LUISS

Department Of Economics And Finance

Chair of Microeconomics

Bachelor's Degree in Economics and Business

Nudging for Sustainable Dorms:

A Field Experiment to Compare the Effectiveness of different Measures in Reducing Electricity Consumption.

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Abstract

My experimental thesis is motivated by a critical issue: climate change. It proposes a practical solution to combat private energy waste, which is a pressing concern for society.

This study focuses on the energy consumption of four residential student units, where my team and I will implement three behavioral interventions, the fourth one being the control group. One intervention is based on private information, while the other two rely on social comparison and public information. In addition, the third intervention offers a monetary award to the best energy saver, utilizing competition as a tool to drive students towards more sustainable energy consumption.

To evaluate the effectiveness of these interventions, our research group will propose to use a rigorous experimental methodology. We aim to determine which nudging intervention is the most effective in terms of cost/energy-saving compared to the control group, moreover, we intend to perform a follow-up study to assess the long-term effects of each intervention.

I expect that the monetary prize intervention will outperform the simple public information intervention, while the ambient orb effects (private information) may have varying effects depending on the agent and his sensitivity to the Orb changing colour. I anticipate significant differences in the effectiveness of the three interventions.

The policy implications of the expected findings are extensive. The methods we propose can be implemented not only in student buildings but also in private homes and public/private offices. By reducing energy waste, our study can contribute to mitigating the impact of climate change. Additionally, our findings can be informative for both policymakers and energy providers on the most effective nudging interventions to encourage energy-saving behavior.

In this thesis, we are analyzing different interventions aimed at promoting energy-saving behavior and reducing energy waste. Through this research, I have identified several policy implications that could contribute to promote sustainable energy consumption. One potential policy implication is to Incentivize energy-saving behavior, especially for the third intervention it is important to show the high effectiveness in encouraging energy-saving behavior, this suggests that policymakers and energy providers could consider implementing similar incentive-based programs to encourage households and businesses to reduce their energy consumption. Another effective policy option is investing in public information Campaigns to raise awareness about energy-saving behaviors. Hence, policymakers should consider investing in public information campaigns to raise the awareness about energy-saving behaviors and encourage individuals to reduce their energy consumption. Smart Metering is another potential policy implication that could contribute to promote sustainable energy consumption. Policymakers should consider providing smart-meters in households and businesses to provide

real-time feedback on energy usage and encourage energy-saving behavior. Finally, education and training, it is important to highlight the importance of education and training in promoting energy-saving behavior, by teaching individuals about energy-saving behaviors and encouraging them to adopt these behaviors in their daily lives, policymakers can contribute to reducing energy waste and promoting sustainable energy consumption.

Overall, this thesis has important policy implications for reducing energy waste and promoting sustainable energy consumption. Policymakers and energy providers can use my finding to develop effective interventions that encourage sustainable behaviors and contribute to mitigating the impact of climate change.

1. Introduction

The increasing demand for energy worldwide is a major concern for governments, organizations, and individuals. The consumption of energy has a significant impact on the environment, therefore, leading to the emission of greenhouse gases, pollution, and climate change.

Italy's total electricity consumption includes a significant portion of domestic electricity use, accounting for around a quarter of the total. In addition to household appliances, the energy efficiency score of buildings in Italy is subpar, contributing to the country's domestic energy consumption. Another major contributor to electricity consumption in Italy is air conditioning, with the demand for these units increasing in recent years due to the rising outdoor temperatures especially during the summer months. Climate change is expected to further exacerbate this trend, with outdoor temperatures projected to increase, particularly in some regions, like Sicily in Italy where temperatures can reach as high as 45 degrees Celsius.

Reducing energy consumption is critical to address the challenges posed by climate change and environmental degradation. The use of energy, especially from fossil fuels, is the main contributor to greenhouse gas emissions that trap heat in the Earth’s atmosphere, leading to global warming. As a result, reducing energy consumption is a key factor in mitigating the effects of climate change. There are two main ways households can reduce their energy consumption. Firstly, they can alter their energy usage patterns, such as reducing the amount of time lighting is used. Secondly, households can make changes to their purchasing habits, such as investing in efficient appliances like a washing machine with a high energy efficiency rating. Behavioral interventions aiming at energy conservation can therefore target either the purchase decision or more directly the consumption behavior, which is exactly what we aim to do in this experiment. In addition to the environmental benefits, reducing energy usage has also economic benefits. Energy-efficient buildings and appliances can reduce energy bills, leading to cost savings for individuals as well as organizations. Moreover, reducing energy waste can decrease the need for additional energy infrastructures, thus reducing the overall costs of energy production and distribution. Therefore, reducing energy consumption is a critical task that requires the collaboration of everyone. In this context, the LUISS Guido Carli University in Rome, Italy, is interested in exploring different behavioral mechanisms aimed at reducing electricity consumption in their residential buildings. The objective of this thesis is to compare three different behavioral interventions in four comparable residential buildings.

The different methods used are:

1. Private Information on energy consumption (Ambient Orb);

2. Public Information on energy consumption;
3. Public Information and Competition on energy consumption.

All interventions will use smart meters installed in each residential unit to update resident's energy consumption information daily. Additionally, the interventions will employ Ambient Orbs and screens placed in common areas to display relevant information.

