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Acronyms

Acronym	Explanation
CPP	Critical Peak Prices Customers
DC	Discrete Choice
EASME	Executive Agency for Small and Medium-sized Enterprises
EECG	Efficiency Coordination Group
EEEF	Energy Efficiency Fund
EIB	European Investment Bank
EU	European Union
GEE	General Equilibrium Effects
GHG	Greenhouse Gas
HER	Home Energy Report
IHD	In House Display
KPI	Key Performance Indicator
PER	Peak Energy Report
PSE	Puget Sound Energy
RCT	Randomized Control Trials
RTP	Real Time Pricing
SP	Stated Preference
UCLA	University of California, Los Angeles
UNEP FI	United Nations Environmental Programme Finance Initiative

Executive Summary

The needs for behaviorally-based interventions for promoting energy efficiency among informed citizens have been identified as a major target for improved social performance, client protection and, ultimately, greater environmental impact. Acknowledging these needs, the EVIDENT project is designed to further investigate the field providing insights for optimized policy actions with greater societal impact.

This deliverable describes the best current practices that are relevant to the EVIDENT project. The main goal of this deliverable is twofold; (a) to report on the current advances in the area of filed and quasi experiments, for supporting behaviorally-based interventions, and (b) to highlight EU-funded projects and initiatives that the EVIDENT project could potentially take advantage of lessons learnt.

The deliverable is divided into two main parts. The first part reviews the best current practices in the academic agenda regarding field and quasi experiments for energy efficiency and provides an overview of research details and related outcomes. The main purpose of the first part is to give the reader (incl. the EVIDENT energy utility and policy-related partners) the understanding of what is the current state of the art (i.e., capabilities, limitations) and to present the novel insights of the methods and toolkits to be developed within EVIDENT.

The second part of the document focuses on related EU-funded projects and initiatives within the European countries. Initially, the second part reviews related to energy efficiency EU-funded projects that are focused on assessing and improving energy efficiency through a series of interventions, behaviour improvement, collaboration, and adoption of good practices. Subsequently, it overviews initiatives related to energy efficiency considered relevant with the scope of EVIDENT. In this direction, six initiatives have been identified and are focused on data and best practices sharing, fostering the creation of networks of experts, policy implementation and funding. The main purpose of this part is to acquaint the reader with the existing developments in the field and to present funding and collaboration opportunities, as well as guides for realistic policy options.

1. Introduction

1.1 Purpose of the Deliverable

The purpose of this deliverable is first to present and review best practices for randomized control trials (RCT), and quasi-experiments (surveys and stated preferences). These experimental practices in recent years gain increasingly attention form researchers and policymakers as means of informative large-scale public policies (Al-Ubaydli et al., 2020). The analytical review of the research-led methods will contribute in designing and implementing experiments that will successfully translate research insights regarding the behavioural factors that are conducive to decision-making and energy efficiency into scaled interventions for having large environmental and economic returns. It will also highlight the limits of our knowledge and ways to seek a closer integration between theory and empirical research.

Second, to describe EVIDENT-related projects and EU initiatives and policies focusing on lessons learnt and potentials for collaborative actions. EU has funded and enacted a wide array of projects and policies to encourage energy efficiency, many of which were originally promulgated during the last decade. The analytical review of related projects and initiatives, either public or private, focusing on best practices will highlight potentials for collaboration for expanding EVIDENT's pilots, research tools and dissemination activities. It will also provide guidance for future exploitation plans by analyzing fields that current initiatives focus on.

1.2 Relation with other Deliverables and Tasks

This deliverable will provide inputs to WP2 "Policy interventions and policy design", WP3 "Intervention preparation and execution" and to WP6 "Prototyping and integration". Best practices are divided into two major revision categories, the first includes the research-led methods such as RCTs and quasi-experiments and the second includes related projects and initiatives.

1.3 Structure of the Document

This deliverable is structured as follows:

- Section 2 – Introduction. This section provides an overview of the deliverable.
- Section 3 – Backward facts on energy demand. This section provides some useful facts about residential electricity usage and insights about the current trend regarding energy efficiency in EU.
- Section 4 –Field experiments. This section focusses in methodological issues surrounding the design of the field experiments and also provides an overview of how experiments have been used in energy efficiency

- Section 5 – Quasi-experiments. This section focusses in methodological issues regarding surveys and stated preferences and includes an overview of the empirical applications that are related to energy consumption.
- Section 6 – Related projects. This section presents related EU-funded projects aiming at exploring potentials for collaborations at any level.
- Section 7 – Initiatives related to energy efficiency. This section includes an overview of the initiatives related to energy efficiency considered relevant with the scope of EVIDENT.
- Section 8 – Conclusions and next actions. This section summarizes the key results from all sections and describes next actions regarding EVIDENT's use cases.

2. Methodology

A major area of growth in the academic literature has been studies focusing on evaluating energy efficiency programs that address behavioral failures and information problems. These empirical studies highlight the role of behavioral failures that could justify policy interventions to address these failures. Much of the discussion around energy efficiency policies reflect both private utilities that initiate energy conservation programs, and public authorities that initiate several types of interventions including behavioral programs, subsidies for efficient appliances, building codes, and weatherization programs. To this end, EVIDENT project focuses on residential energy consumption and how specific low-cost behavioral-based interventions could potentially correct consumers energy-related misperceptions and enhance energy efficiency. With residential energy consumption, as shown in Table 1 below, accounting for almost 26.1% of the total energy consumption, energy efficiency interventions may be a changing factor in reducing Greenhouse Gas Emissions (GHG) and climate change.

An economic rationale for energy efficiency policy exists when agents deviate from optimal decisions. Economic theory postulates that agents in an economy are rational, in that they are fully informed and are also able to conduct complex estimations and are always able to perform actions with the optimal expected outcome. Behavioral economics, challenge the assumption of the rationale agent, and show that consumers often exhibit behavior that leads to a suboptimal outcome. These failures in decision-making may stem from cognitive biases, such as status quo bias, loss and risk aversion, temporal and spatial discounting and behavioral inattention (Fredericks et al., 2015). More specifically, the inattention bias assumes that choice problems may have different facets, and these facets are less salient at the time of choice, even though they might be important to the utility. It seems possible that some consumers might be inattentive to energy efficiency when purchasing energy durable goods.

Another possible cause for energy-related suboptimal choices is imperfect information. Consumers may be unaware of potential investments in energy efficiency or even how much energy appliances such as refrigerators, washing-machines, air-conditions usually consume, which leads to inferior market equilibria. For example, imperfectly informed renters may be less willing to pay more for energy efficient apartments, landlords will have a reduced incentive to invest in energy efficiency. In such cases, behavioral-based interventions could contribute in mitigating market failures and suboptimal equilibria.

Among several interventions the researcher or the policy maker should select the most effective based on a cost-benefit analysis. Experimental methods, field and lab, have been rather popular in recent years in economics for estimating the effect of energy efficiency interventions. Experiments have become a useful tool for providing casual relationships that are difficult to obtain using other approaches once properly designed, taking into account randomization and controlling for the power of the experimental design. Harrison and List (2004), propose a taxonomy based on factors that differentiate field experiments from conventional lab experiments, that is, a conventional lab experiment, an artefactual field experiment, a framed field experiment, and a field experiment.

Each experimental method has advantages and disadvantages however all share some common ground. For example, the experimental design should maximize the variance of the treatment variable and to adjust the samples to account for variance heterogeneity, if necessary (List et al., 2011). Experimental methods should also be designed to maximize power and to achieve identification via randomization, since laboratory and field experiments may suffer from randomization bias. Although, field experiments

could be the most effective and reliable method of analysis, their implementation costs are high which in turn often act as prohibiting factors for the researchers and the policy makers.

Overall, the design and implementation of an experiment is a demanding task and an optimal sample arrangement may be infeasible, however they have proven quite effective as insights have gained across different topics such as labor economics, social policies, public economics, and recently energy efficiency. Through experiments, researchers are able to generate data that test theories, disentangle mechanisms and provide intervention treatment effects for policymakers.

The literature review and the analysis of best practices will shed light on the specifics of the experiments, avoiding common mistakes and poor experiments' performance, that will be designed and implemented in the EVIDENT project. As illustrated in Figure 1, this analysis consists of five steps: (a) background facts on energy demand, (b) field experiments, (c) quasi experiments, (d) projects related to energy efficiency and (e) initiatives for energy efficiency.

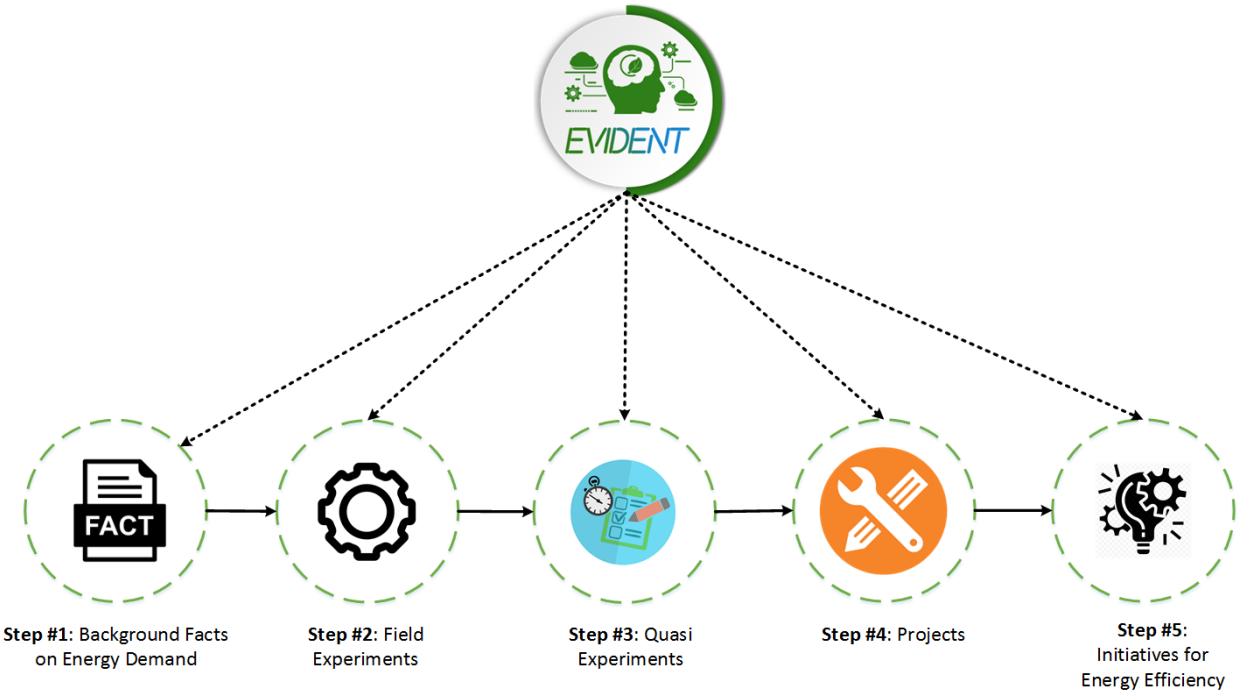

Figure 1: EVIDENT methodology for analysing best practices related to energy efficiency.

3. Background Facts on Energy Demand

To establish project's research priorities, Table 1 presents the breakdown of total energy demand across the sectors of EU-26 economy. Much of the attention focuses on household energy use and transportation, because there are areas where inefficiencies of imperfect information might be more severe. Table 1 also shows that space and water heating and lightning and appliances are the most significant end uses, which suggest that may also be the areas where energy conservation interventions could have the largest impact.

Table 1: EU-27 Energy use (Source: Data are from Eurostat (2018))

By sector (EU-27, Eurostat 2018)	Percentage
Transport	30.5%
Industrial	25.8%
Residential	26.1%
Services	14.2%
Agriculture and Forestry	2.9%
Other	0.5%
Residential categories (EU-27, Eurostat 2018)	
Space heating	63.6%
Lighting and applliances	14.1%
Water heating	14.8%
Cooking	6.1%
Space cooling	0.4%

The EVIDENT project mainly focuses on residential electricity consumption, as both utility companies that participate in the project, CW and PPC, operate in this field. Electricity plays an important role in the residential consumption and according to the Eurostat data; electricity covers 100 % of the energy needs for lighting and space cooling in the EU-27 but also 83.4 % of the other end-uses and 49.2 % for cooking.

Table 2: EU-27 Electricity use (Source: Data are from Eurostat (2018))

By sector (EU-27, Eurostat 2018)	**Percentage**
lighting and space cooling	100%
cooking	49,2%
other end-uses	83,4%

Thus, project's main objective is to run several experiments in various formats for analyzing the impact of behavioral insights on residential energy conservation.

During the last years, there have been efforts by the European Union to cut down on energy consumption and improve energy efficiency in the framework of the EU energy consumption targets within the Europe 2020 strategy. Electricity consumption per dwelling, in the EU-27, overall decreased during the period 2000-2018 approximately by 1.1%, as it is shown in Figure 1. The largest decrease in electricity consumption performed by UK, 20.3% drop, while the largest increase was in Lithuania, 57.8%.

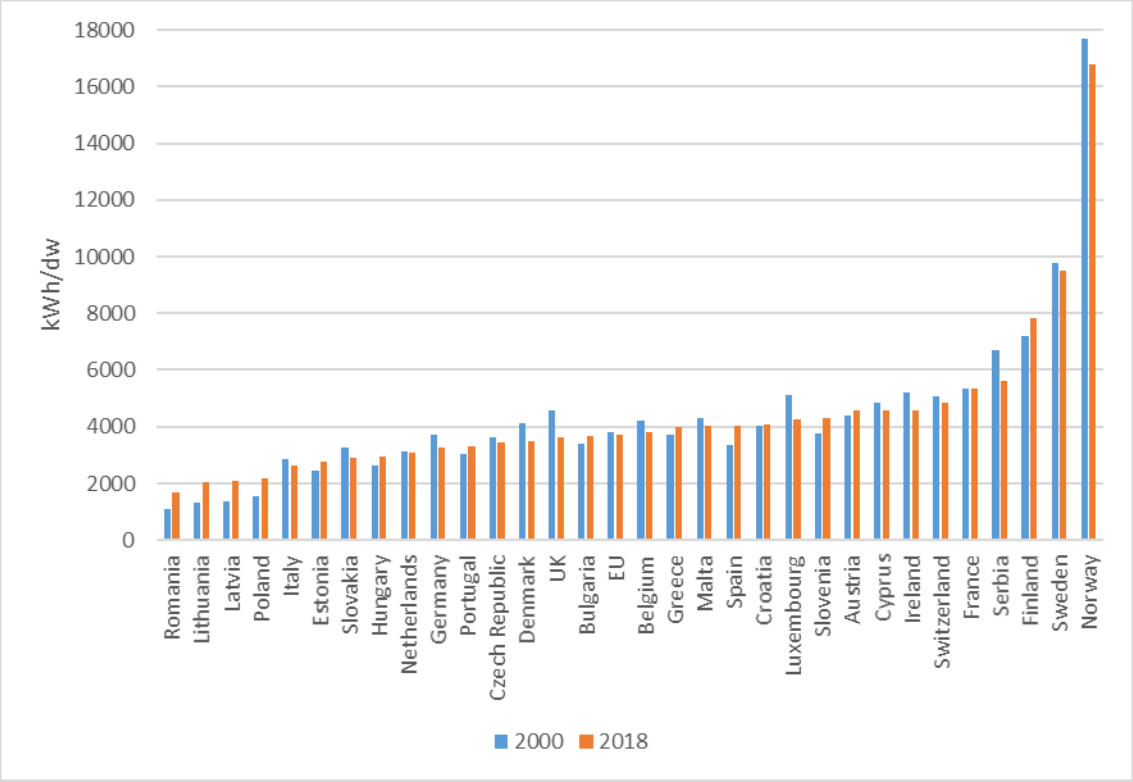

Figure 2: Electricity consumption per dwelling in the EU-27 (Source: Data are from Eurostat (2018)**)**

As it is shown in Figure 2, the European Union (EU) had committed itself to a 20% reduction of energy consumption by the year 2020 compared to baseline projections. This objective was also known as the 20% energy efficiency target. For 2030 the binding target is at least 32.5 % reduction. This translates into a primary energy consumption of no more than 1 312 Mtoe in 2020 and 1 128 Mtoe in 2030 and a final energy consumption of no more than 959 Mtoe in 2020 and 846 Mtoe in 2030. For this target to be met, several measures and policies are in place. For example, in most EU countries run national energy efficiency programs, for decreasing homes' energy consumption. These programs typically feature subsidies for improving homes' insulation, and for using energy efficient appliances.

