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Authors

Outcalt, Sarah
Sanguinetti, Angela
Pritoni, Marco

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Using social dynamics to explain uptake in energy saving measures: Lessons from space conditioning interventions in Japan and California

Sarah Outcault^{a, 1}
Angela Sanguinetti^a
Marco Pritoni^b

^a Energy and Efficiency Institute
University of California, Davis
1605 Tilia Street
Davis, CA 95616
United States
smoutcault@ucdavis.edu
asanguinetti@ucdavis.edu

^b Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley, CA 94720
United States
mpritoni@lbl.gov

¹ Corresponding author: Sarah Outcault. Email: smoutcault@ucdavis.edu.

Abstract

The authors ran a pair of interventions to encourage passive cooling measures in two sustainable energy communities: E-Sogo in Japan and West Village in the United States. The interventions used proven levers for encouraging behavior change (among adult household members), but yielded modest results. Traditional methods of evaluating intervention effectiveness do not reveal why responses are weak, so the authors examined participants' experiences using qualitative data collected during the intervention. Three critical flaws were identified; namely, the interventions had targeted a single household member, promoted measures that impact other members, and failed to support coordination within the household. To understand why those shortcomings led to weak results, the study examines the intersection of the social attributes of cooling measures (i.e., locus of decision and impact on others) and the prevailing social dynamics within households. A game-theoretical model is developed to illustrate how the varied combinations of measure attributes and social dynamics can yield different outcomes across households. By examining the failures of commonly accepted social science methods, the study sheds light on the intersection of social dynamics and household energy practices, a line of inquiry which, when extended further, could make energy interventions more effective and socially valid.

Keywords: Social Dynamics; Air conditioning; Household energy interventions; Behavior attributes

1. Introduction

Rich ethnographic and descriptive research highlights the important role of social dynamics in household energy use (e.g., Bell et al., 2015; Permana, Aziz, & Siong, 2015; Sardinou, 2007; Wilhite, Nakagami, & Murakoshi, 1996; Wilhite, Nakagami, Masuda, Yamaga, & Haneda, 1996). For example, Kleinschafer et al. (2014) found that household members who act as “efficiency champions” can have a significant impact on household norms. In contrast, Fell and Chiu (2014) found that some parents were reluctant to enforce energy saving behaviors among their children, which the authors speculated may have been in an effort to avoid conflict. Considering such dynamics, Collins (2015) suggested that “household-focused sustainability initiatives may be best placed to achieve success if they acknowledge, and utilise, the diverse priorities and roles of household members (p. 30)”, but this has not been common practice.

Despite rich descriptive and ethnographic research, interventions aimed at modifying energy-consuming behaviors in households, including space conditioning, rarely address social dynamics. For example, utility-led behavioral programs involving informational and feedback strategies (e.g., home energy reports), are delivered via paper mailings or emails to the household energy bill payer without explicit directions to disseminate information to other household members who may also be able to adopt the promoted energy-saving measures (Mazur-Stommen & Farley 2013; Ehrhardt-Martinez et al 2010). Further obfuscating the effectiveness of such programs is the fact that impacts are measured in terms of aggregate energy consumption treating the household, instead of individuals, as the unit of analysis.

In contrast to the anthropologic and sociologic perspective of studies describing household dynamics related to energy use, most behavioral energy intervention research is conducted from a psychological perspective, with an individual householder as the unit of analysis (Abrahamse, 2005, 2009). In addition to analysis of consumption data, surveys of a single householder are often used to measure baseline behaviors and behavior change in response to interventions. There is an emphasis on understanding intrapersonal factors, such as knowledge and attitudes, as moderators of intervention effectiveness.

Abrahamse (2005) contrasts these intrapersonal “micro-level” factors with “macro-level” factors such as demographics, technologies, and culture. Interpersonal dynamics among household members are a middle or meso level of influence (between micro- and macro- per Abrahamse; Bell et al., 2015), less acknowledged in energy intervention research. However, conceptualizations of energy behaviors as social practices (Shove & Walker, 2014) or “energy cultures” (Stephenson et al., 2015), embedded in complex social and material contexts, are a ready foundation for more interdisciplinary social science approaches to energy interventions.

1.1 Addressing Social Dynamics in Energy Interventions

Research integrating an understanding of social dynamics with applied energy interventions is limited. This disconnect is problematic, as Carlsson-Kanyama and Linden (2007) discovered. Their research revealed potential unintended side effects of neglecting social

dynamics in energy interventions. Specifically, Swedish households that participated in interventions to modify energy practices (e.g., reduced use of electric dryers and shifting times for doing laundry and dishes) experienced a disproportionate increase in women's workload. Similarly, Hargreaves, Nye, and Burgess (2010) advanced the understanding of the role of social dynamics in households' experiences with an energy feedback intervention (via in-home standalone monitors). They observed:

...how reductions in electricity use are to be made, and by whom, are in no sense trivial questions. They sit at the centre of the complex, dynamic negotiations through which households manage their social interactions and their joint project of living together (reasonably) harmoniously. Smart energy monitors can lead to greater co-operation and greater conflict among the members of the household. One lesson from the trial is that domestic energy consumption is a social and collective rather than individualised process. Future research should perhaps focus more on the household and less on the individual energy consumer, as the key unit of analysis. This might point to a strategy which focuses not on educating individuals about their energy consumption, but on fostering cooperative and energy-saving household dynamics. (p. 6118)

These examples consider the role of social dynamics in energy interventions retrospectively, rather than addressing, or leveraging, them in the design of the intervention itself. The latter is uncommon. A notable exception is Boudet et al. (2016), who conducted an energy intervention with Girl Scouts. The study provided educational sessions to two groups of Girl Scout troops; one received training on in-home energy-saving practices, the other on food and transportation-related energy practices. The Girl Scouts were urged to share educational materials with their families. The Girl Scouts and their parents were then surveyed about their adoption of various behaviors related to the training content. The study found that the girls were effective agents of change in their families, with parents adopting energy-saving practices (albeit to a lesser extent than their daughters) as a result of the girls' training. Furthermore, the study found that the girls were less likely to adopt energy-saving activities requiring parental permission or facilitation (e.g., biking to school, preparing meatless meals) compared to things they could do independently (e.g., unplugging idle devices).

