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Social influence and economic intervention policies to save energy at home: Critical questions for the new decade and evidence from air-condition use

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ABSTRACT

To guide effective energy policy-making towards a fundamental understanding of the mechanisms relevant to behavioral change, it is important not only to investigate whether energy interventions succeed or not, but also to explore the underlying reasons that shape each result. However, certain limitations are hindering a global consensus on the effectiveness of two popular types of energy interventions: the ones based on social influence (peer pressure) and the ones based on economic instruments (rewards and penalties). The aim of this paper is to provide a new perspective on the exploration of the factors that affect the effectiveness of such interventions. Based on a review of studies published during the last two decades, an agenda of six critical research questions is thus set up to identify new priority areas of research. The relevance of this agenda is illustrated via a survey that explores the potential of peer pressure and economic interventions designed to influence residential space cooling energy savings in an urban setting. The survey results provide evidence that such a potential can be affected by the type of targeted behavior (efficiency or conservation), by householder characteristics (openness to change and environmental awareness), and by the existence of past influence events. Interestingly, peer pressure is regarded as highly influential independently of the channel through which it is communicated, i.e. offline or online. These observations can assist public policy in countries with a growing emphasis on changing people's energy behavior to redefine the targeting scope of interventions, thus strengthening their potential.

1. Introduction

The residential buildings sector accounts for a large percentage of the total energy consumption and resulting greenhouse gas (GHG) emissions within an economy. For instance, in the United States (US) this percentage reaches 40% [1]; in other economies, it can be as high as 50%, while the global average exceeds 30% [2,3]. As human behavior has been recognized as one of the most significant factors of residential energy consumption [4,5], policy-makers are interested in ways to motivate the public towards environmentally-friendly and energy-saving behaviors [6,7]. If any intervention policies are to be easily incorporated into government agendas, they need to be cost-effective and socially acceptable [6,8], and behavioral experiments can provide guidance on how to attain strong evidence-based policy-making [9,10] in that direction [11,12].

Depending on their specifications, energy behavioral intervention policies may rely more or less on incentives or social influence [13]. The latter occurs when people's individual values, perceptions, feelings or actions are influenced by their peers [14,15] (i.e. people who are comparable or similar to them), and it is a key behavioral economics concept, often deemed an important guidance point for designing effective interventions [11]. Given the fundamental social construction of energy consumption, scholars are expecting interventions to be more effective when their reliance on social influence and peer pressure is

Abbreviations: GHG, greenhouse gas; AC, Air-Condition; HER, Home Energy Reports; TPB, Theory of Planned Behavior.

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strong, especially when they are framing energy-saving as a socially desirable practice [11]. In addition, scholars have long been examining the results of energy interventions that are based on economic instruments such as monetary rewards (in the form of rebates, incentives, or other benefits) and penalties (in the form of taxation or other charges); under the appropriate specifications, these are also believed to be effective in inducing energy reductions.

However, changing one's behavior is a complex issue with multiple dimensions. Thus, a consensus on the effectiveness of energy interventions does not exist: while particular interventions have been found to be effective in particular settings, this effectiveness might not always be persistent in time or transferrable to other settings. From the beginning of this millennium, this lack of consensus has been attributed to the fact that relevant studies often emphasized the results themselves (i.e. whether intervention succeeds or fails), and not on the underlying conditions that shaped the results [14,16]. Another reason cited for this inconclusiveness is the confounding effect: when changes are reported as a result of a combination of various interventions, it is harder to identify the separate effect of each intervention [16].

In view of the above, this paper contributes to the growing energy behaviors literature by providing a new perspective on the exploration of the relationships relevant to the influence of energy intervention policies. To that end, the paper firstly provides a brief background of past energy intervention experiments. Secondly, it carries out a critical review of the characteristics of experiments conducted during the last two decades. This exercise establishes an agenda of six critical questions to assist future research and evidence-based policy-making to avoid potentially incorrect inferences about intervention effectiveness. Of central importance in this agenda is whether energy interventions target the behavioral counterpart (efficiency or conservation) or population group that is more likely to be influenced in a particular setting. Other important items in the agenda include whether the development of social media technology has affected the energy consumers' perception of social influence, and whether individuals who have been influenced by an intervention in the past have a tendency to be influenced again in the future.

Thirdly, the agenda's propositions are illustrated via a survey that explores the effectiveness of social influence and economic interventions towards encouraging residential energy-saving behaviors in an urban setting. The survey focuses on the use of air-condition (AC) appliances, a residential energy behavior of significant importance in energy and climate policy: space cooling is projected to represent the largest share of global electricity demand growth by 2050 [17], thus saving cooling energy is deemed one of the household actions with the largest GHG emissions reduction potential in many parts of the world [18]. The unique characteristic of the survey is that it compares people's perceptions of the effectiveness of various social influence (online and offline) and economic (rewards and penalties) interventions to modify their efficiency and conservation behaviors. Furthermore, it examines external [19] (socio-demographics), internal [19] (psycho-cognitive), and historical (past influence) factors as possible determinants of intervention effectiveness. To the best of the authors' knowledge, no study has yet attempted to holistically explore the relative effectiveness of these intervention types within a comparative framework and on a large scale-especially while considering the above-mentioned behavioral determinants. Finally, the survey results are discussed, concluding with suggestions for action towards designing influential energy intervention policies.

2. Background

2.1. Residential energy interventions overview

Scholarly work in behavioral science and economics has emphasized the role of human behavior as a crucial factor towards improving sustainable energy performance [4,5,11]. Consequently, various governments have been oriented towards implementing policies aiming to stimulate energy-saving behavior among consumers. Commitment, goal setting [20], modeling, information provision [16], feedback [21,22] and economic instruments [23] are typical examples of tools employed by such interventions. Depending on the way they are designed, interventions have a private or a social dimension; for instance, information on one's own electricity consumption and its resulting expenses has a strong private dimension; however, when this consumption is compared against the one of peers, the intervention acquires a social dimension.

Social influence interventions are based on the social comparison theory [24], which describes how humans tend to compare themselves with their peers. Interventions of this type are also linked with the behavioral economics concept of pro-social behavior, which states that decisions are driven by one's desire not only to satisfy her/his own utility, but also to contribute to the common good. Appropriate social influence and comparison messages can be conveyed to households via channels such as customized home audits [22], letters, media campaigns [25], or via "block leaders" [14]. On the other hand, economic instruments are policies that entail paying the customers back a monetary amount to reward savings or encourage efficiency upgrades [26], or charging them an amount as a penalty for over-consumption. Energy taxation may be considered as such a penalty, even though it has been implemented mostly to raise revenue instead of discouraging excessive consumption [27]. In practice, penalties are used less often [26], as they are associated with negative public reactions and political cost, while rewards are deemed able to add positive associations to energy-saving. Both of these intervention types lean on the neoclassical economics approach, which highlights the tendency for self-utility satisfaction.

The need to inform policy about the public and private dimensions of energy behavior has motivated a significant number of studies to explore the effectiveness of social influence and economic instrument interventions (see Appendix A for examples). This has been largely achieved via the collection and/or analysis of household data as evidence of behavioral change, thus making evidence-based policy-making [9] (commonly employed in several other societal functions) a popular approach in the energy-society intersection [10]. Overall, studies in that direction have revealed mixed trends, but a general observation is that interventions that include a social influence element are likely to succeed [14]. For instance, most of the studies featured in quality reviews such as [14,28,29], report energy reduction results from at least one of their treatments. The magnitude of energy savings associated with social influence interventions varies from 1.2% to 30% [29], with the average being 2% [28]. However, other reviews (such as [22]) demonstrate that some social information programs are not as effective as individual information ones. Furthermore, social influence in the form of peer comparison has been found to increase energy use, in a manifestation of the boomerang effect [30], i.e. users who were previously consuming less than others, might consume more after being exposed to this information. Nevertheless, scholars report that when comparison messages are framed in an injunctive manner (i.e. when the environmental results of the action in question are clearly stated and framed as socially desirable), boomerang effects are eliminated [30]. Economic instruments have also controversial uptake; several studies demonstrate their effectiveness in encouraging savings [16], while others associate them with negative effects, such as increased consumption [22], free-riding [31] and the rebound effect [32].

2.2. Issues and the present study

From the above, it is evident that a global consensus on the effectiveness of residential energy intervention policies has not been reached yet. From the beginning of this millennium, scholars such as Abrahamse and colleagues [16] have attributed this ambiguity to issues such as the following: 1) most relevant studies focus more on whether an intervention succeeds or fails, but not on the underlying factors that shape

each result; 2) as most experiments use a combination of different interventions, it is difficult to evaluate the effect of each intervention separately; and 3) due to time and sample size limitations (i.e. several experiments involve only a small number of households, or only one demographic group, such as students [33,34]), it is difficult to evaluate long-term effects on diverse populations. Thus, the challenge for future experiments is identified to be the provision of a clearer understanding of why interventions succeed or fail, through research on large population groups [11].

