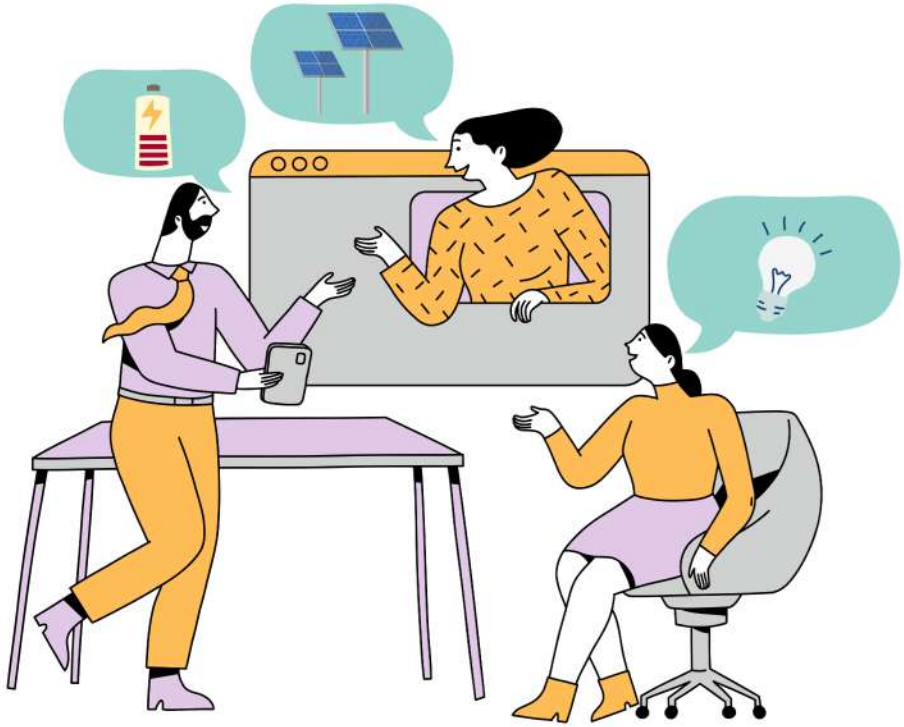
NUDGE

Nudging consumers towards energy efficiency through behavioural science

Advancements in nudging for energy efficiency behaviour



FINAL REPORT

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Context of the NUDGE project

Households are crucial in meeting the EU's goal to cut energy use by at least 11.7% by 2030. Efforts like building renovations and product energy labels aim to shape long-term economic investment decisions. However, the impact on household energy use largely depends on ownership status and financial capacity. **Energy use in the operational phase is more influenced by household behavior, highlighting the importance of understanding and leveraging this behavior over time**.

During the 2022 energy crisis in Europe, as energy costs soared, policymakers urged households to voluntarily conserve energy, initially focusing on gas and later electricity. **Policy measures to encourage energy savings are generally of two types: those offering direct financial incentives, such as taxes or subsidies, and those encouraging behavior changes without direct financial rewards**. One effective method without direct incentives is nudging, involving subtle modifications in choice settings to encourage behavior change. Nudges do not involve regulations, bans, or direct financial rewards, but instead, subtly influence everyday intuitive choices.

The NUDGE project managed to study and implement nudging interventions in residential settings across five EU countries. It involved field experiments in Germany, Croatia, Portugal, Greece, and Belgium, focusing on reducing energy consumption in areas like space heating, household electrical appliances, self-consumption for prosumers, EV charging with self-produced PV power. NUDGE's goal has been **to test behavioral interventions for energy efficiency with actual users and quantify the change in energy-efficient behavior.** It conducted five trials in different countries, each with diverse energy usage scenarios. These trials, designed to test nudging interventions, have managed to guide consumer behavior towards energy use without restricting their choices.

Unveiling the human factor in energy use

The NUDGE project carried out a detailed surveys with two key research goals. First, surveys aimed **to understand energy consumers' behaviour regarding energy efficiency,** identifying what motivates or hinders them from reducing energy consumption. The second goal was **to categorise energy consumers into groups, based on various psychological and social factors that affect their energy-saving actions**, either positively or negatively. The data for this research came from an extensive online survey, completed by 3,129 participants across 29 countries and available in 15 languages. This survey was unique in its approach, applying three theoretical behaviour models: the Theory of Planned Behaviour, the Value-Belief-Norm theory, and the Prototype Willingness model. It focused on examining fifteen psychosocial factors derived from these models. Additionally, the survey included questions on participants' sociodemographic background, their home characteristics, current energy-saving practices, and views on energy monitoring and control platforms.