Energy conservation and the 2030 target can be achieved not only with technological changes in buildings and appliances, but also with behavioral changes in consumption.

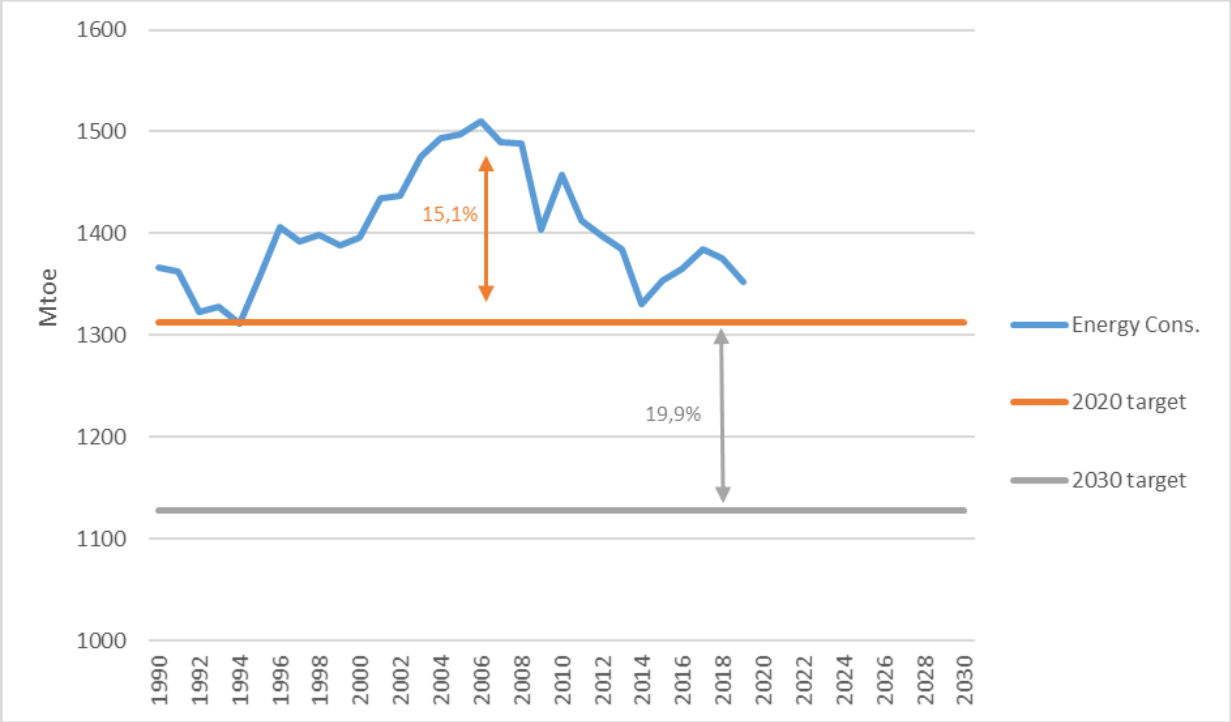

Figure 3: Primary energy consumption in the EU-27, distance to 2020 and 2030 targets (Source: Data are from Eurostat (2018))

4. Field Experiments

The EVIDENT project will implement a number of field experiments for estimating the impact of behavioral interventions in energy conservation. This section will systematically review field experiments and randomized control trials (RCT) focusing on the credible identification of causal effects in the energy conservation field. It is often assumed that certain biases and heuristics dictate consumers' behavior away from an optimal decision-making as for example, inattention to true prices and shrouding of add-on costs, nominal illusion, hyperbolic discounting, and left-digit bias.

Most field experiments reviewed here aim at estimating the impact of various types of information on mitigating consumers' biases and ways to motivate consumers towards an optimal decision-making. Examples include information that is related to social norms and peer comparisons, electricity usage, saving tips, moral suasion, detailed pricing, goal setting, economic incentives and other different types of framing. The subsequent analysis provides estimates regarding the response of the consumers. Does information change beliefs? Can beliefs be turned into action? For how long does the impact hold? Do the frequency and the timing of the information provision play any role? Best practices from RCTs regarding design and research questions will be used as guidance for designing and developing EVIDENT's field experiments in WP2 and WP3.

4.1 Field experiments literature review

4.1.1 Field experiments and their role in public policy

Field experiments and RCTs, since their first introduction by Fisher (1934), have gained widespread acceptance, and there is now a large body of research on field experiments, both in developed and developing countries and across many domains. Policymakers are increasingly turning to insights gained from the experimental method as a means to inform large-scale public policies. Significant merits of the randomization include the reliable identification of internally valid causal effects and the external validity of such estimates. Thus, filed experiments are a useful tool by providing causal estimates that are difficult to be obtained by other methods.

However, one of the major challenges limiting the use of RCTs is the resource intensity they entail as RCTs are typically more expensive and time-consuming to perform than quasi experiments (surveys, lab-experiments, stated preferences). It is even challenging for a Horizon-funded program, since RCTs often require substantial upfront investment in program design. Despite these challenges, RCTs are considered as the "golden standard" in empirical analysis. Freedman (2006), argues that experiments and RCTs offer more reliable evidence on causation than observational studies. Further, Imbens and Athey (2016), claim that a randomized experiment can be unique in the control that the researcher has over the assignment mechanism, and by virtue of this control, selection bias in comparisons between treated and control units can be eliminated.

RCTs focusing on behavioral biases have been successfully used apart from energy conservation, in various other fields, including retirement saving (Thaler and Benartzi, 2004), organ donation (Abadie and Gay, 2006), paying for charity and performance (Gneezy and Rustichini, 2000), influenza vaccination (Chapman

et al., 2010), contractual choice in health clubs (Dellavigna and Malmendier, 2006), car insurance plan choices (Johnson et al., 1993), green product purchases (Ebiling and Lotz, 2015), and encouraging resource conservation (Schultz et al., 2007). All these studies use specific types of information provision, or opt in and opt out choices to solve problems of imperfect information in markets and to help individuals and institutions to overcome cognitive and behavioral biases (Thaler and Sunstein, 2008).

Many researchers on field experiments now focus on how credible and scalable results can be generated that policy makers can trust in implementing and evaluating programs (Al-Ubaydli et al., 2021). The key point towards this direction is to provide a clear and coherent analysis regarding changes in costs and benefits when a program is scaled. Existing discussions of scaling emphasize the statistical procedure to the data gathered that produce actionable evidence, representativeness of the population and representativeness of the situation examined. Another key aspect that is important for scalability and using field experiments in public policy, is spillovers (network effects) as well as the general equilibrium effects. This implies that the public policy program may be much more effective at scale than the original research suggests or the effect could run in the opposite direction. Thus, field experiments should consider possible modifications in their design for estimating treatment effects that will more accurately estimate the impact when the program is implemented at scale.

4.1.2 Designing and implementing field experiments

Field experiments are complex tasks and many different characteristics define their design and implementation and ultimately their success. We begin our discussion by providing a taxonomy (Harrison and List, 2004) for the various types of field experiments that will help us in defining what may constitute an ideal experiment for EVIDENT's use cases in terms of design and analysis.

Harrison and List, 2004 propose some broad terms and terminologies for differentiating various types of field experiments. The first is a *conventional lab experiment* that employs a standard pool of students, an abstract framing and imposed set of rules. The second is an *artefactual field experiment*, which is the same as the conventional lab experiment but with nonstandard subject pool. The third is a *framed field experiment* that is the same as an artefactual field experiment but with field context in either the commodity, task, or information set that the subjects can use. The fourth is a *natural field experiment* that is the same a framed field experiment but where the environment is one where the subjects naturally undertake these tasks and where the subjects do not know that they are in an experiment.

Next, we discuss the main challenges for implementing a field experiment in terms of establishing casual claims and how policymakers can draw conclusions from a localized randomized controlled trial about a policy implemented at scale. Naturally, the first point is about experiment's external validity. The second point includes randomization techniques, such as complete randomization, block designs and factorial designs. Finally, the third point is about the power of the experimental design and refers to methods for computing required sample sizes.

To assess any external validity issues, it is helpful to have well-defined casual studies in various settings. These settings should vary in terms of the nature of the treatments or in terms of the characteristics of the customers participating in the experiment (Banerjee, and Duflo, 2017). This variation increases experiment's potential success in different settings. Duflo et al. (2008) points out four possible hazards to

external validity. The first hazard is the Hawthorne and John Henry effect that refers to the possibility that experiment's participants may know or notice that are participating in an experiment. Consequently, in response to this notice, participants may alter their behavior and bias the estimated outcome. Second, general equilibrium effects (GEE) could substantially bias results, although, GEE are in most cases not captured in an RCT, because they become noticeable only if the program is scaled to a broader population or extended to a longer term. Third, the specific sample problem may occur if the population under treatment is different than the target population when the program increases at scale. Finally, biases may stem if not taken into account special care in the provision of the treatments compared to how this will be actually implemented under a scaled framework (Bolt et al. 2013).

Randomization techniques are used within field experiments for formulating the proper counterfactual and estimating the treatment effect of interest (List and Wagner, 2011, Peters et al., 2016). Randomization is an important task since achieves identification and thus unbiased estimations. Empirical analysis shows that randomization is usually not an issue in economic-related field experiments and it is more frequently apparent in clinical drug trials (Harrison and List, 2004). To this end, and in the absence of data for observed characteristics (demographics could be a case) a completely randomized design could be a useful and simple experimental design. However, the researcher should have in mind that variance of outcome may be generally large relative to other methods. In the case in which observable characteristics of subjects are available, these can be treated as further treatments and divide the experimental sample into blocks. This technique ensures that all treatment effects can be identified and decreases further the variance of the estimate of the treatment effect.

Another important issue regarding ideal field experiments is optimal sample size for each treatment group. List et al., (2011), identify three key elements: a) the significance level, b) the power of the subsequent hypothesis test, and c) the minimum detectable effect size. The first two elements refer to the Type-1 and Type-2 errors respectively and are well established notions in statistical analysis. The effect size represents the size of the treatment effects that the researcher wants to estimate. The optimal size is related to the treatment, for example, whether is continuous or dichotomous, to the outcome of the effect and to the statistic to be used to determine differences in means between treatment and control groups. Furthermore, the optimal size choice depends on the null hypothesis's specification and the researcher should pay significantly more attention if the null hypothesis is that there is a treatment effect. In any case there is a trade-off in the choices a researcher makes especially between significance level and the power of the experiment.

4.1.3 Empirical applications in energy efficiency

This section overviews the main empirical applications related to energy efficiency. In the last years there was an increase of field experiments for estimating the impact of several behavioral biases on decision-making in energy consumption. More importantly, a significant number of these field trials focuses on policies that would offset the impact of the behavioral biases.

Schultz et al. (2007), showed through a framed (randomized) field experiment that social norms could effectively be used to reduce home energy consumption. This experiment, being the first in the energy literature with descriptive and injunctive norms, took place in San Marcos, California with a sample of 290 households. The most interesting result was that using descriptive norms in energy bills, low energy

consumers tended to increase their energy use, causing the so called “boomerang effect”. When these descriptive messages were combined with injunctive message, the energy consumption lowered and the “boomerang effect” eliminated. Likewise, Nolan et al. (2008), run a natural experiment in San Marcos, California (2003-2004) consisting of 981 households. They argue that among different proposed nonnormative information to conserve energy (such as protecting the environment, benefiting society, or saving money) the most influential to consumers’ behavior was the normative social information, nevertheless their influence is under detected.

Allcott, (2001a), by examining approximately 600,000 households in many natural field experiments around the U.S., found that peer comparison-related information led to an average reduction of 2% in energy usage. He also found, that consumers with the larger energy usage were the most likely to conserve more electricity, whereas these with lower energy consumption barely reduced their energy consumption. Following Allcott (2011a), Ayres (2013) evaluated Opower[1] HERs in two more natural field experiments. The two experiments refer to 170.000 customers of two utilities, the utility company providing electricity “Sacramento Municipal Utility District (SMUD)” and the one providing electricity and gas “Puget Sound Energy (PSE)”. The households who received the Opower reports had a significant reduction on energy consumption at the rates of 1.2% at PRSE and 2.1 at SMUD respectively. What is worth mentioning is that the leading reduction was long lasting (7 months for PSE and 12 months of SMUD).

In the same direction, Costa and Kahn (2013) analysed data from a natural field experiment of 84.000 households in California, U.S. The households were divided according to the political party that they were registered (liberals or conservatives) in conjunction with their indicators of living (“green way of life” or not), in order to find if there is a connection between energy conservation “nudges” and an individual’s ideology. Although a reduction in energy use was reported for both liberals/ environmentalists and conservatives, the first had almost 3 times bigger percentage in change of energy usage (-3.6% for liberals. -1.1% for conservatives), despite the fact that it was harder to reduce consumption further. As a conclusion they found that liberals and environmentalists were more responsive to these nudges which highlights the necessity that energy conservation nudges need to be targeted in order for being most effective.

Allcott and Rogers (2014), studied the results of a randomized control trial, using data from the three longest-running Opower programs. These programs initiated at early 2008 and early 2009, when home energy reports with social comparison were send to 234,000 households. In order to find the persistent of the effects mentioned above, some of the treated participants were discontinued from the program after 2 years and some of them continued after this period. What they found was that consumers reduced remarkably their energy use, when they received their first home energy reports. However, it was shown,

[1] Opower was an American company founded in 2007, that provides a software-as-a-service customer engagement platform for utilities. It was the first company that introduced behavioral-based information to energy consumers at a large scale.

that if the treatment was not repeated this effect begun to fade after some months. The same decay effect was apparent to those that discontinued after two years, but this time four to eight times slower than the decay observed before, indicating that habituation is not fully implied.

