BEHAVIORAL ECONOMICS AND GREEN ENERGY ADOPTION: A REVIEW OF NUDGES, EXPERIMENTAL EVIDENCE, AND POLICY APPLICATIONS

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ABSTRACT

This study examines the role of behavioral nudges in fostering green energy adoption, emphasizing experimental evidence and policy implications. Drawing on theories such as Expected Utility Theory, Prospect Theory, and Nudge Theory, the paper explores how psychological and cognitive factors influence energy-related decision-making. Behavioral tendencies such as status quo bias, loss aversion, and social norm adherence are analyzed in their capacity to impede or enhance the adoption of renewable energy technologies. Empirical evidence highlights the efficacy of interventions like green defaults, feedback mechanisms, and competence-boosting strategies in promoting sustainable behaviors. Studies demonstrate significant energy savings through tailored nudges, with persistent effects when interventions account for socio-economic and cultural contexts. Ethical considerations, including transparency and autonomy, are also discussed. The review underscores the potential of combining behavioral insights with economic policies to overcome psychological barriers to green energy adoption. Future research should focus on the scalability of nudges, the integration of emerging technologies, and addressing inequalities to ensure equitable access to renewable energy solutions.

Keywords: behavioral nudges, green energy adoption, prospect theory, nudge theory, expected utility theory, energy policy, psychological barriers.

JEL Classification: D90, Q4, Q5.

1. INTRODUCTION

The global transition to green energy is essential to mitigate escalating climate challenges, meet rising energy demands, and reduce greenhouse gas emissions. Renewable energy sources, such as solar, wind, and hydropower, are pivotal in achieving these goals. However, despite advancements in renewable technologies and supportive policies, adoption rates remain insufficient to meet international climate targets (IRENA, 2024). This gap highlights the need for innovative strategies to complement traditional policy tools.

Behavioral economics offers a novel perspective for addressing the non-technological barriers to green energy adoption. By examining psychological and cognitive influences on decision-making, behavioral interventions—such as nudges—have demonstrated promise in encouraging pro-environmental behavior through cost-effective, non-coercive methods. Unlike traditional policies, which focus on economic incentives, nudges tackle biases like inertia and present bias, making them particularly relevant for fostering sustainable energy transitions (Allcott & Mullainathan, 2010; R. H. Thaler & Sunstein, 2008).

This study investigates the potential of behavioral nudges to accelerate green energy adoption by addressing the following key questions:

How do behavioral nudges, such as defaults and feedback mechanisms, influence consumer and investor decisions?

What role do psychological factors play in promoting or hindering renewable energy adoption?

How can behavioral insights be ethically integrated into policy frameworks to maximize impact?

The objectives of this research are to:

Synthesize empirical evidence on the effectiveness of behavioral nudges in green energy transitions.

Analyze the interplay between psychological factors and renewable energy decision-making.

Develop actionable policy recommendations to enhance the scalability and impact of nudge-based interventions.

By bridging the gap between economic models and behavioral insights, this study aims to provide a comprehensive framework for advancing the global transition to sustainable energy. It offers practical strategies for policymakers, energy providers, and researchers dedicated to promoting renewable energy adoption.

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

This section integrates behavioral insights and traditional policy instruments to analyze decision-making processes related to green energy adoption. By synthesizing Expected Utility Theory (EUT), Prospect Theory, and Nudge Theory, it explores how cognitive biases and psychological tendencies influence the adoption of renewable energy technologies. The framework also examines actionable strategies to address these barriers through behavioral nudges.

2.1. Literature Review

2.1.1. Expected Utility Theory and Prospect Theory

Expected Utility Theory (EUT) posits that individuals make rational decisions by weighing the costs and benefits of available choices to maximize their utility (Neumann & Morgenstern, 1953). The Expected Utility Theory formula calculates the utility of outcomes as follows:

$$EU = \sum_{i=1}^{n} u(x_i)p_i$$

p_i indicates the probability of the outcome x_i and $u(x_i)$ indicates the benefit of obtaining the outcome x_i. Bernoulli observed that a certain amount of money is worth more to a poor person than to a rich person. Thus, as welfare increases, marginal utility decreases. This ensures that the utility function is concave (Trepel et al., 2005).

Shortly after the introduction of Expected Utility Theory (EUT) by Von Neumann and Morgenstern in 1944, its descriptive validity came under scrutiny. A significant challenge arose from the Allais Paradox, introduced by Maurice Allais in 1952, which demonstrated inconsistencies in the decision-making of prominent economists like Samuelson, Arrow, and Friedman. In the Allais paradox, the participant must select one option from a set of choices labeled A, B, C, and D.

First choice

(A): A profit of $1 million will definitely be made,

(B): 10% chance of winning $5 million, 89% chance of winning $1 million, 1% chance of winning nothing,

The second option

(C): 11% chance of winning $1 million, 89% chance of nothing,

(D): 10% chance of winning $5 million, 90% chance of nothing.