Motivated by this need, this paper establishes an agenda of six questions to assist evidence-based research and policy-making towards achieving such understanding in the new decade. These questions are raised after analyzing an international sample of reviews and original research studies published since the beginning of this millennium. This emphasis on the last 22 years was dictated by the fact that the specific period has witnessed a proliferation of research on the behavioral aspect of energy use [35], and especially on residential energy-saving interventions [36]. Furthermore, a specific scientific field is emerging, and a stronger focus on the last two decades serves the purpose of understanding the extent to which the most recent advancements have addressed issues such the ones identified earlier in this millennium by Abrahamse et al. [16].

The papers that formed the basis of this study's international literature review were identified following standard procedures to yield a representative sample of publications in this field [29,37,38]. In brief, reviews and meta-analyses were firstly sought for by searching electronic records and well-established databases (such as Scopus and Web of Science) and using keywords including but not limited to: "energy interventions", "energy-saving behavior", "nudges", "social/peer pressure", "(normative) social influence", "economic/financial instruments", "rewards", "incentives", and "penalties". Subsequently, the results were refined through multiple title/abstract reviews by applying the following criteria: journal or conference papers that include residential energy-saving intervention studies involving social influence or economic tools (or both), published in English during the last 22 years. At the end, a final sample of 16 reviews on various interventions towards promoting energy-saving and other sustainability behaviors was selected. Next, backwards searches were performed on the references of these reviews, to extract original research articles that explicitly describe at least one residential energy-saving intervention based on social influence and/or economic instruments. To these studies, more were added through a second circle of search in electronic databases, using the same keywords and applying the same criteria as before. The whole procedure yielded a final sample of 55 original research papers for detailed analysis. This list of papers is not intended to be exhaustive, but rather to provide a meaningful reflection of the state-of-the-art of the academic publications in the field. Notably, relatively less economic intervention studies were found compared to social influence studies. This is consistent with past observations of a surprisingly small number of direct evidence on evaluating the effectiveness of economic interventions in the energy behavior context [39,40], which also indicates a great potential to explore more in that domain.

3. Research questions for the new decade

Table 1 summarizes the findings from analyzing the 16 review/meta-analyses and the 55 original research papers, while their details are provided in Appendix A. In the spirit of focusing less on the results themselves and more on possible reasons behind their heterogeneity, Table 1 does not include information on each experiment's results (these are already well-documented by the featured reviews). Instead, the focus of Table 1 is to determine: how the distinction between the different counterparts of energy-saving behavior is addressed; how large and diverse is the sample size of households examined, and; whether underlying determinants that are believed to trigger energy-saving behavior are examined. For the latter, this paper follows the distinction between external (socio-demographics and building characteristics) and internal (psycho-cognitive) determinants described by Šćepanović et al. [19]. The observations from analyzing the 71 studies shape the following research questions:

Table 1
Summary of characteristics (given as a percentage of total studies in each category) of the energy intervention studies included in this paper's review.

		Type of interventions examined (number of studies)		
		Social influence (total: 39)[a]	Economic instruments (total: 22)[a]	TOTAL
Year of publication	Between 2000 and 2021	100%	100%	100%
Region	US/Europe	66.6%	68.2%	69.1%
	Rest of the world	23.1%	31.8%	23.6%
	Combination	10.3%	–	7.3%
Sample size	Less than 100	15.3%	4.5%	10.9%
	100–500	43.6%	18.3%	34.5%
	More than 500	41.1%	77.2%	54.6%
Examining only one group	(e.g. students)	30.8%	4.5%	23.6%
Energy-saving behaviors targeted	Efficiency only	2.5%	45.4%	18.2%
	Conservation only	64.2%	22.8%	49.1%
	Both or unclear	33.3%	31.8%	32.7%
Behavioral determinants examined	At least one external[b]	74.4%	86.3%	80%
	At least one internal[b]	48.7%	31.8%	43.6%

[a] The total number of studies on the particular type of intervention (examined either alone or together with the other type).
[b] The sum of each sub-column is not 100%, as some studies consider both types of determinants (external and internal).

3.1. Research question 1: are the appropriate behaviors being targeted?

Residential energy-saving behavior comprises two counterparts: efficiency and conservation. While different terms and definitions are often used interchangeably in the literature, this paper defines the two counterpart behaviors according to the US Energy Information Association standardization [41]: efficiency refers to reducing energy consumption through the adoption of more efficient technologies, while conservation refers to achieving reductions through frequently occurring curtailments in use. Fig. 1 summarizes the main differences between the two: efficiency is considered a "one-off" effort that is however associated with the higher monetary costs of acquiring energy-efficient appliances or undertaking energy-saving retrofits and renovations. On the other hand, conservation is associated with monetary savings from reduced electricity bills, but it requires continuous effort to maintain, and may lead to comfort loss. It is plausible to assume that these two behaviors are treated differently in studies, as the above-mentioned differences might affect consumers' motivation and ability to pursue them.

However, this is not always the case; apart from the ambiguity in definitions, energy-saving behavior has been often treated as one entity, without clear distinction of its counterparts [42]. This has been evident from the beginning of this millennium [16], together with the observation that efficiency has been studied less extensively than conservation. For instance, Nisa et al. [18] acknowledge that the experimental field available for their meta-analysis has mainly targeted frequently occurring conservation actions. In particular, the authors of that

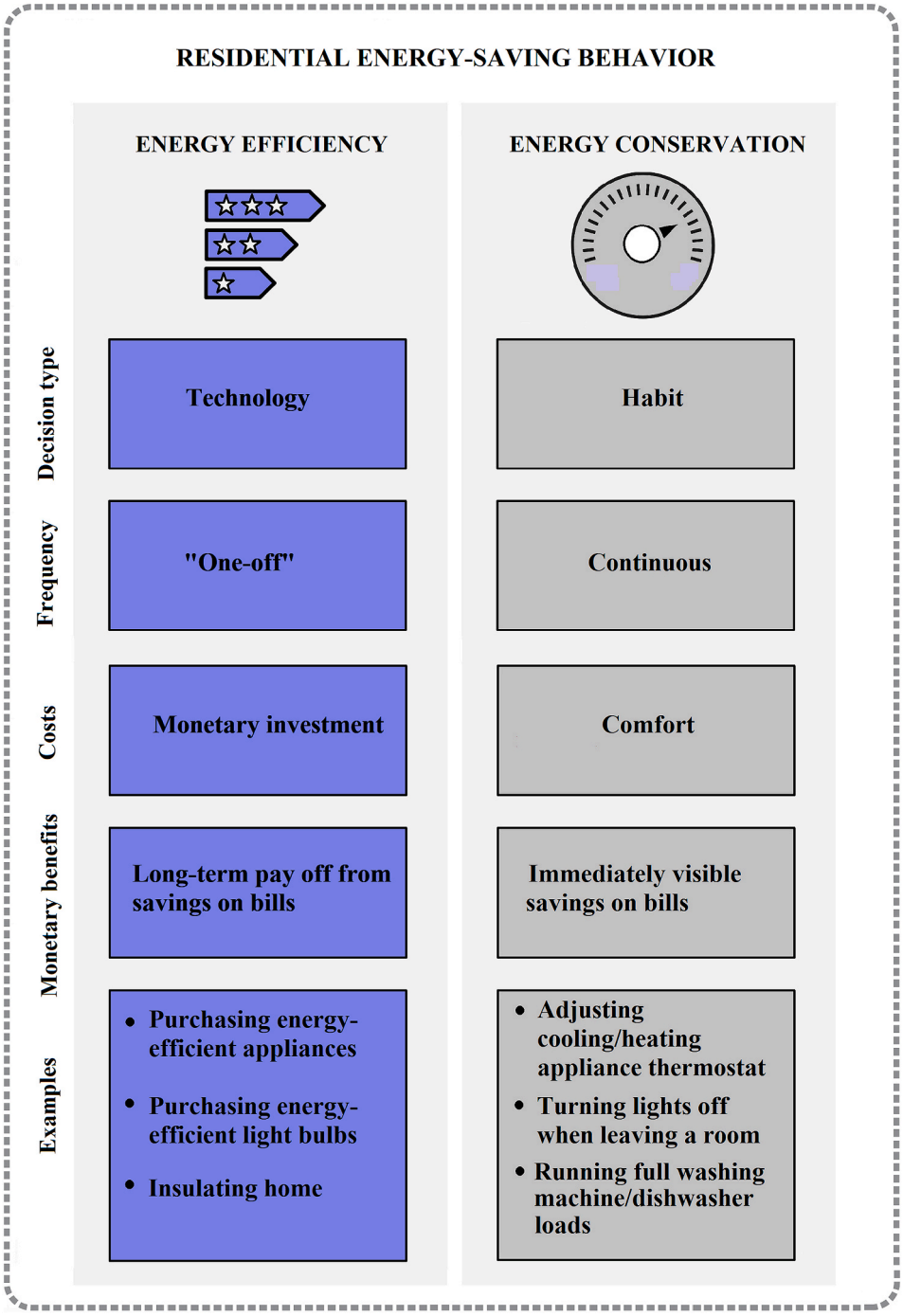

Fig. 1. Main characteristics and examples of residential energy efficiency and energy conservation behaviors.

meta-analysis cite the different foci on energy behaviors as a possible reason behind the discrepancies between their work and other studies. In addition, all the peer comparison studies mentioned by Cattaneo [26] focus on conservation, while all the economic instruments ones focus on efficiency. Wolske et al. also discuss the limited attention of peer comparison studies towards efficiency [43], while Bertoldi et al. [27] make the analogous remark regarding the relationship between economic instrument policies and conservation. This current paper's sample reveals similar trends: most social influence studies explore conservation, while most economic instrument studies explore efficiency.

