Smart Energy Cities: The Role of Behavioral Interventions in Reducing Electricity Demand in Buildings in Principality of Monaco

Fateh Belaïd, Mira Toumi, and Nathalie Lazaric

Abstract With energy powering the most attractive aspects of urban environments in modern society, from health, transportation, and comfort to information, business, and leisure, energy cities are perfectly positioned to design the smart city of the future by leveraging the energy foundations of the city. This chapter focuses on the emerging concept of energy cities through the lens of sustainable behaviors and their role in alleviating climate change. We use the results of a randomized control trial experiment implemented in Monaco to illustrate our arguments on the role of behavioral intervention in empowering citizens on the importance of saving energy. The results will offer a vision of what steps cities are taking to increase environmental awareness and the role of individual behaviors in tackling climate change.

Keywords Energy Cities · Smart and Sustainable Cities · Behavioral change · Residential energy use

1 Introduction

Modern cities and human activities cause significant climate change issues as well as energy and mobility challenges and need to take initiatives to find sustainable solutions. Currently, over half of the world's population lives in an urban

---

F. Belaïd (✉)
King Abdullah Petroleum Studies and Research Center, Riyadh, Kingdom of Saudi Arabia
e-mail: fateh.belaid@kapsarc.org

M. Toumi
GREDEG, University of Côte d'Azur, Valbonne, France

N. Lazaric
GREDEG, University of Côte d'Azur, Valbonne, France

University of Gothenburg, Göteborg, Sweden

F. Belaïd, A. Arora (eds.), *Smart Cities*, Studies in Energy, Resource and Environmental Economics, https://doi.org/10.1007/978-3-031-35664-3_6

environment, and by 2050, this figure is projected to exceed two-thirds (United Nations, 2019). This accelerating urbanization process has resulted in many challenges, including intensive energy consumption, high-carbon GHG emissions, environmental pollution, social inequality, and traffic congestion. This is a long list of challenges included in the Agenda 2030 Sustainable Development Goals, putting the development of energy-efficient, more sustainable, and smart cities at the top of the agenda in the coming years (United Nations, 2022). Here, we examine the role of behavioral intervention in shaping residential electricity consumption within the contexts of "smart cities" and "smart energy cities" (SEC).

The smart cities concept underlines an urban development area using digital and information and communication technologies (ICT) solutions to improve traditional networks and services. Smart cities are designed to address challenges and improve the workability, quality of life, and sustainability of cities. Although the design of the smart city has traditionally focused on technology, smart devices, and urban infrastructure, it now goes beyond the technical-centric nature of using digital solutions for the efficient use of resources. Over recent years, the concept has been expanded to incorporate socioeconomic aspects (Pira, 2021). Accordingly, this paradigm shift allows the smart city approach to expand its potential impacts on the economic, social, and environmental dimensions.

The recent phase of smart cities, the so-called smart city 3.0, rather than adopting a technology-driven or city-driven model, focuses on developing co-creation models involving citizens in developing efficient and practical solutions. This new concept focuses on the inhabitant's role and involvement in addressing community issues and assisting municipality managers in identifying effective and reliable solutions for various city challenges, including social, economic, and environmental problems. The new paradigm strongly suggests that a sustainable future will rely on a combination of innovative technology—improving new technologies and system performance—and promoting more environmentally friendly behavior (Sovacool et al., 2022).

The concept of "smart energy cities," which builds on the concept of smart cities, has been developed recently to recognize the prominent role of energy in the built environment (Thornbush & Golubchikov, 2021). SEC ideas are anchored both in the expansion of "smart cities" concepts and in a sustainability framing. The SEC concept has grown to depict digitally enhanced, zero-carbon cities. Accordingly, Übelmesser et al. (2020) proposed the following definition: "SEC is a concept at the core of the smart city, that uses technology, including information and communication technologies (ICT), to address the challenges of increasing urban energy demand and climate change, while ensuring the quality of life of its citizens … the SEC uses ICT to integrate different domains, resulting in a holistic view of the energy system" (p. 1). Thus, the SEC paradigm is strongly aligned not only with the smart cities concept but also with the climate-neutral city concept and its variants, such as low-carbon, net-zero cities, and postcarbon cities (Thornbush & Golubchikov, 2021).

With many of the world's major cities pursuing important initiatives to improve citizens' urban life and achieve sustainability and climate goals and with energy powering the most attractive aspects of urban environments in modern society, from health, transportation, and comfort to information, business, and leisure, energy cities are perfectly positioned to design the smart city of the future by leveraging the energy foundations of the city. Thus, SEC will serve as an example for other cities going forward. They will harness cutting-edge technologies, such as green energy, superfast telecommunications, autonomous transportation, and artificial intelligence. Using these technologies, they will become desirable and comfortable places to live, work, and relax.