Data of 464.523 households in Italy, were analysed by Bonan et al. (2020) in 2016, by implementing a RCT. The social information was included in the HERs and distributed by an Italian energy company via email. The social information consisted of descriptive and injunctive messages and they found that consistent feedback of both types boosts the effectiveness of social information in reducing energy consumption and that they should be complementary. When descriptive and injunctive messages are in conflict, customers behavior in energy saving is a function of the relative strength of the two types of feedback. These results suggest complementarities between different types of normative messages rather than superiority of any one kind of feedback.

In Allcott, 2011b, 693 households of Chicago received hourly real-time pricing (RTP). Through this experiment he concluded in three main findings. First, he shows that households were statistically significantly price elastic and that lower energy consumption during peak times. What is remarkable, though, is that during off-peak hours there was no increase on average consumption. Secondly, although households responded with energy conservation to the peer comparison information provision, there was not net load shifting from high pricing hours to low. Finally, he found that price elasticity of households can be significantly increased by energy management and information technology.

In a different setting, Carroll et al. (2014) tried to estimate the reducing effects of various feedback mechanisms and time-of-use tariffs. Their experiment run between 2009 and 2010 in Ireland, by installing 5000 smart meters in 2,722 households and separating three treatment groups. These groups were receiving detailed description about the day, time and cost of use accompanied with peer comparisons, information about the appliances' use and tips on conservation methods. What was different among the groups was that the frequency of the billing as the first had bi-monthly billing, the second monthly and the third had IHDs installed. What they found was, firstly, reductions in energy use of 1,8%, with the larger reductions (2,9%) coming from those who received monthly bills. Secondly, all of the groups had significant improvements in forming stock of information, including the control group, while the biggest stock was formed from those who were provided with IHDs.

Delmas et al. (2013), analysed data from 156 field experiments (and 524,479 study subjects) published from 1975 to 2012. The main findings are that individualized feedback by audits and consultant can reduce energy usage. On the other hand, pecuniary feedback and incentives can lead to a relative increase in energy usage. Finally, it should be noted that the overall reduction in energy consumption was about 7.4%. Jessoe & Rapson (2014), conducted a framed field experiment of 437 households in Connecticut, in 2011, exposing all treatment groups to price interventions. They also provided the customers with in-home displays (IHD), displaying in real time information about the quantity of electricity they consumed. Their main result was that this real-time information increased consumers' price elasticity demand. They also found that households that experienced only the price increases reduced energy usage by 0% to 7% relative to control households, whereas those that received additionally real time feedback decreased usage from 8% to 22%.

Investigating how moral suasion and economic incentives influence motivations for energy conservation, Ito et al. (2018), sampled 691 households in Keihanna area, Kyoto, Japan. Through a randomized control trial, they assigned in 2 treatment groups, the moral suasion and the economic incentive and they

examined how these interventions react in peak demand hours on summer 2012- winter 2013 period. The moral suasion group received messages that urged them to voluntarily limit energy usage in peak hours, which had as a result short- run reductions (at the rate of 7%) at the beginning, but no further reductions after the following interventions, showing strong habituation. They also showed that no signs of dishabituation after a three-months interval. On the other hand, economic incentive group demonstrated bigger and more long-lasting energy usage reduction, at the percent of 14%for the lowest critical price and 17% for the higher. Lastly, they showed that there was a significant habit formation for the economic incentive group and no habit formation for the moral suasion.

Wang et al. (2020), implemented a framed field experiment in Los Alamos County, New Mexico, U.S., to estimate consumers' response on a combination of a default-based enrolment and price-based incentives. At the frame of the randomized trial, two treatment groups were formed: the opt-in group that consisted of consumers that had to enrol in the critical peak pricing (CPP) program and the opt-out group, in which consumers enrolled the program by default and had to opt-out. They found that both opt-in and opt-out programs, led to a significant reduction of electricity demand in peak hours. However, the opt-in group had generated a larger aggregate impact, bigger persistency after repeated interventions and had effects also before and after the peak hours on treatment days.

Surdashan (2017), using data from around 500 households in India's National Capital Region, found that there was a reduction of the mean electricity consumption of about 7%, over the entire summer season, when he provided comparing information of the households' electricity usage and their peers. Then he implemented small monetary incentives in conjunction with the peer comparisons and found that the consumption increased compared to using only peer information. Exploiting the lack of evidence on how electricity information feedback affects behavioral changes, Attari et al. (2014), used a randomized control trial from 88 apartments New York Apartment Building. They established "Modlets" in home devices, which provided near-real-time plug level information on electricity use. Their outcome was a 12-23% decrease in electricity demand in treated apartments while the decrease in overall electricity use was similar among treatment apartments. The authors stated that reductions may have appeared due to a Hawthorne or salience effect, rather than the real time information.

Asensio and Delmas (2016), carried out a randomized controlled trial with 118 residential households in Los Angeles. They provided real-time appliance level metering energy feedback over 9 months (6-month baseline period and 100 days of treatment). The first out of the two treatment groups, received information on cost savings whereas the second received information on environmental and health issues that arise from electricity consumption. The results showed that health and environmental related information induced persistent energy savings behavior of 8–10% over in the long run of 100 days. On the other hand, cost-saving information seems able to change behavior in the short-term but have no significant savings after 7 weeks.

Lee et al. (2020), estimated whether feedback eliminates the inefficient energy consumption caused by the habits, through a deductive model. They examined a setting of a framed field experiment in an apartment complex of 704 households in Seoul, South Korea. A treatment group provided with a metering device. The households' electricity consumption data were gathered from the metering device and sent back to the consumers, on a weekly basis. The conclusions were extracted by a combination of a survey, that took place to find out the differences between the perceived and the actual consumption, and a randomized trial that examined the consumption behavior before and after the installation of metering

devices. The survey results showed that intention-action gap exists as there are differences between perceived and actual energy consumption, whereas the experiment further showed that regular feedback prevent misperceptions of individuals' level of energy use, helping them to eliminate their energy consumption (4.55% on average with statistical significance) and at last narrowing their intention-action gap.

Analyzing the experimental evidence of 42,100 households in Southern California, Brandon et al. (2019) investigated if crowding out effects appear when two social nudges are implemented in isolation and in combination. The first nudge was the so- called Peak Energy Report (PER) and referred to the electricity consumption of a household during peak load events, whereas the second, the so-called Home Energy Report (HER) referred the total consumption of a household. After implementing a randomized experiment trial, they showed that when households received PERs only, an energy reduction of 3,8% was noticed. On the other hand, when HERs alone were provided a reduction of was 2,1% was caused. At last, when a combination of both HERs and PERs was received by the customers the electricity consumption was reduced at the level of 6,8%, showing that a limited role for crowd out effects is needed.

Another field experiment on electricity consumption was carried out from Delmas and Lessem (2014), in order to investigate how the combination of private and public information provided to consumers, can affect their energy conservation. The experiment was based on observations from 66 rooms in the residence halls at the University of California, Los Angeles. The students were provided with private information in the form of real time feedback about their energy consumption at the sectors of heating and cooling, lights and plug load. Some students were chosen to be rated as being above or below average energy conservers, with that ratings being publicly exposed with large, prominently displayed posters. What authors found was that there was not statistically significant energy conservation when only private information provided. However, when public information was provided additionally to the private, energy savings of 20% were observed. This energy saving behavior came from high energy users and continued to exist even three months after public information was removed.

Table 3 provides a survey of the related empirical applications on energy efficiency. These works feature natural field or framed field experiments, as well as a meta-analysis of field trial experiments. Finally, the most common achievement among these works is the reduction of energy consumption.

Table 3: Survey of relevant empirical applications on energy efficiency

Reference	Journal	Experiment Background	Evaluation Type	Main Results	Percent change in energy usage
Schultz P.W. et al. (2007)	Psychological Science	290 households in San Marcos (California)	Framed field experiment	descriptive norms induced low energy consumers to increase energy use while injunctive messages eliminated the boomerang effect	-
Nolan J.M. et al. (2008)	Personality and Social Psychology Bulletin	981 households in San Marcos (California) from 2003 to 2004	Natural field experiment	normative social information leads to greatest behavioral change while their influence is under detected	-
Allcott H. (2011a)	Journal of Public Economics	600,000 households in U.S. for a 12-month period	Natural field experiment- RCT	non price interventions could alter consumers' behavior	-2%
Allcott H. (2011b)	Resource and Energy Economics	693 households in Chicago from 2003 to 2006	Framed field experiment- RCT	real-time pricing (RTP) increases households' price elasticity while lowers energy consumption during peak hours	-
Ayres I.et al. (2013)	JLEO	170,000 household customers in Sacramento (U.S.) for 12-month period	Two natural field experiments – RCT	households receiving Opower's HER experienced significant and lasting reduction on energy consumption	On average -1.6%
Costa D.L. & Kahn M.E. (2013)	JEEA	84,000 households in California from March 2008 to May 2008	Natural field experiment- RCT	conservatives are more likely to opt out of receiving HERs	Liberals -3.6% Conservatives -1.1%

Delmas M.A. et al. (2013)	Energy Policy	156 published field trials & 524,479 study participants from 1975 to 2012	Meta-analysis of field trial experiments	individualized feedback leads to largest energy consumption reductions. On the other hand, pecuniary feedback increases energy usage	Average reduction -7.4%
Jessoe K. & Rapson D. (2014)	American Economic Review	437 households in Connecticut during 2011	Framed field experiment- RCT	real-time information through IHD increases price elasticity of demand	• Price only intervention group: 0%-7% • Price intervention+ IHDs: 8%-22%
Attari S.Z. et al. (2014)	National Bureau of Economic Research	88 apartments in New York during 2010	Framed field experiment- RCT	reduction→ result of factors as salience or Hawthorne effect & not real-time information	12-23%
Carroll et al. (2014)	Energy Economics	2,722 households in Ireland from 2009 to 2010	Framed field experiment- RCT	the provision of feedback and information when using smart metering programs decreases households' electricity demand acting as a reminder and motivator	-1,8%
Allcott H. & Rogers T. (2014)	American Economic Review	234,000 households in USA from early 2008 until 2013	Natural field experiment- RCT	consumers reduced remarkably their energy use when they received their first HERs but this effect begun to fade after some months if the treatment was not repeated	-
Delmas and Lessem (2014)	Journal of Environmental Economics and Management	66 residence hall rooms of the University of California (UCLA), from September 2010 to May2011	Conventional lab experiment- RCT	private information combined with public information increases energy savings with most of the savings coming from high energy users	20%

Asensio O.I. & Delmas M. (2016)	Journal of Economic Behavior & Organization	118 Households in Los Angeles (University Village), over 9 months	Framed field experiment- RCT	Health and environmental information have more persistent impact on energy savings while cost saving information exert short term impact	• Health based frames (over 100 days): 8-10% • Cost saving frames: No significant saving after 7 weeks
Sudarshan A. (2017)	Journal of Economic Behavior & Organization	534 households in India's National Capital Region, during 2012 (4 months)	Natural field experiment- RCT & Quasi-Experiment	Households that were provided with only HER reduced consumption, while households that were provided with both price incentives and peer comparison increased consumption relative to the peer comparisons alone treatment group	-7% during summer
Ito et al. (2018)	American Economic Journal: Economic Policy	691 households in Keihanna area, Kyoto, Japan, from Summer 2012 to Winter 2013	Natural field experiment- RCT	Moral suasion- based information exerts a short-term impact on energy conservation. Dynamic pricing schemes sustained reduction during peak periods	• Moral group: -8% initially • Almost no effect after a number of interventions • Economic incentive group: 14% at the lowest peak event & -17 at the highest
Brandon A. et al. (2019)	PNAS	42,100 households in Southern California, during Summer 2014	Natural field experiment- RCT	Both HER+PER when used in isolation reduce peak load electricity consumption. On the other hand, when used in combination almost double their impact on energy conservation	• HER: 3.8% • PER: 2.1% • HER+PER: -6.8%
Wang W. (2020)	European Economic Review	1,648 households in Los Alamos County (LAC), New Mexico, United States, during 2013	Framed field experiment- RCT & survey	Both opt-in Critical Peak prices customers (CPP) and opt-out CPP reduce peak electricity consumption. More specifically, opt-in generated a larger aggregate impact and its treatment effects are more	• ITT on peak hours: Opt-in: 9.8% Opt-out: 5.8% • ATT on peak hours: Opt-in: 14,7%

				persistent. Opt-in succeeded in triggering significant treatment effects among customers during hours before and after peak events	Opt-out: 6%
Lee E. et al. (2020)	Energy Research & Social Science	704 Households in Seoul, South Korea, from September 2013 to December 2014	Framed field experiment- RCT & survey	Improved feedback narrows the intention-action gap by preventing consumers' misperceptions of their energy use	-4.55%
Bonan J. et al. (2020)	Nature Energy	464,523 households in Italy, during 2016	Natural field experiment- RCT	Descriptive and injunctive feedback when used in combination increase energy conservation	-

4.1.4 Review of field experiments in related topics

This section overviews field experiments that were implemented in related to energy efficiency topics. Specifically, water and gas consumption are scarce resources, as electricity, and their consumption entails also environmental impact. By examining empirical researches from other fields, useful insights could contribute in designing and implementing fields trials for energy conservation.

Through the partnership with a metropolitan water utility and the implementation of a natural field experiment, applied to over 100,00 participants in Cobb County, Atlanta, Georgia, Ferraro P.J. and Price K.M. (2013), tried to examine the effect of norm- based messages on the water consumption. For that reason, four groups were formed at the randomized control trial. The treatment groups differed with each other at the fact that the first received only technical advice, the second technical advice and social messages and the third all the previous with the addition of social comparison. The examination of the data indicated that remarkable attention should be given on explaining the customers the reasons they shouldn't consume big amounts of water and not the ways with which they could achieve it. In the terms of their experiment households of the first treatment group consumed 1% less water that those in the control group, whereas the second treatment group had greater reduction (near 4,8%). However, the efficacy of the norm messages had a fundamental difference between low and high-water use consumers, with the messages being more effective to high users. At last, they found strong evidence that this effectiveness of non-incentive strategies declines over the time.

Dolan P. and Metcalfe R. (2015), used two natural field experiments in the gas consumption area to examine firstly, the impact of social norms alone and in combination with the information and secondly, how financial incentives impact the behavior with the presence or absence of norms. For the first experiment, a setting of 569 households was formed (2010-2012) whereas in the second they used data from 2,142 households (2012), both from the U.K. They found that norms can influence the consumption of energy, irrespective of basic information and that the rate of the reduction when using the norms is around 6%. A very interesting finding was the persistence of the effect of the norms in spite the fact that no punishments or sanctions were used to individuals to conform. What is more, they proved that financial incentives have an effect in reducing energy usage, as they changed 8% the energy consumption. When social norm information is provided, then this large effect of financial incentives completely disappears.