Survey results

The initial analysis of the NUDGE project data focused on understanding common energy-saving behaviours. Most participants reported regularly closing windows while heating (87.2%) and conserving water by not leaving hot water running (70.1%) or taking shorter showers (45.6%). Additionally, turning off lights when not in use was a prevalent habit, with 91.5% doing so frequently. Regarding the willingness to share energy data with governments, utilities or 3rd parties, many participants appeared to be hesitant. While 42.5% reported to be uncomfortable sharing their monthly energy data, this percentage slightly increased to 44% for daily and real-time data. However, participants were more open to sharing all types of energy data with family members, with 67% willing to share real-time data and 90.3% only monthly data.

The main part of the analysis focused on gaining a deeper understanding of users' intentions to reduce energy consumption. The study differentiated between specific intentions to cut down heating-related consumption and more general energy-saving goals. It revealed that the rational pathway (captured with the **Theory of Planned Behaviour**) to deciding to reduce the heat was dominant. Both the morally reactive (**Value-Belief-Norm Theory**) along with the socially reactive path (through the **Prototype Willingness Model**) were statistically significant, albeit with much less explanatory power. **Overall, the findings suggest that energy conservation is still strongly practically oriented and tools such as smart meters could aide consumers in curbing their consumption.**

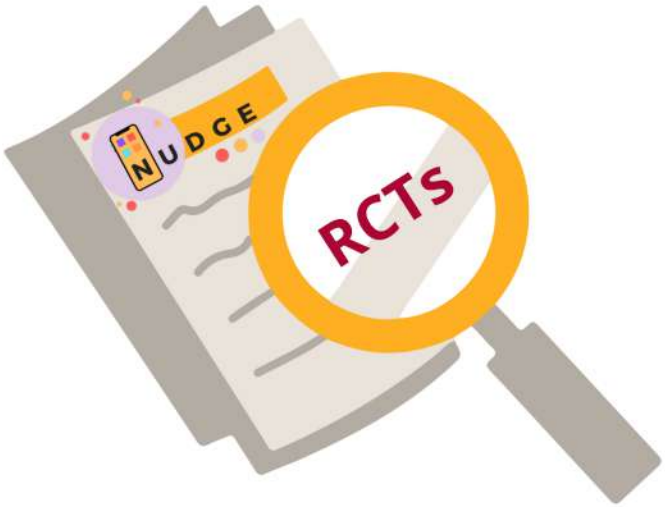
Profiling

The next step in the NUDGE project was to categorise energy consumers into different groups, each with unique traits, to better tailor behavioural interventions like nudging. The research identified six unique groups of energy consumers.

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.

The research method of NUDGE

For assessing the effectiveness of nudging interventions for promoting energy-efficient behaviours, **the NUDGE project utilised a comprehensive and methodical approach, central to which were the Randomised Controlled Trials (RCTs).** RCTs are scientific experiments designed to assess the impact of implementing specific strategies on chosen groups of participants, to establish a clear cause-and-effect relationship between the intervention and its results, such as changes in energy-efficient behaviour.



Participants were grouped either randomly or based on specific criteria, a technique known as a "**between-subjects" design**. In a between-subjects design, a sample is divided into two or more similar groups, either randomly or by matching characteristics, including a control group for time-related behaviour evaluation and attitudinal comparison. It limits learning effects, as the groups and interventions are independent, and allows for exploring various effects of combining treatments, while it also provides a fair and accurate comparison between the behaviours of those who received the nudging interventions and those who did not.

Each pilot's evaluation was tailored to its specific design, data structure, and country context. In cases like the Belgian and Croatian pilots, where a treatment-control design wasn't feasible, **within-subject approaches** were used. Within-subjects designs compare changes before and after interventions without using a traditional control group, and primarily assess the combined long-term effects of multiple interventions. The approach involves half the population receiving an intervention while the other half does not, then switching the groups. A **washout period** was used to help reduce interference from potential confounding effects from external factors.

To extract the causal effects of nudging, the project employed advanced econometric techniques. These addressed confounding factors that could influence outcomes over time and systematic differences between households. A key method used was the "**difference-in-differences**" approach, supplemented by "**two-way fixed effects**" to control for variables, such as seasonal changes and household characteristics.

The selection of the evaluation strategy was crucial, as the goal was to understand the effectiveness of behavioural interventions in the context of everyday household life. **The micro data from smart metering presented challenges due to its complexity compared to laboratory experiments.** However, this detailed evaluation was essential to explore the real-life potential of nudging within policy frameworks. **The evaluation's complexity was heightened due to the energy crisis following the war in Ukraine, which coincided with the field experiments**. This required the project to adopt complex statistical methods to mitigate the impact of these broader overlapping developments

Field experiments in five EU member states

The NUDGE project conducted extensive field experiments in **Greece, Belgium, Germany, Portugal, and Croatia,** that were essential in examining how nudging interventions could encourage energy-efficient behaviours in homes. Throughout the project, a total of **472 households** were directly involved in these pilot trials.