Based on the underlying premise of "smart energy cities," this chapter discusses the role of behavioral insights in shaping the future of urban living. Then, it uses results from a randomized controlled trial (RCT) to illustrate the role of behavioral intervention in increasing the impact of household actions to save energy. This will offer valuable insights and inform policymakers on the importance of behavioral intervention in shaping cities' sustainability. Behavioral interventions can be broadly defined to encompass interventions for which no command-and-control regulations or financial incentives are involved, e.g., providing information, goal setting, invoking values and norms, engaging, and restructuring choice options, or so-called nudges (Lazaric & Toumi, 2022).

The setting of the analysis in this chapter is the Principality of Monaco, a sovereign city-state located on the French Riviera in Western Europe. The uniqueness of our context and experimental framework makes the statistical analysis and the evaluation criteria we have implemented compelling for a variety of reasons. First, despite the growing literature in the field of smart cities, there have been no studies linking behavioral intervention within the concept of "smart energy cities." Second, the analysis takes advantage of a recent field experiment to illustrate how behavioral interventions may reduce the contribution of individuals' activities to carbon emissions and climate change.

This chapter contributes to the literature on SEC in the following ways. It emphasizes the emerging energy city concept and the critical role of behavioral insights in shaping the future of urban living. These findings can help city policymakers leverage behavioral intervention to reduce energy demand in cities to achieve goals toward environmental carbon neutrality. It may also add to the behavioral literature and stimulate studies to rethink how to implement behavioral interventions efficiently and incorporate behavioral insights to improve sustainability in cities.

The remainder of this chapter is structured as follows. Section 2 reviews the literature on behavioral economics in reducing energy demand in buildings. Section 3 focuses on Monaco as a smart energy city and presents Monaco's smart city initiatives. Section 4 presents and discusses the experimental design and Smartlook project's main results, while Sect. 5 provides some concluding remarks and policy implications.

2 Behavioral Economics and Policymaking

To meet challenging climate and sustainability goals, the ambitious curtailment of GHGs is needed worldwide. A low-carbon world will rely on a combination of green technological innovation and sustainable behaviors such as energy sobriety and waste reduction. There is also an unequivocal consensus about the critical role that behavioral change may play in decarbonizing the building sector (Maréchal, 2010; Sovacool et al., 2022). Today, behavioral change interventions are widely implemented in a range of public policy settings with the goal of moving individuals in the desired direction, e.g., toward more sustainable lifestyles, more eco-friendly practices, and more responsible financial decisions. For example, Moran et al. (2020) show that a consumer-oriented policy can reduce GHG emissions by 25% in the European context, and Asmare et al. (2021) show that providing information via a web portal lowers electricity consumption by 8.6% in Lithuania. Thus, a considerable part of CO2 emissions can be reduced or eliminated with lifestyle changes, thus leading to a positive impact on fighting climate change, reinforcing energy security, and ensuring affordable energy access (Belaïd, 2022a, b, 2024).

Governments have used traditional economic tools and other behavioral solutions to foster environmentally friendly practices. Depending on the target behavior and context, traditional tools such as regulations and taxes can be an efficient response to reducing emissions. However, in some specific situations, they will not be enough to drive effective behavioral change or, even more, generate counterproductive behaviors. For instance, in terms of residential energy consumption, it is challenging to implement a law to force people to reduce the electric heating temperature by 1° to save 7% of their energy bill. Indeed, residential energy consumption is a multifaceted sociotechnical process shaped by a variety of interdependent factors (Belaïd, 2016, 2017). In addition, the complexities of consumers' lifestyles and the role of individuals' behavior in the energy demand process have contributed to ambiguities and partial comprehension of residential energy use patterns (Belaïd et al., 2020, 2021; Belaïd & Rault, 2021). Many studies have documented that there is a large gap between theoretical and observed energy consumption. This is due mainly to difficulties in capturing the behavioral aspects of domestic energy use (Bakaloglou & Charlier, 2019; Bakaloglou & Belaïd, 2022). Therefore, policymakers and governments are increasingly becoming concerned about effectively changing consumer behaviors. They rely on behavioral sciences, now widely recognized as a source of alternative or complementary tools to empower citizens toward the greenest sustainable behaviors.