In a separate but related vein of research, Boudet, Flora, and Armel (2016) categorized household energy-saving measures according to their attributes, such as frequency, level of skill required, and locus of decision (who in the home can make the decision to adopt the measure). This behavior segmentation work (see also Karlin, et al., 2014) is intended to guide selection of target measures to promote in energy interventions. For example, Boudet et al. identified a cluster of measures they termed "Family Style", which are characterized by their availability to children and/or teenagers in addition to adults. These types of measures were the focus in the Girl Scout interventions. Thus, measure attributes like locus of decision are an important conceptual bridge between household social dynamics and energy interventions.

Social dynamics may be especially relevant in energy interventions targeting household space conditioning since all household members' thermal comfort may be affected by a change in any one member's behavior. In a lab experiment McCalley and Midden (2004) asked individuals to imagine how they would program a new thermostat. One group was asked to

consider other household members' needs, and the other was not. The former group set (hypothetical) temperature goals that would yield significantly less energy savings, suggesting hesitancy to adopt aggressive energy-saving measures that would impact others. Similarly, Nicholls and Strengers (2015) describes how, among Australian families with children, the weeknight activities that cluster in "practice bundles" and involve other household members (e.g., "screen time") are less flexible than others because they require coordination on multiple fronts to shift the timing or practice itself.

The findings from these studies and the related research reviewed above suggest there are immense complexities involved in shifting social practices. Despite this, there seem to be no studies that focus on the particular role of social dynamics in energy interventions targeting measures related to space conditioning. The present study seeks to fill this gap in the literature by describing the lessons learned from implementing interventions that failed to adequately address social dynamics within households.

1.2 Present Research

The authors conducted a pair of experiments to reduce energy consumption associated with air conditioning use by promoting alternative cooling strategies in two housing communities. The interventions featured well-established behavioral strategies from the field of psychology, such as feedback and commitment. However, similar to many behavior-based residential energy programs, these interventions failed to address the role of social dynamics by recruiting single individuals from multiple-member households and giving no instructions on how to coordinate with other household members. Traditional methods of evaluating the effectiveness of the interventions measured the lackluster results in terms of behavior change and energy consumption, but did not reveal *why* responses were weak. Fortunately, qualitative data collected from participants as a tangential part of these studies shed light on the pitfalls and unintended consequences that resulted from the intervention, and led us to new research questions, which we revisited our data to explore.

This paper is organized as follows. First, to provide context, the pair of case studies are summarized, including details about the interventions, data collection methods, and impact on energy consumption. Next, we explore problems with the methods used in the interventions and what they teach us about social dynamics, energy practices, and efforts to influence behavior. The paper concludes with implications for energy interventions and future research.

2. Case Studies

West Village is a mixed-use complex at the University of California, Davis in central Northern CA. In addition to some commercial space, 2,000 students, faculty, and staff are housed in its residential apartments. Apartments range from 1 to 4 bedrooms and are largely occupied by undergraduate students, many of whom move out for the summer. Electricity (which powers all of the heating and cooling demands, among other things) is included in residential rents, and although there is an electricity quota, it is not enforced for a variety of reasons. As such, occupants have no financial incentive to conserve energy.

Although very hot during the day in summer, Davis experiences significant drops in temperatures during the evening (up to 40° F/22° C). To exploit that, West Village was designed to utilize passive cooling techniques through the positioning and shading of windows, and installation of ceiling fans in every room. However, air conditioning (A/C) is the primary cooling strategy utilized by occupants.

The “E-Sogo Smart House” is an apartment building that Tokyo Gas built in March 2012 as a “smart home” demonstration project with a subsidy from the Japanese government. It has 22 housing units that are occupied by Tokyo Gas employees and their families. E-Sogo was designed to be energy efficient, with an advanced thermal envelope and specialized doors and windows designed to capture breezes for natural ventilation and cooling. The E-Sogo apartment building also has a complex, on-site energy generation and management system. End-use cooling equipment includes room A/Cs in the living rooms and bedrooms, as is now common in Japanese homes.

Achievement of zero-net energy (ZNE) or near-ZNE targets has proven difficult around the world. This is partially due to a failure to measure performance in many ZNE buildings (New Buildings Institute 2016); among the few that have collected such data, several note that consumption exceeds estimates. The apartments at West Village and E-Sogo are among these. Analysis of energy use data provided by each community’s developer revealed that electricity consumption from air conditioner usage varied widely across households and was an obstacle to reaching the buildings’ sustainability objectives (see Noresco 2014a; Mikami et al. 2014, respectively). In fact, electricity consumption from A/C among high users exceeded the median by a factor of 3 and 1.8 in West Village and E-Sogo, respectively (Outcalt et al., 2016), a difference not explained by dwelling size. Since the technologies were new, and the same across units, occupant behavior was deemed the culprit. Large disparities in electricity consumption from A/C use are also common among Tokyo Gas customers in general.

The authors were asked by Tokyo Gas to conduct a behavioral intervention in each community aimed at reducing electricity consumption from air conditioner use. The study was intended to test various methods of influencing behavior to provide initial insight on approaches worth trying with the broader customer base. Both interventions promoted alternative cooling strategies, such as passive cooling and personal cooling strategies, to achieve comfort with less A/C use. Although the overarching structure and approach were similar, there were notable differences in the two studies to account for the differences in climatic and cultural contexts. Table 1 presents an overview of the study details for comparison and a comprehensive discussion of the studies is presented in Outcalt et al. (2016). The relevant details of each study are summarized below.