Trying to examine the impact that injunctive messages have on behavior, Bhanot P.S. (2018) run a natural field experiment on water consumption behavior, consisting of 45,866 households in California. Four groups were formed, with the control group receiving no social information, the second receiving but with no visual cue, the third with a basic visual cue and at last the fourth the visual cue of the third accompanied with an injunctive message. The experiment showed that when injunctive norm messages are sent, the water consumption is being reduced. Secondly, it was found that consumers that have received injunctive messages are not discouraged from receiving social norms in the future. In the same vein, using a large sample randomized control trial Allcott and Sweeney (2014) examined how energy use information of appliances with Energy Star Labels, like natural gas and propane water heaters, affect their purchases. They cooperated with retailers so as to see how sales agents' and consumers' behavior is influenced by different information provision, customer rebates, and sales incentive. The results indicate that

information about the Energy Star appliances failed to be to transferred at the majority of the consumers, but the financial incentives seem to matter in the purchases.

Wichman C.J (2017), examined how the frequency of billing influences the consumption of water through a natural field experiment using data from 59,000 households located in Durham, North Carolina. They found that by turning the frequency of the billing from bimonthly to a monthly basis had as a result an increase in water consumption at the level of 3,5-5,0%. This result was related to the water price and quantity uncertainty. Often in order to achieve policy objectives, non- pecuniary information-based strategies are used. Implementing a randomized control trial, Ferraro P.J. and Miranda J.J. (2013), showed that subjects had little heterogeneous responses to plain information about water reduction and pro-social behavior with the two being in isolation and combined. However, when social peer comparisons were added, evidence of heterogeneous responses were found. Especially, demographics could be a significant impact factor, since households with higher income, used more water and were more responsive to the mixture of the messages and lest responsive to monetary incentives.

Table 4 summarizes six research works related to energy-efficiency topics. In these works, a massive number of households participated in the natural field experiments. The experiments resulted in various outcomes regarding the impact of user knowledge and behavior on energy consumption.

Table 4: Survey of related to energy efficiency topics

Reference	Journal	Experiment Background	Evaluation Type	Main Results	Percent change in energy usage
Allcott H. & Sweeney (2013)	Working Paper, New York University	Over 20,000 calls from the Retailer's call database	Natural field experiment – RCT & survey	information about Energy Star appliances failed to be to transferred, but the financial incentives matter in the purchases	-
Ferraro P.J. & Price K.M. (2013)	Review of Economics and Statistics	Over 100,000 participants in Atlanta (Georgia) during 2006 - 2007	Natural field experiment – RCT	Social comparison messages lead to bigger reduction of water consumption compared to pro-social or technical advice provided	• Group that received only technical advice -1% • Group that received additionally social messages -4,8%
Ferraro P.J. & Miranda J.J. (2013)	Resource and Energy Economics	100,000 households in Atlanta (USA) during 2007	Natural field experiment – RCT	strong norm feedback, which augments technical information with pro-social language and social comparisons show evidence of heterogeneous responses	-
Dolan P.& Metcalfe R. (2015)	Becker Friedman Institute for Research in Economics Working Paper	569 households for the first experiment and 2,142 for the second, both in U.K. from 2010 to 2012.	Natural field experiment – RCT		-
Wichman C.J. (2017)	Journal of Public Economics	59000 households in Durham, North Carolina with collected data from Feb 2004 to June 2014	Natural field experiment – quasi experiment	More frequent billing increased consumption	Increase + 3,5-5%

Bhanot S.P. (2018)	Organizational Behavior and Human Decision Processes	45866 households in San Francisco (California) during 2013-2015	Natural field experiment – RCT	Injunctive norms encourage conservation behavior	-

4.1.5 Results and insights for the EVIDENT project

Based on the previous analysis, there is an increasing interest regarding field experiments for enhancing energy efficiency through behavioral insights. In the period from 2007 until present, we report 19 field experiments related to residential energy consumption (the review includes only papers that are published in the most prestigious economic-related journals, having made significant contribution). As expected, with regard to Harrison and List (2004) taxonomy, most of the referred studies here are framed field experiments while natural field experiments are only a fraction. It is important also to note that most studies (11 in total) include a small number of participants, usually less than 1,000, and only 4 studies are implemented at scale (that is more than 100,000 participants).

Most studies focus on the impact of social comparison as well as of descriptive and injunctive feedback to consumers. These types of messaging usually refer to the overall electricity consumption or induce consumers to switch their energy consumption during off-peak time. The average treatment effect ranges between 1.5% to 8% and is mostly driven by households' demographics, for example, liberal consumers are more likely to be more responsive to messages and decrease energy consumption by a greater amount than conservative consumers (Costa and Kahn, 2013). Furthermore, an important finding is that when messages used in combination almost double their impact on energy conservation. Finally, some studies find that health and environmental information have more persistent impact on energy savings while cost saving information exert short term impact (Asensio and Delmas, 2016) and on average moral suasion-based information exerts a short-term impact on energy conservation (Ito et al., 2018), signalling habituation.

Although, these results are significant and provide useful insights for both the academia and the policy making, still many open research questions remain to be challenged. EVIDENT project will focus on measuring the average treatment effect of different types of messages at a large scale exploiting PPC's large customer database. Most studies reported in the previous section, concentrate their analysis in the U.S. market and it would be interesting to explore the effects in European countries. More specifically, Greece or other Southern European countries have not been included as use cases in related studies in the past and results from EVIDENT's use case conducted in Greece could potentially offer useful generalizable insights. Other research questions that could potentially be explored in EVIDENT and could add value o the existing research is how beliefs could be turned into actions. In other words, what are the key points for the behavioural-based interventions to have a long-term impact. Finally, more research needs to be done in estimating the impact of various types of messages on inducing consumers to switch energy consumption between peak and off-peak hours.

5. Quasi Experiments

This section includes an overview of the surveys and stated preferences that are related to energy consumption. Examples are assessment of the willingness to pay for an energy efficient product, attitudes towards energy consumption and savings behaviour. Also, surveys and stated preferences aiming at eliciting specific biases and heuristics (in example, time preference, inattentiveness and salience issues; myopia or short sightedness; bounded rationality and heuristic decision making; reference-point phenomena) that are related to decision-making for energy consumption. Best practices from quasi-experiments will be used as guidance for designing and developing EVIDENT's platform crowdsourcing tools in D6.2

A quasi-experiment is an empirical interventional survey aiming to estimate the causal impact of an intervention on a target population group. Quasi-experiments share similarities with the traditional randomized trials without the element of random assignments. As a result, quasi-experiments enable the researcher to control the assignment to the treatment condition by utilizing specific criteria instead of random assignments.

5.1 Quasi experiments literature review

5.1.1 Survey literature review

The use of surveys in the area of energy efficiency is well established. Surveys play an important role in the evaluation, measurement and verification of energy efficiency programmes (Baumgartner 2013), and may inform the development of additional experimental analyses. Tools such as surveys are often used as a basis for statistical analysis and to support decision making in programme development (Csutora et al. 2021). Three common areas of questioning within energy efficiency surveys have been noted (Csutora et al. 2021), namely respondent socio-demographics (Yu et al. 2013, Alberini et al. 2016), dwelling characteristics (Pachauri and Jiang 2008, Hu et al. 2017) and energy related behavioural factors (Steemers and Yun 2009, Yun and Steemers 2011).

A key consideration in survey use is its design. To support effective and accurate survey development, attention must be paid to how each variable is measured. Options include the use of single item measures, blocks of questions or pre-established measures. Concerns to the use of single-item measures of specific attributes or variables have been raised, with accuracy and reliability questioned (Azjen 1988). Additionally, the use of blocks of questions pertaining to household characteristics may also not comprehensively identify all related behavioural factors (Yun and Steemers 2011), and if too lengthy may impact volume of respondents. (Rao et al. 2015) note the importance of determining data source, in terms of participants to be targeted, means to reach them and survey distribution when developing a survey. This in turn will likely impact the instrument chosen and the tools included within it. While this suggests some key considerations within survey design, further analysis is needed.

Four common sources of error within survey design have been identified (Baumgartner 2013), namely measurement, sampling, non-response and coverage errors. Sampling errors arise when the characteristics of the population of interest are not fully captured within the sample. As such, respondents

may not be fully representative of the population targeted by the survey, skewing results. This can be addressed through purposive sampling or through increasing the sample size to better reflect the desired population. Non-response occurs where respondents do not fully complete a survey, be that by skipping questions or by leaving the questionnaire unfinished. This may impact findings if those who did not respond may have differed in response from those who completed the question. To address these efforts to keep the response effort low is needed. Examples of actions which could be taken include ensuring the questions are understandable and survey brevity. Non-coverage errors occur when a subsample of the population is excluded from participating due to the recruitment methods employed. For example, if a survey is completed only online those without internet access may be excluded. To address this the recruitment strategy must be carefully considered to ensure that all relevant population groups have an opportunity to participate. Finally, measurement error occurs where a survey does not accurately measure what it purports to measure. This includes biases such as social desirability bias, acquiescence bias, or response errors which may impact the accuracy of responses given. Within social desirability bias (as highlighted in Foukaras and Toma 2014), respondents alter their responses to present themselves in a manner they perceive to be more socially acceptable. This may lead to an over-estimation of respondents' pro-environmental behaviours. To address this questionnaire length, question type and question order should be considered.

Additional limitations of surveys which should be accounted for within the design include inappropriate modelling decisions, poor internal or external validity, or incorrect baseline data (Baumgartner 2013). Efforts to minimise the impact of these limitations should be considered. A further limitation is the inability to identify or predict the behaviour of individuals, reducing the ability to develop models that include energy consumption behaviours (Csutora et al. 2021). Behavioural responses and attitudes have been found to be underreported in surveys, due to difficulties with accuracy and a broader lack of analysis of behavioural biases. To address these limitations, consideration should be given to combining quantitative and qualitative analyses through participatory systems mapping, where stakeholder focus groups are used to inform the development of quantitative analyses (Csutora et al. 2021). Such methods have been used successfully to support better understanding of stakeholder needs and barriers in energy consumption, thus allowing for interventions to better support engaged and lasting action (Salvia 2015, Vaidya 2016).

Survey analyses have been used to examine consumer attitudes towards energy ratings (Hyland et al. 2013) and grant schemes (Collins and Curtis 2016), amongst other areas. A number of cross-European analyses have also occurred. Welsh and Bierman (2014) examined consumers views towards renewable energy sources across 25 European countries. Consumers reported a preference for a larger proportion of solar and wind energy in comparison to coal, nuclear or oil. Foukaras & Toma (2014) conducted secondary analysis of data from the Eurobarometer survey. Analysis of large repeated datasets, such as the Special Eurobarometer surveys on Climate change, allow for the analysis of change over time. Additionally, due to large sample sizes, analysis of factors which may impact environmental behaviour can be identified. Due to the inclusion of participants from across Europe, cross-cultural differences can be identified and planned for within future analyses. Specifically in this instance, data from Cyprus and Sweden on pro-environmental behaviour, eco-product purchasing behaviour, waste separation, environmental attitude, trust in informational sources and socio-demographics was examined. Results suggested the importance of considering variation across the environmental history, policy and actions of

countries when developing interventions. Secondary data analysis was also conducted by Baiardi & Morana (2021) to examine public attitudes on climate change. Environmental concern was found to be related to income, social trust, secondary education, physical distress from hot weather, media coverage, volume of young people and monetary loses. Awareness of the contribution of human behaviour to climate change had increased over time. These past analyses suggest the effective use of surveys in this field.

Table 5 presents a summary of the relevant survey analysis that took place in various EU locations. Overall, the results provide useful insights into the changes that are required to take place to achieve eco-friendly best practices.

Table 5: Summary of relevant Survey Analyses

Reference	Research Question	Location	Area	Results
Hyland et al., (2013)	Modeled the impact of energy rating adverts on property rental or sales price	Ireland	Energy rating certificates	Results suggest a positive effect of energy rating advertisement on both purchase and rental price, though stronger effects for house sales were found.
Collins & Curtis, (2016)	Examined the impacts of a national grant scheme on residential energy efficiency upgrades in Ireland.	Ireland	Energy efficiency upgrades	State obligated retrofits performed negatively in comprehensive retrofits in comparison to private residences. Newer homes were more likely to have more retrofit measures completed.
Foukaras & Toma, (2014)	Examined the factors impacting eco-labelled product purchasing and waste separation.	Cyprus & Sweden	Eco-labelled product purchasing	More likely to buy green if effort is made to consider situational factors, increase 'trust' in information and source, and target information better to different groups.
Baiardi & Morana, (2021)	Examined public attitudes to climate change in the EU.	Europe	Climate Change attitude	Environmental concern was related to income, social trust, secondary education, physical distress from hot weather, media coverage, volume of young people and monetary loses. Awareness of the contribution of human behaviour to climate change increased over time.
Welsch & Bierman, (2014)	Examined the views of consumers on energy sources.	25 European Countries	Energy sources	Consumers reported a preference for a larger proportion of solar and wind energy in comparison to coal, nuclear or oil.

5.1.2 Stated Preferences Systematic Review

Stated Preference (SP) surveys are a research method in which individual preference statements are determined based on choices made between a set of options to estimate their relative value (Kroes and Sheldon 1988). SP effectively aids identification of respondent preferences with lower response costs for respondents themselves (Kroes and Sheldon 1988). For SP to occur, the development of a survey by the researcher is required to allow for the determination of preferences across provided options. While SP was originally developed for use in market research (Green and Srinivasan 1978), more recent analysis has advanced to include preference structures and choice processes within a behavioural choice context (Kroes and Sheldon 1988). Common SP sub-types include conjoint analysis, trade-off analysis, functionality measurement and discrete choice analysis which will be discussed in detail below. SP has been effectively employed across a variety of fields from health to transport (Cherchi and Hensher 2015).

In comparison to revealed preference analysis, or analyses involving direct observation of choices being made in-vivo, a number of advantages to SP have been noted. Kroes and Sheldon (1988) noted three primary benefits of a SP design in comparison to revealed preference. Firstly, it may often be difficult to obtain sufficient variation in responses to examine all variables of interest within revealed preferences. For example, some respondents in revealed preference experiments may simply not choose one of the presented options, or may not do so to a level sufficient to allow for analysis. SP removes this through systematic presentation of item/service attributes. Secondly, it can often be difficult to control all variables of interest in revealed preference situations as they may over-lap. For example, when examining revealed preferences in appliance purchasing it may be difficult to control to a high degree the differences in attributes across options presented. Finally revealed preference analyses may be restricted in being only able to assess those variables that are possible to manipulate in real life situations. Products or services in development or which are hypothetical thus cannot be examined. More practically, increased time and resource costs can be incurred for revealed preference assessments, as greater staff levels are needed to implement such studies. Additionally, when considering cross-cultural studies such as those being completed within EVIDENT, difficulties in controlling options presented across participant groups may occur as market conditions may vary largely across countries. This impact is limited within a SP scenario wherein greater researcher control over attributes presented can occur.

