63% or 57,30 GWh) have been the result of energy efficiency-related investments, whereas only a minority (37% or 25,75 GWh) were the result of new renewable technology being installed (SCOOPE, 2019).

Selected project results
The project includes in its 6 pilots exclusively cooperatives implementing, commitment-based, mainly 2 types of interventions: investment and reporting on consumption. Exchanges and common analysis of results within one cluster, which may resemble a social norms intervention, was also part of the project. Additionally, the project integrated interventions through a collaborative management system in the form of a dashboard tool that coordinated diagnosis and responses for similar/complementary processes. The pilots also included technology suppliers and financers in the discussion to improve the quality of solution-finding. The one-year long project generated savings of over 83 GWh mainly as a result of energy-efficiency and coordination investments and to a lesser extent from the investment in renewables. Some data on the pilots is available on the project website.

2.8. NatConsumers

NatComsumers (CORDIS, 2020) was a project that hoped to change the energy consumption behaviour of individual households through variants of information including simplification and commitment interventions implemented through a consumer-focused demand-response tool (CINEA, 2014).

The project was implemented in four EU Member States: Denmark, Hungary, Italy and the UK. The size of the sample on which the interventions were applied is not evident from the study, therefore representativeness, as any other characteristics of the sample, are difficult to assess. The tool was developed on the basis of at least two assumptions:

- A consumption reduction goal of 5-20% , which was set based on the results of two meta-analyses, which studied 38 (Darby, 2006) respectively 57 (Ehrhardt-Martinez, 2010) feedback pilots developed between 1957-2000 and the VaasaET database that was tracking at the time of the project 140 demand response programmes involving 630.000 residential and non-residential customers around the world. Based on the VaasaET tool it was established that European feedback pilots (68) were able to reduce consumption by 7.30%. Based on the limitations of most of these projects (small scale, short time scale, different geographical areas and experimental designs, generalized feedback), NatConsumers set out to prepare a tool that could be used to overcome these disadvantages while meaningfully assisting consumers by making use of fine-granular smart-meter data (NATCONSUMERS, 2017).
- Consumer behaviour is determined by a wider context factor, household context factors (mainly structural factors), individual context factors (attitudes, motivations or values).

Based on the above assumptions (smart-metered data, socio-demographics, attitudes and values, etc.) the tool defined specific consumer types/patterns and set upon addressing their inefficiencies through customized feedback and a category of preset personalised actions. These made use of natural language and emotional contents to reach and influence consumers. The segmentation process upon which typologies are based is described more into detail in the project Handbook in Chapter 2.1 (NATCONSUMERS, 2017).

The tool designed hoped to raise awareness about how people use energy within their homes, and to give them advice about how to use it more sustainably. Messages were conveyed in a friendly, emotionally intelligent, relevant, simple and interesting language, avoiding jargon and technicalities. At the same time communication was performed on many levels and through many means of communication, not necessarily by use of words. It could, therefore entail nudging, pictures, light, sound, graphical patterns etc. Communication was based on multiple constructed narratives, which were

connected through keywords (or standard expressions) to various consumer typologies. All these elements (narratives, expressions, consumer typologies) were linked to one another by means of logical frames and were programmed to respond to quantitative indicators, including consumer data, read through the system on a real-time bases.

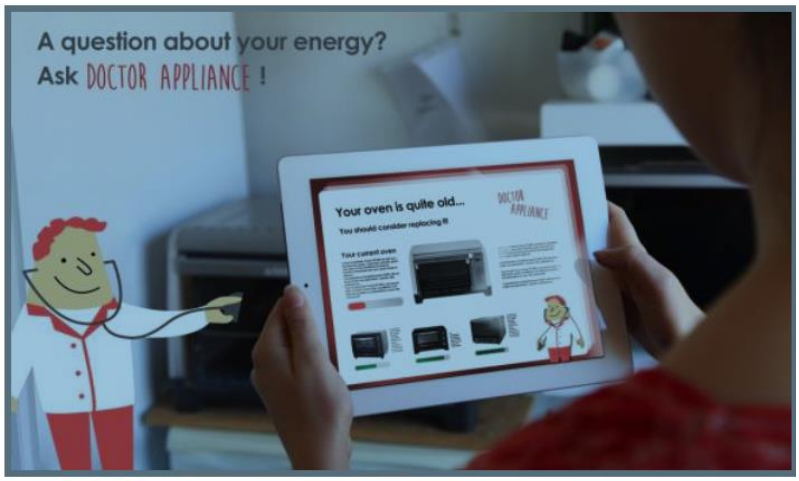
The methodology is visually displayed below:

Source: (NATCONSUMERS, 2017)

This complex analysis-diagnosis-response tool was then designed to be applied by use of ten engagement patterns/strategies implemented on gadgets, electronic devices, as well as through more classical communication instruments (architecture, objects, fabrics), based on the assumption that replicated in different situations, the engagement effects of these strategies will be similar in terms of energy consumption (NATCONSUMERS, 2017).

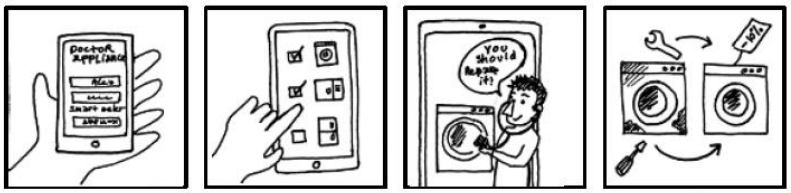
Strategies have been developed across a designer jam session. They will be defined briefly and exemplified below where significant. Some of the examples apply across several engagement patterns :

- a medicalization pattern is based on the logic that compulsive energy consumption may require treatment similar to a disease;



DOCTOR APPLIANCE

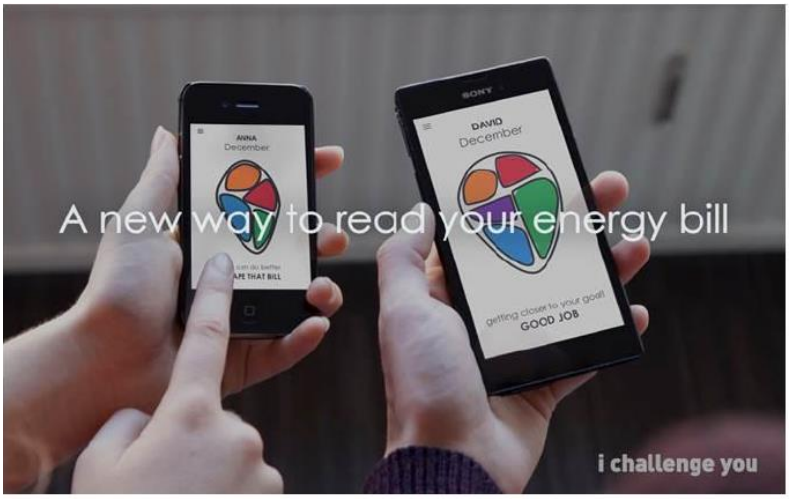
Doctor Appliance is an app that allows you to have a full scan of the state of your appliances. It provides you with suggestions for improving the life of your appliances, detects if there are any irregularities, gives you recommendation on your usage and when it's time to buy another one, shows you other appliances on the market with a detail analysis and all possible incentives and discounts available.