The use of real-time energy data has proved essential in implementing nudging interventions. All pilots employed digital user interfaces to enable the interaction with end consumers but also the operationalisation of behavioural interventions. The collected data have been utilised to provide households with detailed insights into their energy consumption patterns, enabling them to recognise areas where they could improve efficiency. **The analysis of collected data contributed significantly to our understanding of household energy demand and the impact of implementing various nudging strategies, which were found to be influenced by external factors.**

The pilot studies were successful in gathering detailed information in three main areas:

(i) energy consumption in residential buildings through smart meters and controllers, (ii) consumer behaviour change as captured via online questionnaires, and (iii) the adoption and effectiveness of nudging interventions delivered to end users through the employed user interfaces. The trials generated valuable real-life datasets on energy usage (including photovoltaic (PV) production where relevant) over a period exceeding one year for the participating households. Additionally, some datasets included extra user preferences (e.g. target room temperature) and contextual data like weather conditions or indoor air quality conditions and household specifics, enhancing their value for a more nuanced understanding of residential energy demand.

In alignment with the NUDGE project's overarching objective, most nudging interventions tested aimed to use real-time energy data to empower households. This approach was intended to help them thoroughly understand their energy usage patterns and identify potential improvements, thereby promoting more energy-efficient behaviours in their daily lives.

Measuring the impact of nudges

The primary objective of the five field experiments within the NUDGE project was to assess the impact of various nudging strategies. Over an 18-month period, a diverse range of data has been gathered to support this evaluation such as: responses from surveys, usage logs from mobile and online applications, and detailed smart metered data. The pilots, conducted across five different EU member states, tested 13 unique nudges, offering a broad perspective on the effectiveness of these interventions.

Data analysis within NUDGE involved examining information from households in five European countries participating in the project's pilot trials. This analysis was comprehensive, encompassing several types of data:

Continuous **smart meter** readings, capturing household energy production and consumption.

Data from in-house **sensors**, providing continuous measurements of indoor temperature, humidity, air quality, and operational details of devices like gas boiler thermostat settings.

Event-based data recorded by **mobile and web applications**, documenting participants' interactions with digital tools designed for nudging.

Feedback from participants gathered through online **questionnaires**, conducted in four phases – one before and three after each intervention phase.

Additional datasets, such as climate and **meteorological information**, collected by independent organisations.

Control variables included: baseline consumption data, household occupancy, weather characteristics (radiation for PV-pilots, temperature, rain, snow days, heating & cooling degree days/hours), time characteristics (holidays, day of the week), housing characteristics (e.g., surface area, presence of electric heating, PV/EV capacity), user preferences (target room temperature, heating schedules), user engagement, socioeconomic status (e.g., being an employee, mobility needs), peak-load shifting practices, gender for thermal comfort, age and more.

These varied data sources allowed for a thorough analysis of nudging interventions' effectiveness in different residential contexts, offering insights into how these strategies are able to influence energy consumption and user behaviour.

A statistical analysis was conducted to assess the impact of nudging interventions in the five field experiments. The study was built around four key objectives: reducing electricity consumption and heating demand, enhancing self-consumption among prosumers, and improving energy knowledge.

Heating demand

Greece
101 households with gas boilers

Efficient control of heating and hot water preparation for natural gas boilers

Portugal
101 Families with children under 12

Healthy homes for long-lasting energy efficiency behavior, and incl. air quality

Prosumer self-consumption

Germany
111 Households with PV-systems and E-mobility

Optimising the use of self-produced PV power, especially for EV charging

Croatia
82 Households with PV-systems

Promoting distributed self-production for local energy communities

Energy- education

Belgium
55 Children and their families, with smart meters

Interdisciplinary, project-based education of the children on home energy consumption

Overview of pilot implementation and results

Efficient control of heating and domestic hot water preparation for natural gas consuming boilers in Greece

Description

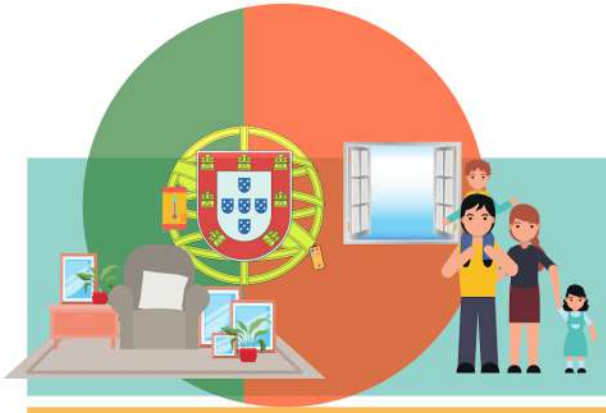
The pilot study in Greece aimed at **improving the efficiency of natural gas boilers used for residential space heating**. A total of 102 participants from five Greek cities took part in this study. Each household was equipped with the DOMX **smart heating controller**, which allowed for efficient control of **legacy gas boilers**.

This device could modulate heating based on weather conditions and pre-set schedules, potentially leading to **energy savings of up to 30%** without compromising user comfort. Pilot participants were able to easily manage their heating through a wireless thermostat, while also having access to the DOMX **smartphone application** for fine grained control and the exposure to nudges.