A critical element of the pro-environmental behavior question is intrinsic human nature. In fact, since it has been proven that individuals are not entirely rational, policymakers and stakeholders should address this bounded rationality and cognitive biases (Maréchal, 2010). In fact, contrary to traditional rational choice analysis, behavioral economics has shown that individuals often rely on heuristics and are easily influenced by their cognitive biases. An interesting illustration is the claim "It only happens to the others" when seeing the consequences of climate change. This sentence, often heard in Western countries, can be explained by the abstract frame of the environmental problem due to psychological distance. This implies that humans are more interested in the present than in the future, in what has an impact on them (or her) rather than what might impact others, and in what happens close to them rather than far away. This starting point for anchoring environmental issues is tricky since it pushes citizens to procrastinate on their potential actions. Behavioral tools then raise opportunities for the awareness that by now, as members of the worldwide community, "we are all the others."

The most famous tool, coming from behavioral economics insights, is the "Nudge." In their popular book *Nudge, Improving Decisions about Health, Wealth and Happiness* (2008), Richard Thaler and Cass Sunstein define a nudge as "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid" (Thaler & Sunstein, 2008, p. 6). Relying on bounded rationality theory, the authors suggest that a considerable part of the decision-making pattern is the result of cognitive boundaries, biases, or habits and that this pattern may be "nudged" toward better options by integrating insights about the former boundaries and biases in ways that promote a more preferred behavior rather than obstruct it. After considerable hype around the concept for several years, the efficiency and ethical outcomes of nudging started to be discussed and questioned to conclude that nudging is not the magic wand able to solve all problems in all settings. From this questioning emerged other tools such as "boosts." In fact, while nudges shape human decisions by changing the choice setting and the encountered information, they boost aim to foster human competencies and motivation by working on his (or her) skills and knowledge. In addition, presenting accurate information by changing the options humans are exposed to "boosts" work to empower an individual to make better decisions with respect to his (or her) personal goals and preferences (Hertwig & Grüne-Yanoff, 2017).

The success of Thaler and Sunstein's book, combined with the considerable body of materials, academic articles, and university programs, made the young behavioral science field gain such legitimacy that several so-called "nudge units" appeared all over the world, while some behavioral economists were involved in policymaking. At the European level, the United Kingdom has pioneered the use of behavioral economics for policymaking with the *Behavioral Insight Team (BIT)*. The BIT nudge unit is a governmental team dedicated to implementing soft methods since its creation in 2010 under the advice of Richard Thaler. The BIT advises the government on several subjects, such as pandemic management or actions to fight global warming. BIT's actions are numerous around the world, and their success has led to the creation of nudge units in other countries. In France, the *French behavioral team*, the DITP (Direction Interministerielle de la Transformation Publique), arose under Emmanuel Macron's presidency and Bercy's supervision. Since 2020, the team has grown with the creation of the Transformation of the Public Service Ministry. In the Principality of Monaco, no specific governmental behavioral team is dedicated. However, led by the government impulse and the success of projects held in their neighborhood, local utilities such as SMEG (Société Monégasque d'Electricite et de Gaz) are inspired and motivated to adopt new behavioral insights to create new ideas for policy development. This is the reason why SMEG in the Principality of Monaco has initiated a partnership with the University Côte d'Azur on new behavioral tools for increasing awareness of opportunities to reduce electricity consumption. Monaco is among the innovating smart cities in southern Europe as an environmentally committed region at the cutting edge of technology. The municipality uses various tools and policy interventions to act in this field. Behavioral tools are one of these options.

3 Experimental Research on Smart Cities

3.1 Smart and Energy Cities Research

A growing interest in smart cities and energy consumption is observed in policy-making and academic areas. Some empirical evidence of the growing interest in smart and energy city studies can be found in Scopus data with the yearly number of publications in social sciences. We observe two similar rising trends.

Figure 1 shows that the number of articles published each year in social sciences on smart cities and energy remained constant from 2006 to 2009. After 2011, there was an increasing number of publications until 2019, when it reached a maximum of 138 articles. This growing interest of governments and several founding agencies explains this rising trend. Figure 2 displays the number of projects referring to a sponsor within the considered period and shows that the main sponsor is the