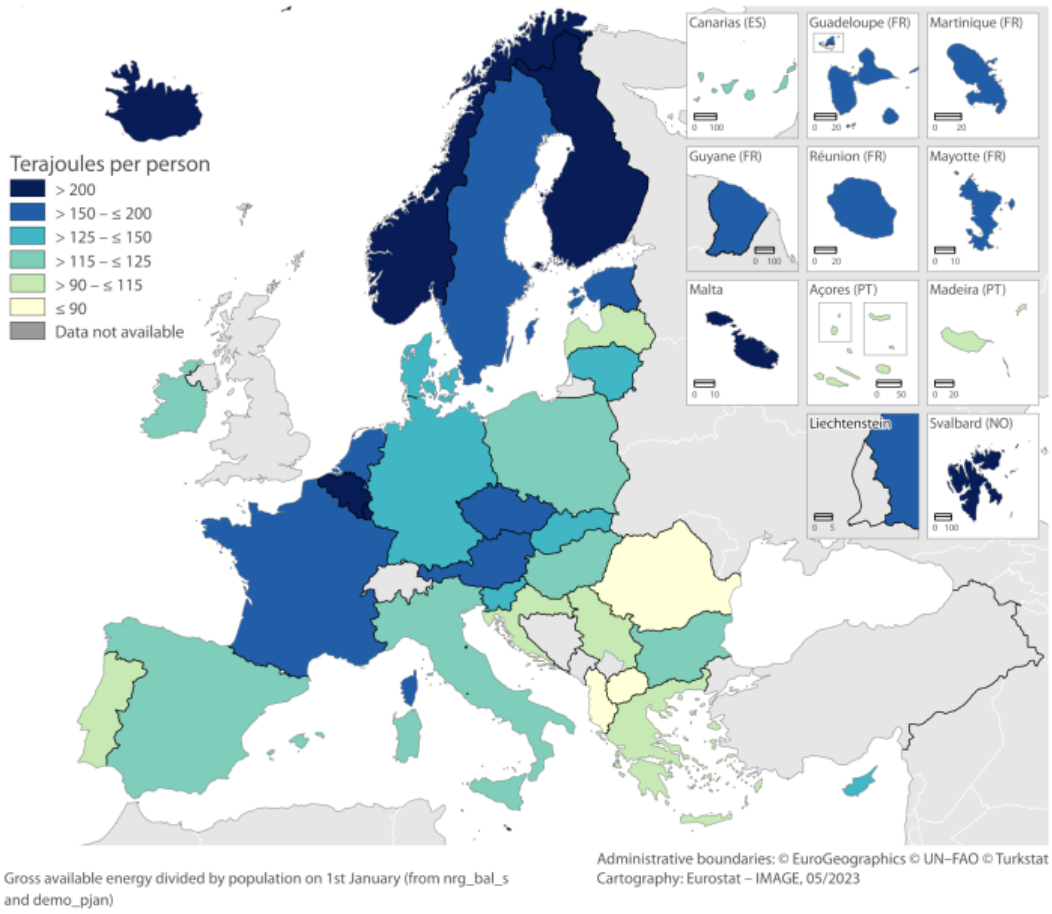
The project aims to use a rigorous experimental methodology to evaluate the effectiveness of each of the three proposed intervention. To do so, our research group will need access to data concerning four residential buildings, one for each intervention and one for the control group that will not receive any treatment.

The implementation of this experiment requires several resources, including smart meters for each residential unit, ambient orbs for the residential building displaying private information and digital whiteboards for the other two buildings receiving interventions displaying public information.

The spillover effects of this research project are likely to be substantial. By examining the effectiveness of different nudging interventions, this study contributes to the field of sustainable energy consumption and provides valuable insights for policymakers and energy providers. The study's experimental design and expected results will shed light on the most effective nudging interventions and provide guidance on how to promote sustainable behaviors and reduce energy waste. The LUISS Guido Carli University will have access to information on the most effective intervention to reduce energy consumption. This information can be used to develop a common policy aimed at reducing energy consumption in all residential building of the university. Moreover, the findings of this thesis have significant policy implications for promoting sustainable energy consumption and reducing energy waste. Policymakers and energy providers can utilize these findings to develop effective interventions that encourage sustainable behaviors and contribute to mitigating the impact of climate change.

This thesis is organized as follows: in Section 2, I will discuss what is nudging and its importance in promoting sustainable energy consumption, in Section 3, I will provide an overview of the relevant literature. In Section 4, I will describe the experimental design, which aims to evaluate the effectiveness of three different nudging interventions in reducing energy waste in residential student units. In Section 5, I will present the expected results of the study, and finally, in Sections 6 and 7, draw conclusions about the policy implications of the findings for promoting sustainable energy consumption and mitigating the impact of climate change.

Figure 1.Per capita energy consumption, 2021, eurostat, Statistics Explained, (terajoule per capita).



[1]

This graph displays the EU's 2021 per-person energy usage in terajoules per capita. The average energy usage per person in the European Union has decreased by 8.2% between 1990 and 2020. However, on a national level, the evolution of the per capita gross disposable energy varies a lot among different countries, from Malta (+135%), followed by Portugal (+21%) and Austria (+15%) and on the other side Romania (-34%), Germany (-37%) and Estonia (-47%). In Italy, electric energy consumption increased by 6% in 2021 compared to 2020. The analysis showed that industry had the highest increase in electric energy consumption, with an 8.2% increase from 2020 to 2021. This could be due to increased production, expansion of industrial activities, or changes in the manufacturing process. The services sector also experienced an increase in electric energy consumption, with a 6.4% increase from 2020 to 2021. This sector includes a wide range of activities such as commerce, tourism, and healthcare. This increase could be due to the expansion of these activities or changes in the way they are conducted.

[1] Per capita energy consumption, 2021, *eurostat, Statistics Explained,* (terajoule per capita).

Finally, the domestic activity sector, which includes households, had the lowest increase in electric energy consumption, with a 1.3% increase from 2020 to 2021. This could be due to changes in consumer behavior, increased energy efficiency, or other factors.[2]

2. Nudging

The concept of nudging was first introduced by Richard Thaler and Cass Sunstein (2008)[3].

Thaler and Sunstein are behavioral economists, and their book had a significant impact in the field of psychology and behavioral economics. The book introduced the concept of nudging as a way to positively influence people's behavior without limiting their freedom of choice. The term "nudge" refers to a gentle push or small encouragement that can be used to improve people's decisions and steer them towards better and more desirable outcomes.

Nudging is a type of intervention that seeks to influence people's behavior by making small changes to their environment or decision-making process. It is an approach that draws from behavioral economics and psychology, aiming to steer individuals towards more desirable outcomes while preserving their freedom of choice. There are two main types of nudges: structural and informational interventions.

Structural nudges aim to change the context in which individuals make decisions. For example, rearranging the placement of healthier foods in a cafeteria can nudge people towards healthier food choices. Making the default option the preferred choice is another example of a structural nudge. An example of making the default option the preferred choice in environmental nudging could be seen in a hotel's towel reuse program. If the default option is set to reuse towels, guests are more likely to participate in the program, as it requires less thought and effort than requesting new towels every day. This can have significant benefits for the environment, as it can help to reduce water and energy consumption associated with laundering towels. Informational nudges, on the other hand, rely on providing individuals with information or feedback to influence their behavior. Displaying real-time energy consumption feedback or providing social norm information are examples of informational nudges. Informational interventions provide individuals with information on their energy consumption, energy-saving behaviors, and the potential benefits of energy conservation. These interventions can be delivered through a variety of media, such as text messages, emails, or websites.

[2] Dati Statistici, 2021, *Terna Driving Energy*.