Create an account | Include your domestic appliances | Scan appliances and get information on their status | Replace the appliances that are not anymore efficient and get discounts as reward

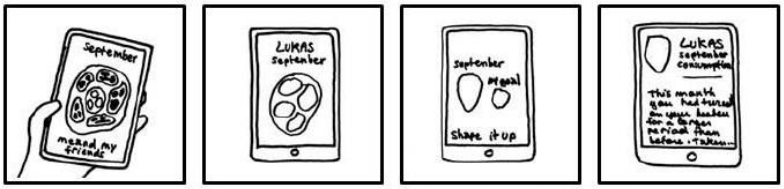
Source: (NATCONSUMERS, 2017)

- an art-like pattern: energy consumption can take the form of artistic expression that catches attention;



I CHALLENGE YOU

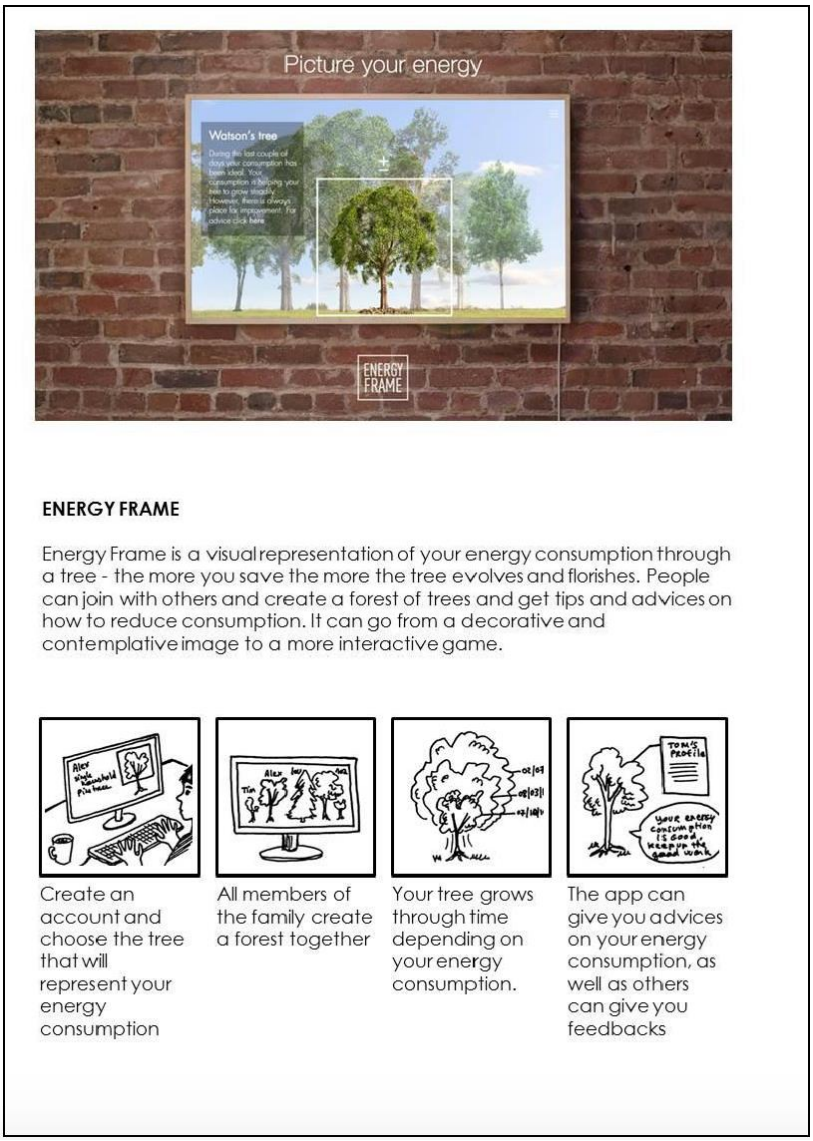
An app that provides you with interactive visualization of your energy consumption by being connected to your smart meter. It is an intuitive and visual interpretation of data that makes it possible for you to surf in different ways through the data. It also informs you how to work better on your energy consumption. There is possibility of adding your friends and family to see how your community is working on their energy consumption.



Include your friends and support each other to achieve goals | Visualize your energy consumption through an artistic shape | Set goals and analyse your energy consumption tracking the changing shapes | Get advices on your energy consumption

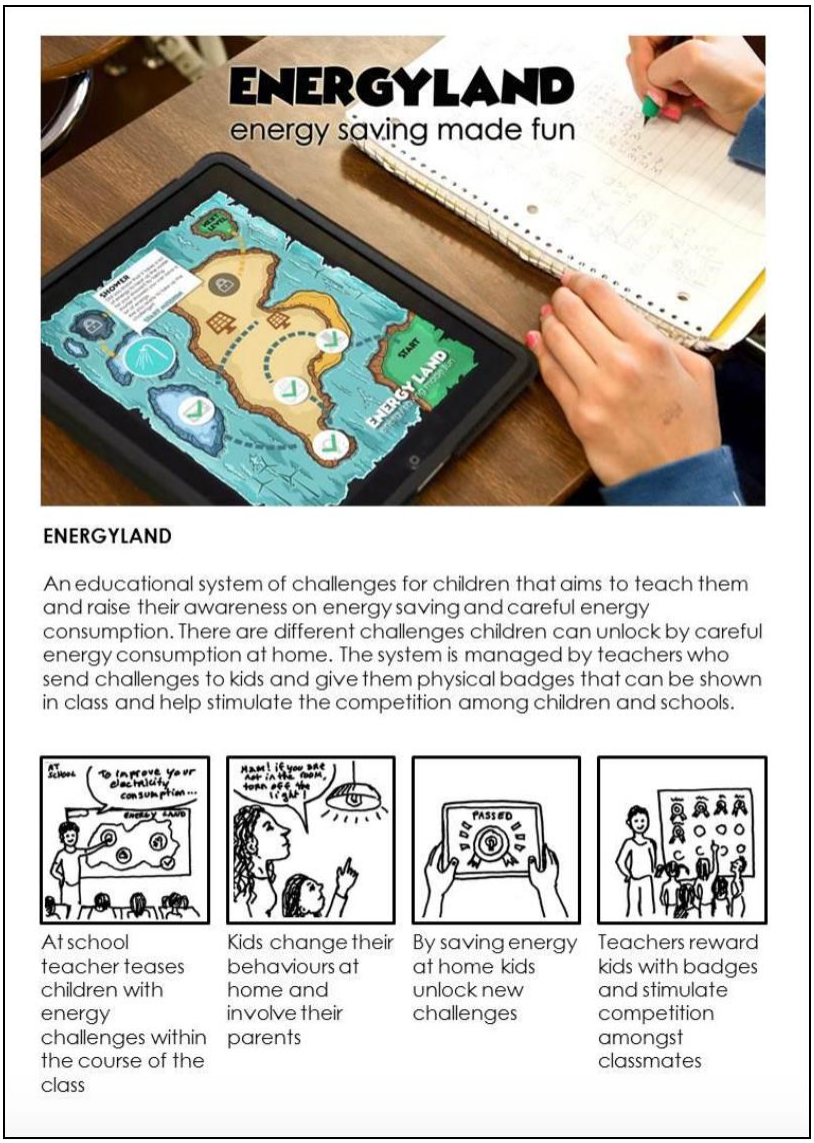
Source: (NATCONSUMERS, 2017)

- a bio-mimetic pattern: energy consumption is a natural entropic process impacting the biosphere;



Source: (NATCONSUMERS, 2017)

- a gamification pattern: energy consumption is similar to a multi-player game;
- a kids leadership pattern: kids' involvement may trigger behavioural changes in adults;