Results

The study tested three types of nudges: NUDGE 1, which provided **historical information** on gas usage and consumption; NUDGE 2, which facilitated the adoption of **energy efficient heating settings** (configuration of lower target room temperatures or activation of weather adaptive control) through just in time prompts; and NUDGE 3, which involved the delivery of **personalised notifications** to encourage the adoption of energy-efficient settings.

The **results were mixed**. While NUDGES 1 and 2 did not show a clear impact on promoting energy-efficient behaviours and savings, NUDGE 3 led to a small decrease in gas consumption when the frequency of nudge exposure was adjusted based on app usage data.



Healthy homes for long-lasting energy efficiency behaviour in Portugal

Description

In Portugal, a study involving 101 families with children aimed to **reduce electricity consumption while ensuring comfortable and healthy living environments.**

The study involved a detailed survey of the buildings and the installation of **smart meters and indoor air quality (IAQ) sensors** in homes.

These devices monitored electricity use, carbon dioxide levels, airborne particles, temperature, and humidity. An **app** was developed to deliver nudging interventions to participants.

Results

The first nudging intervention, which provided **historical electricity usage data**, did not significantly reduce electricity consumption but did increase the **motivation to save energy**.

The second intervention, allowing users to **view IAQ data**, notably increased both the intention to save energy and awareness of households' energy positioning. It also effectively **reduced average CO2 levels,** with many participants acknowledging the usefulness of the IAQ data in understanding air quality factors and expressing a greater motivation to save energy when IAQ considerations were included.

The impact of the third intervention, focusing on electricity use for heating, on both consumption and behavioural change was less clear.

Optimisation of electric vehicle (EV) charging with self-produced photovoltaic (PV) power in Germany

Description

In the German pilot of the NUDGE project, 111 households with **photovoltaic (PV) systems** in the Rhine-Neckar metropolitan area, served by MVV Energie AG, were involved. Among these, 39 had **electric vehicle charging stations** that could be remotely controlled, forming the EV group.

This pilot focused on encouraging energy-saving behaviours and **increased self-consumption of energy** in households with electric vehicles (EVs).

Two digital platforms were used to deliver nudges: a web portal for all participants to **track home energy usage** and the HERMINE **charging app** for the EV group.

Results

The nudging strategies, which included providing **feedback**, raising **awareness** about energy efficiency, and offering **comparisons**, suggestions, and controls, led to a small increase in energy self-consumption, generally between **3-4%**.

However, the EV group showed a more significant response, with **self-consumption rising by 10-12%,** compared to the average increase of 2-3% among all participants.

Notably, those in the EV group who actively opted in for surplus charging saw a substantial **16% increase in self-consumption**.

Promoting distributed self-production for local Energy communities in Croatia

Description

The Croatian Pilot focused on providing relevant **knowledge and resources** to allow users to navigate evolving regulations, optimise energy consumption, **increase energy-efficiency** in homes, and aimed to understand which nudges are relevant to achieve higher **self-consumption and less grid dependence**.

It engaged 82 consumers with PV systems installed in their home, and monitored their **real-time data on both electricity consumption and production**.

A user-friendly **smartphone app** was developed for the pilot to expose participants to nudges, which aimed to **cultivate empathy,** enhance **awareness of energy usage**, and encourage **energy efficiency goal-setting.**

Results

The investigation of the effectiveness of feedback and awareness nudges in adjusting energy consumption and production showed **results** that were not consistent across all households. Nevertheless, goal-setting nudges resulted in some evidence of improvements in efficient energy use.

The outcomes of the pilot suggest that **consumers were more susceptible to adapt their energy use in response to external factors, namely limitations imposed by the regulatory framework, and less because of the nudges.** Specifically, a regulation limiting the amount of energy a household can produce before being considered a commercial enterprise, led to observed behaviours such as increased electricity consumption during high production periods or even shutting down PV systems.

Overall, the diverse nudge strategies collectively seemed to contribute to **fostering energy-conscious behaviour** to some extent. The critical analysis of the obtained results showed the need for more adaptive and personalised strategies as a priority for further studies.

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

Description

In Belgium, the NUDGE project focused on **encouraging energy-saving behaviours in school-age children and their families** through educational initiatives. During the 2021/2022 and 2022/2023 school years, two groups of students participated: one receiving interventions (36 in the first year, 40 in the second) and a control group (28 in the first year, 33 in the second).

The program **integrated nudges into lessons,** complemented by activities that **visualised recent energy use** in students' homes, which were connected to the EnergyID platform.

The curriculum covered five key topics: home gas and other heating methods, electricity consumption, water use, electricity production, and the concept of nudging. This pilot led to the creation of **educational booklets** with valuable information, charts, and exercises.

Results

To assess the impact of nudges, pre- and post-intervention questionnaires were used.