[3] Sunstein, C., Thaler, R., Nudge: Improving Decision about Health, Wealth, and Happiness, University of Chicago.

Both structural and informational nudges can be effective in influencing behavior, but they have different strengths and weaknesses. Structural nudges tend to be more effective for long-term behavior change, while informational nudges can be more effective for immediate behavior change. Structural nudges may be perceived as manipulative by some individuals, whereas informational nudges are typically more transparent and well-received.

Nudging is a versatile and effective approach to behavior change that can be applied to a wide range of domains, including health, financial decision-making, and energy consumption. In the context of energy consumption, nudging interventions are becoming increasingly popular as a promising approach to reducing energy waste. Given the negative externalities of excessive energy consumption, there is a need to design policies that make consumers more aware of their energy use and encourage them to adopt more energy-efficient habits.

The proposed interventions in this study are primarily informational, as they aim to provide individuals with information on their energy consumption and encourage them to save more. However, one of the interventions is structural, which is designed to encourage energy-saving behavior through a monetary incentive.

In summary, nudging is a versatile and effective approach to behavior change that can be applied to a wide range of domains, including energy consumption. In the context of energy conservation, nudging interventions have shown promising results in reducing energy waste and promoting sustainable energy consumption. However, to design effective nudging interventions, it is important to understand the underlying factors that influence behavior. This is where the COM-B model comes in.

The COM-B model is a theoretical framework used in behavioral science to understand and influence behavior. The model proposes that three key components are necessary for behavior to occur: capability, opportunity, and motivation (COM). The COM-B model also suggests that these components are interdependent and interact with each other.

Capability refers to an individual's physical and psychological ability to perform a behavior. Opportunity refers to the external factors that enable or constrain behavior, such as the physical environment, social norms, and access to resources. Motivation refers to the psychological and emotional processes that drive behavior, such as beliefs, attitudes, and habits.

The COM-B model can be used to design targeted interventions that address the specific components of behavior that need to be modified to achieve the desired outcomes. By identifying the barriers and facilitators to behavior change in each component, interventions can be tailored to address the specific needs of the individual or group.

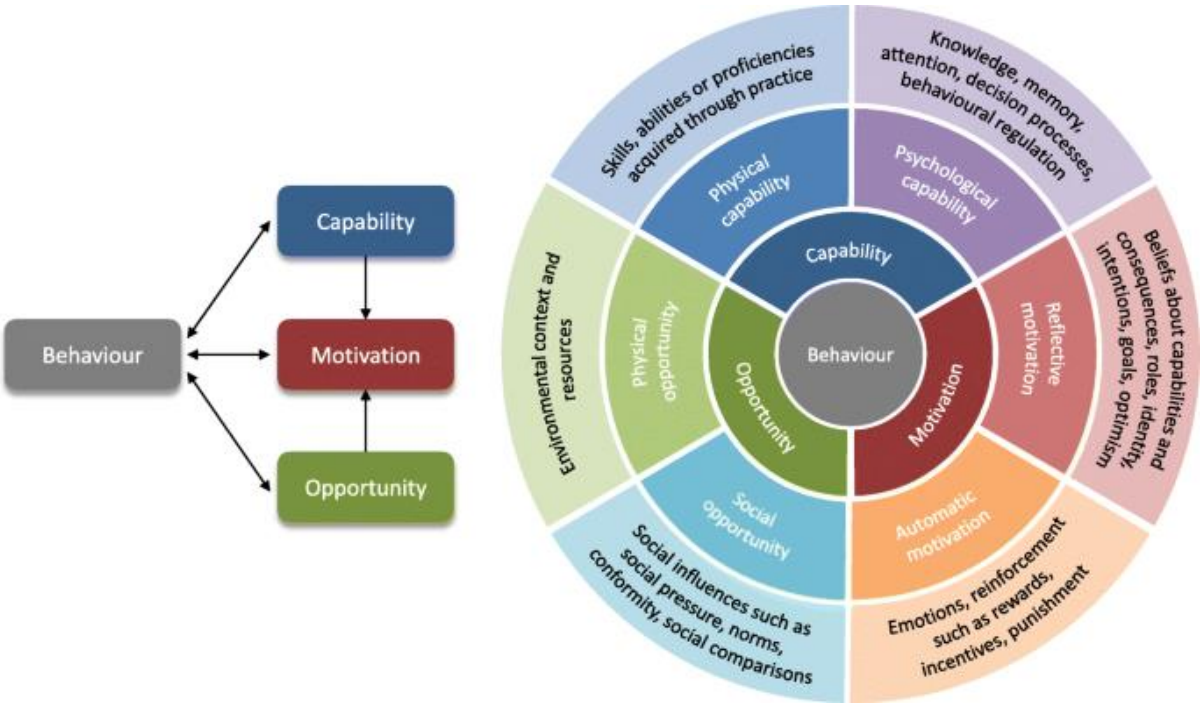
In the context of the proposed intervention, the COM-B model can be used to understand the barriers and facilitators to energy-saving behavior among residential students. For example,

students may lack the capability to save energy due to a lack of knowledge about energy-efficient behaviors, or they may lack the opportunity to save energy due to the physical characteristics of their living space, such as poor insulation. Motivational factors, such as attitudes towards energy conservation, may also influence energy-saving behavior.

To address these barriers and facilitators, the proposed intervention will use a combination of informational and structural nudges that target each component of the COM-B model. For example, one intervention will provide students with real-time feedback on their energy consumption, which will increase their capability to save energy by increasing their awareness of their energy use. Another intervention will modify the environment, displaying a white board in common areas, giving a ranking, and providing monetary incentives for energy conservation to the most deserving agent, which will increase the opportunity to save energy by providing a tangible reward for energy-saving behavior. Finally, the second type of intervention will use social norm information to increase motivation for energy conservation by informing students of the average energy consumption of their peers.

Overall, the COM-B model provides a useful framework for understanding the complex nature of behavior change. By identifying the specific components of behavior that need to be modified, interventions can be designed to effectively promote sustainable energy consumption among residential students.

Figure 2. Com-B Model Framework, Implementation Science.



3.Literature Review

This literature review focuses on the topic of non-price interventions for energy conservation behavior in private households. The review is divided into three streams of literature: private information, public information and social comparison, and labeling. Each stream will be discussed in-depth, starting with a brief overview of the methodology used in each stream. The earliest paper considered in this review is C. Fisher (2008).