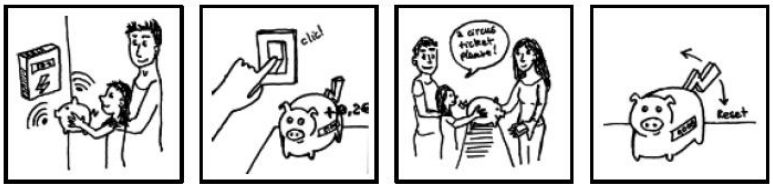


Source: (NATCONSUMERS, 2017)

- a children-scaling pattern: energy saving might be more engaging for children than for adults;

PIGGY BANK

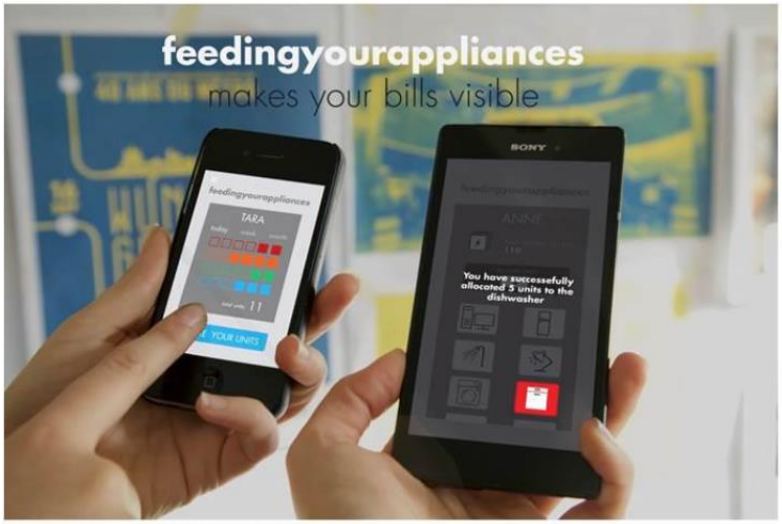
A piggy bank and an app for children show them how much money they save by changing their family energy consumption habits. It makes energy saving simple and engaging for kids because it makes it tangible. By immediate changes such as switching off the lights their piggy bank shows them how much they're saving. The saved energy makes the difference in kids pocket money and engage them in saving more.



Connect your piggybank to the smart meter of the house | Kids save money by changing their energy habits and pushing their family to also change | The money saved is worth at children scale and can be used by them | Kids reset the piggy bank and set new goals

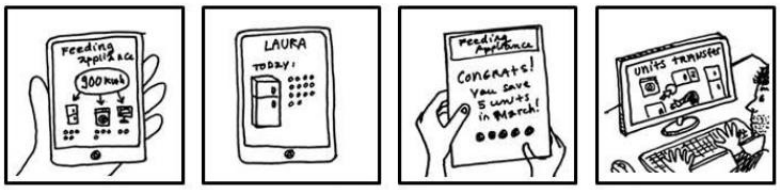
Source: (NATCONSUMERS, 2017)

- a co-operation pattern: energy savings might be more significant when done in cooperation;
- a story-telling pattern: rich narratives might have a more significant impact in terms of savings than blunt language;
- a signaling pattern: consumption signals have to be engaging and attract consumers' attention;



FEEDING YOUR APPLIANCES

The app simplifies household energy management: the kWh are translated into units like "energy Lego bricks". You can allocate your energy units to each of your appliance, reorganize your units according to advices on energy saving. Understanding energy management through reallocating units between your household appliances is very simple. Saved units can be stored for coming months or given to charities.



Your monthly energy consumption is broken down into units displayed by each appliance

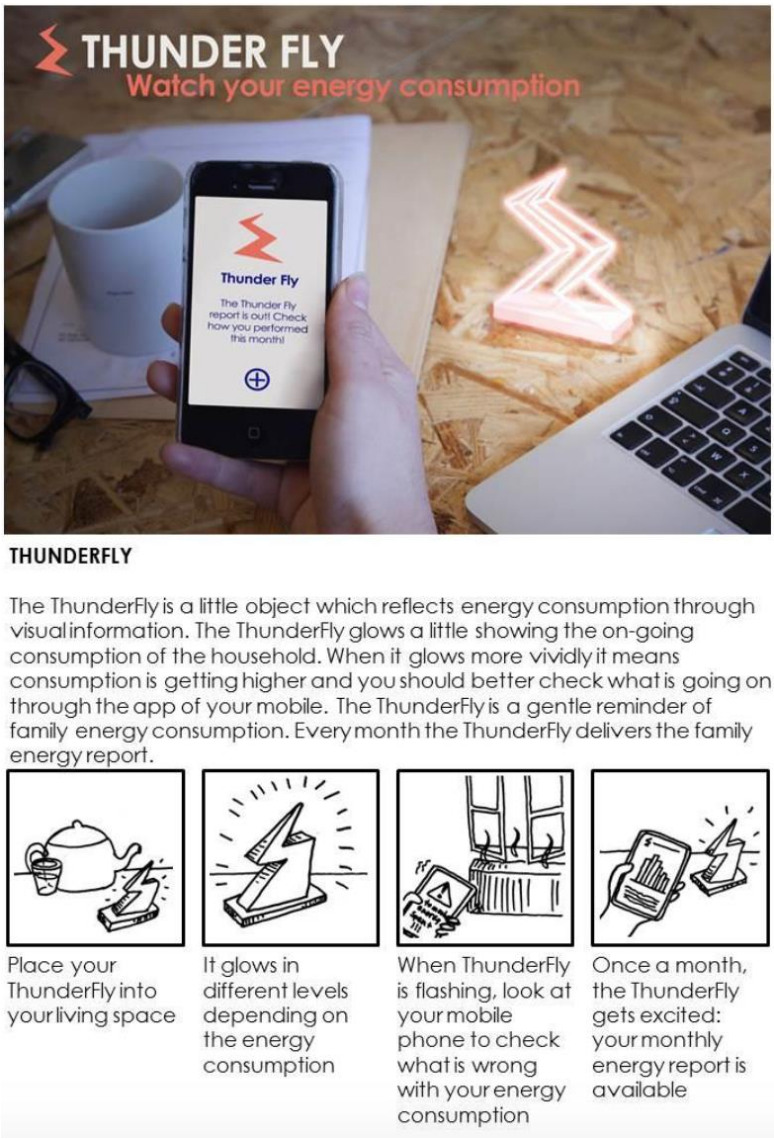
You can control the energy consumption of each appliance

At the end of the month you see how many units you saved

And you can allocate them to appliances you wish or donate them to a charity fighting against energy poverty

Source: (NATCONSUMERS, 2017)

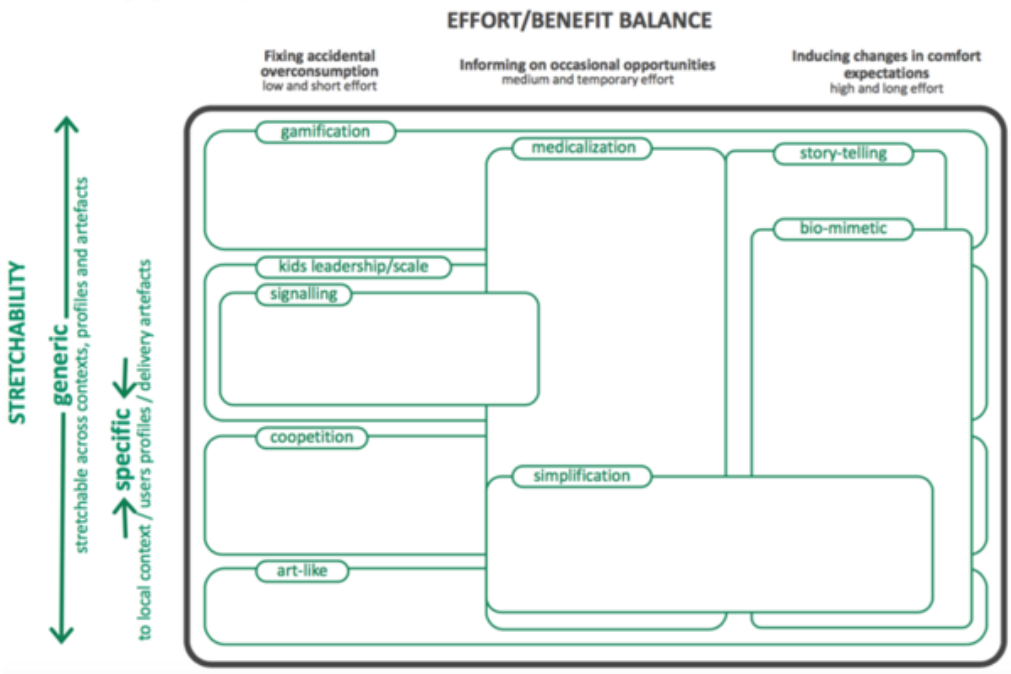
- a simplification pattern: energy consumption needs to be made explicit to the consumer.