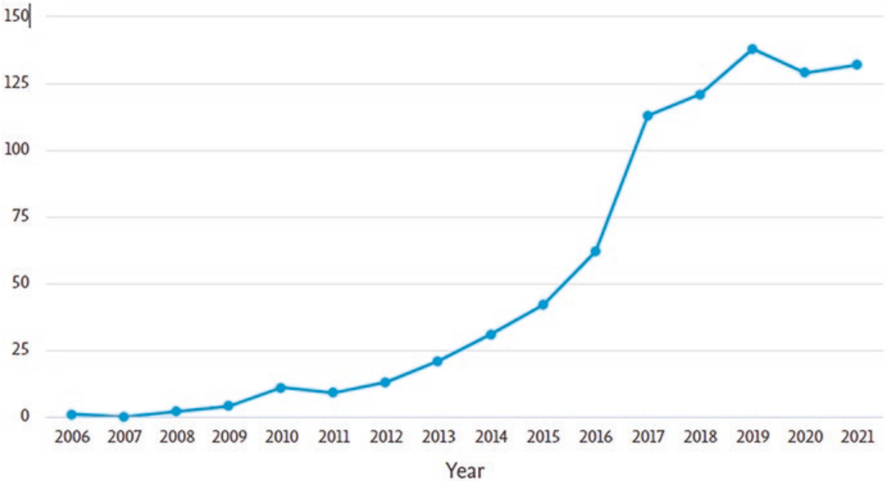

Fig. 1 Smart and energy city studies over time and disciplines. (*Source*: Scopus – Authors' calculation)

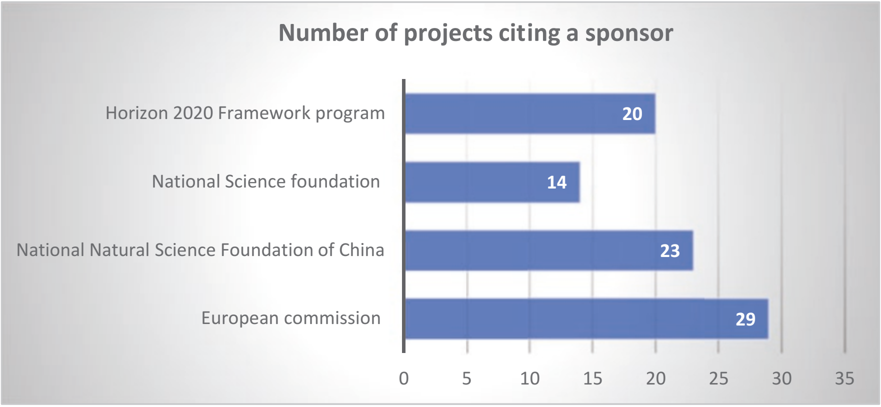

Fig. 2 Smart cities and energy studies sponsors. (*Source*: Scopus – Authors calculation. The ranking is based on the sponsors' occurrence frequency pooled from 2006 to 2021. The sponsors are generated from the list of sponsors referenced on the Scopus platform)

European Commission (29 projects), followed by the National Natural Science Foundation of China (23 projects), the National Science Foundation, and the Horizon 2020 Framework program (20 projects) and the National Science Foundation, i.e., an independent agency of the United States government, intended to financially support theoretical scientific research (14 projects).

As we can see, European institutions devote resources and funds to developing and exploring sustainable energy consumption related to smart cities. In the following, we will present an example of a study resulting from another funding source but in line with the European trend. In fact, the specific case of the Principality of Monaco provides exciting insights into how a city state country that clearly adopted a sustainability-oriented public policy invested in new behavioral strategies to reach its commitment to reducing greenhouse gas emissions in the built environment.

3.2 *Monaco, the Smart Energy City of Southern Europe*

The Principality of Monaco is a very attractive territory and provides important employment opportunities in Southern Europe. The population was 38,300 residents in 2018 for 52,000 salaried jobs. Seventy-six percent of private-sector employees live in France, and 14% live in Principality. A large proportion of its local residents are financially well endowed and live in apartments in tower blocks that were built mostly in the 1970s.

In addition, Monaco hosts and organizes numerous cultural, sporting, and professional events. These specificities have an impact on the environmental and energy balance of the Principality due to transport, energy requirements, and waste production. The downside of this dynamic is negative externalities for air quality and the ecological preservation of the marine environment. Local stakeholders do not necessarily see a conflict between economic and demographic developments, and they try to find local trade-offs to minimize the ecological burden and explore new options toward the energy transition. The challenge of the energy transition is the reduction of energy consumption in the context of economic development and the increase in the share of renewable energy.

Principality implements actions for defining consumption targets and energy sources in the direction of renewable energy. Monaco has only a few power plants and relies heavily on electricity and gas imports from France. In addition, the buildings in Monaco, more than elsewhere in France, are equipped with heating and air conditioning systems. Electricity consumption is, therefore, very sensitive to temperature fluctuations. Principality imports almost all of the electricity it consumes. Although the regional energy supply has been strengthened in recent years, the local government has tried to promote the creation and development of local capabilities and produce local energy. Fossil fuels, such as natural gas and fuel oil, are also imported. The balance is better for thermal energy thanks to the Fontvieille network and sea water heat pumps, which slightly reduce energy dependence.