The primary criticism levelled against SP in comparison to revealed preferences however pertains to the behaviour-intention gap, or the gap between what people say and what they do (Lin et al., 1986). Similarly, the “warm-glow” effect, or the positive feeling respondents obtain as a result of over-stating their socially desirable views, may impact the reliability of findings. Research examining preferences towards energy sources noted a discrepancy across SP and field experiments with greater willingness to use renewable sources in SP (Menges et al. 2005). However, when we consider that stated preference analyses are intended only to determine relative utility weights rather than absolute demand this impact may be mitigated. Additionally, complimentary research methods can be employed in tandem with SP to more fully determine the external validity of findings. Cherchi and Hensher (2015) note that the behaviour-intention gap holds also for revealed preference analyses. For both methods validity may be negatively impacted by incorrect participant recruitment, context or selection of attributes (Iragüen and de Dios Ortúzar 2004, Cherchi and Ortuzar 2012). That being said, hypothetical bias, or the error from an individual not experiencing the actual situation in real life (Hensher 2010) may be particularly relevant in SP analysis due to the reliance on a hypothetical scenario. Efforts to support researchers to enhance the realism of their attribute and level selection has been examined (Bradley and Daly 1994). To better mimic real-life scenarios, researchers must build a complex survey, that maximises participant understanding and ease of completion while maintaining a low response time. Relevance of attributes to real life situations is an important metric of determining complexity of survey attributes. Surveys should be complex enough to

present all relevant attributes, but no more than that. Research suggests high volumes of choice situations may increase errors due to respondent fatigue (Bradley and Daly 1994). Further, respondents may lack the ability or willingness to process information presented to fully evaluate alternatives accurately (Cherchi and Hensher 2015). However the impact of fatigue can be checked through re-presenting earlier choice options to confirm consistency (Petrik 2013) or through removing preferred attributes to shift choices across other alternatives (Rose et al. 2008). Images have also been posited to support the realism of stated preference surveys (Cherchi and Hensher 2015), however only key attributes should be highlighted in images and others controlled to prevent unwanted biases in decision making.

A wide variety of topics have been analysed using SP, as highlighted in Table 6. Recent advances in SP have highlighted both the need for additional qualitative analysis within SP design and use, and for the use of more dynamic SP types (Cherchi and Hensher 2015). Typically qualitative analysis has occurred within the design phases of SP surveys (Louviere et al. 2000), to support the development of attributes and survey design. Qualitative analysis however has also been highlighted as a means to further analyse and mitigate attribute non-attendance, where participants ignore certain attributes when choosing due to perceived irrelevance or personal disinterest (Cherchi and Hensher 2015). Qualitative analysis has also been highlighted as a means to further investigate this. Cherchi and Hensher (2015) highlighted the need for adaptive surveys, or those in which past participant responses inform future choices presented. For example, changes to the attributes or levels presented may be changed based on previously entered preferences by respondents. As such additional analyses which include more adaptive SP designs and which include qualitative analysis across design and implementation are required.

5.1.2.1 Stated Preference in Energy Source Selection

While public support for renewable energy policy initiatives is growing, it is unclear the degree to which individuals are willing to pay for such initiatives. One area which has been the subject of significant analysis is the area of residential energy source selection. A number of past analyses have employed stated preference techniques to examine the perspectives of consumers towards selecting alternative energy sources within their homes.

A number of consumer factors which may impact value placed on energy source attributes have been examined using SP. Analysis of willingness to enrol in voluntary renewable energy programmes suggests the impact of income, home ownership and home value in addition to environmental concerns (Knapp et al. 2020). Analysis of the impact of monetary and non-monetary incentives on consumer participation in green pricing programmes found lower externalities, greater jobs and financial benefits linked with participation (Bae and Rishi 2018). Of note was the identification of two primary respondent groups, pro-environmental and pro-growth. Pro-environment consumers preferred higher shares of renewable sources, closer proximity of green power plants to homes and green spaces, over financial incentives. Growth focused consumers preferred lower shares of renewable energy, green power plants further from homes and monetary incentives.

SP has also been used to examine energy source specific factors impacting selection. Price and energy mix have been found the most impactful factors on consumer energy choices (Kaenzig et al. 2013) with consumers willing to pay more for greater proportions of renewable sources. Consumers past energy experiences may also impact the importance of certain energy source attributes (Amador et al. 2013), with consumer past experiences, satisfaction with current providers and their attitudes impacting energy source choices. Specifically, the relative importance of reliability, the proportion of renewable energy sources and energy audit availability was examined. Consumers with greater past issues with reliability

valued it higher. Education, greenhouse gas concern, and energy saving behaviours were associated with a preference toward renewable sources. In terms of experimental design this study added to typical SP approaches in two key ways. Firstly, user input into the studies design was sought with both a pilot survey and an initial focus group to determine of survey attributes. Secondly, to increase the relevance of findings a pivot alternative, respondents current energy provider, was included. Through the current provider, information on past energy outages, renewable energy percentages and available services was gleamed. Attribute levels were then presented based on current supplier data. The cost attribute was also determined by applying a set percentage to the respondent inputted monthly average bill. As the percentage itself was consistent across respondents' comparison across the three levels could occur. The highest level of renewable energy mis presented to participants adhered to the PECAN-2006 target of 30%, again to support real life generalisations from the present analysis.

5.1.2.2 Stated Preference in Energy Upgrades

Energy upgrades to increase residential energy efficiency have also been the subject of SP analysis. Risk has been highlighted as a primary concern in consumer willingness to pay for insulation and ventilation to aid energy efficiency in homes (Farsi 2010). Analysis of the impact of monetary and non-monetary incentives on heating upgrades found replacement to be more likely when energy bill savings were larger and spread over a longer periods and when rebates were offered (Alberini and Bigano 2015). Respondents were not impacted by potential CO2 emission reductions. Efforts in this study were made to reduce the impact of adverse selection and free riding, questions were asked to those who were not expecting to upgrade their energy efficiency in the near future as they are unlikely to be affected by the target behaviours within the survey. SP methods have also been used in tandem with Discrete Choice. Hediger (2018) examined household use of heating and monetary savings use after energy improvement. Results suggested low direct rebound effects with indirect rebounds of 33%. Zero-rebound households were primarily high-income households, suggesting the role of a comfort threshold.

5.1.2.3 Stated Preference in Appliance Selection

Selection of energy efficient appliances is an area of significant SP analysis. Results of such analyses have considered both monetary and non-monetary interventions. Of monetary interventions, loans with low interest rates or long repayment periods were found to be as effective as rebates. Programmes with both loans and rebates were more effective that those that offered only one (Train and Atherton 1995). Significant analysis of non-monetary factors has also occurred. While consumers are aware of energy efficiency, energy class and use remain primary concerns when purchasing a refrigerator (Damigos et al. 2020). Additionally, while respondents stated having strong understanding of energy consumption, most were unable to estimate their annual energy costs for their fridge. Financial barriers to the purchasing of efficient technologies were also reported. The inclusion of energy efficiency labels on air conditioners increased WTP for a more efficient appliances (Jain et al. 2018). Takama et al., (2012) found that product specific factors significantly impacted choice of stove and fuel, with the exception of high income respondents who were not impacted by cost. A SP survey of 1545 individuals examining willingness to purchase electronic vehicles found respondents willing to pay more for convenience, both in terms of charging and parking (Guerra 2020). Two primary groups of EV preferences were found across respondents. The first group lives in urban areas in housing complexes and places high value on parking convenience and on-street charging. The second group are likelier to be wealthy, married, conservative

and reside in housing outside urban areas. This group are more likely to consider purchasing EV and are more WTP for EV charging, but were less WTP

Table 6 presents a summary of the aforementioned related works covering a wide range of areas, such as energy sources, electric vehicles, and energy-efficient appliances. The compilation of the results provides significant insights into the actual choices of the consumers across different locations

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Table 6: Summary of relevant Stated Preference Analyses

Reference	Research Question	Location	Area	Results
Knapp, O'Shaughnessy, Heeter, Mills & DeCicco (2020)	Impact of energy attitudes, environmental concerns, renewable energy preferences and willingness to pay for a voluntary renewable energy program.	US	Energy source	Higher consumer environmental concern and lower renewable energy premiums linked with greater participation. Income, homeownership and home value mediated differences in participation.
Bae et al (2018)	Factors impacting consumer participation in green pricing programmes.	South Korea	Energy source	Participation linked with green energies with less externalities, more job creation and of greater financial benefit. WTP is highest for fuel cell energy, followed by solar and wind. Two primary consumer groups were found, pro-environment and pro-growth with different strategies needed for each.
Amador, González & Ramos-Real (2013)	Consumer WTP for reliability, proportion of renewable energy sources and energy audit availability when choosing an energy provider	Canary Islands	Energy Source	Consumers previously impacted by poor reliability were more WTP for reliability. Education, greenhouse gas concern, and energy saving behaviours were positively associated with WTP for renewable sources. Older individuals were less willing to change provider, suggesting brand loyalty or sensitivity to costs.
Kaenzig, Heinzle & Wustenhagen (2013)	Examined WTP for renewable energy mixes.	Germany	Energy source	Price and energy mix were the most impactful factors on consumer energy choices.
Guerra & Daziano (2020)	Examined factors impacting WTP for different aspects of Electronic vehicles	US	Electronic vehicles	Respondents were WTP for longer range, quicker charging, less operating costs and more convenient parking. Both residential area (urban/rural) and income impacted WTP.
Farsi (2010)	Examined WTP for insulation and ventilation in rental properties.	Switzerland	Energy Efficiency	Risk was a central concern in residential energy efficiency.
Aberini & Bigano (2015)	Examined homeowners' perspectives towards heating upgrades in residential properties, and the impact of monetary and	Italy	Heating upgrades	Respondents were more likely to choose replacements with larger and longer lasting energy bill savings and when rebates are offered.

	non-monetary incentives on the energy efficiency of replacements.			Respondents were not impacted by CO2 reductions.
Hediger, Farsi & Weber (2018)	Examined household use of heating and financial savings after energy improvement	Switzerland	Heating upgrades	Low direct rebound effects (changes in heating level) were found. When the indirect rebound of energy embodied in goods and services purchased with initial savings are accounted for rebound effects of 33% were noted. There was strong variation in individual responses.
Train & Atherton (1995)	Examined consumer WTP for energy efficient appliances and the impact of loans and rebates.	US	Energy efficient appliances	Loans with low interest rates or long repayment periods were as effective as rebates. Programmes which offered both loans and rebates were more effective than those that offered one alone.
Damigos et al (2020)	Examined the impact of energy labelling, pro-environmental behaviour, peer effects and understanding of energy pricing on appliance selection.	Greece	Energy efficient appliances	Consumers were aware of energy efficiency, with energy class and use primary concerns when purchasing a fridge. While most respondents state having strong understanding of energy consumption, most were unable to estimate their annual energy costs for their fridge. Financial barriers to the purchasing of more efficient technologies were also reported.
Jain et al., (2018)	Examined consumer air conditioner preferences and WTP for better energy ratings.	India	Energy efficient appliances	Consumers were found to value energy efficiency labels on air conditioners and were WTP more for a more efficient appliance.
Takama et al., (2012)	Examined the impact of product-specific factors on stove and fuel decisions in Ethiopia	Ethiopia	Energy efficient appliances	Product specific factors significantly impacted choices, with the exception of high-income respondents who were not impacted by cost. WTP increased in line with wealth.

5.1.3 Discrete Choice Analysis

A form of SP which has become increasingly prevalent is Discrete Choice (DC) analysis (Mahieu et al., 2014). Within DC individual attributes of an item or service are considered in turn (Louviere & Hensher, 1982). As such, while SP predominantly looks at valuations of an object or service as a whole, DC instead examines preferences towards the characteristics or attributes an item embodies. DC analyses are underpinned by the characteristics of value theory (Lancaster and Tsushima 1966). This theory posits that an item is comprised of a set of characteristics each with its own level. DC analyses preference towards different characteristic levels to determine which are more important. Choice experiments are particularly effective in instances where the value of differing aspects of an item or service are examined, rather than the item/service as a whole (Hanley et al. 1998).

A typical DC approach consists of the following steps (OECD, 2018). Firstly, the good or service to be valued is selected and the attributes to be examined are determined. Attributes selected are those most relevant to the good or service, or those which are most likely to be important to consumers. Following this feasible and realistic attribute levels are assigned, with a "do nothing" or baseline level included. A baseline is included to increase the realism and prevent forced choices. Following this an experimental design is determined. Two primary experimental designs have been used, namely complete factorial and fractional factorial designs (OECD, 2018). Complete factorial designs include all possible attribute combinations and levels and examine both the effects for each individual attribute and combinations. Fractional Factorial designs differ in that a smaller subset of combinations alone are presented. Once this is selected choice sets are determined, with arrays varying from 2 to 4 predominantly. Preferences of respondents are then assessed, and results analysed. A process of developing, piloting and improving the questionnaire is required to ensure the validity of results (Kløjgaard et al. 2012a).

While the benefits and limitations highlighted above in relation to SP hold for DC, some additional benefits of a DC analysis have been found. In comparison to SP or other approaches, research suggests choice modelling may be particularly effective where individual aspects of multidimensional choices are examined, rather than changes in value for an item as a whole (Hanley et al. 2001). Limitations pertaining to external validity hold for DC. Face validity, or the process of ensuring biases do not affect DC development particularly when valuing attributes is particularly important (Bateman et al. 2002). However, limited empirical guidance has been provided on selecting attributes and levels (Hall et al. 2004). While there is no established best practice in selecting attributes (Louviere et al. 2000), literature reviews, focus groups, individual discussions and expert opinion can be relied on (Coast and Horrocks 2007). To further support external validity, it is important all relevant attributes are captured. Attributes should approximate real life motivations consumers may encounter (Lancsar and Louviere 2008). Clarity and brevity is also important, and may be supported by qualitative input (Kuper et al. 2008). Levels should be clear and succinct (Kløjgaard et al. 2012b) and must be appropriately spaced (Green and Srinivasan 1978). Should the difference in levels be too small, respondents may dismiss differences leading to dominated levels, or if too large may result in dominating levels impacting respondent willingness for trade-offs. Pilot testing can be used to support this (Lancsar and Louviere 2006).

As was noted for SP more broadly, recent analysis has emphasised the potential role of qualitative analysis with DC approaches (Kløjgaard et al. 2012a). Qualitative analysis may be particularly beneficial within the design and piloting of the DC survey. A recent analysis by Kløjgaard et al.,(2012a) used qualitative analysis,

consisting of interviews with key stakeholders, to determine the attributes and levels most pertinent to the experimental design, in this instance determining treatment paths for back injury. Results suggested increased validity and usability as a result of including qualitative analysis within the development process. Past analysis suggests qualitative analysis can also be beneficial both when determining attribute and levels (Coast and Horrocks 2007, Coast et al. 2012). As such additional analysis and expansion of the possible role of qualitative analysis within DC approaches is needed.

5.1.3.1 Discrete Choice Analysis in Energy Source Selection

One area in which DC has been used significantly is in analysis of energy source selection. Analysis of the energy source attributes which impact consumer selection suggest that while consumers are willing to pay more for more efficient sources, often this was not sufficient to cover capital costs (Scarpa and Willis 2010). When comparing energy source options, consumers were willing to pay more for decreased air pollution, convenience, energy security and lowered greenhouse gas emissions (Kim et al. 2020). Both energy bill and electricity type were found to be key factors considered when choosing energy sources (Huh et al. 2015). Both consumer education and programme cost have been found to impact participation in green energy programmes (Conte and Jacobsen 2016). In terms of specific energy sources preferred by consumers, analysis using DC methods has suggested highly heterogenous preferences (Gracia et al. 2012). This is supported by individual study results which suggest preferences for hydro or mixed energy sources in comparison to wind (Goett et al. 2000), preferences for solar in comparison to wind or a generic green sources (Borchers et al. 2007) and preferences for domestic wind farms over imported coal (Navrud and Grønvik Bråten 2007). Low willingness to have windfarms within own neighbourhoods however was noted. Wind again was found most popular by Kosenius & Ollikainen (2013), though regional differences were between rural and urban communities were found.