Private Information

In the stream of literature concerning private information, the focus revolves around how offering feedback on household electricity usage can empower customers to better manage their consumption and ultimately conserve energy. Fisher (2008) paper delves into a psychological model that illustrates the workings and rationale behind the effectiveness of feedback. The paper identifies pertinent aspects of feedback that may determine its efficacy, including frequency, duration, content, breakdown, medium and method of presentation, comparisons, and combination with other tools. According to the study, the most successful feedback incorporates the following elements: frequent and prolonged provision, specific breakdowns tailored to each appliance, clear and visually appealing presentation, and utilization of computerized and interactive resources.

In a comparative study conducted by Alahmad, Wheeler, Eiden, and Brumbaugh (2012), it was discovered that real-time energy monitors have an impact on residential energy consumption. The research involved equipping 151 residences in Omaha with two different versions of the Aztech In-Home Display (Aztech) as well as the Blue Line Power Cost Monitor (PCM) real-time energy monitors for a duration of 16 months. The results indicated a statistically insignificant 12% decrease in mean electrical consumption in households equipped with a PCM, while no reduction in mean consumption was observed in homes using either variant of the Aztech device when compared to a randomly selected control group. Nevertheless, these devices proved effective in the short term, particularly if utilized by utility companies for widespread distribution to raise awareness among participating residents about their individual residential electricity consumption patterns and the environmental impact of energy conservation.

In their study, Lynham, Nitta, Saijo, and Tarui (2016) investigated the causal mechanisms by which real-time information influences energy consumption through a randomized-control trial involving residential households. The experiment aimed to disentangle two competing mechanisms: (i) the "learning effect," which involves gaining knowledge about the energy consumption of various activities, and (ii) the "saliency effect," which entails having a constant reminder of energy usage. The findings revealed that learning plays a more prominent role than

saliency in driving energy conservation. This supports the implementation of energy conservation programs that target consumer knowledge about the energy usage of different devices and activities.

Brandon, Ferraro, List, Metcalfe, Price, and Rundhammer (2017) developed a formal research design to uncover the mechanisms underlying long-term reductions in energy consumption resulting from a widely adopted nudge. The study isolates the impact of technology adoption by comparing homes that received the treatment with control homes after the initial residents move out, discontinuing the treatment for the home. The research determined that the majority of energy reductions persist even after the treatment ends, indicating the influence of technology adoption in creating lasting behavioral changes. This highlights the significance of technology in designing enduring behavior change and underscores its implications for developing behavioral interventions and assessing their long-term societal effects.

Public Information and Social Comparison

The literature on public information and social comparison focuses on the use of peer-based energy usage information to inspire behavioral changes. Social comparison entails providing households with feedback on their energy consumption and comparing it to that of similar households. The chosen reference group for comparison should be relevant to the treated household, such as individuals who utilize the same energy provider or households within the same postcode area. The reference level also holds significance, as the household's consumption can be compared to either the average consumption of the reference group or a more ambitious group, such as the top 15% most efficient households. The potential impact of social comparison can be attributed to three phenomena. Firstly, individuals often have preferences that depend on reference points, and social norms can serve as such reference point. Conforming to these norms can enhance a person's satisfaction, while deviating from them can result in dissatisfaction due to social disapproval. Secondly, in situations of uncertainty, people may look to others' behavior as a guide, if these individuals possess more information about socially desirable conduct. Consequently, individuals tend to adjust their own behavior based on prevalent patterns within the group. Lastly, social comparisons can evoke feelings of competition, which can be particularly significant if a household's consumption level exceeds the average or if it aspires to belong to the top 15% most efficient households.

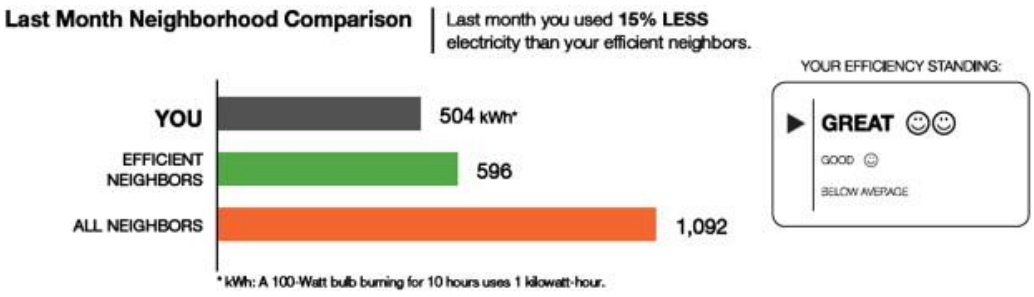
Alcott (2011) evaluates a series of programs implemented by a company called OPOWER, which involved sending Home Energy Report letters to residential utility customers, comparing their electricity usage to that of their neighbors. Drawing from data obtained through randomized natural field experiments involving 600.000 treatment and control households

across the United States, the study estimates an average reduction in energy consumption of 2.0% attributable to the program. This research offers further evidence that non-price interventions can substantially and cost-effectively influence consumer behavior.

Costa and Kahn (2014) conducted a study demonstrating that providing feedback to households regarding their own and peers' home electricity usage, through a home electricity report, is two to four times more effective among political liberals compared to conservatives. The study suggests that energy conservation nudges need to be tailored to specific target groups to maximize their effectiveness.

The provided figure exemplifies the efficacy of social comparison interventions in the context of Home Energy Report letters (HERs), which compare a household's energy usage to that of similar neighbors and offer energy conservation tips. Figure 3 illustrates the average energy savings achieved by residential customers who received the HER letters, in comparison to a control group that did not receive the letters. The data is presented in the form of a bar graph, with each group's mean energy savings displayed as a bar.

Figure 3. Home energy reports: social comparison module. (Alcott, H., 2014, Journal of public Economics)



Labeling

The literature of the labeling stream focuses on how providing information regarding the energy efficiency of appliances can motivate consumers to purchase more energy-saving products. Labels serve as concise summaries of product information that are easily accessible to consumers. This can be achieved by including relevant details about the attributes of the product on the label or by utilizing visual cues to emphasize important information. In the energy consumption scenario, labels can provide information about the energy usage of appliances or the energy efficiency standards of buildings. The third strand of literature centers on assessing the effectiveness of labeling as a non-price intervention for encouraging energy conservation behaviors in private households. A systematic review conducted by M.A. Andor and K.M. Fels (2018) examines the existing empirical evidence from 44 international studies encompassing 105 treatments, analyzing four nudge-like interventions: social comparison, commitment

devices, goal setting and labelling. This paper distinguishes itself by focusing solely on studies that allow for the identification of causal effects. The findings indicate that all four interventions have the potential to significantly reduce energy consumption in private households, although the magnitude of the effects varies considerably. The study emphasizes the necessity of impact evaluations before implementing behavioral policy interventions on a large scale. The results suggest that labeling can be an effective approach to promote energy conservation in private households, and policymakers should consider incorporating it into their energy conservation programs. However, the effectiveness of labeling, like other interventions, may depend on the context and the target population. Thus, careful evaluation and customization of interventions are crucial to ensure their effectiveness.