Results indicated that while the children were interested and engaged in the lessons, there was **no substantial positive effect on their or their families' energy-saving knowledge, intentions, or motivation**.

A decrease in gas consumption was observed in the first cohort but not in the second, possibly due to differing start times and seasonal factors influenced by the COVID-19 pandemic.

The variations in outcomes between cohorts suggest that **external factors like timing and seasonality can significantly impact the effectiveness of such educational initiatives.**

Findings on nudging effectiveness

The findings from the NUDGE project indicate that the success of nudging strategies in encouraging energy savings is highly dependent on specific circumstances. **This variability in effectiveness was observed not only across different pilot locations, but also among various interventions within the same pilot study.** Despite these variations, certain nudging approaches appeared **to be promising**. For example, interactive nudges resulted in energy savings of up to 4%, while automated interventions, like optimized electric vehicle charging, led to savings of up to 16% for those who participated.

However, it is important to note that these strategies were not universally effective. **Nudging did not consistently yield the anticipated levels of energy savings across all participant groups or in every context.** In some instances, regardless of the country or the design of the intervention, nudging failed to significantly influence energy consumption behaviors.

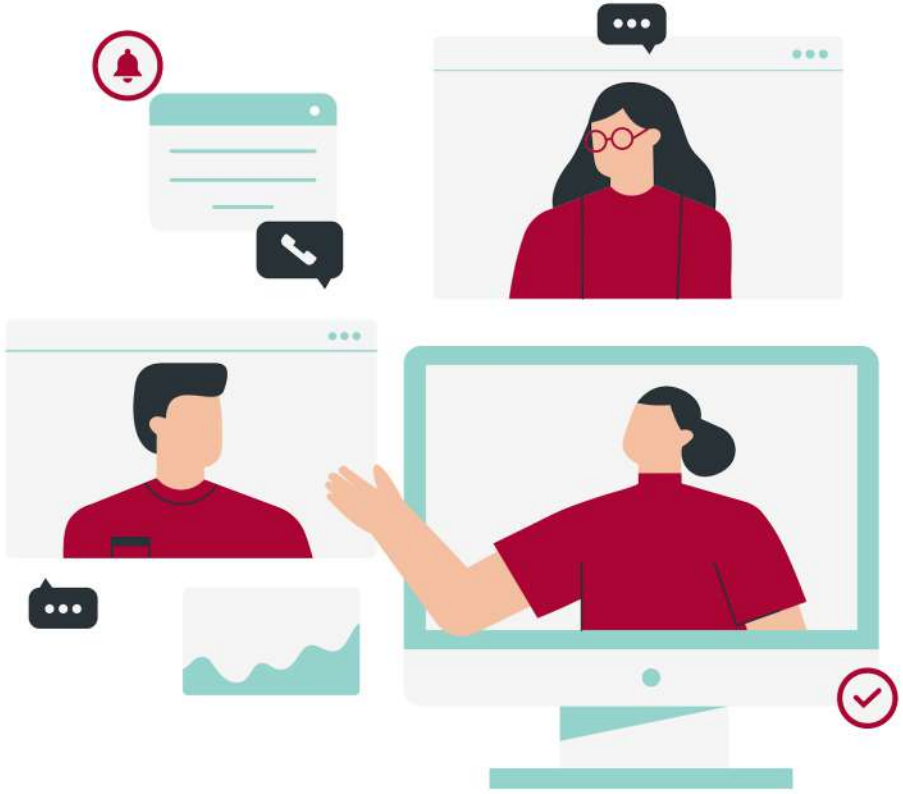
This suggests that **while nudging can be a useful tool in some scenarios, its applicability and impact are dependent on various factors beyond the nudge itself, such as engagement with the medium of delivery, timing, alignment with relevant regulations and so on.**

The inconsistent nature of nudging effectiveness across different settings and interventions is summarised in the following table (next page). Dark green check marks indicate robust evidence supporting the effectiveness of nudging, light green checks for mixed but positive results, and orange minus symbols where evidence is weak or contradictory.

Nudge effectiveness	Comments
 **Increasing self-consumption from PVs**	▸▸ Single digit effect sizes in Germany, but with the stronger increases for the smart charging nudge ▸▸ Mixed results in Croatia attributed to regularly setting
 **Reducing electricity consumption**	▸▸ Decrease in household consumption in Germany ▸▸ Mixed results including positive and negative coefficients as well as group divergence in Portugal
 **Reducing heat consumption**	▸▸ Reductions observed only in one sub-group for Belgium ▸▸ Weak/contradicting evidence in Greece, with comparatively low level of activity on the mobile app
 **Improving energy knowledge**	▸▸ No evidence for improvement in test scores, with concerns about comparability in test results

Considering that nudging is a gentle method of influencing behaviour, it can be significantly affected by external factors. These trials, conducted in real-life settings, demonstrated that various elements can interfere with daily decision-making, thereby potentially reducing the impact of nudges when applied on their own. Nudging tends to work better under specific conditions, where a clear connection between the intervention and its outcome can be derived, and when the timing is right to guide a change in behaviour.