Allais anticipated that people would choose option A over option B. This was because in option A, becoming a millionaire was certain. However, based on the expected utility formula, option B should have been favored. Similarly, in another scenario, option C should have been chosen over option D, but people preferred option D over option C. This means that having a 10% chance of winning $5 million was seen as better than having an 11% chance of winning $1 million. Thus, this situation contradicts the assumptions of expected value theory and leads to a paradox (Aksoy T. and Şahin İ., 2015; Kahneman, 2011).

While EUT assumes rational decision-making, real-world choices often diverge due to psychological biases and incomplete information. For example, in renewable energy investments, traditional EUT models may fail to account for consumers' undervaluation of long-term savings and overemphasis on upfront costs. These shortcomings highlight the need for behavioral models that capture such complexities.

To address these inconsistencies, Kahneman and Tversky (1979) introduced Prospect Theory (PT), which demonstrates that individuals perceive gains and losses asymmetrically. Losses tend to loom larger than equivalent gains, a phenomenon known as loss aversion. PT suggests that individuals evaluate outcomes based on gains and losses relative to a reference point rather than final wealth. Its value function is concave for gains, convex for losses, and steeper for losses, reflecting **loss aversion**. Additionally, PT accounts for **diminishing sensitivity**, where changes near zero are perceived as more significant than those at higher magnitudes (Thaler, 1980).

The **Prospect Theory formula** evaluates the subjective value of outcomes as:

$$f = \sum_{i=1}^{n} \pi(p_i) \cdot v(x_i)$$

Here:

- $\pi(p_i)$ represents the weight assigned to probability (p_i) by the probability weighting function.

- $v(x_i)$ represents the value assigned to outcome x_i by the value function.

PT introduces a two-stage process: **editing** and **evaluation**. In the editing stage, individuals structure information through encoding, cancellation, and other operations. In the evaluation stage, prospects are assessed using subjective probabilities and values. Unlike EUT, PT incorporates framing effects, reference dependence, and psychological principles, offering a nuanced model for real-world decision-making (Kahneman & Tversky, 1979; Trepel et al., 2005).

This insight is particularly relevant in green energy adoption, where the upfront costs of renewable technologies, such as solar panels, often deter consumers despite the long-term benefits of energy savings and reduced environmental impact.

In addition to loss aversion, Prospect Theory's concept of probability weighting—where individuals overestimate small probabilities and underestimate large ones—has significant implications for green energy adoption. For instance, consumers may overestimate the risk of technology failure while underestimating the broader risks of climate inaction.

These findings underscore the importance of designing policies that minimize perceived losses while emphasizing future gains. For instance, framing renewable energy investments as long-term financial benefits rather than immediate expenses could help mitigate loss aversion and foster sustainable energy transitions.

While EUT assumes individuals make decisions by maximizing utility based on objective probabilities and outcomes, real-world behavior frequently diverges due to phenomena like loss aversion and probability weighting, as highlighted by Prospect Theory (Kahneman & Tversky, 1979).

2.2. Theoretical Framework

These insights set the stage for the application of Nudge Theory, which operationalizes these behavioral tendencies into practical interventions (Thaler and Sunstein, 2008). Nudges leverage biases such as inertia, framing effects, and social norms to influence decision-making without restricting individual freedom. For instance, setting renewable energy as the default option exploits the status quo bias (Samuelson and Zeckhauser, 1988), while feedback mechanisms address loss aversion by framing long-term benefits as immediate gains (Frederiks et al., 2015). Thus, Nudge Theory bridges the gap between theoretical models of human behavior and actionable strategies for fostering green energy adoption.

2.2.1. Nudge Theory and Psychological Barriers to Green Energy Adoption

Nudge Theory, popularized by Thaler and Sunstein (2008), provides a framework for influencing behavior through subtle changes in choice architecture. A nudge is defined as any intervention that steers individuals toward a specific decision while preserving freedom of choice and avoiding significant economic incentives. Nudges are particularly effective in addressing complex decisions with long-term trade-offs, such as adopting renewable energy technologies.

Advancements in technology have expanded the scope of nudging. Digital tools, such as personalized energy reports, real-time consumption feedback, and mobile apps, have enhanced the precision and scalability of behavioral interventions. However, these tools also raise ethical concerns about data privacy and consent.

Behavioral economics identifies several psychological barriers that hinder green energy adoption, including the following:

Status Quo Bias: Households often resist change, preferring familiar behaviors over greener alternatives, even when the latter offer substantial benefits (Frederiks et al., 2015; Samuelson and Zeckhauser, 1988). For example, setting renewable energy as the default option in utility plans significantly boosts adoption rates (Pichert and Katsikopoulos, 2008).

Loss Aversion and Framing Effects: The fear of losses outweighs potential gains, deterring investments in renewable technologies with high upfront costs (Kahneman and Tversky, 1979). Framing interventions, such as presenting the financial losses of inaction, have proven effective in countering this bias (Frederiks et al., 2015).

Social Norms and Peer Influence: Social comparisons strongly influence energy behaviors. Feedback mechanisms comparing household energy consumption to neighbors' averages have been shown to reduce energy use significantly (Allcott & Rogers, 2014; Frederiks et al., 2015; PW Schultz, 2014).

Temporal Discounting: Consumers often prioritize immediate costs over long-term benefits, a bias known as temporal discounting. Visualization tools that highlight future savings can make long-term benefits more salient, thereby encouraging investments in renewable technologies (Frederiks et al., 2015).