Monaco's average electricity consumption per inhabitant tends to be below the average of its neighbor France. However, this is mainly because Monaco residents spend only part of the year in Monaco rather than being more energy-saving conscious, which makes comparison difficult. Ninety percent of Monaco's electrical energy is supplied by France and includes a high percentage of renewable electricity (75% for Monaco compared to only 20% for the whole of France). This promotes more careful use of energy and more attention to the environment.

3.3 The White Energy Book on the Energy Transition

In 2008, the local government started actions in the energy transition by implementing a climate-energy policy and a program of actions, the *Climate Energy Plan*, supported by the Department of the Environment. Monaco is also committed to the European Energy labeling process award to extend the *Climate Energy Plan* to promote continuous improvement for energy reduction. In this sense, Monaco was labeled an exemplar city of energy transition in 2014. In addition, the Principality has been engaged within the international community by ratifying the Framework Convention United Nations successively on Climate Change in 1994, the Kyoto Protocol in 2006, and the Paris Agreement in 2016. As an extension of these actions, the signature of the Paris Agreement in 2016 represents a turning point with new, very ambitious goals.

Three primary sources of greenhouse gases in Principality are the consumption of fossil energy for heating (31% of GHG), energy recovery from household waste (30%), and fuel consumption for transportation (31%). The 2017 *White Book on the Energy Transition* describes the aim of reducing greenhouse gas emissions by 80%

(compared to 1990 levels) by 2050 and achieving carbon neutrality in the long run. Actions implemented for reaching these very ambitious goals are the following:

1. Sea water heat pumps. Sea water heat pumps are thermodynamic systems that recover heat energy from sea depths to satisfy heat needs. They are sources of renewable energy. Principality is a forerunner in this area. The first sea water heat pump was installed in the 1960s. Today, Monaco has more than 70 units, along with a public heating network.
2. The e-bikes. With 15 stations, nearly 100 electrically assisted bicycles, and more than 500 users, the service continues to develop in Principality. This is the most visible action and one of the most cited for reducing the energy burden in transport.
3. Support for the acquisition of hybrids and electric vehicles. The Prince's Government grants aid finance for the purchase of new e-mobility registered in Monaco. Those grants are provided to households as well as companies.
4. Retrofitting. The local government is involved in a retrofitting program to reduce buildings' greenhouse gas emissions and ensure that all new buildings conform to environmental standards.
5. Behavioral tools and interventions. Monaco tries to promote large environmental awareness programs and new cultural values around energy consumption and devotes significant resources to behavioral tools. The Smartlook project, in partnership with the SMEG and CNRS/Université Côte d'Azur, detailed below, is illustrative of this new trend.

4 The Smartlook Experiment

Smartlook is a novel way of targeting energy transition with the experimentation of new behavioral tools to reduce electrical consumption and with an enrollment of volunteers to exemplify opportunities for changing energy behaviors (Lazaric & Toumi, 2022).

4.1 Context of the Smartlook Field Experiment in Monaco

The experiment took place in the Principality of Monaco from December 2018 to May 2019 with the support of the main local energy provider (SMEG). The sample included 77 households from a diverse range of buildings with different heating systems and, more importantly, dwellings that were not part of any current retrofitting program.

All participants were volunteers and completed the first questionnaire prior to the beginning of the experiment to grasp information on sociodemographics, ecological concerns, commitment, electricity use, heating system, and curtailment behaviors.

The New Ecological Paradigm (NEP) scale is used as ***a unidimensional measure of environmental attitudes***. It was developed to measure the overall relationship between humans and the environment. A high NEP score is associated with high ecocentric orientation (Stern et al., 1995)

At the end of the experiment, a second questionnaire was sent to capture changes in household composition or energy use. After completing the first questionnaire, households were randomly assigned to one of the experimental treatments or to the control group following the Harrison and List (2004) description of a framed field experiment.

More precisely, control group households received an email informing them they were simply a part of an experiment aimed at gathering information on Monegasque households' energy transition. Households in the three treatment groups received twice-monthly emails containing instructions with a reminder of their electricity use reduction goal and/or a set of boosts. More specifically, Treatment 1 ($n = 16$) set an ambitious electricity consumption reduction goal compared to the previous 6 months' usage (25%) and received boosts on electricity savings. Treatment 2 ($n = 17$) received a modest (15%) electricity consumption reduction goal compared to the previous 6 months of usage and a set of boosts. Treatment 3 ($n = 21$) provided only boosts (advice) about how to reduce their electricity consumption, and finally, the control group (= 23) received neither a goal nor boosts.