At the same time, it is often unclear whether a reported consumption reduction is due to changes in conservation, or efficiency, or both. For instance, some studies from this paper's sample (such as [30,44,45]) investigate the home energy report (HER) programs run by Opower (now Oracle) in the US- the last decade's largest energy behavioral experiment. In these programs, residents were receiving information about how their own energy consumption compared to the one of their peers; they were also receiving energy reduction tips, including both efficiency and conservation measures. The programs were associated with energy savings [44], and a few studies were able to attribute which part of these savings came from changes in efficiency [45], but this has not always been possible.

Such patterns are often dictated by practicality, since considering efficiency limits a study's scope to energy consumers who are homeowners. Nevertheless, this ambiguity may hinder further understanding of why interventions succeed or fail. Given the difference in difficulty

between the two, it is plausible to assume that one-time efficiency may be more effectively influenced by interventions, compared to what happens to repetitive conservation [18]. It is, thus, possible that a particular intervention succeeds (fails) because it targets (does not target) the behavior that is more likely to be influenced in a particular setting. Nisa et al. [18] indicate that this possibility has not been explored adequately in the literature.

Wolske at al [43]. and Šćepanović et al. [19] also suggest that the difficulty of behavior matters, with the latter study indicating that such a parameter has not been examined adequately as a factor that potentially affects interventions. Therefore, a comparison between the potential of each particular intervention to influence each particular behavior may assist researchers to discount possible confounding effects. Finally, while the rebound effect may be addressed when intervention programs target both efficiency and conservation [19], it is necessary to combine the inclusion of both behaviors with an improved understanding of their differences.

3.2. Research question 2: is online peer pressure more/less influential than offline?

Several scholars attribute the heterogeneity of results across social comparison interventions to differences in the medium [29,37] and the structure of the network [46] via which a message spreads, the reference groups used in a comparison, and the social dynamics within groups [19]. Other scholars emphasize the concept of "localization", observing that consumers are motivated to save energy when they are compared against their similar and "local" peers [47]. For instance, Shen et al. [48] observed that comparisons with street-level neighbors were more effective that those with other reference groups. Senbel et al. [49] also attributed the success of energy-saving competitions/games to the fact that they engage friends and close peers. However, the development of social connection platforms such as Facebook and Twitter has modified this localization concept, by transforming dramatically the way information is spread among users – including information on environmental issues [50–52]. In addition, mobile phone, computer and tablet applications [38] allow social connections among people physically located far away from each other, thus facilitating energy consumption comparisons [53] and competitions [49], and potentially changing perceptions of who belongs to one's immediate peer group.

What remains perhaps less explored, is how this change in the understanding of localization affects the potential of interventions designed to influence. Although there are studies [54] that explore the effectiveness of delivering a normative message to residents via online means, instead of offline, there is inadequate comparison between interventions that use offline (local community) peers as a reference point, to those that use online (social media) peers for the same purpose. Shedding light into this distinction may assist governments to prioritize the channels through which they can deploy interventions.

3.3. Research question 3: are the appropriate population groups being targeted?

Various scholars call for governments to implement targeted energy interventions that would be most effective with specific population groups [48]. This is plausible, as an intervention may succeed (fail) simply because it targets the population segment that is most (not) likely to be influenced by it. Thus, it is important for researchers to understand what type of intervention works best for each segment. However, two barriers potentially prevent rigorous understanding of the matter. Firstly, there is no consensus on which segmentation approach is most useful in an energy intervention context, as some population characteristics are studied less often than others. Secondly, a large number of experiments considers a small number of participants, raising questions on the generalization of their conclusions.

Regarding the first barrier, a rich environmental psychology literature highlights the significance of psycho-cognitive factors, i.e. psychological traits and knowledge, in affecting energy consumption. While the role of such traits is studied extensively in direct relation to energy decisions [55–58], their role in affecting these decisions when specific interventions are present has not been studied adequately [16,48]. This paper's review demonstrates that, while there is an increase in studies that examine internal factors such as personality [48,59,60], attitudes [32,61,62] and knowledge [63,64], compared to the past [14,16], the majority of studies does not focus on such characteristics. Table 1 indicates that this is more evident in the case of economic instrument studies; this is perhaps justified by the fact that these tend to follow the self-utility approach of traditional economics, thus more attention is given to economic parameters such as income. However, the limited focus on psychological factors is particularly surprising in the case of social influence interventions, as following the behavior of others is by nature a psychological process [59]. Furthermore, the heterogeneity in results reported in the literature (where socio-demographic segmentation prevails) hints the need to explore a different segmentation paradigm, perhaps one based on internal factors.

Regarding the second barrier, Andor and Fels [29] emphasize that a study's sample size might affect its results. However, several reviews [14,16,18] indicate that intervention experiments often involve a small number of participants, particularly less than 500. In this paper's sample, more than half of the studies involve more than 500 participants; however, this is mainly driven by the fact that several economic instrument studies have access to large-scale data from HER experiments, something that is not often available to social influence studies. In addition, as Table 1 indicates, a significant number of studies considers a single population group only, i.e. students, and this lack of evidence from other groups is often deemed a limitation. Nevertheless, collecting large-scale residential energy data might be costly and require complex agreements with utilities. Once again, the scholars who analyze large-scale HER experiments avoid such limitations and manage to examine the behavior of thousands of households. However, such arrangements are not always available to researchers. A possible way to circumvent this limitation would be to measure intentions on behavioral change and self-reported energy use, instead of actual energy use. While there are valid concerns about gaps between intentions and actual behavior [18], the Theory of Planned Behavior (TPB) [65] provides a platform that recognizes intentions as viable predictor of actual behavior. Attitudes, subjective norms and perceived behavioral control are the three components of TPB [66], which has been found to have an explanatory power of 95% in the case of energy behaviors [67]; this has allowed evidence-based policy-making to deem intentions a proxy variable of real energy consumption actions.

3.4. Research question 4: does past influence create a tendency for future influence?

There is skepticism about interventions' ability to generate time-persistent results [26,29]. No clear consensus on the matter exists [29], as various studies provide evidence that intervention effects can be strengthened over the long-term, at least for some of the groups they examine [34,45,68], while others suggest the opposite [26,69]. Andor and Fels [29] conclude that there is no clear reason behind this discrepancy, and emphasize the need for future research to provide more evidence on the matter. Once again, by employing reviews conducted by Abrahamse and colleagues [14,16] as examples, it is observed that not all energy intervention studies explore long-term effects; it might not be often practical to do so, since measuring such effects would entail follow-up surveys and/or measurements, a practice that is not common in the field [38].

A possible way to circumvent this limitation is to explore whether individuals who have been motivated by an energy intervention in the past maintain a tendency to be influenced again in the future. If this happens, it can be an indication that particular past influence events

have a pervasive effect on changing behavior (for instance, by providing knowledge of energy/environmental issues, which would increase one's likelihood to be influenced by a future intervention). Ito et al. [70] examined, among others, the psychological phenomenon of habit formation, which considers the formation of habits that remain, even when an intervention finishes. The review of Šćepanović et al. [19] indicates that habits/past behavior have been studied for some information-based interventions, but not adequately for nudges, peer pressure and incentives. Wang et al. [71] provide evidence that past experience has a positive correlation with energy-saving behavior; in that context, past experience refers to energy-saving habits and experience with electricity shortfalls. It is possible that another type of past experience, experience with having been influenced by an energy intervention in the past, will affect one's likelihood to be influenced again by a new intervention, perhaps through a habit formation mechanism. Thus, an intervention might succeed because it targets people who have been influenced before, but might be less effective in other groups. However, this paper's review indicates that a parameter examining whether specific target audiences have been influenced by an intervention in the past or not, has not been considered adequately in the literature.