Trust and Credibility: Trust in energy providers and policymakers plays a pivotal role in renewable energy decisions. Transparent communication and endorsements from credible sources, such as local leaders or environmental organizations, enhance trust and adoption rates (Frederiks et al., 2015).

2.2.2. Strategies for Promoting Green Energy Adoption

Nudging strategies provide actionable solutions to address the psychological barriers outlined above. These strategies fall into four key categories:

Green Defaults: Setting renewable energy as the default option by utility providers has been highly effective in guiding behavior. Studies show that individuals are more likely to stick with default options, as seen in Germany, where over 99% of households maintained green energy use when it was the default setting (Schubert, 2017).

Social Incentives: Leveraging social norms through peer comparisons and public recognition fosters pro-environmental behavior. For instance, providing households with monthly energy reports comparing their usage to neighbors' averages has significantly reduced energy consumption (Allcott & Rogers, 2014).

Feedback Mechanisms: Real-time feedback on energy consumption, such as via smart meters or eco-labeling, enhances awareness and promotes sustainable decisions. Comparative data on energy performance relative to peers drives energy-saving behaviors (Sörqvist & Langeborg, 2019).

Reducing Barriers to Action: Simplifying processes, such as solar panel installation, or providing financial incentives like subsidies, reduces friction and improves adoption rates (Cosic et al., 2018).

The effectiveness of nudges also depends on how they are framed and the perceived effort required to comply. Grelle et al. (2024) found that nudges framed in a personal context ("you") are more impactful than those framed societally ("they"). Similarly, low-effort nudges are more widely accepted and effective, underscoring the need for simplicity in design (de Groot & Schuitema, 2012; Hagmann et al., 2019; Rodriguez-Sanchez et al., 2018).

Cultural Context: Understanding the cultural context in which behavioral nudges are implemented is crucial for their effectiveness in promoting green energy adoption. Cultural norms, values, and socio-economic factors significantly influence individuals' perceptions and responses to nudges, necessitating a tailored approach to intervention design. For instance, research has shown that social norms play a pivotal role in shaping sustainable energy behaviors, with descriptive and injunctive norms varying widely across different cultural settings (Allcott, 2011). In regions where community-oriented values prevail, nudges that leverage social comparisons may be particularly effective, as individuals are motivated by the desire to conform to group behaviors. Conversely, in cultures that emphasize individualism, personal choice and autonomy may take precedence, suggesting that nudges should be framed to highlight personal benefits and control (Schubert, 2017). Furthermore, socio-economic factors, such as income levels and access to renewable technologies, can affect the receptiveness to nudges and the feasibility of adopting green energy solutions (Andor et al., 2020; Brick et al., 2023). Therefore, this study will incorporate a culturally sensitive approach, adapting nudging strategies to align with the specific values, beliefs, and circumstances of the target populations. By doing so, the research aims to enhance the relevance and impact of behavioral interventions in diverse cultural contexts, ultimately contributing to more effective strategies for fostering sustainable energy practices.

3. METHODOLOGY

This study employs a qualitative and quantitative approach to examine the effectiveness of behavioral nudges in promoting green energy adoption. The research synthesizes existing empirical evidence from experimental studies, field trials, and policy interventions, drawing on data from a range of socio-economic and cultural contexts. The methodology is structured around two primary components: a review of theoretical frameworks and an analysis of empirical studies. The study follows a structured narrative review approach with elements of systematic review. The literature is selected based on relevance to behavioral economics, green energy adoption, and policy applications. The main sources include peer-reviewed journal articles, reports, and experimental studies published mostly in the last two decades, with more focus on recent studies. The selection criteria include: (1) direct relation to behavioral nudges or energy behavior, (2) empirical or experimental evidence, and (3) policy relevance. The analysis is based on comparative and thematic synthesis, where findings from different studies are grouped and compared to identify common patterns, differences, and key insights.

Guided by the behavioral insights and theoretical constructs presented in the preceding section, this study focuses on empirical evidence and experimental interventions to evaluate the effectiveness of nudges in promoting green energy adoption.

Empirical Evidence Review: A systematic review of existing literature is conducted, focusing on experimental and policy-based interventions that utilize behavioral nudges to promote renewable energy adoption. The review includes both large-scale randomized controlled trials (RCTs) and smaller-scale field experiments that measure the impact of nudges such as green defaults, feedback mechanisms, and social norm interventions. The selected studies are analyzed in terms of their design, sample size, methodologies, and findings. Key studies provide empirical insights into the effectiveness of nudges in varying contexts.

Data Analysis: Quantitative data from these empirical studies are analyzed to assess the impact of specific nudging strategies on green energy adoption rates. This includes evaluating adoption rates, energy consumption reductions, and the persistence of behavioral changes over time. Additionally, qualitative insights from case studies and interviews are synthesized to gain a deeper understanding of consumer perceptions, motivations, and barriers to adopting green energy solutions. These qualitative findings complement the quantitative data, offering a holistic view of nudge effectiveness.