Table 1: Key facts about the case studies

Attributes	West-Village	E-Sogo
Location	Davis, California, United States	Yokohama, Kanagawa, Japan
Type of dwelling	Apartment buildings (663 units)	Apartment buildings (22 units)
# Households recruited	75 Treatment 25 Control	15 Treatment group
# Occupants per household	2-4	2-5
Type of occupants	UC Davis College students; Renters	Families of Tokyo Gas employees; Renters
Type of A/C	Central A/C, single thermostat	Room Mini-Splits with individual remote controls
Data collection methods	Pre- and post-intervention surveys, informal conversations, electricity meter data	Pre- and post-intervention surveys, post-intervention interviews, electricity meter data
# Participants	20 - Baseline survey 7 - Post-intervention survey	15 - Baseline survey 11 - Post-intervention survey 12 - Post-intervention interview
# Households participated	Treatment 62 - Energy analysis (46 Treatment, 16 Control) 18 - Baseline survey 7 - Post-intervention survey	15 - Energy analysis 15 - Baseline survey 11 - Post-intervention survey 12 - Post-intervention interview
Cooling strategies promoted	Single 3-step strategy	14 small actions
Economic incentive to conserve energy	No incentive. Electricity bill included in the rent.	Electricity bills are paid by the occupants. The cost of energy is variable, since electricity is generated on site using a complex system (PV and fuel cells) shared between multiple apartments.

There are notable differences in the social and cultural environments in which the interventions were conducted. To start, cooling strategies in Japan are more localized (i.e., focused on a particular room or person) compared to those in the United States. In addition, as Wilhite et al. (1996) noted, the Japanese have a tradition of active management of space conditioning needs (i.e., requiring interaction with technology throughout the day). By contrast, the “set-it-and-forget-it” approach is very common in American households (Meier, et al. 2012); it involves leaving the thermostat on “hold” indefinitely, making no adjustments for occupancy or time of day. It appeared these patterns held true in E-Sogo and West Village, though systematic efforts were not undertaken to document this.

In addition, cultural norms and expectations of thermal comfort differ between the two countries. For example, in Japan, the range of acceptable temperatures is wider than in the U.S., and is higher in summer and lower in winter (Compare ASHRAE Standard 55 with Japanese manufacturer Kureseru’s “discomfort index meters”; links are provided in the References).

Finally, as Kuijter & de Jong (2012) describe: “The concept of comfort can roughly be approached in two ways: as a universal physiological construct or as a negotiable socio-cultural one (p. 68)”. The latter is influenced by social norms as well as expectations (see Brager and deDear, 1998). Drawing on the same case studies discussed in this paper, Outcault et al. (2016) argues that the American and Japanese participants tended to take these respective approaches to determining thermal comfort. For example, Japanese participants cited the season, cost of electricity and environmental impacts when declaring whether a temperature was comfortable or not.

Although comparisons of the cultural context are useful, it must be noted that comparison between the two case studies is not a goal of this paper.² Rather, the goal is to highlight cross-culturally relevant problems related to the social sciences methods applied in two very different settings, and uncover further insights into household energy practices by exploring those problems.

2.1 West Village

Eligibility for the study was limited to 100 student households in which energy data monitoring devices were already installed as part of a different research effort. Of those, 75 were randomly assigned to the treatment group and 25 were assigned to the control group. As Table 1 notes, the final number of treatment households included in the energy analysis was less than anticipated (62 rather than 100) due to loss of energy monitoring data.

Treatment households received an informational flyer (excerpted in Figure 1) on how to use a three-step “natural” cooling approach by: (1) setting the thermostat to 80° F (~27° C), (2) opening windows from 9 PM to 9 AM to capture cool night air, and (3) using ceiling fans to increase air circulation as needed. The flyers were addressed to the household in general (rather than a specific individual). They came with mounting tape and a note requesting they be

² The significant differences in the intervention and study design, as well as financial incentives to save energy, render futile direct comparisons between the case studies.

affixed on the wall near the home thermostat, which is located in the living room of all apartments.

Each resident in treatment group households ($n = 239$) also received an email invitation to complete a baseline survey (described below), for a \$10 incentive, with a request to commit to trying the “natural” cooling techniques described on the flyer for the month of August (*Would you be willing to commit to trying some of the “natural cooling” strategies described above for the month of August?* Response options: yes or no). Those who submitted the survey and indicated this commitment received weekly reminders by email that nudged participants to continue trying the “natural” cooling approach, and provided examples of potential impact of their actions (“Using natural cooling this week could save as much emissions as a car trip to Trader Joe’s” [the local grocery store]). The research team had no contact with control group households.



Figure 1. Passive cooling messaging for West Village

Treatment evaluation centered on analysis of energy consumption data. Electricity consumption from A/C use was sub-metered for all the apartments and provided to the research team by Noresco (Noresco 2014b). Energy analysis, conducted using R statistical software, revealed no statistically significant reduction in energy use from A/C for the Treatment compared to the Control households or within Treatment households (pre-post analysis; Outcault et al., 2016). Authors attributed this to three factors: minimal effect of the intervention, small sample size,³ and non-equivalent treatment and control groups despite randomization.⁴

Pre- and post-treatment surveys were also conducted that attempted to measure self-reported behavior change and contextual variables. The pre-intervention survey assessed respondents’ knowledge about passive cooling, motivation to save energy, and baseline use of A/C and other cooling techniques. The post-intervention survey assessed uptake of the passive cooling strategy and experience of the intervention, and was sent only to residents who responded to the pre-intervention survey *and* committed to trying passive cooling.

³ Energy data was ultimately available for only 62 (46 Treatment and 16 Control) of the 100 households in the study, further reducing the sample size.

