Behavioural measures for energy efficiency: key findings and policy advice from the NUDGE project

Filippos Anagnostopoulos
IEECP, Institute for European Energy and Climate Policy
Amsterdam Sloterdijk Teleport Towers
Kingsfordweg 151
1043GR Amsterdam
The Netherlands
filippos@ieecp.org

Marta Gabriel
INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering
Portugal
mgabriel@inegi.up.pt

Merkouris Karaliopoulos
AUEB, Athens University of Economics and Business
Greece
mkaralio@aueb.gr

Peter Conradie
IMEC, Interuniversity Microelectronics Centre
Belgium
peter.conradie@imec.be

Anne Kesselring
Fraunhofer ISI
Germany
anne.kesselring@isi.fraunhofer.de

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Abstract

This paper places focus on the innovative findings and forward-looking policy suggestions stemming from the Horizon 2020 NUDGE project. NUDGE has been instrumental in investigating the effectiveness of behavioural strategies to enhance energy efficiency through the implementation of randomized controlled trials (RCTs) in various residential buildings, in energy communities, and schools across five EU Member States. The project provides valuable insights, particularly on the effectiveness of innovative behavioural policy measures and interventions, with a focus on their impact in the current context of an external energy crisis. Embracing core behavioural science concepts, NUDGE employed diverse methodologies and tools to dissect participant behaviours. This thorough approach led to the creation of user profiles, tailored nudging strategies, and a rigorous analysis of their impact. The research incorporated data from user feedback and modern sensor technologies such as smart meters, mobile applications, and indoor air quality sensors in real-world experimental settings. The project's extensive research and experimental efforts have yielded policy recommendations applicable to both governmental and private entities. Notably, this work has been crucial in evaluating the potential integration of behavioural nudges into the policy frameworks of the EU and national decision-makers, providing key insights into their practicality and constraints, especially in times of energy crises. The paper explores the key takeaways from applying nudges, emphasizing significant outcomes, pinpointing areas for ongoing research, and outlining policy advice to boost energy efficiency amidst dynamic consumption patterns and the need for effective monitoring and evaluation in the context of external policy impacts.

Introduction

To achieve the EU's target of reducing energy consumption by at least 11.7 % by 2030, household participation is key. Energy use in homes varies based on ownership and financial means, with day-to-day behaviors playing a significant role in energy consumption. During Europe's 2022 energy crisis, governments encouraged households to save energy, initially focusing on gas and later on electricity. There are two main types of policies to promote energy savings: direct financial incentives (like taxes or subsidies) and strategies that promote behaviour change without financial incentives. Nudging, a method that subtly alters decision-making environments to influence choices, is one such effective strategy. The NUDGE project in the EU investigated the impact of nudges in residential settings across five countries. By conducting experiments in different energy contexts, NUDGE successfully directed consumer behaviour towards more energy-efficient practices without imposing choices on them.

SURVEY RESULTS

The NUDGE project conducted a comprehensive survey with two main objectives: to understand energy consumers' behaviors and motivations related to energy efficiency and to cat-

egorize them based on psychological and social factors influencing their energy-saving actions. This survey, involving 3,129 participants from 29 countries in 15 languages, applied three behaviour models (Theory of Planned Behaviour, Value-Belief-Norm theory, and Prototype Willingness model) to assess fifteen psychosocial factors, alongside gathering data on participants' sociodemographic background, home characteristics, energy-saving practices, and views on energy monitoring platforms.

Key findings included that most participants engaged in basic energy-saving practices like closing windows while heating, conserving water, and turning off lights. However, there was noticeable hesitancy in sharing energy data, especially with governments and third parties, while sharing with family was more acceptable. The study primarily aimed to understand the intentions behind reducing energy consumption, distinguishing between specific intentions for heating reduction and broader energy-saving goals. It found that rational decision-making (Theory of Planned Behaviour) was the predominant factor in reducing heating consumption, with moral (Value-Belief-Norm Theory) and social (Prototype Willingness Model) factors being less influential. The results indicate that energy conservation is still largely driven by practical considerations, suggesting that tools like smart meters could be effective in helping consumers reduce their energy use.