Through this methodology, the study aims to provide a comprehensive analysis of how behavioral nudges can be leveraged to facilitate green energy adoption while addressing the psychological and cognitive barriers that hinder pro-environmental behavior.

4. EMPIRICAL EVIDENCE FROM EXPERIMENTAL STUDIES

The following section examines key empirical evidence from experimental studies on the determinants, barriers, and behavioral interventions that shape green energy adoption. By exploring the influence of psychological and economic factors, as well as the role of behavioral interventions like nudges and boosts, this section provides a comprehensive understanding of how individuals make decisions regarding sustainable energy. It also delves into the impact of social norms and contextual tailoring of nudges in driving green energy behaviors across diverse socio-economic and cultural settings. Together, these studies offer valuable insights into designing effective interventions for enhancing green energy adoption, making it a more sustainable and long-term practice. The subsequent sections present these findings, focusing on the barriers to adoption, the effectiveness of behavioral strategies, and the role of contextual adaptations.

4.1. Methodological Insights from Empirical Studies

To provide greater clarity and context to the empirical findings discussed in this paper, it is essential to examine the methodologies employed in the cited studies. This section outlines the methods used to gather evidence on the effectiveness of behavioral nudges for green energy adoption and discusses potential biases and limitations that may influence the interpretation of results.

Study Designs and Data Collection Methods: The majority of studies cited in this paper utilized randomized controlled trials (RCTs), surveys, and field experiments to evaluate the impact of behavioral nudges. For instance:

- Paunov and Grüne-Yanoff (2023) conducted a 29-week RCT in a student dormitory to compare the effectiveness of nudges and boosts in reducing energy consumption. The trial involved goal-setting, commitment, and feedback interventions for one group, while another group received competence-enhancing tips tailored to household devices.
- Anagnostopoulos (2024) employed large-scale field experiments to test digital nudges, such as smart meters and mobile apps, across multiple European countries. These studies relied on energy usage data collected in real-time to quantify reductions in consumption.

Sample Sizes and Representation: The robustness of findings often depends on the sample size and demographic diversity of participants. For example:

- Allcott (2011) evaluated Home Energy Reports (HERs) using a large sample of U.S. households, which enhanced the generalizability of results. However, smaller-scale studies, such as those conducted by Cosic et al., (2018) on recycling behavior in student settings, may have limited applicability to broader populations.

Temporal Scope of Studies: Many studies focus on short-term interventions, which limits insights into the long-term sustainability of behavioral nudges. For instance, while Paunov and Grüne-Yanoff (2023) demonstrated the initial success of nudges, their effectiveness waned over time, highlighting the need for follow-up research to assess the persistence of behavioral changes.

Potential Biases and Limitations:

- Sample Bias: Some studies relied on self-selected participants, which may introduce bias. For example, participants in energy-saving trials might already possess pro-environmental attitudes, skewing the results.
- Contextual Variability: Regional differences in socio-economic and cultural factors can influence the effectiveness of nudges. For instance, Anagnostopoulos (2024) reported higher adoption rates in high-income households, suggesting income disparities play a role in intervention success.
- Measurement Constraints: Studies employing self-reported data may face accuracy issues due to recall bias or social desirability bias. Complementing self-reports with objective measures (e.g., energy consumption logs) can improve reliability.

By synthesizing these methodological insights, this section underscores the importance of contextualizing empirical findings within the framework of study designs, sample characteristics, and potential biases. These factors not only affect the validity and generalizability of results but also offer guidance for designing future research that addresses these limitations.

4.2. Determinants and Barriers to Green Energy Adoption

In light of the psychological and economic factors that influence green energy adoption, empirical data provides valuable insights into the drivers and barriers to this process. Zeng et al. (2022) examine these determinants and highlight several key factors that significantly affect consumers' decisions to adopt renewable energy technologies. Green Energy Technology Awareness (GETA) and Environmental Concern (EC) emerge as strong positive influencers, with significant β-values of +0.362 ($p < 0.05$) and +0.245 ($p < 0.1$), respectively. These findings underscore the importance of raising awareness and fostering environmental concern as effective strategies for promoting green energy uptake, particularly through targeted educational campaigns and normative messaging.

In contrast, Green Energy Technology Costs (GETCs) and Discomfort (GETD) are identified as critical barriers, with negative impacts of -0.325 ($p < 0.05$) and -0.395 ($p < 0.05$), respectively. These results suggest that perceived high upfront costs and discomfort with new technologies discourage consumers from transitioning to green energy solutions. Strategies such as subsidies to alleviate financial burdens and user-friendly designs to reduce discomfort could address these challenges effectively (Zeng et al., 2022).

Additionally, Openness to Experience (OE) positively influences adoption ($\beta = +0.256$, $p < 0.1$), indicating the potential of interventions tailored to individuals more receptive to adopting innovative technologies. Personalized nudges, such as highlighting the compatibility of green energy with modern lifestyles, could enhance adoption rates among this group.

These statistical insights provide a strong foundation for designing behavioral interventions aimed at mitigating barriers and amplifying motivators for green energy adoption. Table 1 summarizes key determinants of adoption, based on empirical research, and offers statistical insights into how awareness, costs, discomfort, and other factors shape consumer behavior (Zeng et al., 2022).