⁴ It was determined *post hoc* that the Treatment group’s energy use from A/C was significantly lower than the Control’s at the baseline. This is likely a fluke explained by the small sample size, since the groups were randomly assigned.

Participation in the surveys was very low: only 18 completed the pre-intervention survey and 7 of these completed the post-intervention survey. Each participant was from a different household. Eleven of the 18 pre-intervention survey participants agreed to try the passive cooling technique, and 6 of the 7 post-intervention participants reported trying the technique as measured by the following: *Did you try using the Natural Cooling Strategies in the month of August?* (Response options: yes or no). Both surveys were primarily comprised of closed-ended questions, but included a few open-ended questions for more exploratory lines of inquiry.

2.2 E-Sogo

At E-Sogo, 15 of the 22 households were recruited for the study (7 households were excluded because their electricity consumption from A/C was very low at baseline). In particular, the study recruitment letter, which accompanied a pre-intervention survey and was delivered by Tokyo Gas, requested participation by the family member most involved in daily activities related to A/C use [*Whoever has #1 priority in controlling A/C in the household (especially the living room) should complete the survey. You need to be an adult member of this household.*] There was 100% participation in this survey, and 12 of the 15 households participated in a post-intervention survey.

The pre-intervention survey also included: (1) an energy report illustrating the household's energy consumption from A/C, the same for neighbors with lower usage, and a 10% reduction target (see Figure 2), and (2) a request to commit to using up to 14 alternative cooling strategies in order to reduce A/C use for the study period (July 30 to September 22, 2014). The strategies included 8 daytime strategies (e.g., closing blinds to reduce solar gain, changing to lighter clothing), and 6 nighttime strategies (e.g., setting a timer to shut off the A/C after falling asleep, using a cooling pillow). Table 2 lists them all. Halfway through the intervention, each treatment household received a reminder (one per household), noting strategies the household member who completed the baseline survey had committed to. At the conclusion of the intervention, households received another brief energy report detailing how much the household had reduced energy consumption from A/C relative to: the previous year, the 10% target, and the average of all treatment group households.

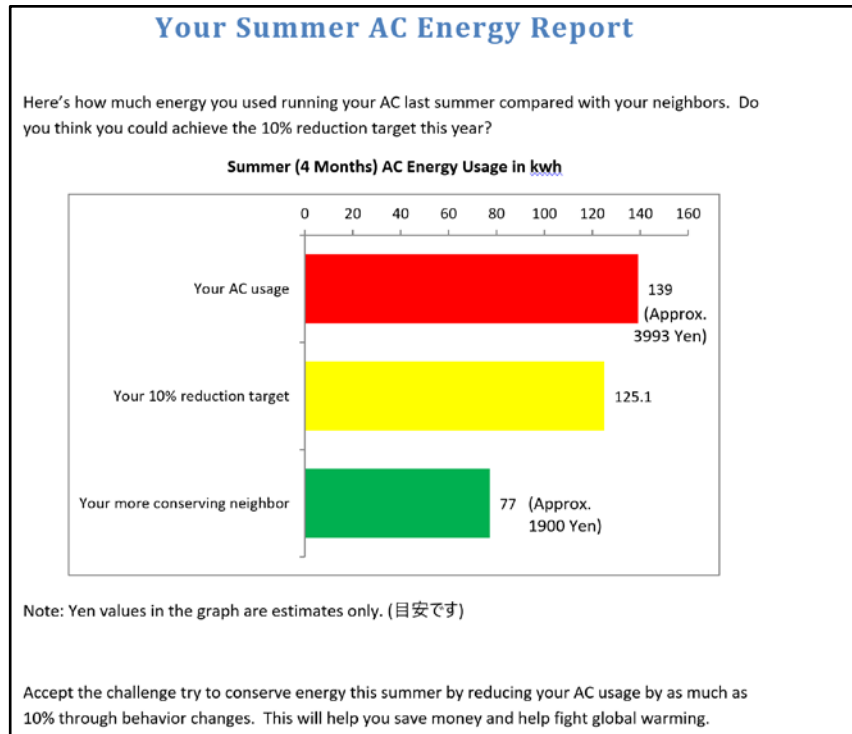


Figure 2. Sample home energy report for E-Sogo household

As with the West Village study, treatment evaluation centered on quantitative analysis of energy consumption data. A/C energy use was sub-metered for all the apartments and provided to the research team by Tokyo Gas. Energy analysis, conducted using R statistical software, revealed that electricity savings from reduced A/C use among treatment group households was modest (3% weighted average, 7% unweighted average), with lower savings rates among households with relatively higher A/C use at baseline.

Also similar to the West Village study, pre- and post-treatment surveys attempted to measure self-reported behavior change and contextual variables. The pre-intervention survey included three modules: (1) questions on A/C usage patterns and behaviors, (2) report on energy use from A/C; (3) and baseline engagement in the 14 alternative cooling strategies and request for commitment to increase frequency of these measures. The post-intervention survey assessed uptake (or increased frequency) of the 14 promoted alternative cooling strategies and experience with the intervention. Fourteen of the 15 pre-intervention survey respondents committed to trying to increase their use of alternative cooling strategies (committing to 11 out of the 14, on average). However, the post-intervention survey revealed that many of the households that committed to a strategy did not in fact use it more often (see Table 2). This was somewhat puzzling, given the initial cooperativeness of participants at E-Sogo. Perhaps they had felt compelled to commit, or their relatively high utilization of various measures at baseline left little room for increase (see Outcault et al., 2016 for details). But another explanation seemed likely, too, which inspired further exploration into why the application of “proven” methods of stimulating behavior change (e.g., commitment, reminders) had not been terribly effective.