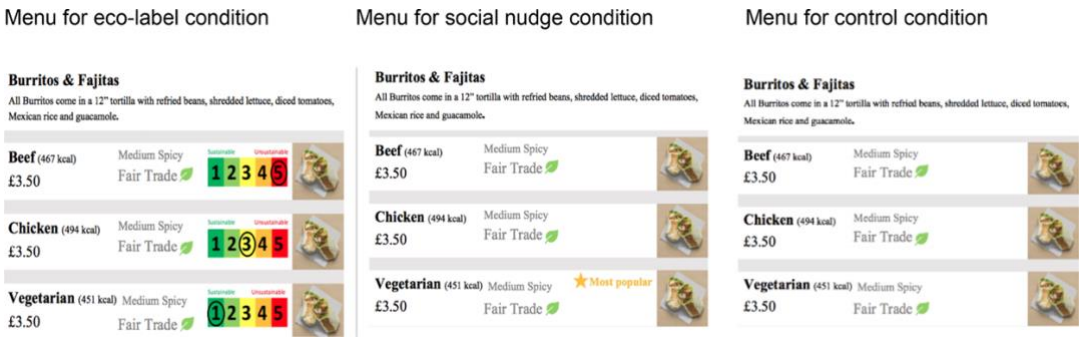
In addition to the mentioned literature streams, a study by M. Delmas and N. Lessem (2014) contributes to the discussion by examining the efficacy of detailed private and public information on electricity consumption. The study was conducted in the residence halls at the University of California - Los Angeles, based on 7,120 daily observations of energy use from heating and cooling, lighting, and plug loads for 66 rooms over an academic year. The findings reveal that while private information alone had no significant impact, combining public information with private information led to a 20 percent reduction in electricity consumption, primarily driven by reduced use of heating and cooling. The effectiveness of public information was particularly notable for those who consumed more energy than the median consumer. These results indicate that combining private and public information can be an effective strategy for promoting energy conservation in private households, especially among higher than average energy users.

In conclusion, the reviewed literature highlights the effectiveness of providing information, feedback, and labeling in promoting energy conservation behaviors in private households. The analyzed studies demonstrate that feedback on household electricity consumption, social comparison with peers, and energy efficiency labeling can drive behavior change and encourage the adoption of energy-efficient products. The findings suggest that behavioral interventions offer a cost-effective approach to promote energy conservation and targeting these interventions to specific groups can enhance their effectiveness. Further research is needed to understand the underlying mechanisms of these interventions and develop more targeted and impactful behavioral interventions.

Figure 4 presents an example of a labeling intervention in the context of a study investigating the influence of eco-labels and social nudges on food choices. The study employed an online experiment using Qualtrics, an online survey software, with participants being asked to select a hypothetical food item from a menu consisting of three choices: a beef burrito, a chicken burrito, or a vegetarian burrito. Participants were randomly assigned to one of three study

conditions, which varied based on the labeling of the burrito: eco-label, social nudge label, or no label control. The study also included a within-subjects component to measure reactance to both labels. The participants were recruited through Prolific Academic, an online research platform, and data were collected over a 24-hour period in February 2020. Furthermore, beyond food choices, labeling interventions can be extended to various behaviors, such as water usage. For instance, in our particular setting and for the specific behavior we aim to address, we could exhibit information concerning the quantity of water bottles consumed during a shower, aiming to encourage more environmentally friendly practices. The accompanying graph illustrates an instance of how labeling interventions can effectively drive behavior change and foster sustainability across diverse contexts.

Figure 4. The menu shown for eco-label condition, social nudge condition and control condition Promoting sustainable diets using eco-labelling and social nudges: a randomised online experiment, 2022, Cambridge University Press.



4. Experimental design

The object of the proposed experimental design is to establish which of the three different behavioral mechanism aimed at reducing electricity consumption in the residential buildings of Luiss Guido Carli is more effective. Specifically, I intend to perform three different treatments: Private information regarding individual energy consumption (Ambient Orbs), individual feedback can be called private information because it is a privately disclosed information about each student's own energy use or environmental impact, which differs from the treatment proposed by M. Delmas and N. Lessem (2014), as it does not include "social comparison"; Public information about the energy consumption of each housing unit in the residence, approximating M. Delmas and N. Lessem (2014), "public information" treatment, public information is information about a specific agent's behavioral impact that is publicly disclosed, through the use of Digital Whiteboards, in both of the residential buildings displaying public information, allowing sustainable behaviors to act as a signal of "green" virtue. This can lead

to reputational benefits and motivate efficient behaviors among consumers; Contest, in which public information and social comparison will be accompanied by a ranking of the various housing units in the residence based on weekly energy consumption. The winning housing unit in the contest will receive a monetary prize. This treatment differs from all the literature I analyzed and can be just the first of many, and I believe that this specific treatment will have far more success than the others two, the results of this experiment, as soon as they will be available, can have strong policy implications, as each Government or Energy Firm can benefit much more from "sustainable behaviors" and good reputation rather than energy bills.

The experiment will last an entire academic year, approximately ten months, because it is important that for the entire duration of the experiment, the rooms are occupied by the same agents, in order not to have a consumption change bias between one agent's and the next due to different habits.

I and the research group of LUISS Guido Carli intend to do a follow-up study the following year, with a subset of rooms that have remained occupied by the same agent's, to see if their consumption habits will return to their original levels or will continue to be more sustainable even after the experiment ended. And compare our data across the three approaches to see which one has the most effective long-term effect. In each treatment, information regarding energy consumption will be updated daily thanks to "smart meters" (devices for automatic measurement of electricity consumption) that will be installed in all housing units of the University residences. Additionally, in the first type of intervention, housing units will be notified if they have exceeded the average consumption of comparable-sized housing units during the day through "Ambient Orbs", luminous devices that can change color depending on the energy consumption of the housing unit. In the second and third intervention, a screen placed at the entrance (or in any other common area) will respectively show the energy consumption of each housing unit (public information) and the ranking.