Table 1.

Key Factors Influencing Green Energy Adoption and Their Statistical Impact

Factor	Description	Impact on Adoption (β-value)	Statistical Significance

Green Energy Technology Awareness (GETA)	Knowledge and understanding of green technologies	0.362	$p < 0.05$
Green Energy Technology Costs (GETCs)	Perceived high upfront costs of renewable technologies	-0.325	$p < 0.05$
Environmental Concern (EC)	Consumers' attitudes toward environmental protection and climate issues	0.245	$p < 0.1$
Green Energy Technology Discomfort (GETD)	Perceived difficulty in using or understanding renewable technologies	-0.395	$p < 0.05$
Openness to Experience (OE)	Willingness to explore and adopt new technologies	0.256	$p < 0.1$

Source: *Zeng et al., 2022.*

4.3. Behavioral Interventions for Sustainable Practices: Nudges, Boosts, and Their Long-Term Effects

Behavioral interventions such as nudges and boosts offer unique approaches to fostering sustainable practices, with varying degrees of effectiveness in different contexts. Paunov and Grüne-Yanoff (2023) explored these methods in a long-term randomized controlled trial conducted in a student dormitory. Their study compared the effects of nudges—behavioral strategies involving goal-setting, commitment, feedback, and social comparison (Abrahamse et al., 2005; Karlin et al., 2015) - against boosts, which focused on enhancing individuals' competence through automated bi-weekly energy-saving tips tailored to household devices (Hertwig and Grüne-Yanoff, 2017).

The findings revealed that boosts significantly outperformed nudges in reducing energy consumption over the 29-week period, with participants in the boosting group consuming approximately 3 MWh less electricity than those in the nudging group. While nudging showed initial success, its effects waned over time. In contrast, boosts maintained their impact, suggesting that interventions aimed at improving knowledge and skills lead to more enduring behavioral changes. These results emphasize the importance of competence-based approaches for long-term energy conservation and underscore the need for policymakers to integrate these strategies into sustainable energy initiatives.

Anagnostopoulos (2024) evaluates behavioral interventions in promoting energy-saving and green energy adoption through case studies across Europe. Key findings show that digital nudges, like smart meters and mobile apps, reduced energy consumption by 5–12%, with higher savings for more engaged households. Social norm-based interventions, providing feedback on neighbors' energy-saving behaviors, led to savings of up to 15%, especially among high-consumption households. Additionally, setting renewable energy as the default option resulted in adoption rates exceeding 90%, illustrating the impact of cognitive biases such as inertia. The report also highlights the importance of tailoring interventions to socio-economic contexts, showing that combining financial incentives with behavioral nudges moderately improved adoption in low-income households. These results suggest that tailored behavioral interventions can significantly influence energy behaviors, offering cost-effective solutions for advancing green energy transitions (Anagnostopoulos, 2024).

A summary of the experimental results is presented in the Table 2 below:

Table 2.

Summary of Behavioral Interventions and Their Impact on Green Energy Adoption

Intervention	Impact	Additional Insights
Digital Nudges (Smart Meters and Apps)	Energy consumption reduced by 5–12%	Higher engagement with real-time feedback resulted in greater savings.
Social Norm Comparisons	Energy savings up to 15% in high-consumption households	Peer feedback significantly influenced behavioral adjustments; descriptive norms played a key role.
Green Defaults	Adoption rates exceeding 90%	Setting renewable energy as the default option minimized cognitive barriers, such as inertia and status quo bias.
Low-Income Targeted Nudges	Moderate adoption improvement with financial incentives	Combined behavioral and financial strategies proved effective in addressing economic constraints.

Source: *Anagnostopoulos, 2024.*

These findings underscore the potential of behavioral nudges to complement traditional energy policies. They also highlight the role of innovative, scalable solutions such as digital platforms in driving the global transition to sustainable energy systems. Further research is recommended to assess the long-term impacts of these interventions and their applicability beyond the European context (Anagnostopoulos, 2024).

Complementing this, the study by Cosic et al. (2018) investigated the impact of nudges on students' ecological behaviors, focusing on recycling practices. Conducted at the Scuola Superiore Sant'Anna in Pisa, this field experiment employed a combination of nudges, including social norm and "easy-to-do" nudges, over a 60-day intervention period. These interventions significantly improved recycling rates for plastic cups, leveraging social norms to influence individual actions. Previous literature (Cialdini et al., 1990; Goldstein et al., 2008) supports the idea that social norms motivate behavior through perceived social penalties for non-compliance and assumptions about others' superior knowledge.

Notably, the nudges' effects persisted three months after the intervention, highlighting their potential for creating lasting behavioral change. This aligns with findings from Paunov and Grüne-Yanoff (2023), suggesting that combining short-term motivators like nudges with competence-building boosts could enhance the longevity and efficacy of sustainable interventions.

Both studies offer valuable insights for policymakers and environmental advocates. While nudges are effective in addressing immediate behavioral barriers, boosts provide the tools necessary for sustained changes in energy conservation and waste management practices. Together, these approaches can form the foundation for comprehensive strategies aimed at promoting green energy adoption and ecological responsibility in various settings.