3.5. Research question 5: how much is "reasonable" for economic instrument interventions?

It is plausible to assume that economic interventions will be successful if the monetary amounts they involve are high enough to stimulate change in energy consumption [27]. Nevertheless, governments might worry that high rewards will be costly, and high penalties/taxation will generate negative reactions. To avoid this, they could determine the optimum level of amounts that will make such measures effective. Subsequently, an economic intervention policy might succeed (fail) because it involves a monetary amount that the public deems reasonable (unreasonable). Thus, governments may consult financial experts, who will analyze various economic parameters to determine how much is "reasonable". Bertoldi et al. [27] discuss various rewards mechanisms, including a design where an X% of the annual bill will be paid back if energy consumption is reduced by Y% compared to the previous year. In some real world examples, the savings targets and corresponding rewards are agreed upon with the consumers in advance [27]. In other cases, voluntary penalty schemes exist [27]. In most cases however, there might not exist prior knowledge of an audience's specific preferences. Therefore, even if certain designs are deemed fair by experts, there is no guarantee that the public will share the same perception of what amount/percentage is acceptable, especially since behavioral economics has demonstrated the complex nature of predicting one's economic and energy decisions [7,72]. That is perhaps why cases were reported where households would have participated in specific efficiency programs even with smaller subsidies compared to the ones they actually received [39]. Hence, for a more informed economic intervention design decision, policy-makers might explore ways to gain prior knowledge of a population's preferences on the matter, i.e. the minimum (maximum) amount/percentage of a reward (penalty) that is likely to be accepted.

3.6. Research question 6: is the representation of geographic locations diverse?

Abrahamse and Steg [14], Nisa et al. [18], and this paper's review reveal that most of the energy intervention studies published in English involve experiments from either the US or European countries [64]. This indicates an encouragingly growing interest towards changing energy behaviors in these nations. On the other hand, this trend constitutes a geographic representation imbalance that might be limiting opportunities to achieve energy savings in different parts of the world. For an aggregated effect on reducing the global GHG emissions that are associated with residential energy consumption, it is important to stimulate change in as many locations as possible, and especially in Asia; the latter is not only the world's most populous continent, but also a continent where rapid population growth and urbanization results in ever-increasing household energy demand.

In addition, this imbalance becomes problematic if it hinders wider understanding of how the consumers' cultural background affects the success rate of energy interventions. According to Hoftstede [73], one important cultural dimension is the degree of individual association with a group: eastern societies, such as the ones in China and Japan, are often associated with collectivism [74], where the group's interests are valued highly. On the other hand, western societies, such as the ones in the US and Europe, are associated with individualism [74], where personal interests are valued more highly. In the context of energy interventions, social influence is expected to be stronger in collectivist cultures [75]. However, current evidence is not conclusive [74], and some scholars argue that the collectivism/individualism distinction between eastern and western societies is not significant [76]. Furthermore, individualism might simply be higher in densely-populated urban areas, and collectivism higher in rural areas [77], regardless the country. Thus, more empirical results are needed, especially from studies comparing individuals from different cultures in different urban settings. One might argue that countries such as the US and the United Kingdom (UK) are multi-cultural and represent groups with backgrounds from different continents; however, studies conducted in these countries do not often provide information on the national background of the household residents, unless supported by detailed national census data (references [68,74,78–80] are examples of exceptions that make intercultural comparisons). To achieve a universal understanding of the patterns relevant to energy behavior, it is important to perform experiments in as many geographic regions as possible, especially in the currently underrepresented ones.

4. Survey

The relevance of the research questions raised above is illustrated via a survey that assesses householders' willingness to engage in efficiency and conservation actions relevant to space cooling, if induced by social influence and economic interventions. The survey was conducted in Hong Kong, a good example of populated and developed cities, where space cooling is one of the largest energy use contributors [81]. Focusing on residents' perceptions and willingness to act, instead of their actual energy consumption, allows the survey to circumvent sample size limitations that the collection of actual consumption data entails. In addition to emphasizing the validity of this paper's agenda of research questions, the survey provides original evidence on the potential of various energy-saving interventions in the specific city.

4.1. Conduction method

A questionnaire with a wider scope of collecting data on energy behavior attitudes and patterns in Hong Kong was the base of the survey, and responses were collected through telephone interviews. The answers to other parts of the full questionnaire are analyzed elsewhere [82], while this paper focuses on validating the significance of our research questions pertaining to social influence and economic interventions (the relevant survey questions are presented in Appendix B). The target population was Cantonese-speaking residents aged 18+, who are the decision-making people of their households. Anonymity was guaranteed to minimize possible social desirability bias [83]. To reach the interviewees, the random sampling method [84] was used. The sample size achieved exceeded 1000 responses and was finally reduced to $N = 931$. The reduction was necessary to exclude responses with less than 95% of the questions answered and the households without ACs.

4.2. Hypotheses and variables

Following the direction set by *Research Question 1*, the survey explores whether a social influence intervention has a different potential to influence efficiency, than to influence conservation. In addition, and following the direction of *Research Question 2*, it attempts a comparison between the potential of offline peer pressure to influence each energy behavior, and this of online peer pressure to do likewise. Subsequently, the following hypotheses are formulated:

Hypothesis 1. If induced by a peer pressure intervention, the consumers' willingness to engage in efficiency actions is different compared to their willingness to engage in conservation actions.

Hypothesis 2. If induced by social media peer pressure interventions, the consumers' willingness to engage in energy-saving actions is different compared to their willingness to do so if induced by local community peer pressure interventions.

To analyze these hypotheses, the survey respondents were asked to indicate to what extent they agree or disagree with specific statements on a 1–10 Likert-type [85] scale. An answer toward unity indicates strong disagreement, while an answer approaching 10 indicates strong agreement. The questions clarify that the objective of the peers' hypothetical actions is to protect the environment (thus the peer pressure is framed as "green"). Therefore, the underlying message receives both injunctive and descriptive meanings, in order to neutralize boomerang effects [13,30]. Furthermore, by exploring the influence potential of each intervention separately, the survey seeks to avoid confounding effects. Finally, as it was identified that there is limited exploration of conservation in economic intervention studies, the questions on rewards and penalties were concentrated on targeting conservation only. Exploring a relationship between penalties and non-efficiency would be redundant by default (as no penalties are given to a consumer who does not acquire an efficient appliance), and having an additional survey question only on the relationship between rewards and efficiency would not serve the purpose of comparing between the two instruments. Ultimately, through the responses, values were assigned to the following dependent variables, which represent to what extent each intervention has the potential to successfully influence each action (i.e. an intervention succeeds if it induces willingness to engage in a specific action).

LC_e – willingness to engage in energy efficiency actions induced by local community peer pressure;

SM_e – willingness to engage in energy efficiency actions induced by social media peer pressure;

LC_c-willingness to engage in energy conservation actions induced by local community peer pressure;

SM_c-willingness to engage in energy conservation actions induced by social media peer pressure;

P*EN*- willingness to engage in energy conservation actions induced by a penalty intervention; and.

REW- willingness to engage in energy conservation actions induced by a reward intervention.

Furthermore, and following the direction of *Research Question 3*, the survey employs as independent variables external (socio-demographic) and internal (psycho-cognitive) factors that potentially affect the interventions' success. The socio-demographic variables include income, age, education, gender and location of residence. Openness to change [86] and environmental awareness are examined as examples of psycho-cognitive factors; the former is a trait closely related to the acceptance of behavioral change [86], while the latter is commonly examined as a driver for energy-saving behavior [87,88]. Moreover, two independent variables related to the respondents' habitual and historical behavior patterns are examined: one explores the number of peer interactions within a typical month, and the other explores whether the residents have been influenced by their peers toward reducing their AC energy consumption in the past-this is introduced to circumvent common practical limitations in addressing *Research Question 4*. Ultimately, the following hypotheses are formed:

Hypothesis 3. The consumers' willingness to engage in energy-saving actions, if induced by interventions, is affected by:

- **A**, external factors.
- **B**, internal factors.

Hypothesis 4. The consumers' willingness to engage in energy-saving actions, if induced by interventions, is affected by the existence or absence of previous influence.

Following the direction of *Research Question 5*, the survey asks how the residents characterize specific economic rewards/penalties, presented as percentages of their electricity bill. Finally, and following the direction of *Research Question 6*, Hong Kong is employed as an example of locales that are often underrepresented in relevant studies.

Several of the above-mentioned parameters are understood to be linked with the major components of the TPB, in the following manner: peer pressure has the potential to strengthen subjective norms, environmental awareness can affect positive attitude towards energy-saving [87], while openness to change and past experience are positively related to perceived behavioral control. These assumptions create a basis for extending the theoretical point of the TPB, thus accepting intentions as a predictor of real actions in this analysis. Fig. 2 maps these relationships while illustrating the transition from this paper's research questions to the survey characteristics.