4.2 The Smartlook Project's Main Results

Table 1 presents the evolution of average electricity consumption across the four treatments.[1] From Table 1, we observe that the boost and modest goal treatment (T2) consumed the least electricity, followed by the boost-only treatment (T3) (Table 2).

The percentage of variation in electricity consumption presented in column (c) shows a similar trend of increased average electricity consumption during the experiment for all treatments due to the winter months. While the highest consumption is observed in the control group with a 31% increase in consumption compared to the average consumption of the whole sample, the T1 and T2 groups had the lowest increases at 12% and 7%, respectively. A Kruskal–Wallis (K-Wallis)[2] equality test of average monthly electricity consumption among treatments confirms that average electricity consumption during the 6 months of the observation period differed significantly across treatments (p value = 0.0001). Additionally, pairwise

---

[1] The statistics are based on average electricity consumption seasonally adjusted data provided by the SMEG.

[2] We rely on the K-Wallis and WMW tests as a nonparametric test to compare two or more independent samples of equal or different sizes. It is an extension of the MWM U test which is used to compare two groups.

Table 1 Evolution of electricity consumption before and during the field experiment

Treatment	Average electricity consumption per household during the pretreatment period (a) (kWh)	Average electricity consumption per household during the treatment period (b) (kWh)	Difference (%) (c)	Diff-in-Diff (%) (d)	*P* value (e)
Boost & ambitious goal (T1)	329.22	369.11	12%	−19%	0.0778*
Boost & modest goal (T2)	236.34	252.47	7%	−24%	0.0177**
Boost only (T3)	295.00	343.49	16%	−15%	0.1237
Control (CG)	314.96	412.67	**31%**	–	–
Average of the panel	296.71	352.82	18.91%		

Note: Column (a) is the average electricity consumption by treatment in kWh during the 6 months before the start of the experiment, June 2018 to November 2018. Column (b) is the average electricity consumption by treatment during the 6 months of the experiment from December 2018 to May 2019. Column (c) is based on treatment and shows the difference in average electricity consumption between the two periods, i.e., during the experiment period minus the average consumption in the 6 months before the experiment in percentage. Column (d) shows the percentage variation (between the periods and with respect to the control group) in the percentage of variation in the control group (CG). Column (e) presents the results of a t test of the difference between the average consumption of the treated groups compared to the control group
***$p > 0.01$; **$p < 0.05$; *$p < 0.10$

Table 2 Average electricity consumption per household during the treatment and pretreatment period

Average electricity consumption per household during the pretreatment period (a)	Control (CG)- Boost & modest goal (T2) = 314.96 − 236.34 = 78.62
Average electricity consumption per household during the treatment period (b)	Control (CG)- Boost & modest goal (T2) = 412.67 − 252.47 = 160.2

comparison by treatment based on a Wilcoxon-Mann–Whitney (WMW) test shows that average electricity consumption over the period of the experiment differed significantly across some treatments (p = 0.0001), although the consumption of the pair T3-CG shows no differences during the first 2 months of the experiment (p = 0.495).

The Smartlook field experiment explored the effectiveness of boosts and goals for driving potential electricity reductions. In fact, in line with the work of Belaïd and Garcia (2016) and Belaïd and Joumni (2020), an urgent need to increase electricity use transparency through the provision of information and education has been observed. Thus, tools to reduce the possible behavioral barriers by bringing new opportunities to adopt conservative energy behaviors may be effective and very robust in promoting new behaviors. Consequently, the combination of goal setting and boost seems efficient for transforming stated environmental concerns into concrete actions. In fact, the results of the study show that modest goals combined with specific information can translate concern for the environment into green behavior. A goal ranging from 15% to 25% reduction in energy use is efficient for households already concerned about the environment and committed to greener behaviors.

Combining goals (ambitious or modest) with boosts might significantly reduce electricity use (see Table 1). In fact, providing boosts reinforces households' knowledge and creates motivation toward sustainable electricity consumption and objective achievement (Martela, 2015). Concerning the type of goal, and in line with Harding and Hsiaw (2014) findings on the need to set realistic goals, it appears that the combination of modest (realistic) goals and boosts produces better results than a more ambitious goal and boosts. This suggests that households would prefer a long-term process of incremental learning to reach long-lasting efficiency in energy reduction.