While quantitative evidence provides valuable insights into the statistical effectiveness of behavioral nudges (Anagnostopoulos, 2024; Paunov & Grüne-Yanoff, 2023), incorporating qualitative perspectives can offer a deeper understanding of individual and community experiences with these interventions (Frederiks et al., 2015). For instance, qualitative data from interviews, focus groups, or case studies can reveal how consumers perceive and respond to nudges, shedding light on emotional, cultural, and contextual factors that influence behavior (Allcott, 2011). Understanding why certain households resist default green energy options despite clear economic benefits could inform the design of more culturally sensitive and user-centered interventions (Schubert, 2017). Balancing quantitative metrics with qualitative narratives ensures a more comprehensive evaluation of nudge effectiveness, enabling policymakers to design interventions that are both empirically robust and socially resonant (Thaler and Sunstein, 2021).

Social Norms and Contextual Tailoring in Behavioral Nudges for Green Energy Adoption: Behavioral nudges leveraging social norms and contextual adaptations have demonstrated their potential to encourage green energy adoption, but their effectiveness varies based on regional, cultural, and socio-economic factors. Studies from the United States, Germany, and South Africa highlight critical lessons in applying these interventions to promote energy conservation and sustainability goals.

The Role of Social Norms in Green Energy Adoption

Social norms, both descriptive and injunctive, have been pivotal in shaping sustainable energy behaviors. For example, Allcott's (2011) large-scale randomized controlled trial in the United States evaluated Home Energy Reports (HERs) that provided households with feedback comparing their electricity use to similar households. By leveraging descriptive norms (average neighborhood consumption) and injunctive norms (smiley emoticons to reinforce approval or disapproval), HERs reduced electricity consumption by an average of 1.9–2.0%. Notably, high-energy consumers achieved the largest reductions, while injunctive norms mitigated the boomerang effect among low-energy households.

These interventions proved cost-effective, with an estimated cost of $0.03 per kilowatt-hour saved, significantly less than traditional subsidies for energy-efficient appliances. The persistence of savings over time further underscores the habit-forming potential of periodic feedback, making social norm nudges a scalable and economical tool for fostering energy-efficient behaviors. Extending these insights to green energy adoption, descriptive norms, such as feedback on neighborhood participation in renewable energy programs, and real-time feedback on energy savings from solar panels, could enhance the uptake of green technologies (Allcott, 2011).

Contextual Tailoring: Insights from Germany and South Africa

The contextual effectiveness of behavioral nudges is evident in comparative studies from Germany and South Africa. In Germany, Andor et al. (2020) applied HERs to 11,630 households, yielding a modest 0.7% reduction in electricity consumption—significantly lower than U.S. results. This disparity was attributed to Germany's lower baseline electricity consumption and less energy-intensive practices. However, high-energy households in Germany achieved reductions of up to 3.1%, showcasing the importance of targeted interventions. Despite these successes, the cost of CO_2 abatement was significantly higher in Germany ($505 per ton) than in the U.S., raising questions about cost-effectiveness.

In contrast, South Africa’s experience during Cape Town’s severe drought (2015–2018) highlights the influence of socio-economic disparities on nudge effectiveness. Brick et al. (2023) evaluated interventions, including social recognition, public good messaging, and financial feedback, to reduce water consumption. High-income households achieved savings of up to 2.3% through social recognition, while middle-income households responded better to financial feedback. However, structural barriers, such as inadequate infrastructure, limited the responsiveness of low-income households.

To better understand the effectiveness of behavioral nudges for green energy adoption across different regions, the following table summarizes key data from studies conducted in the United States, Germany, and South Africa (Table 3):

Table 3.

Effectiveness and Cost-Effectiveness of Behavioral Nudges for Green Energy Adoption Across Different Regions

Study	Location	Sample Size	Intervention	Effectiveness	Cost-Effectiveness	Key Insights
(Allcott, 2011)	United States	Large-scale trial	Home Energy Reports (HERs)	Reduced electricity consumption by 1.9–2.0%	\$0.03 per kWh saved	High-energy consumers showed largest reductions, and injunctive norms mitigated the boomerang effect among low-energy households.
(Andor et al., 2020)	Germany	11,630 households	Home Energy Reports (HERs)	0.7% reduction in electricity consumption (average)	\$505 per ton CO2 abated	Lower baseline electricity consumption and less energy-intensive practices led to lower effectiveness compared to the U.S., but high-energy households showed up to 3.1% reduction.
(Brick et al., 2023)	South Africa (Cape Town)		Social recognition, public good messaging, financial feedback	High-income households: 2.3% savings		Socio-economic disparities influenced effectiveness; high-income households responded better to social recognition, while middle-income

						responded to financial feedback.

Source: *Compiled by the author.*

Based on the results presented above, a comparative view shows that the effectiveness of behavioral nudges varies significantly across regions. For example, energy savings in the United States are higher than in Germany, which can be explained by differences in baseline energy consumption and behavioral patterns. In both cases, high-energy users respond more strongly to interventions compared to low-energy users.

In addition, the results from South Africa show that socio-economic factors play an important role. High-income households respond better to social recognition, while middle-income households react more to financial feedback. This suggests that the same type of intervention may produce different results depending on income level and local conditions.