5. Results and discussion

5.1. Correlations and descriptive statistics

The respondents' socio-demographic and psycho-cognitive characteristics are detailed in Ref. [82], while their peer-related habitual/historical characteristics are presented in Appendix C. The survey's socio-demographic findings are consistent with official governmental statistics [81], indicating that the respondents constitute a representative sample. Table 2 summarizes the correlations and descriptive statistics of all variables; for this, Spearman's ρ [89] was preferred over Pearson's r [90], as initial Shapiro-Wilk [91] and Kolmogorov-Smirnov [92] tests revealed that the variables do not follow normal distributions. Table 2 demonstrates positive correlations among the dependent variables; this indicates that energy consumers who are likely to be influenced by economic interventions are also likely to be influenced by social influence interventions. Clearly, this correlation is stronger in the case of conservation, as the economic interventions mentioned in the questionnaire were targeting conservation only. Finally, the correlation between penalty and reward influences is also strong, indicating that consumers who are likely to be influenced by one economic instrument are also likely to be influenced by the other.

5.2. Interventions' influence potential

Figs. 3 and 4 show the percentages of the respondents who attributed different values of the 1–10 scale to the parameters that describe the dependent variables. Subplots (a) and (b) of Fig. 3 reveal a noticeable trend for the influencing potential of both online and offline peer pressures to be higher for efficiency than for conservation; therefore, **Hypothesis 1** is supported. Despite this difference, the respondents deem both peer pressures very influential in their AC energy decisions: approximately 25–30% of the respondents assign values of 8–10 to them, while values of 1–4 are the least common. The high values assigned to social influence interventions can be taken as an indication of prevailing collectivist culture in Hong Kong. On the other hand, the fact that Hong Kong is a densely populated city does not seem to render

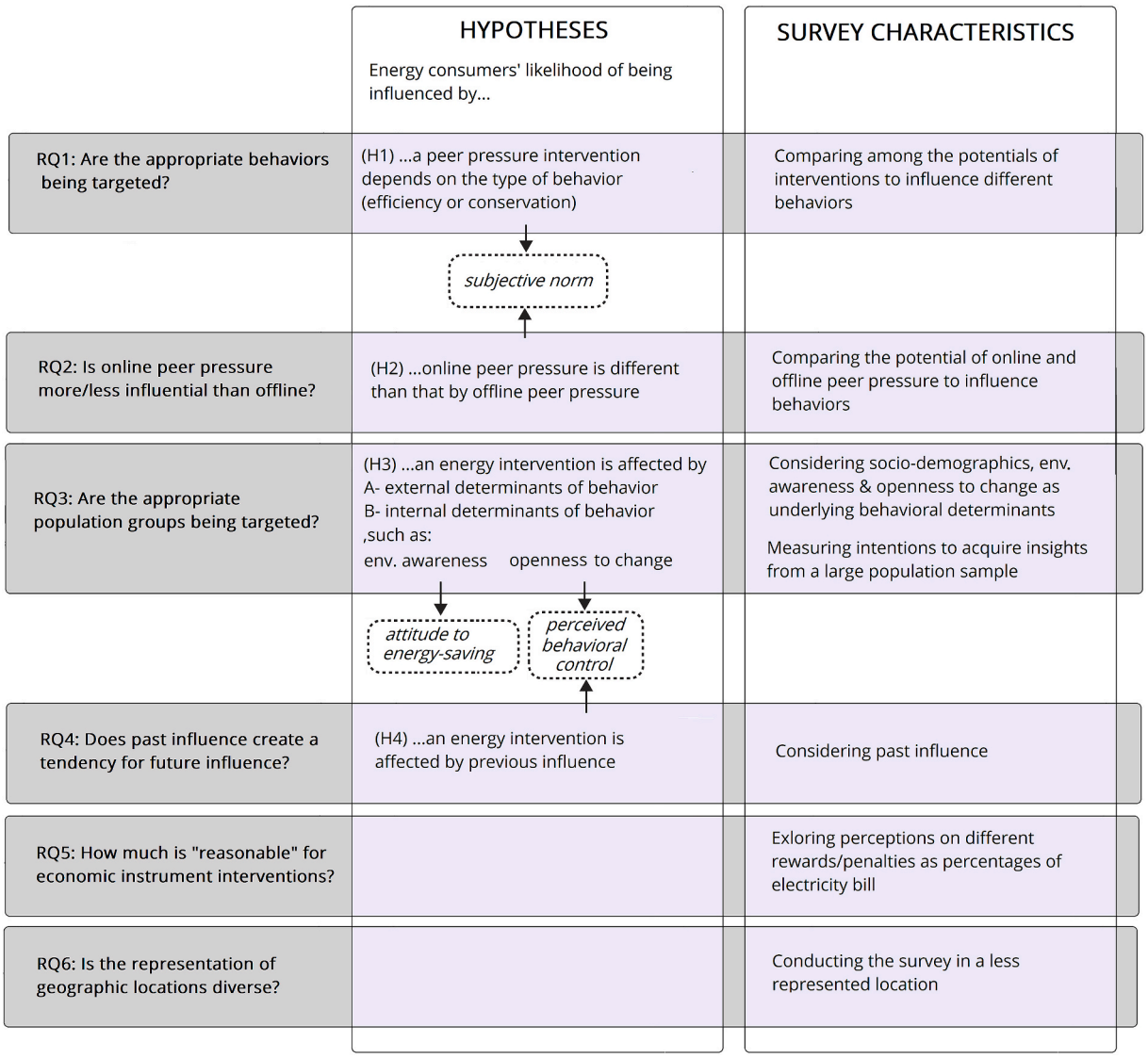

Fig. 2. A mapping of how each research question (RQ) of this study shapes a hypothesis (H) and/or certain survey characteristics. The connection between the parameters relevant to hypotheses 1–4 and the three major components of the TPB (subjective norm, attitude and perceived behavioral control) is also highlighted.

it individualistic. Fig. 3 additionally reveals that, for each behavior, both online and offline peer pressures are almost equally influential; therefore, **Hypothesis 2** is not supported.

Similarly, Fig. 4 demonstrates that approximately 25–30% of the respondents assigned very high values to the influence from economic instruments, while 0.7–3.4% assigned low values to it. This indicates that rewards and penalties are almost equally influential; however, all the percentages associated with them are lower by 1–5% compared to the corresponding ones for the peer interventions. This hints that social influence has a stronger potential to stimulate behavioral change, and is consistent with past studies [14].

5.3. Regression analysis

Though the variables do not follow normal distributions, linear regression can still be applied, as the number of observations *N* is large [93]. One major finding from the regression analysis shown in Table 3 is that the dependent variables are explained adequately neither by income, age, education, and residence location, nor by the number of peers encountered; this does not support **Hypothesis 3A**. The absence of a strong relationship between the influence potentials and socio-demographics confirms similar findings from studies such as the one by Dolan and Metcalfe [54]. The non-significant relationship between peer influence potential and number of peers encountered seems surprising, and in partial contrast with observations in other Asian locales; for instance, Hori et al. [77] found that local community interactions are strongly linked with energy-saving in Asia, especially in Chinese rural areas. However, this difference can be attributed to the fact that Hong Kong is a highly urbanized area, where the daily level of close interactions among neighbors might be weaker compared to rural areas. Nevertheless, even if the number of social interactions is not important, Hong Kong residents still seem to evaluate them highly in the context of energy decisions. Combining this observation with the similarity between online and offline peer pressure, perhaps hints that social media have indeed changed the localization concept in cities: the extended use of technology may allow people to appreciate social influence highly, without necessarily exercising it in the offline realm, and regardless of the number of offline interactions they are having. This is also hinting that a large number of influencers will not necessarily enable an energy intervention to succeed; instead, a few carefully selected individuals may be enough to motivate change.

The other major finding of Table 3 is that environmental awareness, openness to change and past influence are statistically significant (at the 0.01 level) in explaining all the dependent variables. Therefore,

Table 2
Correlation coefficients and descriptive statistics of this study's variables, with coefficients with an absolute value of 0.20 or above and significance at the 0.01 level being highlighted. The correlations among independent variables (7)–(13) are less significant for the purpose of this paper, and have been analyzed in detail in Ref. [82].