Source: (NATCONSUMERS, 2017)

It was concluded that different patterns may be more effective in different situations, whereas some were found to be more generally applicable (streatcheable) and others more context-specific. The project generally supported an effort/benefit balance implementation rationale: For accidental overconsumption, the project concluded that gamification, kids leadership and scale, signaling, competition and art were more appropriate; medium and temporary effort required more occasional and informing strategies such as medicalization and simplification; for high and long-term efforts that involved more broad changes at the level of lifestyle, story-telling and bio-mimetic patterns were considered more appropriate with some gamification, kids, cooperation and art-like strategies applicable to some extent. The logic is illustrated below:

24. Tentative scheme o the different engagement patterns alongside stretchability and effort/benefit balance



Source: (NATCONSUMERS, 2017)

The project also established some more specific trends: high tech solutions, and especially the ability to monitor consumption as quickly as possible, were found to be more acceptable by the population under 35 years and especially in Italy; the Italian population was also found to prefer more artistic pattern-based simplification concepts; some simplification instruments that were associated with familiar concepts, such as the physical Thynderfly gadget in Norway, were more favoured due to the evocation of nostalgic sentiments in relation to a device that had been used before at the national level. In Hungary, individuals favoured Thunderfly for a different reason: the existence of a physical object that would monitor consumption instead of a virtual one. This was associated with the preference of low-income populations for less IT-based solutions.

Despite an elaborate methodology on the development of the instruments, its impact and that of the implementing devices were difficult to apprehend, as there was no ex-ante and ex-post collection of consumption data or other type of quantifiable information. The only two assessments performed were: 1) to establish the attractiveness of these engagement concepts and possible challenges, and this happened at an initial stage before implementation. This took place in a rather presupposed interaction (i.e. not actual interaction) with the instruments across focus groups organized in some of the countries of implementation; 2) The impact of the instruments applied were assessed based on

estimated consumption data, as described above. The only data collected in the project served the segmentation purposes and is available in a raw format on Cordis.

The project concluded that overall consumption reductions are possible and that the highest impact is possible at the level of the most intensive consumers. The project also concluded that countries with lower degree of rollout of smart meters (e.g. Hungary) have a lower chance to generate reductions in consumption due to difficulty to use data and, consequently, tailored program interventions.

Table 4. Reduction in electricity consumption (data in TWh and % variation)

Country	Baseline2020 (TWh)	Reduction in electricity consumption compared to baseline TWh (and %)		
		User Acceptance 25%	User Acceptance 50%	User Acceptance 75%
IT	72.6	70.8 (2.5%)	68.9 (5.0%)	67.1 (7.4%)
HU	8.6	8.5 (2.3%)	8.3 (3.5%)	8.1 (5.8%)
DK	7.3	7.2 (2.7%)	7.0 (5.5%)	6.8 (8.2%)
UK	124.8	121.7 (2.4%)	118.6 (5.0%)	115.5 (7.5%)

Source: (NATCONSUMERS, 2017)

Selected project results
Natconsumers involved the development of an interactive energy consumption feedback tool programmed to create a number of consumer profiles based on energy consumption and other socio-demographic or value-related consumer characteristics and the corresponding response patterns. The project was implemented in 4 countries (Denmark, Hungary, Italy and the UK) and was more tool-development focused than implemented to test effectiveness on consumption behaviour change. After development, the tool would eventually implement two types of interventions: simplification and feedback on own consumption (due to profiling and energy advice) and social norms to some extent due to the various patterns of responses employed. In terms of consumption reduction, the general aim was to generate energy savings of anywhere between 5-20% of final energy consumption based on the conclusions of previous feedback programmes. Data collected for initial segmentation is available on the project website.

2.9. Briskee & Cheetah

Briskee & Cheetah (Briskee and Cheetah, 2020) were implemented as twin projects between March 2015-Dec. 2017 and December 2016-November 2019 in 8 EU countries (France, Germany, Italy, Poland, Romania, Spain, Sweden, UK) on representative samples of 18.300 individuals/households (for Cheetah) and 15.000 individuals (for Briskee) (Briskee and Cheetah, 2020),

BRISKEE addressed household decision-making and its effects at three levels: Micro, meso and macro. At the micro level, the project investigated the factors influencing individual decision-making. This data was used to assess the impact of household decisions on residential energy demand overall (the meso level), which were later used to model the general impact on the economy (the macro level).

Research in the project relied essentially on an online survey designed to investigate a number of variables regarding household attitudes, values, personal and social norms, cognitive abilities, preferences in relation to risk, time, loss aversion, ambiguity with regard to price options, and prudence instances. Additional socio-demographic or structural information was collected and analyzed through multivariate analysis in order to enable better framing of conclusions in terms of barriers or opportunities with regard to technology adoption. Moreover, some of the participants (54% of the sample), chosen randomly, have been incentivized by receiving the sums described in the treatments via a prepaid credit card, whereas the rest have been exposed just to hypothetical situations. Payments averaged 54.43 euros and ranged from 0 to 250 euros or equivalent depending on the national currency. These monetary incentives allowed the researchers to test the extent to which such barriers as lack of capital or high upfront cost play a role in the energy consumption behaviour of the sample population (Hesselink & Chappin, 2019).

The survey also highlighted factors underlying the implicit discount rate, such as risk and time preferences, environmental preferences, social norms or barriers to energy efficiency (such as the lack of capital). These were used as dependent variables to explore the relation between the factors underlying the implicit discount rate and attitudinal and socio-demographic variables.

Conclusions of the project were that participants who were more loss- and risk averse or who had a lower time discount factor were less likely to adopt energy efficiency technologies (EETs) including retrofitting measures, with variations across within countries (details on the raw data are accessible here) (Grassmann, 2018). Some of the findings proved that for standard time discounting, risk aversion, and loss aversion, the choice of EETs is sensitive to covariates reflecting socio-demographic information, dwelling characteristics or environmental attitudes with important variations between countries, which were, however, inconclusive due to too small samples. Income,

education, planned moving, rental status or access to capital were also found to be correlated with the adoption of EETs (Schleich, 2018).