PROFILING

Based on the insights from the survey, the NUDGE project went further and was able to categorize energy consumers into distinct categories groups, each with unique traits, that have a better explanatory power and potential increase of effectiveness in tailoring messages and for campaigns like nudging. The research identified six unique groups of energy consumers:

- Environmentally Conscious and Well-Informed: These consumers are aware and proactive about saving energy. They are idealistic energy savers, offering a combination of high concern about the environment with good knowledge and strong sense of personal responsibility for action
- Concerned but Comfort-Oriented: While these consumers care about energy saving, they prioritize comfort. They do have concern about the environment, awareness of consequences but lack of know-how to practically save energy
- Concerned but Lacking Awareness: These individuals care about energy issues but lack full understanding. They exhibit clear intentions for acting in an energy-friendly manner but have a strong concern about comfort, and are concerned about the monetary cost involved in higher energy consumption
- Materialistic, Avoiding Personal Responsibility: This group is focused on material gains and doesn't take personal responsibility for energy saving. It is combining lower than average energy-saving intentions with a low anticipation of personal responsibility to act and high concern for the financial implications of energy-saving activities
- Influenced by Social Factors: The energy-saving actions of these consumers are heavily influenced by others' opinions and behaviours. They show low intentions for heating-related energy saving behaviour but strong sense of subjective norms, with no distinct differentiation in other features.
- Indifferent: This group shows little concern or interest in energy saving. It has low perception of self-efficacy and possible impact of personal action, coupled with a low concern and awareness about environmental matters.

The first group has been identified as suitable for engaging in energy-saving activities without further support. The other five groups each have specific characteristics that can either hinder their energy-saving intentions (e.g. financial concerns) or allow to suggest particular types of interventions to enhance existing intentions to save energy.

Methodology

The NUDGE project evaluated the effectiveness of energy-efficient nudging interventions using Randomised Controlled Trials (RCTs). RCTs, key to discerning cause-and-effect in behaviour changes, grouped participants either randomly or by specific characteristics in a between-subjects design. This design, which includes a control group, allows for independent group analysis and accurate behavioral comparisons. In situations like the Belgian and Croatian pilots, where RCTs weren't feasible, within-subject designs were employed. These designs, involving alternating intervention groups and a washout period, focus on long-term, multiple intervention effects.

Advanced econometric techniques were used to isolate nudging's causal impact, accounting for time-influenced factors and household differences. The "difference-in-differences" method, supported by "two-way fixed effects", was crucial for controlling variables like seasonal changes. Selecting the right evaluation strategy was essential to understand household behavioral interventions. Despite challenges from the complexity of smart meter data and the overlapping energy crisis during field experiments, these detailed evaluations were vital to assess nudging's real-life policy potential.

THE PILOTS

The NUDGE project carried out field experiments in Greece, Belgium, Germany, Portugal, and Croatia, involving 472 households to study the effectiveness of nudging in promoting energy-efficient behaviors. Utilizing real-time energy data and digital interfaces, these pilots provided households with detailed insights into their energy consumption, helping them identify efficiency improvement areas. The analysis of this data enhanced our understanding of household energy demands and the varying impacts of nudging strategies under different external conditions.

Key findings were gathered in three areas: residential energy consumption via smart meters, behaviour change through online surveys, and the effectiveness of nudging interventions via user interfaces. The data, enriched with additional details like user preferences and contextual factors, spanned over a year, including information on photovoltaic production where applicable. Aligned with NUDGE's goal, the interventions mainly focused on empowering households with real-time energy data to better understand and improve their energy usage, fostering more efficient energy behaviors.

The Greek pilot: Efficient control of heating and hot water preparation for natural gas boilers

The Greek pilot study focused on enhancing natural gas boiler efficiency for home heating. It involved 102 households across five cities, each fitted with the DOMX smart controller. This controller adjusted heating based on weather and schedules, offering up to 30 % energy savings without affecting comfort. Participants controlled their heating via a wireless thermostat and a smartphone app, which also provided detailed control and nudging features.

The Portuguese pilot: Healthy homes for long-lasting energy efficiency behaviour, and incl. air quality

The pilot in Portugal involved 101 families with children and aimed to lower their electricity consumption without compromising their comfort and health. The project included a thorough assessment of the buildings and the installation of smart meters and IAQ sensors in the homes. These devices measured electricity consumption, CO_2 levels, particulate matter, temperature, and humidity. A mobile app was designed to provide nudging interventions to the participants.

The German pilot: Optimising the use of self-produced PV power, especially for EV charging

The German pilot involved 111 households with PV systems in the Rhine-Neckar metropolitan area, who were customers of MVV Energie AG. Of these, 39 had remotely controllable electric vehicle charging stations, forming the EV group. The pilot aimed to promote energy-saving behaviours and higher self-consumption of energy among households with EVs. Two digital platforms delivered nudges: a web portal for all participants to monitor home energy usage and the HERMINE charging app for the EV group.