Spearman's rho	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) LC_e	1														
(2) LC_c	**0.54**[b]	1													
(3) SM_e	**0.70**[b]	**0.58**[b]	1												
(4) SM_c	**0.51**[b]	**0.80**[b]	**0.61**[b]	1											
(5) *PEN*	**0.28**[b]	**0.51**[b]	**0.34**[b]	**0.56**[b]	1										
(6) *REW*	**0.26**[b]	**0.47**[b]	**0.30**[b]	**0.50**[b]	**0.62**[b]	1									
(7) Income	0.04	−0.07[a]	0.00	−0.10[b]	−0.09[b]	−0.11[b]	1								
(8) Age	0.00	−0.02	0.04	0.00	−0.07[a]	−0.07[a]	**−0.30**[b]	1							
(9) Education	0.03	−0.04	−0.04	−0.05	0.00	−0.04	**0.47**[b]	**−0.47**[b]	1						
(10) Gender	0.04	0.14[b]	0.08[a]	0.15[b]	0.10[b]	0.10[b]	−0.05	−0.05	−0.07[a]	1					
(11) Location	−0.01	0.01	0.00	0.01	0.02	0.04	−0.04	−0.16[b]	−0.10[b]	0.04	1				
(12) Env. awareness	**0.30**[b]	**0.42**[b]	**0.34**[b]	**0.45**[b]	**0.39**[b]	**0.34**[b]	0.03	−0.07[a]	0.08[a]	0.16[b]	0.05	1			
(13) Open. to change	**0.38**[b]	**0.43**[b]	**0.40**[b]	**0.43**[b]	**0.40**[b]	**0.37**[b]	−0.04	−0.06	0.02	0.13[b]	−0.01	**0.35**[b]	1		
(14) Number of peers	0.05	0.00	0.03	0.02	0.03	−0.02	**0.25**[b]	**−0.24**[b]	**0.27**[b]	−0.03	−0.03	0.06	0.05	1	
(15) Past influence	−0.14[b]	**−0.21**[b]	−0.16[b]	**−0.20**[b]	−0.13[b]	−0.17[b]	−0.06	0.15[b]	−0.12[b]	−0.06	−0.04	−0.09[b]	**−0.26**[b]	−0.12[b]	1
Mean	7.68	7.32	7.56	7.32	7.28	7.47	5.15	7.27	4.99	1.57	9.95	8.56	6.55	31.9	1.63
Standard deviation	2.34	2.34	2.34	2.35	2.53	2.36	2.11	3.06	1.77	0.49	5.18	1.84	2.35	117	0.48
Min	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1
Max	10	10	10	10	10	10	8	13	7	2	17	10	10	999	2

[a] Significant at the 0.05 level.
[b] Significant at the 0.01 level.

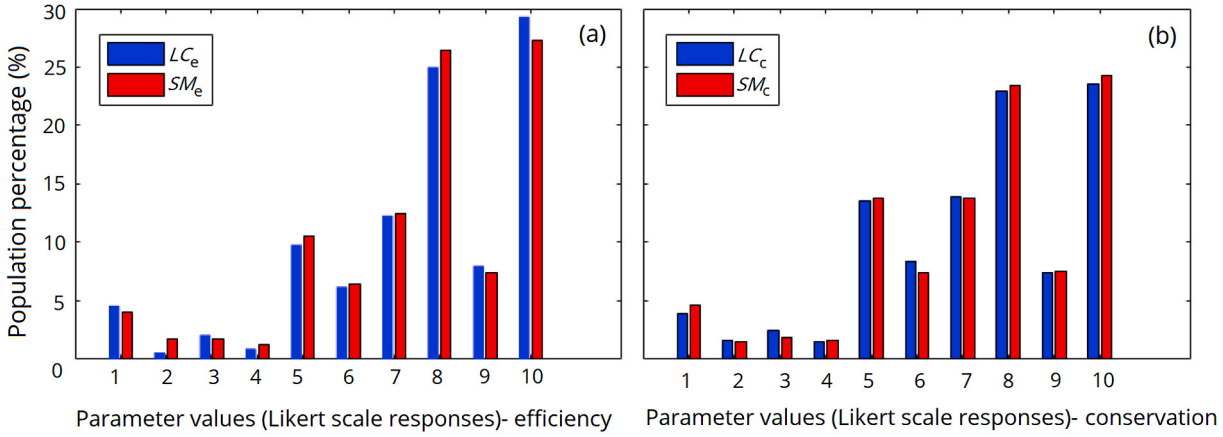

Fig. 3. The distribution among the population of the perceived potential for local community and social media peer pressure to influence residential (a) cooling energy efficiency behavior (LC_e, SM_e) and (b) cooling energy conservation behavior (LC_c, SM_c).

Hypotheses 3B and **4** are supported. As it was clarified that the interventions mentioned in the questionnaire aim at protecting the environment, it is plausible that their influence potential is explained by environmental awareness. Similarly, their statistically significant relation to openness to change is plausible, as people who are open to change their habits, are more likely to be affected by interventions. Finally, the tendency of people who have been previously influenced to be more likely to be influenced again perhaps hints peer pressure's ability to create sustained change, through persistent habits or knowledge. Please note that these three variables were understood to be linked with the three main components of TPB.

5.4. Public perceptions of quantified rewards/penalties

Table 4 displays the respondents' perceptions of quantified rewards and penalties; it indicates that a penalty in the form of surcharging an additional 2–4% of the electricity bill is deemed reasonable by more than 30% of the respondents, and thus such a measure could be implemented without negative reactions. On the other end, a reward in the form of paying back the consumers 4–8% of their bill is deemed reasonable by approximately 36–47% of the respondents, therefore no further incentive would be necessary.

6. Policy implications in view of climate change

Driven by these findings, this paper suggests policy actions. As the illustrative case study is in Hong Kong, the recommendations herein are directly applicable to that city and they can support existing initiatives by governmental and non-governmental organizations that are placing considerable emphasis on changing people's energy behavior [94–96]. At the same time, while no claim is made that the survey findings will generalize across all locations, they do provide support for the relevance

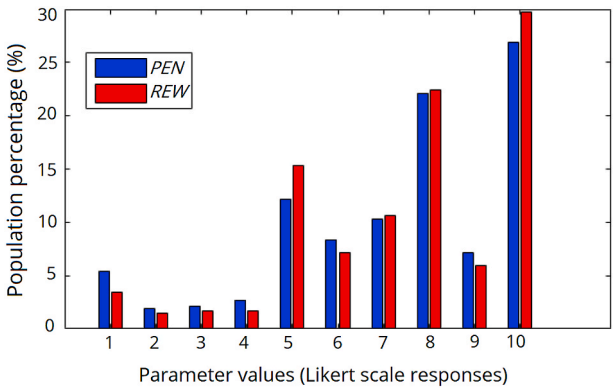

Fig. 4. The distribution among the population of the perceived potential for penalties (*PEN*) and rewards (*REW*) to influence cooling energy conservation behavior.

of this paper's general agenda of six questions towards guiding the design of future energy interventions. Therefore, the following policy recommendations are relevant to other regions and countries as well, especially to locales with similar climate to that of Hong Kong, and with equally increasing needs for space cooling and ambitious climate change mitigation targets. In terms of such targets at the national level, China has pledged to achieve carbon equality by the year 2060, while Japan and South Korea have pledged to reach the same milestone by 2050 [97]. At the same time, these countries are within the top consumers of residential AC units in the world, with the US being second in that list [17]. Furthermore, while China tops the list, only 60% of the households in the country are currently equipped with ACs [17]. This is expected to change dramatically, not only in China, but also in other countries that lie within hot climate zones, where projected rise in temperature [98–100] and socio-economic trends are transforming ACs into a necessity. For instance, AC energy use is projected to grow faster than any other building energy use in the US by 2050 [101]. By the same year, it is expected that the AC stock will be increased dramatically in India, Indonesia, Mexico and Brazil [17]. In turn, such trends are projected to have significant impacts on the frequency and intensity of electricity peak demand [17,102], a variable that is crucial in the design of smart energy technology infrastructure. All these reasons create additional pressure to governments towards implementing intervention policies that would effectively motivate their citizens to use their ACs wisely.

6.1. Expanding the scope of targeted behavior for peer comparison interventions

Abrahamse and Steg [14] found that the effectiveness of social influence is independent of the type of behavior, but that conclusion refers to a categorization of behaviors based more on their degree of visibility, and not less on the effort they require. This current study provides evidence that peer comparison interventions have a higher potential to influence efficiency than to influence conservation, supporting pre-existing speculations about the required level of effort making a difference [18]. Thus, social influence programs can potentially be strengthened by expanding their targeting scope to include efficiency measures. Facilitating comparison with conscious peers can be effective in encouraging people to acquire energy-efficient ACs, an action that is expected to reduce consumption drastically [16]. For instance, additional efforts to mobilize peer pressure towards efficiency may increase the effectiveness of the US Energy Star labeling program [103,104], which might be already successful in information provision [103], but does not always deliver the expected results [104]. To maintain reductions, however, it is important for such efforts to continue encouraging conservation. As people may approach AC energy conservation

Table 4
Perceptions regarding hypothetical penalty and reward measures, as declared by various percentages of the survey respondents (VL = very low, L = low, RES = reasonable, H = high, VH = very high).

	Perception assigned to measure (% of respondents)					
Measure	VL	L	RES	H	VH	Total
Penalty						
(% of annual bill)						
2	13.4	20.9	33.1	16.5	14.7	99.5
4	4.6	12.4	30.5	24.8	25.9	99.2
6	1.6	4.9	18.3	30.8	42.6	99.2
8	1.1	2.5	8.8	23.5	62.2	99.1
10	0.7	0.7	5	13.2	78.4	99.1
12	0.5	0.6	3.3	8.3	85.3	99.1
Reward						
(% of annual bill)						
2	37.0	37.3	22.6	1.7	0.9	98.5
4	15.9	34.6	37.8	8.8	2.1	98.1
6	6.8	16.0	47.1	20.7	8.5	98.1
8	3.6	8.5	36.5	31.0	19.5	98.0
10	1.4	4.2	24.6	34.3	34.8	98.0
12	1.1	2.9	17.1	30.8	47.2	98.0

Table 3
Regression analysis results, highlighting coefficients with an absolute value 0.20 or above and significance at the 0.01 level.