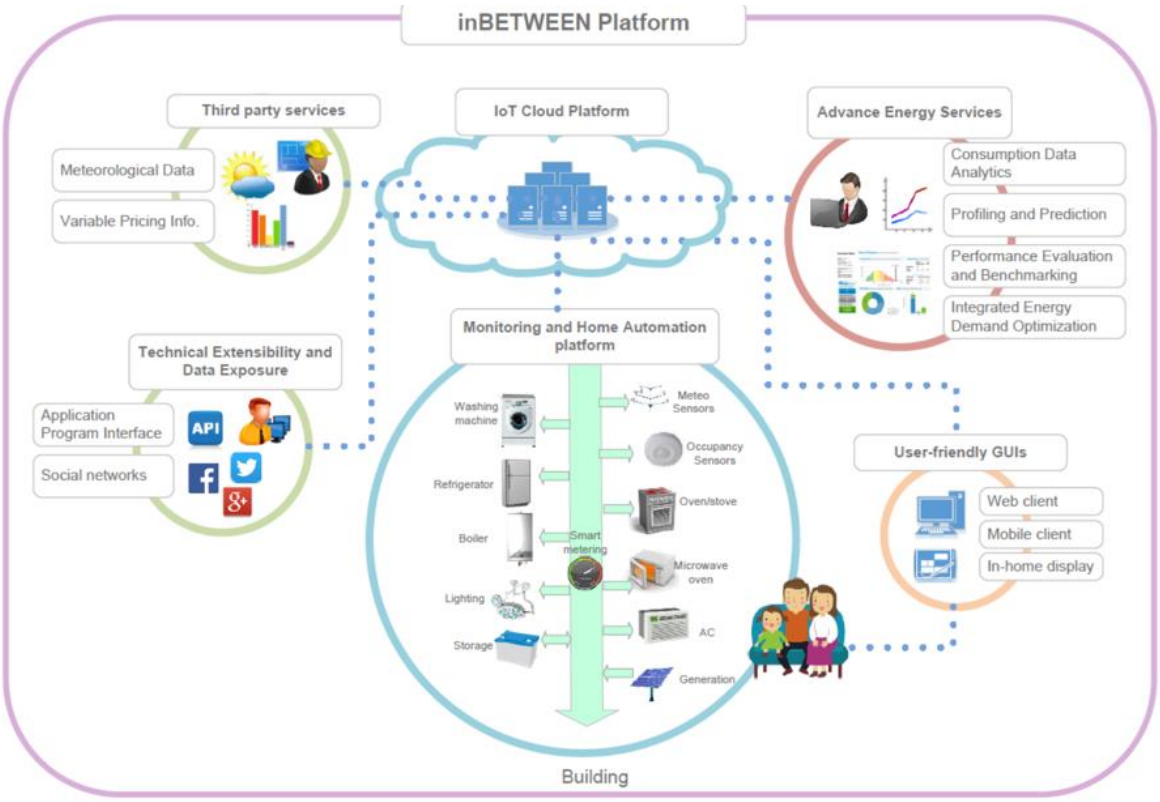
By applying demographically representative discrete choice experiments (DCE), CHEETAH provided empirical evidence on household response to essentially two types of interventions: monetary incentives (subsidies) and information including simplification (labelling) and their importance in deciding to adopt energy-efficient technologies. Results were used to make projections at the meso and macro level. A number of conclusions have been drawn in the study: Consumers have a general preference for highly efficient equipment, and that the communication of savings data may be meaningful when making a choice. However, energy literacy proved to be a determinant factor and an opportunity to cause behavioural change. Price discounts were observed to be important but highly ineffective with high-income households which generally perceived them as an indication of quality reduction. Correlations varied from country to country and between socio-demographic categories as apparent in the raw data (CHEETAH, 2021).

Selected project results
Briskee & Cheetah relied on essentially two methods when investigating in representative samples the propensity of households to adopt EETs for use across 8 EU Member States: an online survey that tested the role of attitudes, values, personal and social norms, cognitive abilities, preferences in relation to risk, time, loss aversion, ambiguity independently or mediated by a number of socio-demographic and structural aspects; the application of discrete choice experiments that involved monetary incentives (subsidies) and information including simplification (labelling). Results have highlighted various degrees of correlation between these variables and differences across countries and have been deemed significant in terms of broad policy-making and energy transition costs. Raw data is available for both projects (Grassmann, 2018) (CHEETAH, 2021).

2.10. InBetween

InBetween, implemented between November 2017-October 2020, targeted sources of energy waste in households and non-residential buildings and designed interventions that would motivate consumers to prevent over-usage. Interventions varied from just identifying performance deviations by way of a home automation monitoring platform and correction opportunities, to offering incentives for behavioural change through user-tailored energy conservation measures, or both.

The project rationale is synthesized below: Essentially, a cloud platform monitores the production and consumption of all used whitegoods and other appliances in real time, based on installed sensors. Information was processed in correlation with a number of external and consumption-relevant data (such as weather forecasting, market price variation, etc.) and used to establish a consumer profile that would help anticipate consumer-specific tendencies in terms of energy consumption. The analysis resulted in both visual analyses of the state of the art and tailored recommendations on the optimal solutions to be implemented in order to improve consumption parameters.



Source: InBetween

Interventions can be categorized either as *information including simplification*, due to the information signals transmitted to the consumer; *feedback on consumer's own consumption* given the amount of consumption data collected in the system; *monetary incentives* due to

the budget savings opportunities accessed with reduced energy consumption; *curtailment* given the fact that consumers had to apply various energy conservation measures along the way. The interface was secured through a mobile app or web interface.

Model pilots were implemented in France consisting of 42 apartments and in Austria encompassing 8 single family houses and 6 non-residential buildings: 2 hotels or guest houses, a kindergarten, a school, and two community office buildings. The demo sites addressed had many differences in term of size, typology, climate, and usage patterns. Without claiming to be representative samples of some sort, the project aimed at a common implementation processes based on a common evaluation methodology (InBetween, 2018), planning and pilot deployment that would guarantee some kind of future replicability of the process in other locations (IDS, 2018). A market analysis guideline was even issued to facilitate replication.

The interaction with the platform was monitored through various tools (Google analytics), whereas behavioural change, agency and capacity were assessed by means of a questionnaire (InBetween, 2018), interviews with users and other energy and non-energy related KPIs (AIT, 2018), which are related to a number of baselines for comparison (consumption at various times the past or comparison with similar consumers). Research established that high degrees of agency and energy management capacity/skill may result in important energy savings. Therefore, the provision of the appropriate tools that might increase interest and willingness to engage was generally deemed necessary, while the conclusions also identified a number of barriers that needed to be avoided in order to maximize results (AIT, 2018).

The data collected indicated variation between demo sites in their baseline and in terms of impact, but also in the process (IDC, 2018). With regard to the role of the app, data indicated a variation of interaction with the app with a higher engagement during the second part of the project when the system was stabilized and product dissemination better established, with variations between sites of implementation. Consumers were mostly interested in two services provided by the app: activity monitoring and benchmarking, whereas they also spent quite an important amount of time accessing the tips segment. Interviews and some data revealed that heating-related practices were mainly influenced by the app. However, consumption data was unable to support these responses sufficiently.