2.3 Case Studies Neglected Social Dynamics

As previously mentioned, a single household member was engaged for aspects of each case study and no directions were provided on whether and how participants should involve the other members of their respective households. In E-Sogo, the adult household member most involved in A/C operation was recruited. It was assumed that this person could, and would, champion the promoted alternative cooling strategies to other household members, and be able to report, through the surveys, on behalf of the family. These same assumptions were not made for the non-related peers that shared a dwelling in West Village. All treatment household members were recruited individually to participate in the study; however, no more than one member of a given household actually engaged with the study (i.e., took the pre-intervention survey, etc.). Furthermore, uptake varied widely by measure without any obvious difference in their level of difficulty or inconvenience.

The disappointing and inconsistent responses to well-established tools for promoting behavior change begged the question: What did we do wrong? Scanning back through the data, particularly from open-ended questions, we noted that participants had cited various issues related to their family members (or roommates) when discussing the challenges they faced in trying to adopt certain measures. This suggested that new insights might result from taking another look at the studies – this time through the lens of the ethnographic research in this area. Specifically, it suggested that neglecting social dynamics in participant recruitment, intervention design, and measurement may have meaningfully influenced the impact and evaluation of the interventions. Thus, from apparent failure arose a new research objective: to explore why the interventions failed, and more precisely, what answers could be derived from investigating the intersection of social factors and the cooling measures we had promoted. Indeed, it is precisely because of the problems encountered in the interventions that new methods were developed which led to additional insights.

3. Methodology

Our investigation into the role of social dynamics in measure uptake has four parts; we: (1) describe the attributes of each measure as they relate to social dynamics; (2) describe the general patterns in household social dynamics related to cooling; (3) analyze the implications of the social dynamics with respect to the cooling measures promoted in the case studies; and (4) analyze measure uptake in relation to (1), (2), and (3). Figure 3 depicts the relationships examined in this inquiry.

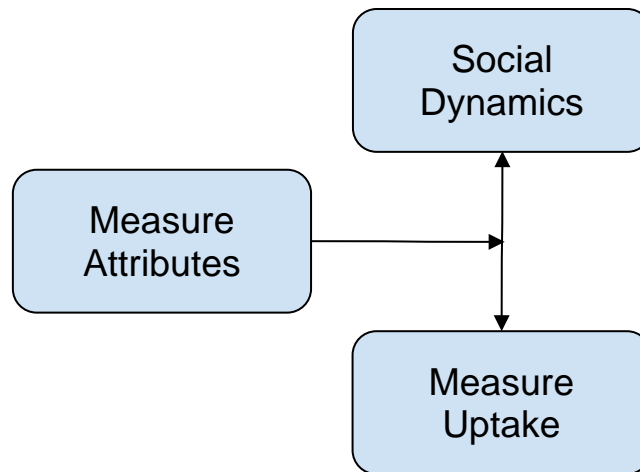


Figure 3. Approach used in this study

The first goal of this inquiry was to explore the role of social dynamics in determining *which* promoted cooling measures would be adopted. To this end, the promoted measures were assessed through the lens of their relationship to the social dynamics within a household. Specifically, each measure was coded on three attributes (see Table 2). First, a binary attribute was coded to indicate whether the measure would impact other occupants. Second, the locus of decision (Boudet et al., 2016), which refers to the household member(s) who can make the decision to adopt a measure without assistance or permission, was determined. The three levels of this attribute were adopted from Boudet et al.: adults; adults and teens; or adults, teens and children.

The second goal was to identify the social dynamics within participating households to gain insight into *how* households may have adopted the promoted cooling measures. To this end, general patterns in the social dynamics related to space conditioning among study households were identified via content analysis of pre- and post-intervention surveys in both communities, and in-person conversations with participants. In E-Sogo, these conversations took the form of in-depth interviews. Members of twelve households participated, with one or two individuals from each being interviewed. In about half the cases the interviewee had completed the survey, and in the remainder, the spouse had completed the survey.⁵ Interviews were conducted by one of the study authors through an interpreter and lasted approximately 30 minutes. The interviews followed a semi-structured protocol covering questions on the participants' experience with the intervention and approach to cooling. Sample questions include: *What was your experience like (using the strategies more frequently)? What was the biggest challenge to implementing the energy savings behaviors you tried? Why?* The interview recordings were translated and transcribed into English. The transcriptions were analyzed using grounded theory. Analysis of patterns in social dynamics relied most heavily on follow-up interviews with E-Sogo households since these were the richest sources of qualitative data.

In-person conversations with West Village participants took the form of informal conversations one author had while installing sensors in several treatment group apartments.

⁵ It was explained by Tokyo Gas that many wives were too shy to participate in an interview and sent their husband instead despite having been the one who completed the survey.

Several participants were asked about ceiling fan, A/C and window use and responses shed light both on the way participants cool their homes, but also on social dynamics in the households.⁶

Finally, participants' self-reported uptake of specific measures promoted in each case study is presented and discussed. Self-reported uptake was measured in the post-intervention survey for each community; the questions and results are summarized in Table 2. Triangulating these data with the two attributes (i.e., locus of decision and impact on others) enabled a reflective discussion on the role of social dynamics in the case studies and the implications for future interventions.

4. Results and Discussion

The results and discussion are organized into three main sections. First, an analysis of the specific cooling measures promoted in the case studies is presented, and measures are categorized according to their implications for social dynamics. Then, an overview of the patterns in household social dynamics related to cooling in the two case study households is presented. This provides an introduction to the social context of the interventions, i.e., dynamics that were already operating when the interventions occurred. Finally, the majority of the analysis triangulates these two frameworks to build an understanding of how the problems associated with applying traditional social science methods that neglect social dynamics diminished the outcomes of these case studies.

4.1 Social Context-Related Attributes of Cooling Measures

Table 2 presents the attributes, impacts, and uptake of measures promoted by the two case studies.