Concerning boost only (treatment T3), although no electricity reduction has been observed, we could notice a significant impact on the specific environmentally concerned household with a high NEP scale score. This result can be interpreted as a profile-dependent result illustrating the complexity of the link between individual concerns and energy consumption (Nauges & Wheeler, 2017). Moreover, it confirms the need for thinking of nonmonetary incentives as context and target dependent. In fact, not only must the goal be realistic and associated with boosts, but it must also be sent to the right citizens who will be sensitive to it. Another interesting result, in line with the work of Pullinger (2014) and Shove et al. (2020), highlights that individuals with more time (retirees) and NGO members are more likely to have the resources and motivation to change their electricity use behavior. Moreover, higher education and greater environmental commitment are good predictors of such actions.

When focusing on low-concern households, it appears that none of the boost and goal settings were efficient in reducing electricity consumption. However, in the former household category, we observed a significant impact on education and some curtailment behaviors. These results contribute to the discussion on the difference between curtailment and energy-efficient behaviors. In fact, as argued by Nauges and Wheeler (2017), for some citizens with low environmental concern or low intrinsic motivation, monetary tools, and other behavioral interventions are required to encourage sustainable behavior and, more importantly, conditions for learning to play a detrimental role in maintaining changes over time. Indeed, Smartlook results outline the important issue of the translation of environmental values and concern for concrete behaviors with respect to the available dwelling materials and local conditions (Welsch & Kühling, 2009; Woersdorfer & Kaus, 2011; Babutsidze & Chai, 2018).

5 Conclusions

Reducing GHG emissions to prevent potentially catastrophic global climate change necessitates an essential reduction in energy consumption in the built environment. It is largely acknowledged that cities may contribute significantly to efforts to alleviate climate change. On the other hand, there is a remarkable consensus about the critical role that behavioral change may play in reducing residential energy consumption. However, the debate is still evolving concerning the optimal mechanism and effective instrument to promote individuals' actions on energy efficiency. Building on the emerging concept of "smart energy cities," this chapter examines options for reducing energy consumption in buildings. More precisely, it focuses on the role of behavioral change in reducing electricity demand in the residential sector. First, we discussed the leading role that behavioral economics may play in reducing the carbon footprint of residential energy demand. Then, we provide a brief overview of smart city research and initiatives in Europe and Monaco. Finally, we build upon a field experiment conducted in the Principality of Monaco to explore the complementarity of different behavioral interventions and their impact on residential electricity demand. Accordingly, we used three treatments: (Treatment 1) reduction goal combined with information; (Treatment 2) modest electricity reduction goal combined with information; and (Treatment 3) only information.

This research constitutes a step toward a more accurate evaluation of the behavior-driven energy demand reduction in the residential sector. In addition, the study offers various exciting results. Boosts appear to be a novel and promising instrument that involves a few prerequisites before it can be implemented. Goal setting is a standard and effective strategy that has a more substantial impact when implemented in combination with other instruments. The empirical findings illustrate the impact of boosts and goal setting on energy savings, as well as their complementarity and effectiveness in motivating individuals to reduce their energy use. This result suggests that behavioral change programs using multiple intervention methods save more energy than those using fewer intervention options. In addition, targeting more agents who are more sensitive or responsive to these kinds of interventions will significantly reduce the built environment's carbon footprint.

Given the increasing global recognition of the crucial role of behavioral change in achieving climate goals, the empirical results have several implications for the policymaking process and policy intervention. The results call for developing more proactive behavioral change programs using innovative instruments to curb residential energy consumption and related GHG emissions. In parallel, the discussion provides specific guidelines for harnessing empirical behavioral studies to improve the effectiveness of behavioral intervention programs. Endorsing these guidelines will be valuable in designing and executing successful energy efficiency programs.

References

Asmare, F., Jaraitė, J., & Kažukauskas, A. (2021). The effect of descriptive information provision on electricity consumption: Experimental evidence from Lithuania. *Energy Economics, 104*, 105687.

Babutsidze, Z., & Chai, A. (2018). Look at me saving the planet! The imitation of visible green behavior and its impact on the climate value-action gap. *Ecological Economics, 146*, 290–303.

Bakaloglou, S., & Belaïd, F. (2022). The role of uncertainty in shaping individual preferences for residential energy renovation decisions. *Energy Journal, 46*(4), 127–158.

Bakaloglou, S., & Charlier, D. (2019). Energy consumption in the french residential sector: How much do individual preferences matter? *The Energy Journal, 40*(3), 77–99.

Belaïd, F. (2016). Understanding the spectrum of domestic energy consumption: Empirical evidence from France. *Energy Policy, 92*, 220–233.

Belaïd, F. (2017). Untangling the complexity of the direct and indirect determinants of the residential energy consumption in France: Quantitative analysis using a structural equation modeling approach. *Energy Policy, 110*, 246–256.

Belaïd, F. (2022a). Mapping and understanding the drivers of fuel poverty in emerging economies: The case of Egypt and Jordan. *Energy Policy, 162*, 112775.