5.1.3.2 Discrete Choice Analysis in Household heating preferences

Household heating preferences have also been considered through DC analysis. Cost and household characteristics (Nesbakken 2001), building features and region (Braun 2010) and income, education, household structure and location (Chen 2021) impact heating choices. Energy attributes also impact heating choices, particularly safety and smoke (Chen 2021), with high quality low cost sources preferred. Rouvinen and Matero (2013) found 75% of respondents were willing to change their current appliance type. Good acceptability of hybrid energy systems have been found, though impacts of socio-demographic factors such as age, household characteristics and education were noted, with rural habitants less likely to consider the space requirements of the heating system and older respondents less likely to change their existing heating system and more likely to value comfort with a technology (Ruokamo 2016). Willingness to invest in hybrid technologies was impacted by operating cost and comfort. This suggests DC methods as an effective means of analysing household heating preferences.

5.1.3.3 Discrete Choice Analysis in Appliance Selection

DC analysis has been effectively employed to examine consumer preferences towards different appliance features. Zha et al (2020) examined consumer attitudes towards refrigerators and washing machines using

a mixed logit model. Branding, energy rating and socio-demographic factors impacted appliance choices, with both a value-action gap and residential rebound effects noted. Financial literacy also contributed to appliance selection (Brent and Ward 2018). The impact of appliance choice on energy demand has also been examined (Vaage 2000).

While most studies have examined appliance purchasing for homeowners, in recent years attention has turned to rental properties. Rental properties differ in that they are associated with split incentives for both tenants and landlords. As such, efforts to support consumers in selecting energy efficient appliances may differ for this demographic. Lang et al., (2021) examined the role of imperfect information and attentional biases on energy efficiency investments for rental properties. This study conducted a multiple price list experiment representing owners' decisions to replace a central heating appliance, using within-subject information disclosure and between subject variation in information provision to determine how tenants value energy improvements in the context of rent increases. Results found that through informing tenants of decreased energy bills tenants were willing to accept increased rent. This suggests the importance of highlighting potential savings of energy investments to all relevant stakeholders.

5.1.3.4 Discrete Choice Analysis in Energy Efficiency Improvements

An area in which DC has been successfully employed is that of residential energy efficiency improvements. Such analyses have been used to examine willingness to invest in more efficient heating technologies (Lang and Lanz 2020) with low willingness found. Results suggested home-owners average valuation of energy efficiency exceeded monetary savings suggesting the role of a non-cost benefit. This high valuation of energy efficiency holds also in rental properties with energy efficiency as important as price and location for owners and tenants (Franke and Nadler 2019). Energy ratings were considered more strongly by owners, suggesting a need for better communication of financial implications of energy ratings for tenants. While willingness to invest in energy efficiency improvements have been considered, DC has also been used to examine consumer factors impacting retrofit choices. Damigos et al., (2021) found energy vulnerability and sociodemographic factors impacted household preferences between hypothetical selection between three alternative energy interventions, namely a retrofit, heating system upgrade and appliance upgrade.

Adaptations to DC approaches have also been examined. Petrovich et al., (2019) examined homeowner preferences towards retrofitting properties with solar panels using an adaptive choice-based conjoint analysis (ACBC). This approach considers knock out criteria or cut off rules to reduce the number of options consumers consider when making choices and mimic real-life scenarios. The use of ACBC designs have been found to be more engaging by participants and have lower standard errors than typical choice-based analyses (Cunningham et al. 2010). Aesthetics and peer adoption increased likelihood of own adoption for consumers.

Table 7 presents the related works on discrete choice analysis in a series of different aspects that form the consumers' behaviour. There has been a significant amount of research in the last years in the domain in different scenarios and locations hence the results in the table can offer a holistic view in the discrete choice analysis.

Table 7: Summary of relevant Discrete Choice Analysis

Reference	Research Question	Location	Area	Results
Conte & Jacobsen (2016)	Examined consumer and program factors impacting participation in voluntary green electricity programs	US	Energy Source	Both consumer education and cost of the programme contributed to participation.
Huh et al., (2015)	Examined customers' preferences and WTP for enhanced electricity services.	South Korea	Energy source	Energy bill and energy type were the most important factors when choosing energy source. Customers were WTP 2.2% more for increased renewable energy sources.
Goett et al., 2000	Examine attitudes and WTP for renewable energy and associated attributes including sign-up bonuses, type of renewables, billing options, bundling with other services and charitable contributions.	US	Energy source	Consumers reported interest in renewables. Consumers preferred hydro or mixed energy sources in comparison to wind.
Borchers et al (2007)	Examined consumers attitude to different energy sources, specifically wind, solar, biomas and farm methane.	US	Energy source	Consumers preferred solar to wind or a generic “green” energy source.
Navrod & Braten (2007)	Sought to examine consumer preferences towards energy sources including, wind, hydro and gas.	Norway	Energy source	There was a preference for domestic wind farms over imported coal. Low willingness to have windfarms near own neighbourhoods was noted.
Gracia et al., (2012)	Examined preferences towards wind, solar and biomas energy sources	Spain	Energy source	Preferences were highly heterogenous.
Kosenius & Ollikainen (2013)	Examined consumer preferences in energy sources	Finland	Energy source	Wind was the most popular source. Regional differences between rural and urban communities were found.
Kaenzig et al., (2018)	Examined consumer views of nuclear, coal and renewable energy sources.	Germany	Energy source	Cost and energy type were the most important energy attributes for consumers.
Kim et al., (2020)	Explored public WTP for decreased air pollution, convenience, energy security and greenhouse gas emissions.	South Korea	Energy Source	Greatest WTP was observed for enhanced energy security, for which WTP was near double the second highest WTP (residential ease). While respondents were willing to pay for each, lowest WTP was reported for reductions in air pollution.

Scarpa & Willis (2010)	Examined WTP for renewable utility energy sources including solar thermal, pellet, heat pump, micro-wind, biomas boilers and solar photovoltaic.	UK	Energy source	While there was some WTP, it was insufficient to cover capital costs.
Nesbakken (2001)	Examined the relationship between energy consumption and heating technology.	Norway	Household heating	Cost, both operational and up-front, impacted household choices. Household characteristics also impacted.
Braun (2010)	The impact of building, socio-economic and regional characteristics on residential heating choices were examined.	Germany	Household heating	Building features and geographical region each impact the choice of heating system. Income was observed to have a small effect only.
Rouvinen & Matero, (2013)	Examined the impact of heating device features on resident heating choices when renovating.	Finland	Household heating	Purchase price was the primary factor impacting consumer choice, though non-financial aspects also contributed. 75% of respondents would seek an alternative system to the one they currently use.
Ruokama (2016)	Examined factors impacting hybrid household heating system choices, specifically district heat, wood pellet, storage heaters and heat pumps.	Finland	Household heating	Participants reported acceptability of hybrid energy systems, though views were impacted by age, household characteristics and education. Rural habitants were less likely to consider the space requirements. Older respondents were less likely to alter their heating system. Willingness to invest in hybrid technologies was impacted by operating cost and comfort.
Chen (2021)	Examined factors influencing household heating choices in rural residences.	China	Household heating	A preference for high quality, low-cost options was noted. Energy specific attributes (safety and smoke), Income, education, household structure and location impacted choices.
Zha et al., (2020)	Examined consumers' attitudes towards refrigerators and washing machine features when purchasing.	China	Appliance selection	For refrigerators respondents preferred foreign brands and lower energy ratings. For washing machines most preferred low price, low energy products. Highly educated and younger respondents were less likely to be aware of energy ratings.

Vaage (2000)	Examined household energy demand in Norway.	Norway	Appliance selection	Energy prices significantly impacted both appliance choice and energy demand.
Brent & Ward, (2018)	Sought to examine the role of financial literacy on the purchase of energy consumer durables	Australia	Appliance Selection	Results suggest financial literacy as a driver of low investment in energy efficiency, with greater Financial Literacy influencing WTP and makes choices more consistent with standard preference models
Lang & Lanz, (2020)	Examined residential consumers WTP for energy efficient and low-carbon technologies.	Switzerland	Efficiency improvements	Home-owners average valuation of energy efficiency exceeds heating cost savings suggesting a role of a non-cost benefit. Information about private and pro-social benefits had minimal impact on WTP. Limited willingness to invest in new technologies was found.
Petrovich, Hille & Wustenhagen, 2019	Examined the preferences of property owners towards retrofitting properties with solar panels.	Switzerland	Efficiency improvements	Aesthetics and peer adoption impacted likelihood of own adoption. Those in the premium segment highly valued aesthetics, were willing to pay for visual integration, and were more ecologically concerned than those seeking value.
Franke & Nadler (2019)	Examined the impact of energy efficiency on owner and tenant perspectives on energy ratings and the impact on housing choices.	Germany	Efficiency improvements	Energy efficiency was highly important to both groups, matching the importance of rental price and location. Owners were much more aware of energy rating certificates and considered them more strongly.
Lang et al., (2021)	Examined owners' decisions to replace heating appliances and tenants valuation of energy improvements in the context of rent increases.	Switzerland	Appliance selection	Tenants were willing to accept a rent increases for increased energy efficiency on average. Found that it is not sufficient to incentivise landlords to renovate, rather the financial implications of renovations should be carefully communicated to tenants.
Arpan et al., 2018	Impact energy promotional messages framing and individual moral concern on message evaluation and WTP.	US	Renewable energy programmes	Political orientation as the most consistent predictor of WTP

Damigos et al., (2021)	This study seeks to examine the impact of energy poverty on household preferences in energy efficiency investment decisions across alternative energy interventions, namely a retrofit, heating system upgrade and appliance upgrade.	Greece	Efficiency improvements	Both energy vulnerability and sociodemographic characteristics impacted household preferences.

5.1.4 Serious Games

Serious games are an interactive environment which aims to support behaviour, attitude or knowledge development, while supporting user fun and engagement. Such games provide a safe environment for consumers to explore the impacts of their behaviour and actions (Johnson et al. 2017), with the distinguishing aim of supporting engagement through inclusion of feedback, competition, goals or similar game strategies. A game-based approach is intended to support greater emotional involvement (Torre et al. 2021). Common elements within serious games include the provision of feedback, challenges, social engagement, sharing with peers, rewards, leader boards and rankings (Johnson et al. 2017). Two sub-types of serious games have been noted, namely simulation-oriented and education-oriented (Wu et al. 2020). Simulation-oriented games are those in which the real-life contexts in which the activity takes place are mimicked in an attempt to increase the validity of findings. Education-oriented games alternatively focus on the provision of information related to a specific topic and support users in gaining knowledge. A limitation of simulation oriented serious games includes the lack of generalizability from simulated environments to real-world settings (Wu et al. 2020). For example, those games set in office environments may not impact residential behaviour, etc. However, where simulated environments match the environments in which the behaviour change is hoped to occur, generalization is anticipated. A further limitation of Serious games is their cost to develop, as many versions in response to user feedback are required (Boem, 1988), particularly for educational oriented serious games. A number of approaches have been developed to support the creation of serious games. One such framework is that of Oja and Riekki, (2012). This fourth-dimensional framework was developed to support educational game design and evaluation. The four steps include determining user requirements, determining and embedding learning outcomes, planning for user engagement and establishing the learning context.

The role of serious games in energy consumption has been established (Johnson et al. 2017, Wu et al. 2020). Serious Games have primarily been used to support energy education, consumption awareness and pro-environmental behaviour (Morganti et al. 2017). Wu et al., (2020) conducted a review of the literature examining the use of serious games in energy consumption. 21 serious game projects were found between 2009 and 2018. Results suggested a positive impact of serious games on residential energy use, while maintaining a fun and interactive environment. Advantages of serious games highlighted included the ability to visualise energy data, the creation of consumer coalitions to increase competition or collaboration across users and user encouragement of others participation. While past systematic reviews suggest a positive role for such games, research to date has primarily been exploratory. Further concerns regarding the reliability and validity of findings in this area have been raised due to reported weaknesses in experimental design (Johnson et al. 2017, Morganti et al. 2017). This suggests a need for additional quantitative and qualitative research. Specifically, additional analysis of the impact of different game elements, demographic factors and long-term effects has been noted found (Johnson et al. 2017). Different housing contexts (particularly those in which the user may have limited agency over energy use), and user inclusion in game design have also been highlighted as areas in need of further analysis (Boomsma et al. 2018). In terms of experimental design, past research was found to primarily rely on self-reported outcomes suggesting a need for more robust analysis. Further, a need for qualitative analysis of experiences and impacts is highlighted. Past Horizon 2020 projects in this space have also highlighted areas for future investigation. Casals et al., (2020) highlighted issues with participant attrition, game understanding, lack of engagement and ecological validity.

More recently serious games have sought to include objective measures of behaviour to support their impact in real world settings. Fijnheer and van Oostendorp (2016) suggest a need for objective real-life energy use data to be included within serious games to support generalisation of effects into real-life. Pasini et al., (2017) examined user engagement interventions for occupant energy behaviours including direct measurement through sensors. AlSkaif et al., (2018) noted the potential for smart meters to be combined with serious games to enhance energy efficacy intervention effects through engagement. As such, while research suggests positive effects of serious games, further analysis of how best to include objective measurement is ongoing.

A number of relevant serious games have been developed (See Wu et al. 2020) for a comprehensive list) some of which key studies are shown in Table 8 below. Serious games have been effectively employed to support increasing understanding of the complex systems involved in supporting communities to transition to renewable sources (Ouariachi and Elving 2020), increase consumer energy efficiency through increasing awareness of energy use (Casals et al. 2020, Smale and Kloppenburg 2020) and providing education (Cooremans and Schönenberger 2019, Torre et al. 2021).

Table 8: Summary of relevant Serious Games

Reference	Serious Game	Location	Area	Results
Ouariachi & Elving, (2020)	We-energy game: a serious game in which the difficulties and urgencies in providing renewable energy for a town are examined through players assuming roles and negotiating to achieve set goals.	Netherlands	Renewable Energy Sources	The potential role of university settings to develop the knowledge and awareness of younger generations, in anticipation of impacting future behaviour, is suggested.
Smale & Kloppenburg, (2020)	Platforms in Power: Used serious-game style workshops to examine how households interact with energy platforms, which were defined as digital platforms in which household's manager energy consumption, exchange and storage across members.	Netherlands	Residential Energy Consumption	Participants were motivated to engage with platforms to identify energy consumption behaviours or suggestions. Moderate interest in using such a platform to share energy use or for energy justice was found.
Cooremans et al., (2019)	This study presents a serious game to support training and capacity building on energy efficiency. Within this game individuals play to role of an energy manager, who is delivering an energy efficiency project.	Switzerland	Energy Efficiency Training	The game scored highly in usability; however no empirical analysis of effects occurred.
Casals et al., (2020)	This study outlines the lessons arising from the H2020 EnerGAware project, in which a serious game was developed to reduce energy consumption in social housing.	United Kingdom	Energy Consumption	Positive effects on awareness and engagement in energy saving behaviour and some electricity and gas savings. The serious game had limited impact on behaviour change, with small differences found between experimental and control conditions over time.
Lanezki et al., 2020	Changing the game – Neighbourhood: Serious Game for energy consumption named.	Germany	Energy Sources	Found a co-design approach, in which stakeholders were involved in development, effective in expanding learning content, balancing difficulty and ensuring suitability of the serious game. Co-design occurred across content development, playability, and usability testing.