However, when these conditions are not met, nudges might not be able to strongly impact household energy consumption, amidst a variety of other influencing factors.



A worthy addition to the policy making toolbox

The main goal of NUDGE has been to examine how **energy policy can benefit from behavioural insights**, based on psychology and behavioural economics. These insights can help design 'nudges' that change how choices are presented and influence people to adopt more energy-efficient and conservation-oriented behaviours. Our research shows that nudges can effectively encourage energy savings and efficiency measures under certain conditions. They are also low-cost, non-coercive, and adaptable to different contexts and behaviours related to energy use and self-consumption. However, behavioural interventions also face some challenges, such as reaching specific groups like high energy users, testing different methods for long-term impact and measuring the effects of nudges as energy policy instruments.

Drawing on over three years of hands-on research from five pilot sites, we hereby present **several guiding recommendations and some useful lessons that will be useful 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. Policies and measures should focus on the six main elements influencing behaviour: perceived behavioural control, subjective norms, attitudes, personal moral norms, willingness, and age. When scaling up nudging to broader populations the pre-conditions of behavioral change must be considered carefully. Such a nuanced approach will enable the creation of more targeted and effective nudging strategies, catering to the unique needs and motivations of different households, ultimately leading to more efficient energy use and enhanced energy conservation efforts.

Ensure that nudging interventions are closely and clearly linked to the specific energy-saving behaviours they intend to influence. Given that the impact of such interventions is often modest, policymakers should set realistic expectations regarding the effectiveness of these nudges and identify constraints that must be considered. Establishing a direct and unmistakable connection between the nudge and the resulting behaviour change is necessary to confidently attribute any changes in energy consumption to the intervention, considering the minimal effect size and the influence of various external factors.

Certify that nudging campaigns are aligned with existing regulatory and market frameworks. For instance, in situations where regulations, like those in Croatia penalising self-generated energy exceeding household consumption, conflict with the objectives of nudges, the effectiveness of these nudges is diminished. Therefore, policymakers need to either adjust regulatory frameworks to support nudging strategies, or alternatively tailor nudges to fit within the constraints of current regulations. This alignment creates a more conducive environment for nudges to effectively encourage energy-saving behaviours.

For the type of nudges, **focus on implementing default options that require minimal effort from consumers.** Given the generally low engagement with new initiatives and the diverse motivation levels among energy users, utilising existing situations and channels, such as energy bills or regular maintenance checks, can be more effective. Leveraging digital infrastructures like smart meters to set energy-saving choices as the default, with simple opt-out options, can encourage more consumers to adopt energy-efficient behaviours effortlessly.

Real-time feedback on energy consumption is one of the most crucial elements in increasing consumer awareness and enabling informed adjustments in usage patterns. Technologies like smart meters, IoT and smart sensors facilitate the delivery of just-in-time relevant information that supports users in their efforts to modify behaviours, for example following a pledge to save energy. The Energy Efficiency Directive includes provisions for expediting the deployment of smart meters across Europe, making the relevant data available to consumers as promptly as possible to support effective energy management.

It is important to **prioritise ethical considerations and data confidentiality**, ensuring informed consent, upholding transparency about the interventions and data collection, and respecting individual autonomy and rights of users and citizens. Measures utilising nudging interventions should emphasize in clear communication how consumer data is used and protected in accordance with national laws, thereby fostering transparency and trust.

Policy makers could **take steps to integrate energy education into schools and other forums** to boost energy literacy. This can be complemented by the widespread roll out of smart meters and energy monitoring dashboards, thus enabling consumers to track and comprehend energy usage. Regulatory bodies and energy providers are in position to actively disseminate information about these tools. Employing non-educational channels to present energy-related information and tips in straightforward, engaging ways can further raise awareness and enhance the impact of individual energy-saving actions.

To effectively improve energy efficiency using behavioural interventions, **it is recommended that these means are integrated with regulatory measures, traditional energy-saving practices, incentives, and technology adoption, all within a solid ethical framework.** There should be collaboration among governments, energy providers, technology firms, and consumer groups. This approach can be enhanced in the **presence of a platform for knowledge exchange** to facilitate learning across sectors. It is also important to emphasise the importance of **having dedicated teams available for long-standing programmes and ongoing monitoring and evaluation processes** for continuous improvement. The success of these interventions depends on a comprehensive approach that combines **supportive policies, evolving social norms, and ongoing research and adaptation to new conditions.**

Discussion for decoding nudging results

The NUDGE project explored the effectiveness of nudging interventions across various settings, uncovering both successes and challenges. Key findings emerged from analysing participant behaviour in response to nudges, with significant influences from external factors like the COVID-19 pandemic, energy price fluctuations, and policy changes. These elements played a critical role in participant engagement, perceptions, and actual energy-saving actions. The research delved into diverse aspects, from interaction with digital tools and self-assessment of energy-saving behaviours to specific responses in different country pilots. Each pilot revealed unique insights into the effectiveness of nudging, shaped by local contexts, regulatory environments, and individual participant behaviours. The project's comprehensive approach, combining survey data with real-life monitoring, provided a multifaceted view of nudging's potential and limitations in real-world settings, for which there are several explanatory components hindering the success of the nudges in some contexts.