Measure uptake. Indicators of measure uptake are presented for consideration in relation to social context attributes. For West Village, measure uptake is presented as the percent of post-intervention survey respondents who reported trying the measures listed. For E-Sogo, measure uptake is presented as the percent of post-intervention survey respondents who reported increased frequency of measure use during the intervention. There was wide variation in uptake rates across measures within each case study (i.e., 0% to 40% for E-Sogo, and 14% to 86% in West Village). There are many potential explanations for this, but the focus here is on the role of social dynamics.

Table 2: Measures promoted in the two case studies and their social context-related attributes

Behaviors promoted	Impacts other occupants?	Available to other occupants?	Measure uptake

⁶ The sensor data quality was poor so it was not used, as intended, to corroborate self-reported use of windows and ceiling fans.

		(locus of decision identified)	
West Village (n = 7)			
<i>Did you try using the Natural Cooling Strategies [...] in the month of August? Yes or No (% Yes reported)</i>	✓	Adults and teens	86%
<i>Did you ever open the window(s) at night during the month of August? Yes or No (% Yes reported)</i>	✓	Adults and teens	71%
<i>[If “Yes” to above:] Which windows in your apartment did you open?</i>			
Living room windows (% of total)	✓	Adults and teens	14%
Bedroom windows (% of total)	✓	Adults and teens	71%
<i>When you had your window(s) open, was the A/C in the apartment [...] off [the whole time]? (% Yes reported)</i>	✓	Adults and teens	57%
<i>In a typical day [...] did you use the ceiling fans in your bedroom or living room when it was warm in the apartment [More, Less, or The same as in July]? (% More reported)</i>	✓	Adults and teens	43%
E-Sogo (n = 11)			
<i>During the study period - August-September 22, on a daily basis, did you do [strategy listed below] more, less or as] often as you did in July? (% More often reported)</i>			
Daytime			
Avoid A/C unless it is uncomfortably hot	✓	Adults and teens	9%
Change to lighter clothing		Adults, teens, and children	36%
Use “cool” setting instead of “dry”		Adults and teens	27%
Cool only occupied rooms & close door	✓	Adults and teens	9%
Close windows and blinds	✓	Adults and teens	10%

Turn A/C off and use fan	✓	Adults and teens	11%
Run errands when hot and turn down/off A/C	✓	Adults	18%
Use cooling towel or pillow		Adults, teens, and children	40%
Nighttime			
Use “cool” setting instead of “dry”		Adults and teens	9%
Open windows when cool outside	✓	Adults and teens	18%
Set timer to shut bedroom A/C off	✓	Adults and teens	0%
Turn A/C off and use fan	✓	Adults and teens	0%
Precool bedroom and turn A/C off	✓	Adults and teens	0%
Use cooling towel or pillow		Adults, teens, and children	20%

Measures that impact others. Most measures promoted (14 out of 19), if adopted by a study participant, would have likely impacted other household occupants (see Table 2). First, many of the promoted measures would have changed ambient thermal conditions in shared areas of the home, including all measures related to A/C, window, or fan operation. Some measures may also have impacted others by restricting their choices with respect to cooling strategies. The three-component passive cooling strategy (i.e., opening windows, turning off A/C, and using fans) promoted at West Village is an example. Optimal passive cooling requires *all* roommates to open bedrooms doors and windows. One occupant opening a window negates (or should negate) the option for others to use A/C.

Measures that do not impact non-adopting occupants in either manner are considered here as having negligible impact on others (e.g., using a cooling towel). Only five measures (one at West Village and four at E-Sogo) had negligible potential impact on others.

Measures available to others. All measures promoted in the interventions were available to multiple household members. In fact, all 19 measures were potentially accessible to any adult household members, in terms of “locus of decision”. All but one measure (i.e., running errands when hot) were also accessible to teenagers and children (adults would typically be “the decider” when organizing a family outing). Since West Village households were occupied by young adults (i.e., college students), all measures promoted at West Village were available to everyone in the household. In sum, household members that were not directly recruited to engage in the study had the potential to adopt, or thwart, every measure promoted in the interventions.

The pre-intervention surveys revealed that universal availability does not equate to universal use. For example, as Figure 4 illustrates, not all household members operate the A/C even though they could. There are many potential reasons for this; those related to social dynamics are explored in the next section.

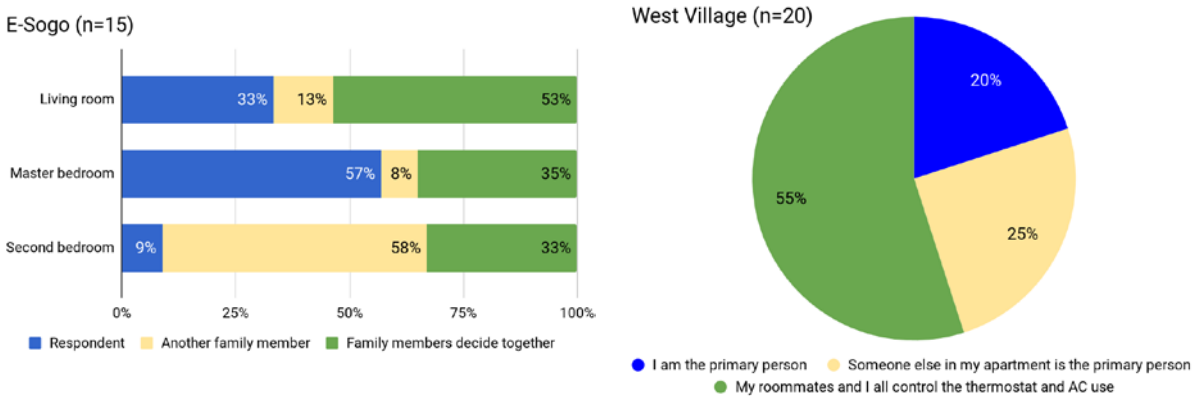


Figure 4. Person controlling the A/C units

4.2 Social Dynamics Related to Household Cooling Practices

The second goal of our exploratory research was to identify patterns in social dynamics related to cooling strategies among participating households. Using a grounded theory approach to analyzing interview and survey data, three general patterns in social dynamics were identified: coordination, imposition, and independence. Definitions and examples of the patterns are presented. The implications for various measures and their uptake are discussed.