(Mylonas et al. 2017)	GAIA project: Based within an education environment in which students, staff and parents identify opportunities for energy waste reduction is education buildings. H2020 funded	Italy, Sweden, Greece	Energy Use	Energy savings of between 15-20% were attained. Researchers highlighted the importance of competition to support student engagement.
Bekebrede et al., (2018)	Go2Zero: A serious game for decision making stakeholders in cities in which alternate strategies in reducing carbon emissions are examined. H2020 funded	Netherlands, Croatia, United Kingdom, Spain Italy Germany	Energy Sources	Good usability and representation of the complexity of the topic was reported. Users reported feeling increased understanding of the topic following use.
Mancebo et al., (2017)	The Green BPMS-Game: A game which seeks to motivate employees to comply with energy efficiency initiatives they interact with within their work.	Spain	Employee Energy Behaviour	Protocol for evaluation only reported

6. Related projects

This section includes an overview of the projects that are related to EVIDENT. In this direction, twenty one projects have been identified and are focused on assessing and improving energy efficiency through a series of interventions, behaviour improvement, collaboration, and adoption of good practices.

6.1 Related projects overview

SHAPE ENERGY (https://shapeenergy.eu): Social Sciences and Humanities for Advancing Policy in European Energy project focused on developing the EU's expertise in using and applying energy-related social sciences and humanities. A platform was developed aiming to unite stakeholders associated with energy-related research towards developing practical initiatives. In this direction, many activities have been designed to facilitate discussion and collaboration towards shaping the EU energy agenda. The platform facilitates the building and sharing of a deep understanding of what is needed and what is possible, as well as stretching collective ambition. SHAPE ENERGY project spans a wide range of sciences, such as business, communication studies, demography, economics, education, environmental social science, history, human geography, law, philosophy, psychology, science and technology studies, sociology, social anthropology, social policy, and theology.

START2ACT (https://start2act.eu/): Engaging European Start-ups and Young SMEs for Action for Sustainable Energy project focuses on reducing residential energy consumption through modifying the consumers' behaviour in their everyday lives, by approaching them at their workplace. With a focus on EU start-ups and young SMEs, START2ACT highlighted the potential of energy savings through a set of innovative educational and capacity-building measures. A key intervention area is the behavioural change regarding the use of office equipment where START2ACT aims to leverage many available solutions and tools that offer great potential for energy and money savings. In addition, START2ACT aimed to trigger sustainable procurement of office equipment connected to the operation of an organization, including the selection and furnishings of premises (e.g., lighting, heating, ventilation, etc.). In this direction, every organization or institution can contribute to and/or benefit from START2ACT's activities.

FESTA (http://www.festa-project.eu/): Fostering Local Energy Investments in the Province of Matera project is concerned with fostering local energy investments on public buildings and spreading the PPP approach through innovative Energy Performance Contracts (EPC) in convergence regions. To this end, FESTA will a) define the technical, financial, legal, and administrative specifications of a package of investments that are economically sustainable and attractive for private investors, b) assess a PPP scheme and define an EPC model for the energy efficiency of public buildings, also to create a better condition to renewal this aged (> 30 years) buildings, c) publish the call for tender and to procure the bundled investments through EPC and sign the investment contracts, d) become a best practice for the mobilization of local energy investments of the area where municipalities are preparing the SEAPs, and e) to share all this advances with local actors and other EU stakeholders.

EeMAP (https://energyefficientmortgages.eu/): Energy Efficient Mortgages Action Plan project delivered a standardized framework based on a market benchmark to stimulate energy efficiency investments in

the EU's housing stock through a private banking financing mechanism. The main project outputs consist of a framework for creating an energy passport, as well as recording the energy efficiency history of a property by recognizing the improvements made, a framework that can integrate the "green value" of a property through the collected market data, and the framework for an energy efficiency mortgage product. The underlying methodology incentivizes the acquisition of energy-efficient properties or the improvement of the energy efficiency of existing properties by way of preferential financing conditions linked to the mortgage. The Energy Efficient Mortgages Initiative is designed on the premise that the banking industry has the potential to play a game-changing role in supporting the EU in meeting its EU energy savings targets and delivering on its COP21 commitments by bringing energy efficiency into the conversation with potential borrowers and then financing the operation.

EMPOWERING (https://www.empowering-project.eu/): Empowering Local Public Authorities to Build Integrated Sustainable Energy Strategies project aims to bridge the gap of skills needed to plan energy measures in the new 2030 framework for Climate and Energy Policy in terms of greenhouse gas emission reduction, renewable energy, and energy efficiency. The main actions include the development and sharing of alternative technologies, taking into account that the benefits of a global consensus to reduce greenhouse gas emissions that will be multi-facetted for the environment, the quality of human life, and the sustainability for the next generations. EMPOWERING aims to address energy-saving challenges involving local municipalities and regional authorities in sound transnational exchange and learning activities. The improved knowledge and competencies of local authorities will be put into practice during the development of the mitigation part of SECAPs and in the upgrading of the existing SEAPs, while regional authorities are supported in shaping regional energy vision to 2050 highlighting the main energy challenges and identifying possible financial strategic actions to be implemented.

EEPLIANT (https://www.eepliant.eu/): Energy Efficiency Compliant Products projects main aim was to assist in delivering the intended economic and environmental benefits of the Ecodesign Directive 2009/125/EC and the Energy Labelling Directive 2010/30/EU, by strengthening market surveillance and increasing compliance with the Directives and the relevant implementing measures. The project objectives were achieved through the joint monitoring, verification, and enforcement activities of fifteen Market Surveillance Authorities and one national agency. The consortia of the three EEPLIANT actions, which are comprised of Market Surveillance Authorities and National Agencies, have been carrying out coordinated market surveillance actions across different product sectors. They have been reviewing and testing the energy performance of the various appliances, such as air conditioning, ventilation, heaters, refrigerators, and lighting. These products are being sampled from the market following a risk-based approach. In case of any non-compliance found, the market surveillance authorities took appropriate enforcement action on their own markets.

COMBI (https://combi-project.eu/): Calculating and Operationalising the Multiple Benefits of Energy Efficiency Improvements in Europe project aimed to identify and address several knowledge gaps towards developing more cost-effective energy efficiency policies and optimized long-term strategies in the EU. In this direction, five main innovations were leveraged: a) data gathering on energy savings and technology costs per EU country for the most relevant 20 to 30 energy efficiency measures in the residential, commercial, industrial, and transport sectors, b) development of adequate methodologies for benefit

quantification, monetization, and aggregation, c) quantification of the most important benefits, d) development of an openly available calculation tool that greatly simplifies the evaluation of co-impacts for specific energy efficiency measures to enable decision-making, and e) development of a simple online visualization tool for customizable graphical analysis and assessment of multiple benefits and data exportation. Project outcomes will help relevant stakeholders to define cost-effective policies and support policy-makers in the development and monitoring of energy efficiency strategies and policies in the future.

PROFIT (https://projectprofit.eu/): Promoting Financial Awareness and Stability project's goal was to promote financial awareness and improve the financial capability of citizens and market participants. To this end, a platform was developed that supports the following functionalities: a) personal financial educational toolkits available to the wider public, b) crowdsourcing tools that will process financial data and extract and present collective knowledge, c) advanced forecasting models that exploit the market sentiment to identify market trends and threats, d) novel personalized recommendation systems to support financial management according to the user's profile. The project outcomes will assist the identification of vulnerable customer groups, for which financial literacy training can improve real outcomes, lead to the establishment of novel training programmes and toolkits for specific customer groups, and carry out financial risk assessments and actions focused on these groups.

ENERGee Watch (https://energee-watch.eu/): Peer to peer learning in regional and local authorities to timely and accurately define, monitor and verify their sustainable actions is a European project featuring a peer-to-peer learning program that enables regional and local authorities to properly define, monitor, and verify their sustainable actions. The learning will focus on regional/provincial authorities and their agencies to empower them to make use of best practices. In this direction, ENERGee Watch will enable the sharing of experiences between regional/local public authorities in the field of energy, collaborate with European organizations for defining methodologies suited to local needs, and evaluate the European energy policies. The regional observatories will contribute strongly towards building a representation of the regional impact on climate change and a framework for identifying areas of responsibilities and priorities for action.

FEDARENE (https://fedarene.org/): European Federation of Agencies and Regions for Energy and Environment is the premier European network of local and regional organizations which implement and coordinate energy and environmental policies. The main focus of FEDARENE is to promote the exchange of experience and the development of transnational projects. Multiple local and regional agencies, governments, and departments working in relevant fields are represented in FEDARENE. As a result, the diversity of members implies that there is a wide range of expertise, therefore providing solutions to all energy and environmental concerns. Through the organization of events and networking activities, FEDARENE unites European organizations to share know-how, develop projects, and replicate successful initiatives. Furthermore, it provides a discussion forum, as well as a collaboration platform, for energy stakeholders, such as public authorities, non-governmental organizations, citizens, SMEs, and institutions.

EnerGAware (http://www.energaware.eu/): The main objective of the Energy Game for Awareness of Energy Efficiency in Social Housing Communities project was to decrease energy consumption and

emissions in an affordable housing pilot and increase the affordable housing tenants' understanding and engagement in energy efficiency. In this direction, the EnerGAware project developed and validated a serious game that will be linked to the actual energy consumption player's home and embedded in social media and networking tools. Furthermore, the EnerGAware solution delivered an innovative ecosystem, where users can play and learn about the potential energy savings from adopting energy-efficiency measures while modifying their behaviour. Through this gamified approach, the users can learn how to balance energy consumption, comfort, and financial costs. Energy savings achieved both virtually, in the game, and at the users' homes will enable progression in the serious game. Finally, the social media features enable users to share their achievements, compete with each other, advise, and form virtual energy communities.

2020Energy (http://www.2020energy.eu/): The main objective of 2020Energy is to create a serious game and 1) introduce the concept of sustainable development and the associated vocabulary: economic, social, environmental, equitable, liveable, bearable, sustainable, 2) to raise awareness to the reduction of energy consumption, improvement of energy efficiency and promotion of renewable energies and 3) to get aware of the issues at the individual, local and global levels. The developed game addresses 9 scenarios from energy saving to energy renewables.

NUDGE (https://www.nudgeproject.eu/): Nudging Consumers towards Energy Efficiency through Behavioural Science project aims to design interventions that will result in lasting energy efficiency behaviour. In NUDGE, a broad range of methodologies and tools are leveraged, namely field experiments and surveys to assess the intervention impact coupled with randomized control trials to assess the effectiveness of the interventions. A mix of multiple approaches will be employed, including qualitative and quantitative research methods, stakeholder consulting, as well as the collection of pilot data and translation into meaningful Key Performance Indicators (KPIs). The research and experimentation are focused on the design of policies and the formulation of specific recommendations. Furthermore, behavioural science methods will be utilized to study the bases of individual behaviour and adapt the corresponding intervention. These new interventions will be tested in different EU states, presenting targeted variables, involved demographics, and intervention forms.

inBETWEEN (http://www.inbetween-project.eu/): ICT Enabled Behavioural Change towards Energy Efficient Lifestyles will leverage ICT for the user behaviour change towards creating more energy-efficient lifestyles. The utilized will assist users in identifying energy wastes, teach them how more energy can be conserved, and motivate them to act accordingly. A user-centric approach is applied throughout the project including aspects from the 'theory of social practice'. Apart from detecting energy-saving opportunities and offering incentives for behaviour change, a significant part of the motivation aspect will also be associated with the ability and means to act through the InBetween solution. InBetween will deliver a collaboration platform offering advanced energy services, that brings added value without significant disruption of everyday activities. The platform enables users to integrate their monitoring devices with advanced energy analytics and optimization services. Through these analytics, a comprehensive recommendation and feedback solution will be developed that will further facilitate and motivate the behaviour change.

ENCHANT (https://cordis.europa.eu/project/id/957115): Energy Efficiency through Behaviour Change Transition Strategies project aims to assess existing knowledge, analyse available data in the field and design realistic intervention programmes, applying them in six EU member states. This intervention program will evaluate a large selection of intervention types addressing a large variety of psychological biases alone or in combination and evaluates their realistic saving potentials. The knowledge created in the ENCHANT project will be implemented into an algorithm-based web application for supporting the decision-making of energy stakeholders, policymakers, regional authorities, and municipalities in designing effective and targeted energy efficiency campaigns.

WHY (https://www.why-h2020.eu/): Climbing the Causality Ladder to Understand and Project the Energy Demand of the Residential Sector project will integrate causal modelling to quantitatively analyse people's everyday decisions in terms of energy consumption and reactions to relevant interventions. This will lead to innovative methodologies both for short-term and long-term load forecasting, which will be benchmarked across several heterogeneous use cases. Additionally, the WHY toolkit will be used to assess several scenarios simulating different policy measures. In general, the project aims to provide greater insight into household energy consumption and improve energy demand modelling in leading energy system models.

CONSEED (https://www.conseedproject.eu/): CONSumer Energy Efficiency Decision Making aims to understand the decision-making process of consumers involving energy utilities and to highlight the impact of an energy utility operating costs towards improving the consumer behaviour. In this direction, a theoretical framework was developed using the available knowledge, while empirical data on consumer behaviour were collected using field experiments, consumer surveys, and experiments. The empirical data were used to validate the theoretical framework and provided evidence-based research regarding consumer decisions when buying an energy utility. Furthermore, research indicates that many of the challenges relating to energy efficiency policies derive from the large number of factors that potentially play a role in influencing consumer decisions. The importance, as well as the relationships among these factors, were investigated, while the aspects that are likely to provide the greatest impact in terms of future energy efficiency policy were extracted.

BRISKEE (https://www.briskee-cheetah.eu/briskee/): Behavioural Response to Investment Risks in Energy Efficiency carried out a large survey of multiple European households in order to analyse the investment behaviour and extracted empirical evidence of the factors underlying the implicit discount rates and their relation with the adoption of energy-efficient technologies. BRISKEE considered consumer decision-making and its implications at micro, meso, and macro levels. At the micro level, factors influencing individual decision-making were elicited in the survey, while at the meso level, the impact of policies addressing decision-making on long-term energy demand was investigated. Finally, at the macro-level, the effects of energy-efficiency improvements on the economy were assessed. Taking into account these factors, BRISKEE modelled the diffusion of energy-efficient technologies and energy demand in the EU residential sector until 2030, as well as the macro-level impacts of changes in microeconomic decision-making and energy policies.

EVIDENT will investigate the BRISKEE reports regarding the policy implications ('D7.3 Full report on policy implications from the micro-, meso-, and macro-level analysis'), as well as the lessons learned from 'D6.1 Summary Report on Main Findings'.