Overall, these findings indicate that behavioral nudges are context-dependent and should be carefully adapted to regional and socio-economic characteristics to achieve better outcomes.

Green Nudges: Applications for Green Energy Adoption: Schubert (2017) examines the effectiveness and ethical implications of green nudges—behavioral interventions designed to encourage environmentally responsible behaviors, such as adopting renewable energy or reducing resource consumption. The study highlights several examples of successful green nudges, emphasizing their context-dependent nature. For instance, in Schönau, Germany, a change in the default setting to renewable energy resulted in over 99% of households maintaining green energy use, compared to the national average of only 1% (Schubert, 2017). Similarly, in large-scale field experiments involving 600,000 U.S. households, Opower's Home Energy Reports, which compared energy consumption to that of neighbors, reduced energy use by 1.4–3.3%, illustrating the potential of peer comparison and social norms in influencing sustainable behaviors. The study also discusses the impact of descriptive norms on behaviors like hotel towel reuse, which increased by 9–10% when guests were informed about the reuse practices of their peers (Table 4).

Table 4.

Statistical summary of the study

Intervention	Location	Outcome
Default Setting	Schönau, Germany	99% adoption of renewable energy vs. 1% nationally.
Home Energy Reports (HERs)	600,000 U.S. households	Energy consumption reduced by 1.4–3.3%.
Hotel Towel Reuse	Various locations	Towel reuse increased by 9–10% with social norms.
Behavioral Framing	Denmark, Smart Grid adoption	Increased awareness and adoption of renewables.

Source: *Schubert, 2017.*

However, Schubert (2017) critically addresses the ethical dimensions of nudges, particularly concerns related to autonomy and manipulation. Nudges, while effective, may undermine individual autonomy by shaping choices in ways that individuals may not consciously endorse, raising ethical questions about their transparency and the potential for coercion. This ethical framework offers valuable insights for the design of behavioral policies, ensuring they balance effectiveness with respect for personal freedoms and autonomy.

While these studies demonstrate the effectiveness of behavioral interventions, several gaps remain. For instance, there is limited evidence on the long-term sustainability of nudges and their impact in developing regions. Additionally, cultural and socio-economic factors may influence the effectiveness of interventions, necessitating further contextual research.

In addition to the limitations discussed above, there are also broader critical perspectives on the use of nudges:

First, "nudge backlash" can occur when individuals feel that their choices are being manipulated. This can reduce trust in policymakers and decrease the effectiveness of interventions.

Second, rebound effects may reduce the overall impact of energy-saving behaviors. For example, individuals who save energy in one area may increase consumption in another area, which offsets the initial benefits.

Third, there is political and ethical criticism of nudging. Some researchers argue that nudges can be used as a tool of soft control, especially in neoliberal policy frameworks, where responsibility is shifted from institutions to individuals. In this case, structural problems may not be fully addressed.

Moreover, empirical evidence on unsuccessful or weak nudges is limited, as many studies focus mainly on positive results. This creates a potential bias in the literature. Therefore, future research should pay more attention to negative results, long-term limitations, and differences across contexts.

These critical perspectives show that nudges should not be seen as a complete solution. Instead, they should be combined with traditional policies, such as regulation and financial incentives, to achieve more effective and balanced outcomes.

5. POLICY IMPLICATIONS AND RECOMMENDATIONS FOR GREEN ENERGY ADOPTION USING BEHAVIORAL NUDGES

The transition to green energy is critical for addressing climate change, but adoption rates of renewable technologies remain insufficient to meet global climate targets. Despite technological advancements and supportive policies, non-technological barriers, such as psychological biases, inertia, and social norms, hinder widespread adoption. This study highlights the potential of behavioral nudges—subtle interventions that alter choice architecture without restricting freedom of choice—as an effective policy tool for overcoming these barriers. Below are key policy implications and recommendations based on the empirical findings and theoretical insights from this research.

5.1. Design Policies that Use Green Defaults to Maximize Renewable Energy Adoption

Empirical studies consistently show that green defaults—where renewable energy is automatically set as the default option—significantly increase adoption rates. Research from Germany (Schubert, 2017) demonstrated that over 99% of households remained in a green energy program when it was the default, compared to just 1% when participation required active choice. This aligns with the findings of Prospect Theory, which suggests that individuals are more likely to accept default options due to cognitive biases like inertia and loss aversion.

Governments should require green energy defaults in utility contracts and energy programs. This could be implemented by setting renewable energy as the default option for all consumers, with the freedom to opt-out if desired. This strategy can be particularly impactful in regions with low renewable energy adoption and can encourage large-scale transitions to sustainable energy sources.

5.2. Incorporate Social Norms and Peer Comparisons into Policy Frameworks

The role of social norms in shaping behavior is a powerful lever for encouraging green energy adoption. Studies, such as Allcott's (2011) on Home Energy Reports (HERs), demonstrate that feedback comparing household energy consumption to neighbors' averages effectively reduces consumption. Descriptive norms, which provide information about what others are doing, can be particularly influential when combined with injunctive norms that convey approval or disapproval of behaviors.