4.2.1 Coordination

Coordination refers to a social dynamics pattern whereby a household's approach to cooling takes into account, and satisfies, the needs of multiple occupants. Coordination may involve **cooperation**, where multiple occupants compromise or use complementary strategies. This quote on A/C use from an E-Sogo interviewee illustrates: *My husband and I work together to save energy*. Similarly, in West Village, of the 11 respondents who reported joint thermostat control, 4 indicated the household members talk to each other before changing the thermostat (Figure 5).

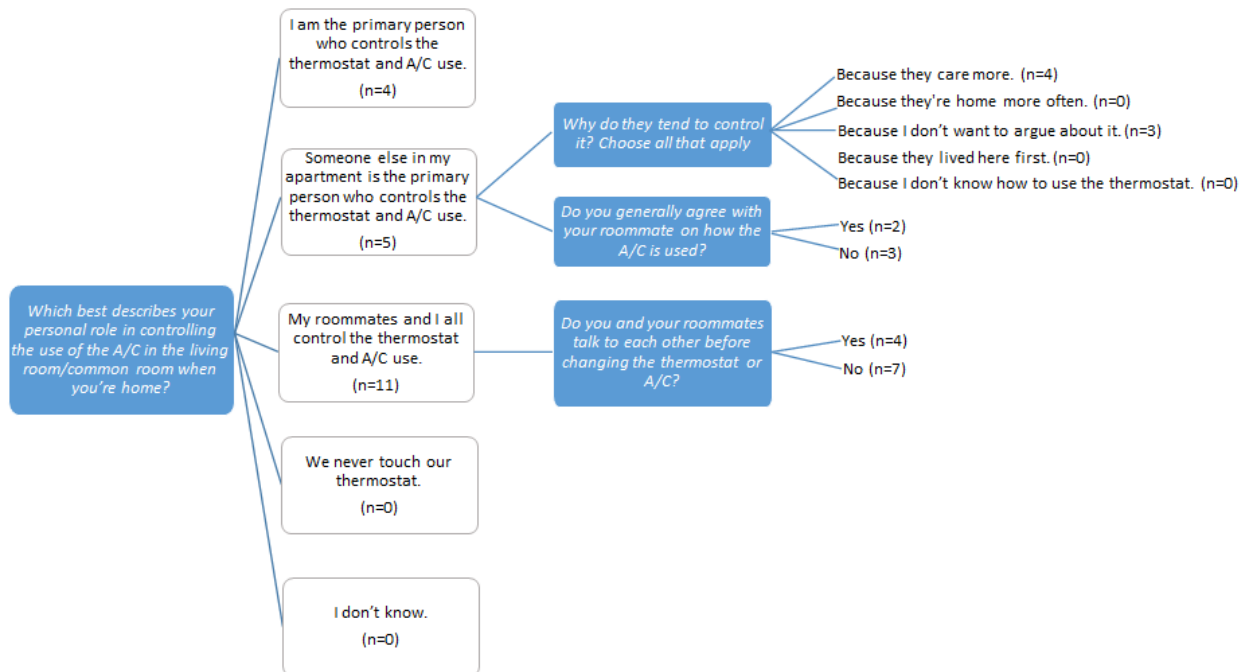


Figure 5. Pre-intervention survey questions about thermostat control in West Village households

In other cases, in E-Sogo in particular, coordination was more implicit; the needs and preferences of others guided one's actions with respect to cooling. For example, E-Sogo interviewees described how they proactively prioritized the thermal comfort needs and preferences of other household members (e.g., young children, pets, and adults with heat sensitivity), as these quotes from E-Sogo interviews illustrate:

I use the air conditioner for my children. Whenever I am by myself I don't use air conditioners.

We couldn't turn off the A/C because we have children.

By contrast, other households struggled to coordinate the use of cooling measures, both before and during the case studies. These quotes from E-Sogo interviews describe the challenges with coordination:

If I were by myself it would not be so difficult to do energy saving activities. But it's really difficult to get my family members to take the same action. Whenever I have a guest or friends to my house I can't force them to save energy.

I actually tell them [what to do] but my husband does not listen so he does not put them into practice.

In West Village, there was a slightly different type of failed coordination attempt reported. In the post-intervention survey, one participant reported opening her bedroom window at night during the study period, but was unsure whether the A/C was off the whole time (presumably since others in the home could also control it). If not properly coordinated, this and other strategies involving the A/C and windows could actually increase energy use.

Thus, some strategies not only impact multiple household members, but actually *require* coordination in order to achieve intended outcomes. Other such measures promoted in E-Sogo included cooling only occupied rooms (which in a full house might require getting occupants together in the same room, or fewer rooms), and running errands during the hottest time of the day (which could require getting everyone together and *out* of the house).

Measures involving the A/C impact both the ambient conditions and other occupants' options for cooling. For that reason, most of the examples relating to coordination - successful or otherwise - refer to A/C use (as opposed to alternatives such as cooling towels), as the following quotes illustrate:

If the family acts as one - get[s] together to do same thing at the same time - that would be easier. For example, [if] everybody stays in [the] same room, like a living room, ... we need to turn on only the air conditioner in the living room... If we are able to act as one, [it] would be much easier for us to save energy.

When our daughters were much smaller it was very easy to get together and stay in one room and just turn on the air conditioner for that single room only. But recently, one goes to her own room and the other goes the other room.