CHEETAH (http://www.cheetah-project.eu/): Changing Energy Efficiency Technology Adoption in Households delivered evidence-based input in order to influence energy-efficient policy design and evaluation in the EU residential sector. To achieve this, the CHEETAH project investigated the interrelations among microeconomic factors, sectoral energy demand, and macroeconomic effects, based on a consistent methodological framework. Specifically, CHEETAH provided empirical evidence on the household response to established and new energy-efficiency policies, as well as on factors driving adoption of energy-efficient technologies, considering the differences across households, technologies, and countries. Furthermore, at the meso level, the project investigated and forecasted the impact of the energy demand in the EU residential sector until 2030. Finally, CHEETAH explored the impact of changes in microeconomic decision-making and energy-efficiency policy on employment, GDP, and exports until 2030.

PENNY (https://www.penny-project.eu/): Psychological, social and financial barriers to energy efficiency aimed to advance the understanding of consumer decisions relating to the use of energy, as well as the adoption of energy-efficient technologies. To this end, PENNY conducted field experiments through A/B testing, enhancing the design of policies towards improving energy-efficient behaviours. An extensive analysis of consumer behaviour was carried out regarding energy consumption, the investment in energy-efficient products, and the renovation of buildings. Finally, ex-ante assessment using improved energy economy models was carried out, generating quantitative information regarding the expected impacts of EU and global policies in view of the Paris climate agreement to limit global warming to 1.5-2 degrees Celsius.

PEAKapp (http://www.peakapp.eu/): Personal Energy Administration Kiosk application: an ICT-ecosystem for Energy Savings through Behavioural Change, Flexible Tariffs and Fun PEAKapp focused on the development of an ICT-to-Human ecosystem to trigger lasting energy savings through behavioural change and continuous engagement, resulting in increased consumption of clean and low-priced energy from the market. A software platform was developed in order to connect the users and facilitate their interaction with energy providers. Furthermore, the platform leverages social networks and gamification techniques to connect customers and motivate them towards energy-efficient practices. Additionally, PEAKapp integrated smart home functionalities in order to boost the efficiency of building energy consumption and energy management systems. The PEAKapp ecosystem was validated in multiple European households by leveraging behavioural science and relevant KPIs.

6.2 Results and insights for the EVIDENT project

Table 9 lists the aforementioned projects and presents a classification based on their outcomes. According to this classification, most of the reviewed projects were focused on influencing policies relevant to energy efficiency. Additionally, a considerable number of projects are concerned with the knowledge exchange

among energy stakeholders, public authorities, and organizations, as well as with the behaviour improvement of users towards minimizing energy waste and adopting energy-saving practices. Furthermore, the design of an energy efficiency assessment framework is also a common outcome among the identified projects. Finally, several projects aim to develop tools and platforms that facilitate learning and collaboration, through the use of gamification.

Table 9: Projects related to EVIDENT

Outcomes Projects	Policy Influence	Knowledge Exchange	Empirical Research	Behaviour Improvement	Assessment Framework	E-Learning Tools	Collaboration Platform	Gamification
SHAPE ENERGY	✓	✓						
START2ACT				✓		✓		
FESTA	✓	✓						
EeMAP	✓				✓			
EMPOWERING	✓	✓						
EEPLIANT	✓				✓			
COMBI	✓	✓			✓			
PROFIT				✓		✓		
ENERGee Watch	✓	✓					✓	
FEDARENE		✓					✓	
EnerGAware				✓		✓		✓
2020Energy				✓		✓		✓
NUDGE	✓		✓	✓				
ENCHANT			✓	✓	✓	✓	✓	
inBETWEEN				✓			✓	
WHY	✓			✓	✓			
CONSEED			✓	✓	✓			
BRISKEE	✓			✓	✓			
CHEETAH	✓			✓	✓			
PENNY	✓		✓	✓	✓			
PEAKapp		✓		✓			✓	✓

It is apparent, that there are ample outcomes from related projects that can be exploited by EVIDENT. In this direction, the exploited outcomes can be classified into four categories, namely field experiments, lab experiments, gamification, and policies.

Lab experiments: EVIDENT consortium will leverage the outcomes of NUDGE, ENCHANT, CONSEED, and PENNY related to the lab experiments aiming to assess the role of behavioural insights in energy efficiency. In particular, consumer profiling approaches (e.g., NUDGE - 'D1.1 Profiling of energy consumers: psychological and contextual factors of energy behaviour', PENNY – 'D2.2 Energy efficient behaviour and

the underlying processes') will be investigated, while the consumer energy efficiency awareness will be evaluated (e.g., PENNY - 'D3.1 Energy literacy and the level of energy efficiency'), towards identifying the nature of behavioural biases and literacy in Task 1.2 - Behavioural biases and financial literacy.

Field experiments: EVIDENT will also consider field experiments related to the energy efficiency that were carried out in the context of CONSEED, inBETWEEN, and EnerGAware. Specifically, the design and implementation of trials will be investigated (e.g., CONSEED - 'D4.1 Report on Field Trial Evidence on the Effectiveness of Providing Information on Energy Costs and Energy-related Decisions in Households' and inBETWEEN - 'D4.1 inBETWEEN Methodology for Implementation') in the context of Task 2.1 - Design of RCT and surveys protocols for the pilots and all task in WP3 - Intervention preparation and execution.

Gamification: In the context of EVIDENT, the consortium will explore public materials from the EnerGAware and 2020Enegy projects that leverage gamification technologies to elicit the incentives of the home users regarding the electrical energy usage, intends to increase the housing tenants' awareness regarding energy efficiency and consumption, introduce concepts such as the sustainable developments. Related approaches and methodologies (e.g. EnerGAware - 'D2.3 Game Requirements', 'D3.1 Game Design and Software Specifications and Architecture', and PEAKapp - 'D1.4 Documentation of functionalities – Serious Game specification'), as well as prototypes (e.g., EnerGAware - 'D3.2 Serious Game Early Prototype' and PEAKapp - 'D2.2 The Smart phone/tablet app') related to energy consumption scenarios will be investigated during the design and the development phases of the EVIDENT gamification engine that will take place in the tasks of WP2 - Policy intervention and pilots design and more specifically in T2.2 - Serious game for energy efficiency.

Policies: The design and evaluation of policy interventions are core objectives of the EVIDENT project. To this end, prior policy interventions (e.g., inBETWEEN - 'D3.11 List of intervention and the associated demand reduction', PENNY - 'D2.3 Report on innovative interventions aimed at facilitating the adoption of energy efficient products' and NUDGE - 'D5.4 Compilation of provided policy briefs') and methodologies that analyse policy impacts (e.g., COMBI - 'D6.1 Literature review on macroeconomic effects of energy efficiency improvement actions' and 'D8.2 Full Policy report: Multiple impacts in policy making and evaluation', NUDGE - 'D2.2 Research methodology for assessing the effectiveness of interventions regarding change of energy-efficient behaviour' and PENNY - 'D4.2 Scenarios and analysis of policy interactions in the EU') will be examined towards the implementation of WP5 - Policy measures and more specifically in Task 5.1 - Impact evaluation plan and policy measures.

7. Initiatives related to energy efficiency

This section includes an overview of the initiatives related to energy efficiency considered relevant with the scope of EVIDENT. In this direction, six initiatives have been identified and are focused on data and best practices sharing, fostering the creation of networks of experts, policy implementation and funding.

7.1 Initiative's overview

EEEF (https://www.eeef.lu/) **European Energy Efficiency Fund** is an innovative public-private partnership aiming at supporting the achievement of EU climate goals European Union (EU 2030 Climate Target Plan to cut greenhouse emissions by at least 55% by 2030 and to achieve climate neutrality by 2050), promoting a sustainable energy environment and enabling projects in European cities, regions and communities to build resilient, energy efficient and green infrastructure. The EEEF focuses on financing energy efficiency, small-scale renewable energy, and clean urban transport projects (at market rates) targeting municipal, local and regional authorities and public and private entities acting on behalf of those authorities. In particular, the EEEF facilitates sustainable investments for viable and financially-sound projects often hindered or decelerated. Investors backing the funding are the European Commission, the European Investment Bank, Cassa Depositi e Prestiti[2], Deutsche Bundesstiftung Umwelt[3] and DWS[4]. Based in Luxembourg, the EEEF funds has funded projects in several EU Member States such as France, Germany, Italy, Lithuania, Netherlands, Portugal and Spain.

EECG (Energy Community Homepage (energy-community.org)) **Energy Efficiency Coordination Group** is a regional coordination platform that steers the implementation of the energy community energy efficiency. Its key task is to facilitate the transposition of transnational energy efficiency acquis into the national level and to support the effective implementation in practice. In addition, the EECG coordinates and acts as implementation partner of diverse regional technical assistance and investment programmes. The EECG includes representatives from ministries and agencies in charge of energy efficiency, the European Commission and a community of donors such as the European Bank for Reconstruction and Development, the World Bank, etc.

BUILD UP (https://www.buildup.eu/en) the **European portal for energy efficiency in buildings** was established by the European Commission in 2009 to support EU Member States in implementing the

[2] Cassa Depositi e Prestiti is an Italian joint-stock company under public control managing a major share of the postal savings of Italians to help support the growth of the country, providing financing to major strategic sectors.
[3] German private foundation aiming at promoting innovative, exemplary and solution-oriented projects for the protection of the environment, with particular emphasis on small and medium-sized enterprises.
[4] Formerly known as *Deutsche Asset Management*, it is a German asset management company principally owned by Deutsche Bank.

Energy Performance of Buildings Directive[5] and it is funded and managed by the Executive Agency for Small and Medium-sized Enterprises (EASME) on behalf of the European Commission. The portal is intended to collect and disseminate knowledge on energy reduction in buildings for the benefit of all relevant audiences, bringing together new practitioners and professional associations with the aim to exchange best practices and knowledge and to transfer tools and resources. BUILD UP targets professionals working in the building sector (public or private) with an interest on the latest developments at technical or practice level, policy legislation, financial issues, etc. related to energy efficiency.

E3P (https://e3p.jrc.ec.europa.eu/) **European Energy Efficiency Platform** is a tool provided by the European Commission (Joint Research Centre) to facilitate knowledge exchange in the online community of energy efficiency experts. The platform is meant to engage experts from Europe and beyond, bringing together knowledge from different stakeholders (research, industry, policy, NGOs) and supporting policy-makers at all levels, from local, to regional, national and EU level by providing a one-stop platform for the collection and analysis of scattered data relevant for energy efficiency. The core features of the E3P are two mutually reinforcing collaborative tools, both aiming at supporting the development, the implementation and the monitoring of energy efficiency policy: the Data Hub[6], a one-stop-shop for the collection of data and the wikEE[7] for experts' collaboration.

PF4EE (https://www.eib.org/en/products/mandates-partnerships/pf4ee/index.htm) **Private Finance for Energy Efficiency** is an instrument is a joint agreement between the European Investment Bank (EIB) and the European Commission which aims to address the limited access to adequate and affordable commercial financing for energy efficiency investments needed for the implementation of National Energy Efficiency Action Plans or other energy efficiency programmes of EU Member States. It is managed by the EIB and funded through the Programme for the Environment and Climate Action (LIFE programme). The two core objectives of the initiative are:

- to make energy efficiency lending a more sustainable activity within European financial institutions, considering the energy efficiency sector as a distinct market segment; and
- to increase the availability of debt financing to eligible energy efficiency investments.

The initiative is already in operation in several Member States: Czech Republic, Spain, France, Belgium, Italy, Portugal, Croatia, Greece, Cyprus, Poland and Latvia.

EEFIG (http://eefig.eu/) **Energy Efficiency Financial Institutions Group** was established in 2013 by the European Commission (Directorate General for Energy) and the United Nations Environmental Programme Finance Initiative (UNEP FI). The group addresses barriers to energy efficiency financing

[5] OJ L 153, 18.6.2010, p. 13–35
[6] https://e3p.jrc.ec.europa.eu/more-about-data-hub
[7] https://e3p.jrc.ec.europa.eu/about/news-section

through both policy design and market-based solutions to increase the scale of energy efficiency investments across Europe. Composed of over 300 representatives from more than 200 organisations. Through a multi-level stakeholder dialogue, working groups identify opportunities and barriers in the long-term financing for energy efficiency, and propose policy and market solutions. A consortium of energy efficiency finance experts is supporting and coordinating work across EEFIG working groups, organise events and workshops and update the members and the public through various communication channels.

7.2 Results and conclusions

Table 10 lists the aforementioned initiatives and presents a classification based on their areas of influence. According to this classification, most of the reviewed initiatives were focused on the creation of networks of experts in energy efficiency, although initiatives in the areas of data sharing, policy implementation and funding are also significantly represented.

Table 10: Initiatives related to EVIDENT

Areas Initiatives	Data sharing	Network of experts	Policy implementation	Funding
EEEF				✓
EECG		✓	✓	
BUILD UP	✓	✓		
E3P	✓	✓		
PF4EE				✓
EEFIG		✓	✓	

A common element of initiatives mentioned in section 7.1 is that they all entail the involvement of multiple stakeholders, providing opportunities for the EVIDENT project.

For example, the collaboration tools of the European Energy Efficiency Platform (E3P) can provide EVIDENT with access to expert knowledge, and the experts themselves, while the platforms can be used to disseminate the results of EVIDENT.

Furthermore, when formulating the policy insights based on the results from the underlying research of the EVIDENT project, initiatives such as the European Energy Efficiency Fund (EEEF) and the Energy Efficiency Coordination Group (EECG) can show both the funding opportunities, and provide as guides for realistic policy options.

The EVIDENT consortium partners will be monitoring the activities of the above initiatives, and will be inviting their representatives to the project's events, while activity seeking mutually beneficial collaborations. These activities will be listed in future EVIDENT deliverables.

8. Conclusions

This deliverable is regarded as an initial sketch for the roadmap to be followed by EVIDENT. Overall, it discussed the current advances in the area of field and quasi experiments in energy efficiency, and existing developments in EU-funded projects and other types of initiatives. It attempted to set the ground to the design and implementation of the use cases to be introduced by the EVIDENT in the area of energy efficiency.

The state-of-the-art sections of this report included overviews of methods, tools and fields of science relevant to the EVIDENT project. More, elaborative reviews and analyses will be performed in the respective deliverables of each unique research and development pillar of EVIDENT.

Regarding the structure, this deliverable was divided into two main parts. The first part reviewed the best current practices in the academic agenda regarding field and quasi experiments for energy efficiency and provides an overview of research details and related outcomes. The main purpose of the first part was to give the reader (incl. the EVIDENT energy utility and policy-related partners) the understanding of what is the current state of the art (i.e., capabilities, limitations) and to present the novel insights of the methods and toolkits to be developed within EVIDENT.

The second part of the document focused on related EU-funded projects and initiatives within the European countries. Initially, the second part reviewed related to energy efficiency EU-funded projects that are focused on assessing and improving energy efficiency through a series of interventions, behaviour improvement, collaboration, and adoption of good practices. Subsequently, it overviewed initiatives related to energy efficiency considered relevant with the scope of EVIDENT. In this direction, six initiatives have been identified and are focused on data and best practices sharing, fostering the creation of networks of experts, policy implementation and funding. The main purpose of this part was to acquaint the reader with the existing developments in the field and to present funding and collaboration opportunities, as well as guides for realistic policy options.

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