Inherent limitations

The NUDGE project's research into nudging interventions indicates their potential to enhance energy-efficient behaviours in specific situations and among particular groups. Nonetheless, the effectiveness of these interventions varies across different scenarios, possibly due to external influences and distinct characteristics of the study designs. This study contributes new insights to the existing body of knowledge, utilizing comprehensive data, control groups, and techniques to assess the real-world impact of nudges. Earlier research has pointed out some limitations and lacked consistency across studies. There is a tendency in academic circles to possibly overstate the success of nudging, partly due to the selective publication of positive outcomes. Additionally, findings from controlled settings, like laboratories or surveys, may not effectively apply in everyday situations. The outcomes of the NUDGE project underline the necessity for a nuanced and context-sensitive approach to nudging, underscoring that successful implementation requires adaptation to specific local conditions.

Real-world challenges

The outcomes of the NUDGE project, showing varying results across different contexts, may be influenced by uncertainties stemming from external events and specific aspects of the study design. The COVID-19 pandemic disrupted participant engagement and the installation of smart energy management equipment, with some participants joining late in the per-intervention phase. Additionally, this phase coincided with periods of isolation and increased remote work, potentially impacting the representativeness of baseline data. The study's sample size, the short duration of the nudging interventions (1-3 months), and the monitoring period likely affected the robustness of the results. Seasonal factors, like holidays or weather conditions that limit the potential for further improvement, also seem to have hindered the effectiveness of nudging.

Engagement

The NUDGE project revealed limited interaction of participants with digital nudging tools, highlighting a crucial insight: nudging's effectiveness is not only about its inherent qualities, but also depends on initially engaging the users. A significant portion of participants, ranging from less than 10% to about 25% in some cases, did not use the tools at all. On average, tools were used around three times a week, with notable variations. Effective engagement with the app is essential for successful nudging, making the low usage a potential barrier to implementation. The study also distinguished between general app usage and specific interaction with nudging content. Many users, including frequent app users, had minimal or no exposure to the nudges. Most participants fell into the group with low engagement and exposure, while those with high engagement and exposure were less than 10%. In the Portuguese pilot, nudges displayed on the app's main screen saw higher interaction, unlike push notifications which were largely overlooked.

Energy prices

The NUDGE project found that participant behaviour during nudging periods was likely influenced by the effects of Russia's invasion of Ukraine on global energy prices. This impact was explored by examining how changes in energy prices affected energy-saving behaviours, using both survey responses and smart meter data. The analysis aimed to separate the impact of price changes from the pure effect of nudging. Participants in the German and Croatian pilots initially cited the war as the primary factor influencing their energy-saving behaviour, likely due to their proximity to Ukraine and reliance on Russian gas. In contrast, participants from Greece, Portugal, and Belgium identified rising energy prices, linked to the war, as their main motivator. Greek and Belgian participants reported reducing gas usage in response to higher prices. About 10 months into the war, concerns across all countries focused on energy prices. By Spring 2023, signs of a "return to normality" were observed, with weather becoming the main determinant of energy-saving behaviour in Germany and Croatia, particularly among households with photovoltaic capacity.

Self-assessment of energy-saving behaviour

The NUDGE project also investigated participants' self-perceptions of their energy-saving behaviours and the emotions these actions evoked, through responses gathered through surveys: before the first intervention started and following the conclusion of the subsequent three interventions. Generally, participants from all pilots reported positive emotions associated with saving energy. These positive feelings remained consistent over the 1.5-year survey period, unaffected by significant economic and political shifts. Nearly all participants rated their energy consciousness positively, considering it above average. While there were variations in self-assessment scores among different pilots (for instance, Croatian participants viewed themselves more favourably as active energy community members), these self-perceptions remained stable across the surveys. This suggests that, on average, participants did not perceive a change in their behaviour due to the nudging interventions.

Perverse Incentives in Croatian energy policy

In the Croatian pilot, a policy that reclassifies households as renewable traders if they produce more electricity than they consume created unintended incentives to either reduce solar power generation or increase energy usage. Nearly half of the survey participants considered limiting their solar output to avoid this status. Smart meter data con firmed that many actually reduced production or used more energy as the year-end deadline approached. This combination of survey and consumption data provided insights into diverse consumer reactions and the ineffectiveness of nudging interventions in this context, as digital tools were used to navigate conflicting regulatory incentives.