In terms of behavioural changes the project reached a number of general conclusions with regard to potential energy saving measures in residential buildings: 1) increased knowledge and interaction with thermostats could lead to higher engagement and savings; 2) noise reduction technologies might shift consumption to other use times and thus optimize consumption; 3) behavioural change-focused nudges should both focus on selfish (economic) and altruistic (environmental) benefits for better results; 4)

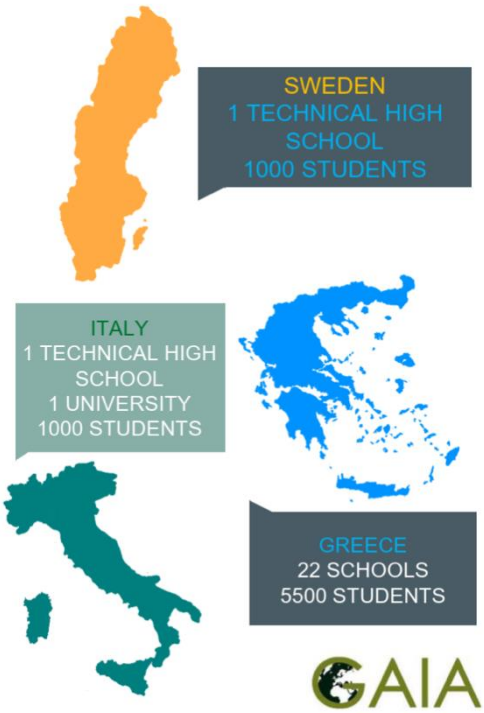
consumption parameters evaluations should point out improvement potential even if a high degree of savings have been reached; 5) an optimized frequency of nudges could be more effective. The project concluded that maybe the most valuable information sent to households would relate to the monthly energy bill and the monthly savings potential if energy efficient behaviours were to be adopted. The project reached a number of conclusions also with regard to non-residential sites, however, these will not be mentioned as they remain marginal in terms of the objectives of the current output (IDC, 2018).

The project was influenced by four important biases: The app's usage was quite short due to project put-offs. Secondly, the public targeted was rather more technology-keen than average, therefore conclusions could not be generalized. Thirdly, behaviour could only be related to winter energy consumption, as it was the period observed in the project. Fourthly, data was only collected from two residential users in each site, making it insufficient for generalization (IDC, 2018).

Selected project results
The main objective of InBetween was to develop an integrated and real-time data collection and demand response system imbedded in a mobile app and implemented in a non-representative sample pilot in both residential and non-residential contexts. Based on a consumption diagnosis, the app delivered interventions in the form of simplification, feedback on consumption, monetary incentives and curtailment. In terms of results the project noted in 38% of the sites significant energy consumption savings as a result of app download and use especially during the second year of implementation. Platform users have proved excellent engagement progress and user satisfaction. Questionnaire data and KPI analysis are available for this project (InBetween, 2018), (AIT, 2018).

2.11. GAIA

GAIA (Feb. 2016-May.2019) aimed at causing behavioural change with regards to energy consumption within 27 school communities in Italy, Greece and Sweden while targeting 6,900 faculty, staff, 3,084 students, 213 educators and parents at various levels of education, from primary and secondary to high schools and universities. The project implemented gamification and educational scenarios based on real-time energy consumption data by way of multiple ICT tools (including web-based, mobile, social and sensing elements which connect with school infrastructure) and educational scenarios related to sustainability awareness and energy savings.



Source: GAIA

In terms of methodology, the project performed 3 steps: 1) Building energy consumption profiling to understand school fluxes and their individual contribution to consumption; at times not affected by school activities; and during normal activity; the calculation of the gap between these two levels, which is the consumption level that can be challenged through measures; 2) Trail implementation of energy reduction measures for one week including the visualization of partial results, based on which the school agrees with the pilot strategy; 3) Implementation of pilots and permanent monitoring of consumption.

In terms of KPIs (Mylonas, Georgios, 2019) the project registered reduction in energy consumption of 15-20% and more with a general outperformance of project aims, whereas surveys indicate positive behavioural change in 75% of participants. The project also succeeded to have a high spill-over effect including in related households (8,000 students affected directly and indirectly in total), though concrete effects are rather

assumed than documented. Data on the project is scarce and more details on methods and results are difficult to access.

Selected project results
GAIA implemented a set of intervention in educational contexts in pilots run in 3 European Member States. Interventions were designed to reduce documented energy consumption and resulted in a positive behavioural change for 75% of participants in addition to a massive spill-over effect and final consumption reduction between 15-20%. Information on methods and KPIs is available, though scarce and particularly synthetic with regard to impact analysis. The benchmarking process is otherwise documented in detail (Mylonas, Georgios, 2019).

2.12. ENTROPY

ENTROPY (Sept 2015-Nov.2018) had two main objectives: 1) to reduce energy consumption and the related carbon emissions of buildings 2) and to cause behavioural change in that respect. To that end it integrated various technologies to facilitate end-users' knowledge and motivation towards energy consumption behaviour in relation to objects that they usually employ in their daily working routine: the Internet of Things and installation of low-cost sensors on consumer appliances, which provided the capacity for interconnecting numerous devices, the identification of energy spills and the development of energy-efficient communication protocols to address them; advanced data modelling and analysis supported knowledge extraction and the realization of solution-centered interventions. Interventions concerned *information including simplification* through targeted recommendation and *social norms* through gamification components that triggered interaction with peers across social networks. The core idea of the project was to increase the energy literacy of the consumer which was deemed a high-effect low-cost measure.

The interventions have been implemented via mobile applications (for consumption tips or gaming), together with ex-ante, interim, and ex-post surveys in order to perform social and psychological profiling as well as to establish developments in key indicators. Interaction with the end-users took place on a smart phone application, where consumers could see visualizations of their real consumption and receive real-time recommendations for consumption change.

The project was implemented in three pilot sites (ENTROPY, N/A): a technological park in Italy, a technological park and university campus in Spain, and a technological park in Switzerland, with a total targeted population size of approx. 42,000 students and employees. The methodology involved a baseline modeling through a comprehensive consumption data evaluation and the elaboration of detailed building thermal models and saving methodologies based on the structural specifications of each building and their destination. These were used to generate a number of saving scenarios and simulations, which were then overlapped with the real-time situations to generate integrated solutions via a number of mobile instruments employed by students and employees either in game or consumption input formate (described in Chapter 4 of the impact report (Ramallo-Gonzales, 2018).

Various KPIs (Genoud, 2016) had been identified to monitor project impact (Ramallo-Gonzales, 2018), including the interaction of users with the apps. Performance is reported both pilot-based and in the form of general conclusions: Despite pilot variation on various indicators, general trends were observed: generaly high preexisting personal norms to save energy due to the high level of education and environmental awareness of

participants. Despit this, the project acknowledged a general increase of the motivation to save energy as a result of the interventions. In one of the pilots this was as high as 31.3%. What was seen to also be situated on an upgoing curve was the intention to save energy, which was low at the beginning, or the increased competence (knowledge) to save energy of 15.9%, based on self-assessment, across cases and pilots. This feature is related in the project to the positive long-term impact of energy saving literacy. External factors on attitudes and norms have generally been deemed limited due to the targeted nature of the information offered via apps. Energy savings were observed to be positive in all pilots. Impact (motivation, attitudes, personal norms, subjective norms, behavioural intention, energy-saving habits, collective competence, etc.) is broken down on pilots and sample characteristics in the section 3, *Performance evaluation of Behavioural Change Section* of the above-mentioned results report.

Savings and app interaction have been identified as strongly correlated. At this point messages and interaction as well as real time analytics delivered to end-consumer played an important role. However, it was concluded that a balance needed to be established (2-3 messages per day) in the frequency of daily messages in order to secure positive results. What have been established to be possible challenges are the following: the difficulty of constructing building energy profiles that are highly accurate and which are used to create effective interventions; constructing attractive and engaging messages that would trigger meaningful behavioural change due to lack of data models; EU GDPR rules can hider data collection and use; the lack of clarity in technology interaction can put non-proficient technology users at a disadvantage, which may render interventions futile.

Selected project results
ENTROPY was implemented in three industrial and educational pilot sites in Italy, Spain and Switzerland targeting in total aprox. 42,000 students and employees my means of an analytical tool that collected consumption data from appliances via IoT and delivered targeted saving solutions via various types of apps (nudging or games) based on a rationale that improving the energy saving competence of the consumer is the corner-stone of energy efficiency. The project was deemed successful for two reasons: for the positive impact on energy behaviour and consumption and for delivering a commercial-level energy saving tool. Synthesized data both on pilots and per project is available in the KPI report of the project (Genoud, 2016).