Variable	LC_e		LC_c		SM_e		SM_c		*PEN*		*REW*	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Socio-demoraphics:												
Income	0.07	0.04	−0.03	0.04	0.05	0.04	−0.06	0.04	−0.10[a]	0.04	−0.10[b]	0.04
Age	0.02	0.03	−0.02	0.03	0.02	0.03	−0.01	0.03	−0.06[a]	0.03	−0.07[b]	0.03
Education	−0.01	0.05	−0.12[a]	0.05	−0.10	0.05	−0.01[a]	0.04	−0.02	0.05	−0.10[a]	0.05
Gender	−0.09	0.15	0.12	0.14	0.08	0.15	0.20	0.13	0.12	0.16	0.07	0.14
Location	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01
Knowledge:												
Env. awareness	**0.20**[b]	0.03	**0.30**[b]	0.03	**0.21**[b]	0.03	**0.33**[b]	0.03	**0.29**[b]	0.04	**0.23**[b]	0.03
Psychological trait:												
Openness to change	**0.33**[b]	0.04	**0.38**[b]	0.04	**0.37**[b]	0.04	**0.39**[b]	0.04	**0.38**[b]	0.04	**0.36**[b]	0.04
Habitual/historical:												
Numbers of peers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Past influence	**−0.45**[b]	0.16	**−0.63**[b]	0.14	**−0.50**[b]	0.15	**−0.56**[b]	0.14	**−0.24**[b]	0.16	**−0.46**[b]	0.15
R-squared	0.17		0.32		0.20		0.33		0.23		0.23	

[a] Significant at the 0.05 level.
[b] Significant at the 0.01 level.

with reluctance, equating it with thermal comfort loss, it is important for social influence programs to continue providing practical information on how conservation actions can be performed wisely to save energy without necessarily scarifying comfort.

Furthermore, as this study demonstrates, the influence potential can be equally high for both online and offline peer pressures; it can also be independent of the number of peer interactions in the physical realm. This observation may facilitate policy efforts to mobilize peer pressure through awareness campaigns, and increasingly through social media. As social influence approaches are considered to be more effective for 'visible' sustainability behaviors (such as recycling) [14], the development of social media technology may enhance the effectiveness of peer interventions, by making energy consumption (traditionally a private affair) more visible. In addition, as face-to-face interactions are believed to empower social influence [14], policy-makers may use technology to establish platforms that allow the public to communicate face-to-face with various stakeholders (educators, building industry professionals and energy specialists) who otherwise might not have opportunities to communicate with one another. In that direction, there can be less emphasis on the number of the people one interacts with, but more on strategically placing into networks a few influential individuals with the appropriate profile to act as "environmental champions" [46] or "block leaders" [43]. The design of such programs should also ensure that such individuals are recognized as peers (thus comparable to the target audience), and not as distant figures.

6.2. Expanding the scope of targeted behavior for economic instruments interventions

This study provides evidence that, while economic instruments are perceived as somewhat less effective compared to peer interventions, they are still deemed influential in changing conservation behavior. Thus, they may be implemented as supporting components to the social influence measures, and expand their targeting scope to include conservation measures. As conservation is harder to maintain, economic measures might act as a supplementary push to stimulate action on a regular basis. Furthermore, policy-making in several countries may consult public perception of specific, quantified rewards/penalties; the example of Hong Kong indicates that these do not necessarily have to be high. Nevertheless, is perhaps necessary to introduce pecuniary measures initially at a small scale or on a voluntary basis, so that a timely evaluation of the responses can take place.

The proliferation of smart city technology in the US and in East Asia [105,106] and Southeast Asia [107], together with the increasing demand for smart home and energy services can facilitate the expansion of such voluntary programs. Smart technology is already providing households with advanced energy visualization and control tools, together with new channels for financial gains from wise management of their energy consumption. Blockchain technology (which has the characteristics of a digital currency) is recognized as a promising technology in the energy sector [108], one that allows safe and reliable transactions between energy users and other entities. Governments may consider taking advantage of this technology to facilitate the allocation of rewards to citizens who manage their energy consumption according to certain sustainability standards.

6.3. Redefining the scope of target audiences for interventions

This paper's findings create optimism that socio-demographics should not be considered as a barrier to the outreach of interventions. Instead, interventions may be strengthened when they target population segments defined by personality traits, knowledge and influence history. In this direction, governments should explore opportunities to evaluate a population's openness to change levels. This trait might not be limited to environmental and/or energy issues, but applicable to general lifestyle; thus, it might be possible to understand which segments mostly identify with this attitude by utilizing data from other fields. While this will require efforts to guarantee privacy data protection, acquiring knowledge of this and other psychological traits may enable energy interventions to better utilize tools such as micro-targeting [109] (i.e. understanding and satisfying individual preferences). One again, smart technology and the development of secure protocols for data process can provide significant assistance towards that direction. Similarly, governments should seek mechanisms to evaluate the levels of environmental awareness among the population, to allow energy interventions to effectively use tools such as social marketing [110,111] (i.e. promoting a lifestyle that contributes to the common good). To that end, governments should also aim at reinforcing environmental awareness through appropriate educational programs. In Hong Kong, environmental awareness was not correlated with education, hinting that well-educated individuals might not necessarily have adequate environmental knowledge; therefore, such knowledge should be provided to students through specialized courses in the curricula of various educational levels, and to professionals through information programs. Finally, the significance of past influence creates optimism that people who have been influenced to save energy in the past will have a higher tendency to continue acting in the same way in the future. Thus, carefully crafted intervention programs may provide persistent results if they target the groups that have been previously influenced. At the same time, the significance of this parameter creates the urgency for programs to reach people who have never been targeted before, thus stimulating behavioral change on large scales.

7. Conclusions

The aim of this paper was to provide a new perspective on phenomena relevant to the potential of energy policy interventions to influence change in residential energy consumption, a process that is of crucial importance towards meeting decarbonization and climate targets in various countries. On the basis of a detailed review of studies published during the last two decades, an agenda of six research questions was formulated to highlight gaps in the current understanding of the likely effectiveness of interventions, and to suggest research paths for the new decade. Ultimately, the agenda identifies new issues for targeting social influence and economic policy instruments. Critical research questions that evidence-based energy policy-making should consider thus focus on issues related to better understanding what type of energy behavior and which population groups to target; the potential differences between online and offline peer pressure; and public perceptions regarding specific economic rewards and penalties.

The relevance of these research questions is illustrated with a survey of Hong Kong residents' perception of the extent to which different types of interventions can influence their willingness to engage in AC energy-saving actions. The survey explored the influence of local community and social media peer pressure on energy efficiency and conservation behaviors. It also examined the relationship with the external (socio-demographic) and internal (psycho-cognitive) determinants of behavior. The survey results have thus confirmed the importance of clearly distinguishing between efficiency and conservation as targets of intervention. In addition, the results provide evidence that parameters like openness to change, environmental knowledge and influence history can affect the success potential of interventions - regardless of socio-demographic characteristics. Moreover, the results suggest that social media are changing the concept of localization in social interactions, as consumers may be equally influenced by their online and offline peers. This may facilitate policies that mobilize peer pressure, especially given that physical social interactions appear to be less important; this would be particularly useful in countries where economic or physical barriers prevent extended and physical social interaction among citizens. Finally, modest financial rewards or penalties are perceived as acceptable economic interventions by a significant portion of the population; this type of willingness to pay bodes well for the implementation of

economic policy interventions in the future.

The agenda suggested in this paper points to an expansion of the scope of energy intervention policies to target behaviors that have been neglected in the past. The survey illustrates this by providing evidence that targeting efficiency in behavioral change is feasible and desirable, at the same time as it supports reformulating economic policies to target conservation. Furthermore, it suggests that the way target audiences are being segmented should be redefined, by considering psycho-cognitive and history characteristics. Governments should explore ways to understand these characteristics among the population, because evidence may enhance the potential of employing micro-targeting and social marketing in energy intervention policies. There may be privacy challenges that such approach will entail and these need to be further explored; however, together with sustaining environmental awareness at high levels and mobilizing peer pressure through technology and "environmental champions", such a new direction may enable a greater number of interventions to become more effective. These suggestions are likely to be relevant to energy policy globally, even if air conditioning in Hong Kong has been the first case surveyed for illustration. The results reflect core features of human behavior that would probably be influential in all countries with growing interest in stimulating the public adoption of energy efficient technologies and conservation practices, and especially in locales where climate change and consumption patterns are expected to lead to increased cooling energy needs.