The Croatian pilot: Promoting distributed self-production for local energy communities

In Croatia, the pilot project was conducted to help users cope with changing regulations, reduce energy use, improve energy-efficiency at home, and find out which nudges work best to increase self-reliance and lower grid dependence. The project involved 82 consumers who had PV systems in their houses, and tracked their real-time data on electricity consumption and production. A smartphone app was designed for the pilot to deliver nudges to the participants, which aimed to foster empathy, raise awareness of energy usage, and motivate energy efficiency goal-setting.

The Belgian pilot: Interdisciplinary, project-based education of the children on home energy consumption

The pilot in Belgium aimed to promote energy-saving habits among schoolchildren and their families through educational interventions. Two cohorts of students took part in the project during the 2021/2022 and 2022/2023 academic years: an experimental group (36 in the first year, 40 in the second) and a control group (28 in the first year, 33 in the second). The project incorporated nudges into the curriculum, along with activities that showed the recent energy consumption in the students' households, which were linked to the EnergyID platform. The program addressed five main themes: home gas and other heating sources, electricity use, water consumption, electricity generation, and the notion of nudging. This pilot resulted in the development of educational booklets with useful information, graphs, and tasks.

MEASURING THE IMPACT OF NUDGES

The NUDGE project's primary aim was to evaluate various nudging strategies through five field experiments over 18 months. These experiments, conducted across five EU countries, tested 13 different nudges. Data for this assessment included continuous smart meter data on energy use and production, sensor data on indoor conditions and appliance use, interaction records from digital nudging tools, and feedback from online questionnaires. Additional data like climate and meteorological information were also considered. Various control variables were accounted for, such as baseline consumption, household characteristics, user preferences, socioeconomic status, and more. The statistical analysis aimed to determine the effectiveness of nudges in reducing electricity and heating demand, increasing self-consumption among prosumers, and enhancing energy knowledge.

Results

NUDGING EFFECTIVENESS

A summary of the NUDGE project's outcomes shows that nudging strategies for energy savings are not equally effective in all situations. The effectiveness varied not only among different pilot sites, but also within the same pilot experiment with different types of nudges. Some nudging approaches seemed to work better than others. For instance, interactive nudges achieved up to 4 % of energy savings, while automated interventions, such as smart electric vehicle charging, resulted in up to 16 % of savings for those who opted in.

However, these strategies did not always work as expected. Nudging did not always lead to significant changes in energy consumption behaviors across all groups of participants or in every context. In some cases, regardless of the country or the design of the nudge, nudging had no noticeable effect on energy use.

This implies that nudging is not a one-size-fits-all solution, but rather its suitability and impact depend on various factors beyond the nudge itself, such as engagement with the delivery channel, timing, alignment with relevant regulations and so on.

Table 1 illustrates the varying effectiveness of nudging across different settings and interventions. Dark green check marks indicate strong evidence for the effectiveness of nudging, light green checks for mixed but positive results, and orange minus symbols where evidence is weak or contradictory.

Nudging is a subtle way of shaping behaviour, but it can be easily affected by other factors. These experiments, done in real-world situations, showed that different things can influence daily choices, which might weaken the effect of nudges when used alone. Nudging works better when certain conditions are met, such as having a clear link between the nudge and its result, and having the right timing to encourage a behaviour change. But when these conditions are not there, nudges might not have a strong influence on household energy use, among many other factors that affect it.

Table 1. The varying effectiveness of nudging across different settings and interventions.

Country Pilot	Hypothesis	Result
DE1	Nudges are effective in increasing the self-consumption of participants.	✓ ✓
DE2	Nudges are more effective in increasing the self-consumption of participants with controllable electric vehicles than of the ones without.	✓ ✓
DE3	Nudges are effective in reducing the overall electricity consumption of participants.	✓ ✓
HR1a	Nudges are effective in increasing the self-consumption of participants.	✓
HR1b	Nudges are effective in increasing the self-consumption of participants.	–
BE1	The energy course positively impacts the knowledge level of (a) children attending the energy course and of (b) their parents.	–
BE2	The energy course is effective in reducing the gas consumption of the parents.	✓
GR1	Nudges are effective in reducing the gas consumption of participants.	–
GR2	Nudges are effective in reducing the heating time of participants.	–
PT1	Nudges are effective in reducing the electricity consumption of participants.	–
All1	Nudges are effective in increasing the intention to save energy of participants.	✓
All2	Nudges are effective in increasing the motivation to save energy of participants.	✓

POLICY IMPLICATIONS

Behavioural insights from psychology and behavioural economics can inform energy policy and help design 'nudges' that alter the way choices are framed and motivate people to adopt more energy-efficient and conservation-oriented behaviours. This is the main objective of NUDGE, which has tested the effectiveness of nudges for encouraging energy savings and efficiency measures under certain conditions. Nudges are also low-cost, non-coercive, and adaptable to different contexts and behaviours related to energy use and self-consumption. However, behavioural interventions also encounter some difficulties, such as targeting specific groups like high energy users, evaluating different methods for long-term impact and measuring the effects of nudges as energy policy instruments.