Variable behaviour for EV charging in the German pilot

In the German pilot of the NUDGE project, the emphasis was on electromobility, particularly examining smart charging for electric vehicles . Analysis of daily load profiles showed that prosumers (those with controllable EVs) differed from typical German residential patterns, displaying higher midday peaks and less evening activity. Despite an overall positive response to smart charging features, their actual usage was limited. Many participants did not use these features or started using them late. While participants had a routine of charging 3-4 times a week, often more during high photovoltaic output, their charging behaviour varied greatly based on individual household needs. The ability to utilize the midday solar peak was observed, yet no consistent pattern emerged in the charging behaviour between afternoon and evening.

Nudge effectiveness masked by energy prices in the Greek pilot

In the Greek NUDGE pilot, the focus was on whether nudging motivated changes in heating settings to reduce energy consumption. By analysing sensor and mobile app data, researchers assessed how households adjusted boiler operational parameters (such as the heating balance curve). While a decrease in thermostat target temperature was noted during the second intervention, it was not clearly linked to the level of exposure to, or acceptance of, the app's prompt messages. Interestingly, lower thermostat settings were more common in households not exposed to nudges. The findings suggest that nudging had limited impact on energy consumption, aligning with survey responses that attributed energy-saving behaviours to rising energy prices and overlapping global developments (war in Ukraine).

Nudging more effective for improving Indoor Air Quality in Portugal

One of the nudges in the Portuguese pilot focused on improving indoor air quality (IAQ) in homes. Participants received real-time data about IAQ, including CO2 and particulate matter levels, and were advised to take actions like opening windows during high concentration levels. Analysis of IAQ data before and after the nudging intervention showed a significant decrease in CO2 levels. Surveys revealed that the app's data motivated participants to take actions enhancing IAQ. IAQ behaviour is not directly related to monetary savings as the case is with electricity consumption, and the majority of pilot participants repeated in all survey waves that the increased energy prices are the main determinant of their energy-saving behaviour. These findings suggest nudging had a notable effect on IAQ behaviour, contrasting its limited impact on electricity consumption, which is more directly tied to monetary savings.

Conclusion

With the conclusion of the NUDGE project, its contribution to understanding energy-saving behaviours has become realised. This project has enhanced the understanding of the scientific community and of policy makers regarding the details of how individual attitudes, and economic and wider societal factors, play a crucial role in shaping energy behaviour of households. The findings underscore the importance of incorporating behavioural insights into the development of future energy policies.

Government bodies, utility companies, and other stakeholders can utilise these insights to design more effective energy saving strategies. The project's application of Randomised Controlled Trials (RCT), the real-world monitoring in pilots and the use of advanced econometric methods in analysing in-depth data has proven valuable. This methodology has enhanced our ability to guide and measure behavioural change and offers practical applications, such as in reporting energy savings and distinguishing between behavioural and structural energy efficiency.

The NUDGE project's experiments have provided insightful contributions to the understanding of nudging, by tracking behaviour changes over time, and in various countries. This project represents a significant step in developing behaviourally informed approaches to energy policy, underscoring the subtle and variable effectiveness of nudging. It demonstrates that understanding the effectiveness of nudging requires more than a straightforward assessment; it demands an in-depth exploration of the contexts, methods, and reasons that determine its success. This approach paves the way for new research opportunities, promising further investigations and applications in this crucial area of behavioural interventions. The findings from the NUDGE project indicate that nudging, as a strategy to promote energy efficiency, cannot be universally applied and should not be the sole approach.

Looking ahead, there are several key areas for further exploration:

- The need for a broader and more representative sample size, encompassing a wider range of clusters and residential buildings, to enhance the accuracy and generalisability of the results across the residential sector.
- The possibility of combining nudging strategies with financial incentives and policy support, to bolster energy efficiency efforts more effectively.
- The exploration of more refined nudging approaches, particularly those that reduce the need for manual interaction, given the low usage of apps and exposure to nudges observed in the project. This could involve automated nudging solutions or the development of more personalised nudges, tailored based on participant feedback gathered through surveys.

In conclusion, the NUDGE project stands as an example of how behavioural science can inform and enhance energy policy. Its comprehensive approach, combining rigorous scientific methods with real-world application, has opened new pathways for understanding and influencing energy-saving behaviour in households. The lessons learned from NUDGE will undoubtedly influence the development of more sophisticated and effective energy-saving strategies, which will likely integrate behavioural insights with technological advancements and policy frameworks. The project results serve as a reminder of the complex relationship between human behaviour, regulation and energy consumption, highlighting the need for continued innovation and research in this field. The NUDGE project has thus contributed to the current body of knowledge and offers its findings to support endeavours for behaviourally informed energy policy.

The information in this present document has been deprived and summarised from all major NUDGE project's deliverables.
For more information, please check the following links:

www.nudgeproject.eu/knowledge-hub
www.cordis.europa.eu/project/id/957012/results

From end of 2024, find all materials on: http://ieecp.org/projects/nudge

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