To apply a more rigorous experimental methodology, I will need access to data from four different residences with similar (virtually identical) characteristics, one for each treatment plus one for the control group, where no intervention is carried out, used as a benchmark for the three residences where there will be an actual intervention going on.

To implement these interventions, I will need:

- One "smart meter" for each housing unit in the four residences;
- One "Ambient Orb" for each housing unit in the first treated residence;
- Two screens or digital whiteboards, one for each residence involved with public information

To collect data for the experiment, we will install "smart meters" in each housing unit of the four residences. These meters will automatically measure electricity consumption and transmit

data to a central database daily. In addition, I will use “Ambient Orbs” and Screens to display information about energy consumption in the different treated residences. I will also collect demographic and socioeconomic data from the agents, such as age, gender, education level, family income, number of brothers and sisters if any, to control for potential biasing factors that may affect energy consumption behavior.

Measuring the effectiveness of non-price interventions for energy conservation behavior in private households can be challenging, as it often involves complex behavior change that is influenced by various factors. However, there are several methods that can be used to measure the effectiveness of these interventions: Energy consumption data is the first method I will use to determine if the experiment was successful, I will compare the energy usage of the three buildings receiving intervention with the control group. This will be done by installing smart meters in each of the targeted dormitories. By comparing energy consumption data, it is possible to determine whether the intervention has led to a reduction in energy use. The second method that I and the research team of the University will use, together with the first one, are Surveys and Questionnaires used to gather information about personal data that we will use in our regression, such as Gender, Household, Family Income, Number of siblings (if any) and Nationality. This type of information will help us to better understand differences in consumption among different rooms. Another method is the social network analysis, this type of analysis can be very useful especially in the second and third intervention, because they rely on social comparison, this can be fundamental to understand how information and behavior spread through social networks. I want to give you an example of how a social network analysis works: Suppose for instance that a utility company wants to promote energy conservation behavior among its customers by providing them with information about their energy use and encouraging them to set conservation goals. The company could use social network analysis to identify clusters of customers who are connected to each other through social ties, such as family, friends, and neighbors. By analyzing the structure of these social networks, the company could identify influential customers who are well-connected to others and who could potentially spread information and behavior related to energy conservation. The company could then target these influential customers with the intervention, providing them with personalized information about their energy use and encouraging them to set conservation goals. By leveraging the influence of these customers, the company could potentially reach a larger audience and promote behavior change more effectively than if it had simply provided the intervention to all customers. After implementing the intervention, the company could use social network analysis again to measure the spread of information and behavior related to energy conservation through the social network. By analyzing changes in the structure of the social network and the behavior

of its members, the company could determine whether the intervention was effective and identify areas for improvement. Overall, social network analysis can be a powerful tool for promoting behavior change related to energy conservation by leveraging the influence of social ties and identifying key players in social networks.

Lastly, I will perform a cost-benefit analysis to compare the costs of the intervention to the benefits in terms of energy saving. This can help determine whether the interventions are cost-effective.

Overall, measuring the effectiveness of non-price interventions for energy conservation behavior in private households requires a combination of methods that are tailored to the specific intervention and context. A multi-method approach that combines quantitative and qualitative data can provide a more comprehensive understanding of the effectiveness of these interventions.

In our specific setting, I will investigate the effectiveness of the three different interventions in reducing energy consumption. I will collect data on energy usage from smart meters installed in each residential unit, personal information for surveys and then I will use the following regression to better understand our findings:

$$\begin{aligned} Cons_{i,t} = \ & \beta_0 + \beta_1\,(Treatment_i) + \beta_2(Day_t) + \beta_3\,(Month_t) \\ & + \beta_4\,(Number\ of\ occupants_i) + \beta_5(Gender_i) \\ & + \beta_6\,(Number\ of\ Siblings_i) + \beta_7(Nationality_i) + \varepsilon_{i,t} \end{aligned}$$

Where:

Energy consumption: The dependent variable that we want to analyze. This can be measured by the smart meters installed in each housing unit and collected on a daily basis.

Treatment: A categorical variable that represents the three different treatments you are testing, with the control group as the reference category (i.e., Treatment 0). This variable takes on the value of 0 for the control group, 1 for the Ambient Orb treatment (Private Information) , 2 for the Public Information treatment, and 3 for the Contest (Competition) treatment.

Day: the day variable is a categorical variable that represents each day of the week. It can help to identify whether there are any weekly patterns in the consumption data, such as higher consumption on weekdays compared to weekends. By including this variable in the regression, it is possible to estimate the effect of the day of the week on the consumption of the housing unit. Similarly, the month variable is a categorical variable that represents each month of the year. It can help to identify any seasonal patterns in the consumption data, such as higher

consumption in the winter compared to the summer. By including this variable in the regression, it is possible to estimate the effect of the month on the consumption of the housing unit.

Number of occupants: A dummy variable representing whether the housing unit is a single or shared room. This variable takes on the value of 1 if the room is a shared room (i.e., double occupancy) and 0 if the room is a single room. This variable can account for potential differences in energy consumption between single and shared rooms.

Gender: A binary variable representing the gender of the occupant. This variable takes on the value of 1 if the occupant is female and 0 if the occupant is male. This variable can account for potential differences in energy consumption between male and female occupants.

Siblings: A continuous variable representing the number of siblings the occupant has. This variable can account for potential differences in energy consumption due to family size.

Nationality: A categorical variable representing the nationality of the occupant. This variable can account for potential cultural differences in energy consumption behavior.

The coefficients (β) associated with the treatment variable will tell you whether each of the three treatments is associated with a significant change in energy consumption relative to the control group. The coefficients associated with the Day, Month, Number of occupants, Gender, Siblings, and Nationality variables can account for potential confounding factors and help to control for them in the analysis.

To interpret the results of the regression analysis, you can examine the coefficients associated with each variable to determine whether they are statistically significant and whether they have a positive or negative effect on energy consumption. For example, if the coefficient for the Private Information treatment is negative and statistically significant, this would indicate that the Private Information treatment is associated with a significant reduction in energy consumption compared to the control group. If the coefficient for the Number of occupants variable is positive and statistically significant, this would indicate that shared rooms tend to consume more energy than single rooms.

Overall, the regression analysis can help you identify which of the three treatments is most effective at reducing energy consumption while controlling for potential confounding variables such as day of the week, room type, gender, number of siblings, and nationality.

To determine if the coefficients are statistically significant, I will perform a hypothesis test using a t-test.