Based on over three years of practical research from five pilot sites, we offer several guiding recommendations and some valuable lessons that will be helpful for the design and implementation of behavioural measures as part of the toolbox for energy efficiency.

Develop and implement energy conservation strategies that are specifically tailored to diverse energy usage profiles and motivations of households

To design and execute energy saving plans that suit the varied energy consumption patterns and motivations of households, policies and measures should address the six key factors that affect behaviour: perceived behavioural control, subjective norms, attitudes, personal moral norms, willingness, and age. When applying nudging to wider populations, the necessary conditions for behavioural change must be taken into account. This will allow for more specific and effective nudging strategies that meet the distinct needs and motivations of different households, leading to more efficient energy use and improved energy conservation actions.

Ensure that nudging interventions are closely and clearly linked to the specific energy-saving behaviours they intend to influence

To influence specific energy-saving behaviours effectively, nudging interventions should have a clear and direct link to them. Policymakers should be aware that the impact of such interventions is usually small, and they should consider the limitations and challenges that may affect their outcomes. To measure the causal effect of the nudge on the behaviour change, it is important to establish a strong and unambiguous connection between them, given the low effect size and the presence of various confounding factors.

Certify that nudging campaigns are aligned with existing regulatory and market frameworks

To ensure that nudging campaigns are compatible with the existing legal and market conditions, policymakers need to consider the potential conflicts between them. For example, in Croatia, regulations that impose penalties on self-generated energy that exceeds household consumption may undermine the goals of nudges that aim to promote energy-saving behaviours. In such cases, policymakers have two options: either they revise the legal frameworks to facilitate nudging strategies, or they design nudges that fit within the boundaries of current regulations. This compatibility creates a more favourable environment for nudges to effectively influence energy-saving behaviours.

Focus on implementing default nudges that require minimal effort from consumers

When designing nudges, choose default options that make it easy for consumers to save energy. Since many energy users are not very interested or motivated by new initiatives, it is better to use existing situations and channels, such as energy bills or regular maintenance checks, to nudge them. By using digital infrastructures like smart meters to make energy-saving choic-

es the default, with easy opt-out options, more consumers can adopt energy-efficient behaviours without much effort.

Provide real-time feedback on energy consumption

One of the key factors for raising consumer awareness and enabling informed changes in usage patterns is real-time feedback on energy consumption. Smart meters, IoT and smart sensors are some of the technologies that enable the provision of timely and relevant information that helps users to alter their behaviours, for instance after committing to save energy. The Energy Efficiency Directive contains measures for accelerating the installation of smart meters across Europe, making the data accessible to consumers as soon as possible to support effective energy management.

Prioritise ethical considerations and data confidentiality

A key aspect of ethical practice and data protection is to respect the informed consent, autonomy and rights of users and citizens, as well as to be transparent about the data collection and the interventions. Nudging measures should communicate clearly how the consumer data is handled and safeguarded in compliance with national laws, thus enhancing trust and transparency.

Integrate energy education into schools and other forums

A possible way to improve energy literacy is to incorporate energy education in schools and other venues. Smart meters and energy monitoring dashboards can also help consumers to understand and manage their energy consumption. Regulatory bodies and energy providers have the responsibility to inform the public about these tools. Moreover, using non-educational channels to convey energy-related information and tips in simple, appealing ways can increase awareness and amplify the effect of individual energy-saving actions.

Behavioural interventions can help enhance energy efficiency, but they should not be used in isolation. They should be part of a broader strategy that includes regulation, conventional energy-saving methods, incentives, and technology adoption, all guided by ethical principles. There should be cooperation among different stakeholders, such as governments, energy providers, technology firms, and consumer groups. A platform for knowledge exchange can also help improve this strategy by enabling learning across sectors. Moreover, it is essential to have dedicated teams for long-term programmes and ongoing monitoring and evaluation processes for continuous improvement. These interventions can only succeed if they are supported by a holistic approach that integrates supportive policies, evolving social norms, and ongoing research and adaptation to new conditions.

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