2.13. PENNY

PENNY (September 2016 – August 2019) addressed the psychological, social and economic factors behind efficient energy usage and the adoption of energy efficient products. To that end, it performed a number of scientific experiments through A/B testing[2] to assess the role of extrinsic incentives, environmental self-identity, social values, bounded rationality, cognitive misperceptions and energy literacy in taking consumption or adoption-related decisions.

Interventions were diverse and they involved the following trials, leading to a number of conclusions (for some of these interventions analyses and results have been more thorough and are indicated below):

- A large field experiment on household energy conservation in Italy examined the association between individual values and heterogeneous responses to social information. This led to the conclusion that informational interventions might be more effective with individuals who care about the environment and that interventions should be designed in terms of intrinsic goals, moral suasion, and appeal to intrinsic values.
- A field experiment on the effectiveness of energy saving goals in Germany revealed the fact that self-set goals and plan-making can be effective in changing behaviour. The intervention was scaled up through a mobile energy savings application that would allow randomly selected subjects to set themselves energy consumption goals for one month. The instrument was promoted commercially at the level of a city with over 300.000 of inhabitants. However, adoption was unexpectedly low (1,600 individuals initially while only 180 remained for a longer period of time). The experiment led to the conclusion that upscaling might render even promising nudges ineffective.
- A study among Dutch and Hungarian households revealed that measures targeting energy efficiency or renewable energy sources can be successful in a larger category of environmental policies, whereas curtailment behaviours and changes in time of use were found less acceptable. The study also concluded that revenues of push measures should be allocated in a way that benefits people or the environment and strengthen the extent to which people see themselves and their government/organization as a pro-environmental, as that increases the acceptability of policies.

[2] A/B testing is a randomized experimentation process wherein two or more versions of a variable (web page, page element, etc.) are shown to different population segments at the same time to determine which version leaves the maximum impact

- A large online survey performed in Switzerland, Italy, the Netherlands and Germany reached similar conclusions as the one reported in the previous bullet point. Also, it proved that effective environmental policies need to target biospheric values, environmental self-identity and personal norms; financial messages are, according to the survey, the second-best type of intervention to promote sustainable consumption behaviour. The survey collected socio-demographic and economic characteristics and information on the dwellings, their structural, legal situations and amenities, on the household members, including their norms, values, identity and behaviour, financial and energy literacy and risk or loss aversion. Results have been used to test the effectiveness of various interventions and the most suitable policy responses (ETH, 2018).
- A field experiment employed game apps for behavioural change with school pupils aged 10-14 in Italy and Switzerland by devising two intervention groups (one engaged and one less engaged). Conclusions were along the following lines: pupils, as proved by the number of permanent app downloads, are enthusiastic about gamification approaches for environmental education. However, no measures in terms of energy consumption were performed to establish the extent of internalized efficiency behaviour.
- A randomized field trial with 661 households in Switzerland, coupled with home visits, showed that limited knowledge about energy costs may affect the adoption of efficient energy-using durables. Home visits and related customized information reports determined households to purchase appliances that were on average 18% more efficient than compared to the control group. Details on the sample, implementation and results are available here (ETH, 2019).
- An A/B experiment exposing three groups (a total of 20,371 visitors and 6,441 orders) to three types of online information about energy efficiency on an online refrigerators shop, suggested contrary to expectations, that displaying products' energy costs in a salient and transparent way reduced sales of energy efficient products and increase that of less efficient ones. It was established that in information policies the format (monetary savings versus energy costs) is a strong moderator of the effectiveness of information policies on investments. Details on the sample, implementation and results are available here (ETH, 2019).

Selected project results
PENNY assessed the role of extrinsic incentives, but also environmental self-identity, social values, bounded rationality, cognitive misperceptions and energy literacy in promoting energy efficient behaviour through multiple types of interventions. Most of them underlined the importance of energy literacy in efficient consumption behaviour. However, more nuanced conclusions have been reached: informational interventions should be well-targeted as they have proved to be more effective with individuals that had environmental values. Therefore, the display of environmental costs on products may not be generally appealing, but on the contrary, may increase the interest for less efficient equipment; Online apps may as well be little appealing for the general public; gaming apps turned out to be better accepted by youngsters, however, no documented long-term impact on their behaviour could be shown; environmental measures may need to be associated with individual or institutional norms. Household visits and targeted advice may trigger important positive behavioural change. Some data is available on these field trials, but only in synthetic form (ETH, 2018) (ETH, 2019).

2.14. MOBISTYLE

MOBISTYLE (Oct. 2016-June 2020) targeted people's perception of indoor climate as opposed to their understanding of building energy efficiency parameters as an important driver of efficient energy consumption. By making use of ICT-based solutions, the project provides more understandable information to consumers by essentially associating information on energy use and indoor climate (collected through sensors) with a number of relevant effects on the quality of life, such as indoor environmental quality or personal health to cause effective behavioural change. The intervention can essentially be categorized in two categories: information including simplification and social norms.

The project provided a number of tools for various uses in order to generate behavioural change at various levels of social activity: a dashboard (for non-residential buildings), a game (for households), an office app, and expert tools. The tools used the collected consumption information from the sites to elaborate a number of behaviour typologies based on which they designed targeted solutions for the end-consumers. The game, for instance, provided incentives in the form of recognition, achievements and suggestions to users.

Impact was only recorded in the product development process, which was essentially an anthropological approach, and not applied at the level of the end-product to apprehend real impact: 30 people from five countries (Italy, Denmark, Netherlands, Slovenia and Poland) of different age groups, gender, profession, and usage of technologies were involved in product development through various investigative procedures, such as: surveys, focus-groups and participant observation (Podjed, 2017). The information collected fed into the development of typical personas that would enable researchers to identify what is the typical/dominant behaviour and what are the opportunities to transform passive energy consumption attitudes into involved ones. Personas identified the typical understanding of health in relation to the built environment, interaction with technology and with peers. The study established that participants are focused on health and wellbeing in their daily lives but that their perception of health can generally be narrow (Tisov, 2017). Furthermore, they have different technological literacy levels which need to be considered and adapted for, whereas their social interaction was generally deemed low and might need to be improved in order generate effective behavioural change.

As a result, the project concluded that targeted consumers need to be provided nudging software that is carried by a convenient technology tool (mobile phone in this case), which they should be able to personalize and control to some extent for a better feeling of participation and empowerment. Goal commitment is also considered to be an important feature as it generates meaningfulness of behaviours. At the same time the device should

avoid being too intrusive in terms of frequency of nudging to avoid disengagement. Advice should be authorized and trusted in order to be adopted, visualized in order to overcome aversion to technicalities. Energy is generally perceived as something difficult to understand. Furthermore, advice should be adapted to cultural and personal needs and avoid generalization. Early adopters are always a good transfer factor. The study also concluded that social pressure plays an important role in delivering results, however, for interaction in large communities to be successful, more social effort might have to be invested, as large communities tend to falter due to social bond breakdown.

Selected project results
MOBISTYLE created several intervention instruments to target consumption behaviour through the corner-stone philosophy of changing the perception of indoor climate. The dashboard (for non-residential buildings), game (for households), office app, and expert tools collected data and communicated information based on consumer-typologies. Research performed (essentially through anthropological measures) had an exclusive product development goal, and not its testing, while its population sample was small (30 persons) and non-representative of the five countries involved (Italy, Denmark, Netherlands, Slovenia and Poland).