For a t-test, you would calculate the t-statistic as follows:

$$t = \frac{\beta - \beta_h}{\sigma(\beta)}$$

where β is the estimated coefficient, β_h is the null hypothesis value (i.e., no effect), and $\sigma(\beta)$ is the standard error of the coefficient. You can then calculate the p-value using the t-distribution with n-k-1 degrees of freedom, where n is the sample size and k is the number of predictors in the model. If the p-value is less than a chosen significance level (e.g., $\alpha = 0.05$), then you can reject the null hypothesis and conclude that the coefficient is statistically significant.

Alternatively, if the sample size is large (typically $n > 30$) and the distribution of the data is approximately normal, I can use a z-test instead. The z-test is similar to the t-test, but uses a standard normal distribution instead of a t-distribution.

It's also worth noting that some statistical software packages, such as R or Python, will automatically calculate the t-statistic and p-value for each coefficient in the regression model, so I don't need to perform these calculations manually.

The p-value in a hypothesis test represents the probability of observing a test statistic (such as a t-statistic or z-statistic) as extreme or more extreme than the one calculated from the sample data, assuming that the null hypothesis is true.

In the context of a regression analysis, a small p-value (typically less than 0.05) indicates that the coefficient is statistically significant, meaning that it is unlikely to have occurred by chance alone. This means that there is strong evidence to support the alternative hypothesis that the coefficient is different from zero, and that the predictor variable has a significant effect on the outcome variable.

Conversely, a large p-value (typically greater than 0.05) suggests that there is insufficient evidence to reject the null hypothesis, and that the coefficient is not statistically significant. This means that the predictor variable is not a significant contributor to the outcome variable, and that any observed relationship is likely due to chance or other factors not accounted for in the model.

It's worth noting that the p-value alone cannot tell you the magnitude or direction of the effect of the predictor variable on the outcome variable. To understand the practical significance of a coefficient, I should also consider the magnitude of the coefficient, the confidence interval, and the effect size measures.

5. Expected Results

I formulated three main hypotheses to test:

1. The second intervention, the one dealing with Public Information, approximating M. Delmas and N. Lessem (2014) treatment, is more effective than Private Information (Ambient Orbs).
2. The third intervention, Competition/Contest, is more effective than Public Information.

3. The first intervention, Ambient Orbs, are more effective in our specific scenario relative to past experiments.

The first hypothesis is based on historical data, past experiments, and my analysis of the related literature. My analysis suggests that while private information can be effective in promoting more sustainable behaviors, public information can provide an additional motivation for energy conservation, that is achieving a "green" reputation. This hypothesis is also supported by M. Delmas and N.Lessem, (2014) , which found that public information combined with Private Information was more effective in promoting energy saving behaviors than private information alone. Therefore, I expect that the second intervention, which deals with public information and social comparison, will be more effective than the first intervention, which involves Ambient Orbs.

The second hypothesis is something that I personally expect, even if there is no evidence in favor of this since no one has ever tested this specific intervention. My hypothesis assumes that Competition can be a powerful motivator for behavioral change, especially if the agent has a monetary prize to win. Therefore, I expect that the third intervention, which involves the Contest, will me more effective than the other two interventions.

The third hypothesis is context related, since my setting is very different from the ones of past experiments, and not just the setting but also the participants. Given their young age and propensity to be more sustainable, there is a possibility that agents will pay more attention to the Ambient Orbs as an instrument of energy conservation behavior than people from standard households. This hypothesis is supported by the idea that the effectiveness of non-price interventions for energy conservation behaviors in private households can depend on various factors, including the context and the specific population being targeted. Therefore, I expect that the first intervention, which involves Ambient Orbs, will be more effective in this specific scenario relative to past experiments.

Overall, my hypotheses are based on a combination of past research findings, my analysis of the literature and my understanding of the context and the participants in this specific scenario. By testing these hypotheses, I hope to contribute to the growing body of literature on non-price interventions for energy conservation behavior in private households.

6. Discussion and Policy Implications

In this chapter, I discuss the use of green nudges as an environmental policy instrument for promoting energy conservation behavior in residential areas. Based on a review of empirical studies, we find that green nudges have a substantial impact on behavior and the environment,

but that their effectiveness is context dependent. While green nudges have a large potential to reduce negative externalities, they can also help solving environmental problems and should be seen as one policy instrument among others in the regulator's toolbox.

Drawing on the experimental design, I derived several policy implications that can guide policymakers in developing effective energy conservation policies and interventions in residential areas. First, the results of our experiment provide insights into the effectiveness of different types of information provision on energy consumption. Private information about one's energy consumption and public information about energy consumption in each housing unit will be tested. Policymakers can leverage these strategies to promote energy conservation by providing individuals with feedback on their energy usage and making energy consumption more transparent.

Second, our experiment examines the impact of social comparison and competition through a contest, where public information about energy consumption will be accompanied by a ranking and a monetary prize for the winning housing unit. The findings can inform policymakers about the potential benefits of incorporating social comparison and rewards elements in energy conservation programs. This may involve implementing competitions, rewards, or recognition to incentivize individuals to reduce their energy consumption.

Third, our use of smart meters to automatically measure and transmit electricity consumption data is a crucial component of the experimental design. The results of our experiment can highlight the value of smart metering in promoting energy efficiency and conservation. Policymakers can consider promoting the widespread adoption of smart meters in residential areas to provide individuals with real-time feedback on their energy usage and encourage behavior changes.

Fourth, the experimental design requires the installation of smart meters, ambient orbs, and screens or digital whiteboards in the residences. The findings can emphasize the importance of investing in the necessary technological infrastructure to support energy conservation initiatives. Policymakers may need to allocate resources for the installation and maintenance of such infrastructure to enable effective implementation of energy-saving interventions.

Fifth, our rigorous methodology, including the control group and statistical analysis, allows for a comprehensive evaluation of the treatment effects. The policy implications highlight the significance of conducting evidence-based evaluations of energy conservation interventions. Policymakers should prioritize rigorous evaluation frameworks to assess the impact and cost-effectiveness of policies and interventions designed to reduce electricity consumption.

Sixth, by collecting demographic and socioeconomic data from the residents, the experiment enables to examine variations in treatment effects across different groups. Policymakers can

gain insights into the effectiveness of the interventions for specific population segments. This information can guide policymakers in designing targeted interventions that consider the unique characteristics and preferences of different groups within the residential areas.