Policymakers should integrate social norm-based nudges into energy consumption programs. This can include providing households with comparative feedback on their energy usage relative to their neighbors, which has proven effective in reducing energy consumption. Additionally, using real-time feedback on the adoption of renewable energy technologies (e.g., participation rates in renewable energy programs) can drive individuals to align their actions with community behaviors, increasing overall adoption rates.

5.3. Leverage Real-Time Feedback to Combat Temporal Discounting

The psychological phenomenon of temporal discounting, where individuals prioritize immediate costs over long-term benefits, presents a significant barrier to the adoption of green technologies. Feedback mechanisms, particularly through smart meters and mobile apps, have been shown to reduce this bias by providing consumers with real-time data on their energy consumption and the long-term savings of renewable energy options (Sörqvist and Langeborg, 2019).

Governments and utilities should incentivize the use of smart meters and mobile apps that offer real-time feedback on energy consumption. These tools should include features that visualize potential long-term savings from renewable energy adoption, making future benefits more salient and reducing the bias toward immediate costs. Additionally, policies should encourage energy providers to integrate these tools into their service offerings, ensuring that they are accessible and widely used.

Address Financial Barriers with Targeted Financial Incentives: One of the strongest barriers to green energy adoption is the high upfront costs of renewable technologies, such as solar panels. As shown in the empirical studies by Zeng et al. (2022), the costs of green energy technologies are a major deterrent for many consumers, outweighing the perceived long-term savings. Loss aversion, as articulated in Prospect Theory, makes consumers more sensitive to immediate costs than to long-term benefits, further exacerbating this issue.

To address the financial barrier, policymakers should offer targeted financial incentives, such as subsidies, low-interest loans, or tax credits for renewable energy technologies, particularly for low- and middle-income households. These incentives can be paired with nudges that emphasize the long-term savings and environmental benefits, making the value proposition of green energy technologies more appealing and tangible.

Tailor Nudging Strategies to Regional and Socio-Economic Contexts: The effectiveness of behavioral nudges is not universal and varies based on regional, socio-economic, and cultural contexts. For example, studies in Germany and South Africa have demonstrated that the success of feedback-based interventions can depend on factors such as energy consumption habits and income levels (Andor et al., 2020; Brick et al., 2023). Tailoring interventions to address these contextual factors is essential for ensuring their effectiveness.

Tailor nudging strategies to specific regional and socio-economic contexts. For example, interventions in areas with higher energy consumption should focus on high-energy users, while in low-income areas, financial incentives and educational campaigns may be more effective. Policymakers should invest in segmentation strategies that account for demographic and behavioral differences among target populations to enhance the impact of nudges.

Ensure Ethical Transparency in the Design and Implementation of Nudges: The effectiveness of nudges raises important ethical considerations. As noted by Schubert, (2017), while nudges can drive behavior change, they may also manipulate individuals into choices they do not fully endorse, potentially undermining autonomy. The lack of transparency in nudging practices can lead to ethical concerns, especially when personal data is involved.

Ensure ethical transparency in the design and implementation of nudges by clearly informing consumers about the intent and operation of nudging interventions. Publicly disclose how data is used and ensure that individuals have control over their participation in nudge-based programs. Ethical considerations should be central to policy development, ensuring that interventions respect individual autonomy while promoting collective environmental goals.

The ethical implications of using nudges to promote green energy adoption require careful consideration, particularly regarding individual autonomy and transparency (Schubert, 2017). While nudges are designed to subtly steer behavior without restricting freedom of choice, they may inadvertently manipulate individuals into decisions they might not consciously endorse (Thaler and Sunstein, 2021). For instance, setting renewable energy as the default option exploits status quo bias (Samuelson and Zeckhauser, 1988) but may fail to account for individual preferences or fully inform consumers about their choices. To address these concerns, policymakers must prioritize ethical transparency in the design and implementation of nudges. This includes clearly communicating the purpose of the intervention, ensuring that individuals can easily opt out, and safeguarding data privacy, especially when leveraging digital tools like smart meters or mobile apps (Frederiks et al., 2015). Balancing the effectiveness of behavioral nudges with respect for autonomy and informed consent is essential to ensure that these interventions remain both impactful and ethically sound.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

The findings of this review reveal that behavioral nudges, when effectively designed, can significantly influence green energy adoption. Green defaults, social norms, feedback, and competence-enhancing interventions have demonstrated measurable success in driving pro-environmental behaviors. These interventions leverage cognitive biases to create low-cost, scalable solutions for accelerating the transition to renewable energy.

However, the effectiveness of nudges is context-dependent, requiring careful consideration of socio-economic, cultural, and behavioral differences. Ethical concerns such as the potential for manipulation and the need to preserve individual autonomy must be addressed in policy design.

Future research should explore the integration of behavioral nudges with advanced technologies such as smart meters, AI-driven feedback systems for energy tracking. Longitudinal studies are needed to evaluate the durability of nudge effects over time. Additionally, there is a critical need to investigate how nudges can address energy inequalities, ensuring that interventions are inclusive and accessible to diverse populations.

By advancing these research directions, behavioral nudges can serve as a cornerstone for sustainable energy policies, fostering widespread adoption of renewable energy technologies.

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