3. Conclusions

The present report has presented a synthetic description of a number of rather high-visibility projects due to their selection for H2020 funding. Focus has been on the types of interventions applied, the behavioural changes achieved and the nature of circumstances that have increased or diminished impact, with a slight focus on emotional factors.

The reviewed projects present a variety of situations with interesting results for their own scientific purposes. Despite generally engaging in evidence related to sustainable energy consumption behaviours, their approaches have different foci. This pointed out the high over-all interest in energy consumption reduction and the complexity of the tasks involved in what is generally affirmed as a unitary, consensus-based, European engagement to improve the quality of life for European citizens and to reduce the impact of energy consumption on the environment for the long-term. Most of these projects make use of modern technology to collect and analyze large sets of real-time data that describe the practical manifestation of end-consumer behaviour (consumption profiling), combine them with results of sociological and anthropological instruments of various sophistications destined to understand individual decision-making patterns, motivations and preferences (psychological profiling), to generate real-time consumption advice that respects both professional rigor and personal interaction strategies, with project specific nuances of various sorts. Some are more successful than others and nuances can generate important variation.

Projects vary in their approaches and nuances. Generally most of the projects analyzed investigate the contribution of modern technology to day to day sustainable consumption habits based on a rather comprehensive consumption data input and end-consumer profiling. Whereas most look into the usual interaction of end-consumers with energy and the most appropriate means to target wastefulness through curtailment strategies, other stand rather out by relying on personal values (PEAKapp, MOBISTYLE, etc.) such as environmental care or health and lifestyle-related choices to transform what are rather blunt and unattractive consumption technicalities that solicit a prevailing rational, and somewhat ineffectual approach to behaviour change, into information that is personally valued and more attractive to motivate sustainable behaviour. The impact of more rational impetus (such as the importance of price or sustainability related data) for consumer choices is also investigated in innovative ways (PENNY) and brings out evidence about the interaction of these components with the individual brain and decision-aiding circumstances that lie beyond the process of purely individual cost-benefit calculations, such as the way in which information is presented (PENNY), the intrusiveness of nudging (ENTROPY), the interaction with peers (MOBISTYLE) and personal dispositions (Briskee), to name a few.

Of course, limitations are evident and rather natural given the precise scopes of single projects, their financial restrictions and short livelihood: limited project time, implementation issues, small and biased population sample, absence of effect measurement data, etc. come up a number of times. Despite the impossibility to address all of these in one project, the knowledge of these limitation is useful for the purpose of ENCHANT-related activities in order to avoid challenges and circumstances experienced by other projects but also in order to take them into account when informing the recommendation engine with real life situations for more accurate decision-making models.

Moreover, despite an initial assumption that most of these sets of data would be readily available in a raw format for reanalysis, their availability was quite scarce. Most of the time data was presented in synthetic reports in logics that were specific and useful to the projects they had been collected for. Therefore, this data collecting process will necessarily involve a later discussion on how to engage the available information in a useful manner in ENCHANT and on how to overcome limitations.

The present desk-assessment of projects is rather the first part of a more complex task: to collect evidence on the ground and to rely on scientifically proven conclusions of a large body of research enterprises and living labs in order to inform a complex policy-making engine. The rationale behind this approach is to overcome as much as possible the limitations of individual research projects, including the present one, and generate a tool that can take into consideration a complexity of real-life situations, pre-simulate and avoid risks and help deliver solutions at a much faster pace and with a higher degree of sophistication. This deliverable is connected to deliverable D3.3 Report on Data-Review on Energy Behavioural Data, which will be issued at a later stage and on a larger body of projects that are beyond the reach-out of the H2020 horizon, and it will mainly consist of the analysis of scientific literature selected in deliverable D2.1 Literature Review on Energy-Related Behavioural Interventions of WP2, the current one and other sources identified through snowballing and the recommendation of academic consortium members.

Two objectives have been pursued along the current task: to scrutinize the information available out there and to attempt to match it with the expectations and needs of other WPs that will use these results for more practical tasks. In terms of the second objective, the present report expects a wide set of input from consortium partners, in terms of what data should be looked into more and what project conclusion should be analyzed into more detail. The realization of these exchanges might stretch beyond the current deliverable deadline, but it will also inform the second and more complex deliverable D3.3

Report on Data-Review on Energy Behavioural Data, preparing complex and robust set of information to support the task of our partners.

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Appendix: Consolidated meta-analysis table

Project name	Sample type	Intervention type	Feedback mechanism	Effect size	Sample size	Country
PEAKapp	representative sample	Information, Gamification, Commitment	Data Tracking, Energy consumption data	7.1% decrease for "Heavy users"	2,500 households	Austria, Latvia, Estonia, and Sweden
TRIBE	non-student or mixed sample (excl. representative samples)	Gamification	-	-	5 pilot buildings, 1.300 regular users (employees, tenants...) and almost 12.000 eventual users (visitors).	Turkey, Spain, Sweden, England, Germany, Austria and France
enCOMPASS	student and non-student sample (4 target groups (residents, public administration employees, school students and staff)	Information, Commitment, Personal and Social Norms	Data Tracking, Energy consumption data	-	318 buildings (ca 2000 participants)	Germany, Greece and Switzerland
Energise	non-student sample (households)	Information, Social Norms	Data Tracking, Energy consumption data and qualitative surveys	-	320 households	Denmark, Finland, Germany, Hungary, Ireland, Netherlands, Switzerland, UK
eTEACHER	non-student sample (households)	Commitment	Data Tracking, Energy consumption data	-	10 buildings	Spain and Romania

Feedback	non-student sample	Gamification, Information	Data Tracking	-	-	Portugal, Spain, Germany, Holland, Switzerland and Denmark
SMART-UP	non-student sample	Feedback information	Pre-post Survey	80% of participants took action to reduce the amount of energy that they use	4,463 vulnerable households	UK, France, Italy, Spain and Malta
ENABLE	non-student sample	Social norms	-	-	-	Bulgaria, France, Germany, Hungary, Italy, Norway, Poland, Serbia, Spain, Ukraine and the UK
NUDGE	non-student sample	Information, Commitment	-	-	-	-
SONNET	non-student sample	Information	Energy Consumption data	-	-	Warsaw (Poland)
SCOoPE	non-student sample	Commitment, Information	Data tracking	10%-15% reduce energy consumption in energy-intensive agro-food industries	25 indusries	France, Italy, Greece, Portugal and Spain
NATCONSUMERS	non-student sample	Information	Data Tracking	5-20% energy consumption reduction	-	Denmark, Hungary, Italy and the UK
Briskee&Cheetah	non-student sample	Monetize	Data tracking		18.300 individuals/households (for	France, Germany, Italy, Poland, Romania, Spain, Sweden, UK

					Cheetah) and 15.000 individuals (for Briskee)	
InBetween,	non-student sample	Information, Feedback, Monetary Incentives, Curtailment	Data tracking	-	39 users	Austria and France
GAIA	non-student sample	Gamification	Data tracking	15-20% reduction in energy consumption and 75% positive behavioural change in paricipants -	6900 persons	Italy, Greece and Sweden
ENTROPY	non-student sample	Information, Social norms	Data tracking	15.9% energy saving	42.000 students and employees	Italy, Spain and Switzerland
PENNY	non-student sample	Social norms, Information, Commitment	Data tracking	18% decrease in energy consumption	661 households (field experiment)	Switzerland, Netherlands, Germany, Hungary
MOBISTYLE	non-student sample	Information	Data tracking	-	30 people	Italy, Denmark, Netherlands, Slovenia and Poland