Finally, the experiment proposes conducting a cost-benefit analysis to evaluate the economic feasibility of each intervention. This analysis can provide policymakers with crucial information on the costs associated with implementing energy-saving measures and the potential energy savings resulting from these interventions. Policymakers can utilize this analysis to prioritize interventions that yield significant energy savings relative to their costs.

Overall, the experimental design outlined in our thesis has several policy implications that can guide policymakers in developing effective energy conservation policies and interventions in residential areas. By leveraging the insights gained from our experiment, policymakers can promote energy conservation behavior among individuals, reduce negative externalities, and contribute to environmental sustainability.

In conclusion, the policy implications derived from this experimental thesis highlight the significance of evidence-based policy development in promoting energy conservation in residential areas. Our findings emphasize the potential of green nudges as an environmental policy instrument to reduce negative externalities and promote sustainable behavior. Policymakers can leverage the insights gained from our experiment to design effective energy conservation policies and interventions that consider the unique characteristics and preferences of different population segments. By prioritizing rigorous evaluation frameworks, investing in the necessary technological infrastructure, and conducting cost-benefit analyses, policymakers can promote energy conservation behavior among individuals, reduce negative externalities, and contribute to environmental sustainability.

Here you can find several examples of possible green nudges that policymakers can use to encourage individuals to reduce their energy consumption: providing real-time feedback on energy usage through smart metering can help individuals become more aware of their energy consumption and encourage them to conserve energy. Additionally, setting default thermostat settings to more energy-efficient temperatures can nudge individuals towards more sustainable behavior.

Social comparison can also be an effective nudge in this context. For instance, providing individuals with information about their neighbors' energy use and how it compares to their own can encourage them to reduce their energy consumption. Similarly, implementing competitions or rewards for the housing unit that consumes the least energy can incentivize individuals to conserve energy.

Policymakers can also use labeling and information provision as nudges to encourage individuals to make more sustainable choices. For instance, providing energy ratings on appliances and information on the energy savings associated with different behavior changes can encourage individuals to purchase energy-efficient products and adjust their behavior accordingly.

Overall, the use of green nudges in the specific context of energy conservation in residential areas can be an effective and cost-efficient way to promote sustainable behavior and reduce negative externalities. Policymakers can use these nudges in combination to design effective and tailored policies that encourage individuals to reduce their energy consumption and contribute to environmental sustainability.

7. Conclusions

After conducting a comprehensive investigation into the potential of nudges to promote sustainable behavior and reduce energy waste in a dormitory setting, this thesis contributes to the field of environmental nudging through the implementation of various nudges aimed at increasing awareness of energy consumption and promoting sustainable behaviors, this study provides a comprehensive assessment of the impact of these nudges on energy consumption and behavior.

The combination of quantitative and qualitative methods provides valuable insights into the effectiveness of different nudging strategies in a real-world dormitory setting. The findings of this study will add to the existing body of research on environmental nudging and its efficacy in promoting sustainable behavior. Additionally, the results will help identify the most effective approaches for reducing energy waste and encouraging sustainable behaviors among dormitory residents.

The practical implications of this study extend beyond the dormitory setting to businesses and organizations seeking to reduce their environmental impact and promote sustainability. The insights gained from the research can inform the development and implementation of effective energy conservation programs and initiatives in various contexts. By understanding the factors that influence sustainable behavior, businesses and organizations can design targeted interventions that align with individuals' motivations and preferences, leading to more successful outcomes.

Furthermore, this study's contribution to addressing climate change is significant. By investigating the effectiveness of nudges in reducing energy waste, it contributes to the broader efforts of mitigating climate change and promoting sustainability. The findings can inform

policymakers and stakeholders in designing and implementing strategies that encourage energy efficiency and conservation at both individual and collective levels.

In my personal educated consideration, the experiment has the potential to shed light on the prevalence of competition as a motivator for sustainable behavior. While I believe that the monetary prize in the contest treatment (Third treatment) may have a greater influence, there is also an expectation that new generations prioritize social norms and environmental concerns over monetary gain. The increasing awareness and concern about climate change among young people suggest a growing willingness to respond to environmental challenges collectively.

Considering that the participants in the experiment are young and teachable, this study has the potential to leave a lasting impact on their attitudes and behaviors. It may cultivate a sense of sustainability, consciousness, and efficiency, leading them to become more environmentally conscious citizens. The experience gained through the experiment may also motivate participants to adopt technologies such as ambient orbs or smart meters to monitor and manage their energy usage more effectively.

In summary, this thesis makes a significant contribution to the understanding of environmental nudging and its potential to promote sustainable behavior and reduce energy waste. The findings have practical implications for businesses and organizations, while also supporting global efforts to address climate change. The study's impact on participants may extend beyond the experiment, fostering sustainable attitudes and behaviors among young individuals and contributing to a more environmentally conscious society. Overall, this research provides valuable insights into the effectiveness of nudging strategies in promoting sustainability and reducing energy waste in a real-world setting. To further elaborate on the significance of this research, it is important to consider the broader context of global sustainability challenges. Climate change and other environmental concerns have become increasingly urgent issues, and promoting sustainable behavior is a crucial part of addressing these challenges. As such, understanding the most effective ways to encourage sustainable behavior is critical for policymakers, businesses, and individuals alike.

Environmental nudging offers a promising approach to promoting sustainable behavior, as it relies on subtle interventions that can have a significant impact on behavior without relying on traditional methods such as regulation or financial incentives. By investigating the effectiveness of these nudges in a real-world dormitory setting, this study provides valuable insights into the potential of nudges to promote sustainable behavior and reduce energy waste.

Furthermore, the study's focus on young individuals is particularly noteworthy, as young people are increasingly recognized as key players in promoting sustainability and mitigating climate

change. By examining the efficacy of nudges on this demographic, this research sheds light on the most effective strategies for fostering sustainable attitudes and behaviors among young individuals.

Overall, the findings of this study have important practical implications for businesses, organizations, and policymakers seeking to reduce their environmental impact and promote sustainability. By understanding the most effective approaches to promoting sustainable behavior, these stakeholders can design targeted interventions that align with individuals' motivations and preferences, leading to more successful outcomes.

In conclusion, this research makes a valuable contribution to the field of environmental nudging and the broader efforts to promote sustainability and mitigate climate change. The findings have important practical implications for businesses, organizations, and policymakers, while also supporting the cultivation of sustainable attitudes and behaviors among young individuals. As the world faces increasingly urgent sustainability challenges, the insights gained from this research can inform the development of effective strategies to address these challenges and promote a more sustainable future.

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