The arguments in this paper also reflect extensions of the theoretical point of the TPB that intentions are relatively accurate predictors of real behavior. Even though such link has not always been robust, the latter theory has demonstrated an adequate explanatory power for energy-saving actions [67]. This has allowed other relevant studies to rely on self-reported data and intentions [112], but surely more generalizable and concrete conclusions need to be established through future research into actual behavioral change measurements, with indicators such as electricity consumption before and after adoption of more efficient technology, or conservation through altered behavior. It has not been feasible yet to conduct such studies in this research project, although many electrical utilities globally are collecting detailed data on residential energy consumption with the purpose of understanding trends in order to encourage users to save energy [95]. Finally, future research should build an orientation towards geographic diversity, to achieve a global understanding of the factors and phenomena relevant to change in energy behavior.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Table A
List of the 16 reviews/meta-analyses and the 55 original research papers considered in the analysis summarized in Table 1.

Year	Author(s)	Journal/Conference	Ref.	Year	Authors(s)	Journal/Conference	Ref.
	Reviews/meta-analyses						
2005	Abrahamse et al.	Journal of Environmental Psychology	[16]	2018	Gillingham et al.	Annual Review of Resource Economics	[113]
2007	Wilson and Dowlatabadi	Annual Review of Environment and Resources	[114]	2018	Andor and Fels	Ecological Economics	[29]
2008	Fischer	Energy Efficiency	[115]	2018	Bird and Legault	Current Sustainable/Renewable Energy Reports	[36]
2013	Abrahamse and Steg	Global Environmental Change	[14]	2019	Cattaneo	Energy Efficiency	[26]
2013	Delmas et al.	Energy Policy	[22]	2019	Nisa et al.	Nature Communications	[18]
2015	Karlin et al.	Psychological Bulletin	[37]	2020	Wolske et al.	Nature Energy	[43]
2017	Farrow et al.	Ecological Economics	[28]	2021	Han and Wei	Environment, Development and Sustainability	[35]
2017	Šćepanović et al.	Renewable and Sustainable Energy Reviews	[19]	2021	Chatzigeorgiou and Andreou	Renewable and Sustainable Energy Reviews	[38]
	Original research papers						
Year	**Author(s)**	**Journal/Conference**	Ref.	**Year**	**Author(s)**	**Journal/Conference**	Ref.
2002	McMakin et al.	Environment and Behavior	[116]	2015	Alberini and Towe	Energy Economics	[117]
2004	Staats et al.	Environment and Behavior	[118]	2016	Alberts et al.	Energy Policy	[68]
2005	Kurz et al.	Journal of Applied Social Psychology	[119]	2016	Alberini et al.	The Energy Journal	[32]
2007	Schultz et al.	Psychological Science	[13]	2017	Pellerano et al.	Environmental and Resource Economics	[120]
2007	Abrahamse et al.	Journal of Environmental Psychology	[121]	2017	Anderson et al.	Applied Energy	[62]
2007	Petersen	International Journal of Sustainability in Higher Education	[122]	2017	Ma et al.	Energy and Buildings	[79]
2008	Nolan et al.	Personality and Social Psychology Bulletin	[123]	2017	Weber et al.	Energy Economics	[124]
2011	Allcott	Journal of Public Economics	[44]	2017	Houde and Aldy	American Economic Journal: Economic Policy	[31]
2012	Smith et al.	Journal of Environmental Psychology	[74]	2017	Elinder	Proceedings of the National Academy of Sciences, USA	[125]
2012	Zhao et al.	Energy Policy	[126]	2017	List et al.	Agricultural and Applied Economics Association Annual Meeting	[127]
2012	Peschiera and Taylor	Energy and Buildings	[128]	2017	Olsthoorn et al.	Energy Economics	[60]
2013	Costa and Kahn	Journal of the European Economic Association	[129]	2017	Sudarshan		[130]

(*continued on next page*)

Table A (*continued*)

Year	Author(s)	Journal/Conference	Ref.	Year	Authors(s)	Journal/Conference	Ref.
						Journal of Economic Behavior & Organization	
2013	Jain et al.	Energy and Buildings	[131]	2018	Byrne et al.	Review of Economics and Statistics	[132]
2013	Suter and Shammin	Energy Policy	[133]	2018	Outcault et al.	Energy Research & Social Science	[78]
2013	Ayres et al.	The Journal of Law, Economics & Organization	[30]	2018	Erell et al.	Energy and Buildings	[61]
2013	Han et al.	Energy Policy	[64]	2018	Ito et al.	American Economic Journal: Economic Policy	[70]
2013	Mizobuchi and Takeuchi	Energy Policy	[134]	2019	De Dominicis et al.	Palgrave Communications	[63]
2013	Galarraga et al.	Energy Economics	[135]	2019	Bator et al.	Energy Research and Social Science	[136]
2014	Allcott and Rogers	American Economic Review	[45]	2019	Brandon et al.	Proceedings of the National Academy of Sciences, USA	[137]
2014	Delmas and Lessem	Journal of Environmental Economics and Management	[34]	2019	Henry et al.	Energy Policy	[138]
2014	Dillahunt and Mankoff	17th ACM Conference on Computer Supported Cooperative Work & Social Computing	[139]	2019	Holladay et al.	Journal of Public Economics	[140]
2014	Boomhower and Davis	Journal of Public Economics	[39]	2020	Brülisauer et al.	Energy Policy	[141]
2014	Davis et al.	American Economic Journal: Economic Policy	[142]	2020	Kandul et al.	Economics Letters	[143]
2014	Datta and Gulati	Journal of Environmental Economics and Management	[144]	2020	Myers and Souza	Journal of Environmental Economics and Management	[145]
2015	Ito	American Economic Journal: Economic Policy	[146]	2020	Risch	Energy Economics	[147]
2015	Schultz et al.	Energy	[69]	2020	Lazaric et al.	Journal of Evolutionary Economics	[148]
2015	Shen et al.	Energy Policy	[48]	2021	Xu et al.	Energy and Buildings	[149]
2015	Komatsu and Nishio	Applied Energy	[59]				

Appendix B

Table B
Sample of the survey questions relevant to this study's variables. The questions pertaining to the population's socio-demographic and psycho-cognitive variables are presented in Ref. [82].

Question	Variable type	Answer type	Parameter
In the future, if my local community peers switch to a more energy efficient AC model to protect the environment, I will do the same to protect the environment as well.*	Dependent, social influence	Likert scale	LC_e
In the future, if my social media peers switch to a more efficient AC model to protect the environment, I will do the same to protect the environment as well.*	Dependent, social influence	Likert scale	SM_e
In the future, if my local community peers reduce their day-to-day AC energy consumption at home to protect the environment, I will do the same to protect the environment as well.*	Dependent, social influence	Likert scale	LC_c
In the future, if my social media peers reduce their day-to-day AC energy consumption at home to protect the environment, I will do the same to protect the environment as well.*	Dependent, social influence	Likert scale	SM_c
I am willing to start consuming less day-by-day AC energy, if I am to receive a penalty for AC energy overconsumption.	Dependent, economic instrument	Likert scale	*PEN*
I am willing to start consuming less day-by-day AC energy, if am to receive a monetary reward because of this.	Dependent, economic instrument	Likert scale	*REW*
How many peers do you interact with in a typical month?	Independent, habitual/ historical	Numerical	–
In the past, I have been influenced by my peers to reduce my AC energy consumption in order to protect the environment.	Independent: habitual/ historical	YES/NO	–
If you receive a monetary reward because you have lowered your AC energy consumption and this reward is a percentage (%) of your annual electricity bill that will be returned back to you, how would you describe the following amount of a reward (2%–12%)?**	Other, perceptions-economic instrument	Categorical	–
If you receive a monetary penalty because your AC energy consumption is very high and this penalty is an extra charge percentage (%) of your annual electricity bill, how would you describe the following amount of a penalty (2%–12%)? **	Other, perceptions-economic instrument	Categorical	–

*How much do you agree with the following statements? On a scale of 1–10, with 1 being strongly disagree and 10 being strongly agree.
**Choose from very low/low/reasonable/high/very high.

Appendix C

Table C
Peer-related habitual and history characteristics of the residents ($N = 931$) who participated in the survey.

Characteristic	Details	Total (%)
Habitual/historical		
-Number of peers interacted with in a typical month	Less than 9	36.5
month)	10–19	27.8
	20–29	12.3
	30–49	10.7

(*continued on next page*)

Table C (*continued*)

Characteristic	Details	Total (%)
	50 or more	11.9
-Influenced by peers to reduce AC consumption in the past in the oapast	YES	36.8
	NO	63.2

Credit author statement

Constantine Spandagos: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. Erik Baark: Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition. Tze Ling Ng: Conceptualization, Funding acquisition. Masaru Yarime: Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

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