Belaïd, F. (2022b). Implications of poorly designed climate policy on energy poverty: Global reflections on the current surge in energy prices. *Energy Research & Social Science, 162*, 102790.

Belaïd, F. (2024). Decarbonizing the residential sector: How prominent is household energy-saving behavior in decision making? *The Energy Journal, 45*(1), 125–147.

Belaïd, F., & Garcia, T. (2016). Understanding the spectrum of residential energy-saving behaviors: French evidence using disaggregated data. *Energy Economics, 57*, 204–214.

Belaïd, F., & Joumni, H. (2020). Behavioral attitudes toward energy saving: Empirical evidence from France. *Energy Policy, 140*, 111406.

Belaïd, F., & Rault, C. (2021). Energy expenditure in Egypt: Empirical evidence based on a quantile regression approach. *Environmental Modeling & Assessment, 26*(4), 511–528.

Belaïd, F., Youssef, A. B., & Omrani, N. (2020). Investigating the factors shaping residential energy consumption patterns in France: Evidence form quantile regression. *The European Journal of Comparative Economics, 17*(1), 127–151.

Belaïd, F., Rault, C., & Massié, C. (2021). A life-cycle theory analysis of French household electricity demand. *Journal of Evolutionary Economics*, 1–30.

Harding, M., & Hsiaw, A. (2014). Goal setting and energy conservation. *Journal of Economic Behavior & Organization, 107*, 209–227.

Harrison, G. W., & List, J. A. (2004). Field experiments. *Journal of Economic Literature, 42*(4), 1009–1055.

Hertwig, R., & Grüne-Yanoff, T. (2017). Nudging and boosting: Steering or empowering good decisions. *Perspectives on Psychological Science, 12*(6), 973–986.

Lazaric, N., & Toumi, M. (2022). Reducing consumption of electricity: A field experiment in Monaco with boosts and goal setting. *Ecological Economics, 191*, 107231.

Maréchal, K. (2010). Not irrational but habitual: The importance of "behavioral lock-in" in energy consumption. *Ecological Economics, 69*(5), 1104–1114.

Martela, M. (2015). Fallible inquiry with ethical ends-in-view: A pragmatist philosophy of science for organizational research. *Organization Studies, 36*(4), 537–563.

Moran, D., Wood, R., Hertwich, E., Mattson, K., Rodriguez, J. F., Schanes, K., & Barrett, J. (2020). Quantifying the potential for consumer-oriented policy to reduce European and foreign carbon emissions. *Climate Policy, 20*(sup1), S28–S38.

Nauges, C., & Wheeler, S. A. (2017). The complex relationship between households' climate change concerns and their water and energy mitigation behavior. *Ecological Economics, 141*, 87–94.

Pira, S. (2021). The social issues of smart home: A review of four European cities' experiences. *European Journal of Futures Research, 9*(1), 1–15.

Pullinger, M. (2014). Working time reduction policy in a sustainable economy: Criteria and options for its design. *Ecological Economics, 103*, 11–19.

Shove, E., Trentmann, F., & Wilk, R. (2020). *Time, consumption and everyday life: Practice, materiality and culture*. Routledge.

Sovacool, B. K., Newell, P., Carley, S., & Fanzo, J. (2022). Equity, technological innovation and sustainable behavior in a low-carbon future. *Nature Human Behavior, 6*, 326–337.

Stern, P. C., Dietz, T., & Guagnano, G. A. (1995). The new ecological paradigm in social-psychological context. *Environment and Behavior, 27*(6), 723–743.

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: improving decisions about health, Wealth, and Happiness, 6*, 14–38.

Thornbush, M., & Golubchikov, O. (2021). Smart energy cities: The evolution of the city-energy-sustainability nexus. *Environmental Development, 39*, 100626.

Übelmesser, L., Klingert, S., & Becker, C. (2020). Comparing smart cities concepts. In *2020 IEEE international conference on pervasive computing and communications workshops (PerCom Workshops)* (pp. 1–6). IEEE.

United Nations. (2019). *Department of Economic and Social Affairs, Population Division. World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420)*. United Nations. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

United Nations. (2022). *Sustainable development*. https://sdgs.un.org/goals

Welsch, H., & Kühling, J. (2009). Determinants of pro-environmental consumption: The role of reference groups and routine behavior. *Ecological Economics, 69*(1), 166–176.

Woersdorfer, J. C., & Kaus, W. (2011). Will non owners follow pioneer consumers in the adoption of solar thermal systems? Empirical evidence for northwestern Germany. *Ecological Economics, 70*(12), 2282–2291.