While A/C use clearly requires coordination in order for all occupants' needs to be accounted for, even measures that do not impact others can be the subject of coordination, as the following quote from an E-Sogo interviewee illustrates:

I have a boy age 6, my wife and myself, so there are three of us. The three people are totally different [in their sensitivity] to temperature. For example, I don't feel hot [when] my wife already feels very hot... If one person is the only one who thinks it is very hot, instead of using the air conditioner, we let her use the electric fans to cool herself. We try not to set up a link between a [comfortable] temperature for each person and usage of the air conditioner.

From the data, it appears that the "coordination" dynamic could have been applied to the adoption and use of any measure available to multiple household members, whether it impacts others or not. There were only a few examples of successful coordination yielding measure uptake. Most evidence on this pattern related to the absence of coordination, which pointed to other social dynamics at play.

4.2.2 Imposition

Another pattern of social dynamics that emerged – Imposition - arose when one occupant adopted cooling strategies to suit his/her own needs or desires without regard to the impact on other occupants. For example, in the West Village pre-intervention survey, about one-third of the participants reported that they and their roommates “just change the thermostat and A/C when we want to without discussing it with each other” (see Figure 5). Imposition as a social dynamic was also identified through the evidence of participants’ responses to it.

In particular, three types of responses to the “Imposition” dynamic were found: **acceptance, adaptation, and resistance**. “Acceptance” is when an occupant puts up with the impacts of another’s space conditioning action; e.g., some West Village study participants reported refraining from controlling the apartment thermostat to avoid arguing with roommates. An E-Sogo participant described why he puts up with his wife’s air conditioner use: *I can endure without the air conditioners running but my wife can’t endure heat*. “Adaptation” is when an occupant takes an action to achieve comfort in response to another’s space conditioning action; e.g., one E-Sogo interviewee told us he retreats to the roof because he does not like how cold his wife keeps the house. “Resistance” occurs when one occupant confronts another occupant with respect to his/her space conditioning action, or retaliates by overriding that action with another that imposes his/her preference instead. Conflict often results. When West Village participants were asked if they ever argue with roommates about the thermostat and A/C, 44% said “Yes”. Similarly, E-Sogo participants were asked in the post-intervention survey whether family members objected, complained, or were uncomfortable with the new strategies; five out of eleven said “Yes”.

Given the potential ramifications, some participants were reluctant to impose unwelcome measures on their household members. Several West Village participants were discouraged from using the passive cooling techniques for this reason. In this quote, one participant revealed her concern with trying to adopt the strategy promoted by the intervention: *My housemates might not be on board to [keeping] the A/C off*.

By definition, the “imposition” social dynamic can only relate to cooling measures that impact other occupants, which includes most of the measures promoted in the case studies. Thus, imposition dynamics could have prevented or thwarted uptake of most promoted measures. For those who prefer to avoid the social dynamics of (and consequences associated with) the “imposition” model, a third way is available.

4.2.3 Independence

Independence as a dynamic related to cooling was characterized by the use of strategies that circumvent the need to coordinate or impose (or be imposed upon). This was achieved either by measures that do not directly impact others, or measures that impact ambient thermal conditions *only* for the adopter--when occupying a separate area. For example, room air conditioners in E-Sogo meant people occupying different areas of the home could control their respective A/C use independently, as this quote illustrates:

In the past there was one air conditioner per household, but now it's per room and per person. Each person has the control...so in my case, my wife has her own air conditioner, so her [air conditioning habits are] different from mine.

In this case, occupying separate areas was a more voluntary or “naturally-occurring” practice, as opposed to reactively adapting to an imposition of someone else’s preferences. Similarly, authors learned while installing sensors in the West Village apartments that occupants spend most of their time in their private bedrooms with the doors closed (and occasionally use ceiling fans to manage their comfort); as one participant noted: *I can control the temperature in my own room*. Thus, study participants were accustomed to taking independent approaches to cooling. This dynamic affected how participants responded to the intervention.

In E-Sogo, measures that did not directly impact others, which were therefore amenable to the independence dynamic, included using cooling towels or pillows, changing to lighter clothing, and using A/C “cool” instead of “dry” setting (a change in A/C mode that alters how the equipment operates but does not affect the cooling delivered). Post-intervention survey data indicated that these were the three measures most often adopted/increased in response to the intervention (Table 2). The West Village three-part passive cooling strategy, if adopted in its entirety, would impact all occupants. However, some participants adopted only parts of the strategy; specifically, they largely engaged in measures in their own space that did not impact their roommates. For example, all five post-intervention survey respondents who reported “opening windows at night” opened their (private) bedroom window, but only one also opened the (communal) living room window. In sum, there was evidence in both case studies of greater uptake of measures that did not impact others over measures that did (or would have).

4.3 Integrated Framework

It is likely that the prevailing social dynamics made some measures more feasible than others. This section describes the various pathways study participants may have taken to adopt promoted measures (or not), given the social dynamics in their home. Integrating the two frameworks developed above, Figure 6 depicts relationships between social dynamics and attributes of energy-saving cooling measures using a game-theoretic approach.

If an intervention engages a single occupant, that “Participant” has two general choices if s/he wants to adopt the promoted measures: (1) **Engage others** in their household in Coordination, or (2) **Go it alone**. Coordination can occur with respect to any of the measures. If the participant adopts promoted measures without engaging others, but those measures impact other occupants, the Imposition dynamic is initiated. If the participant adopts measures that do not impact others, the Independence dynamic is initiated.

Other Occupant(s) must then respond to the actions of the “Participant”. When engaged, the “Occupant” may **Cooperate** or **Resist**. A cooperative response initiates the Cooperation dynamic. Resisting cooperation forces the Participant to Go it alone or abandon the measures. When the other Occupant(s) are impacted by the Participant adopting measures, the Occupant can **Accept** the imposed conditions, **Adapt** (using measures that do not impact others), or **Resist** by adopting measures that counteract the Participant’s. When the Participant takes care

of his/her needs independently without impacting others, the other Occupant(s) must do the same, or else initiate a Coordination or Imposition dynamic (unrelated to the intervention).

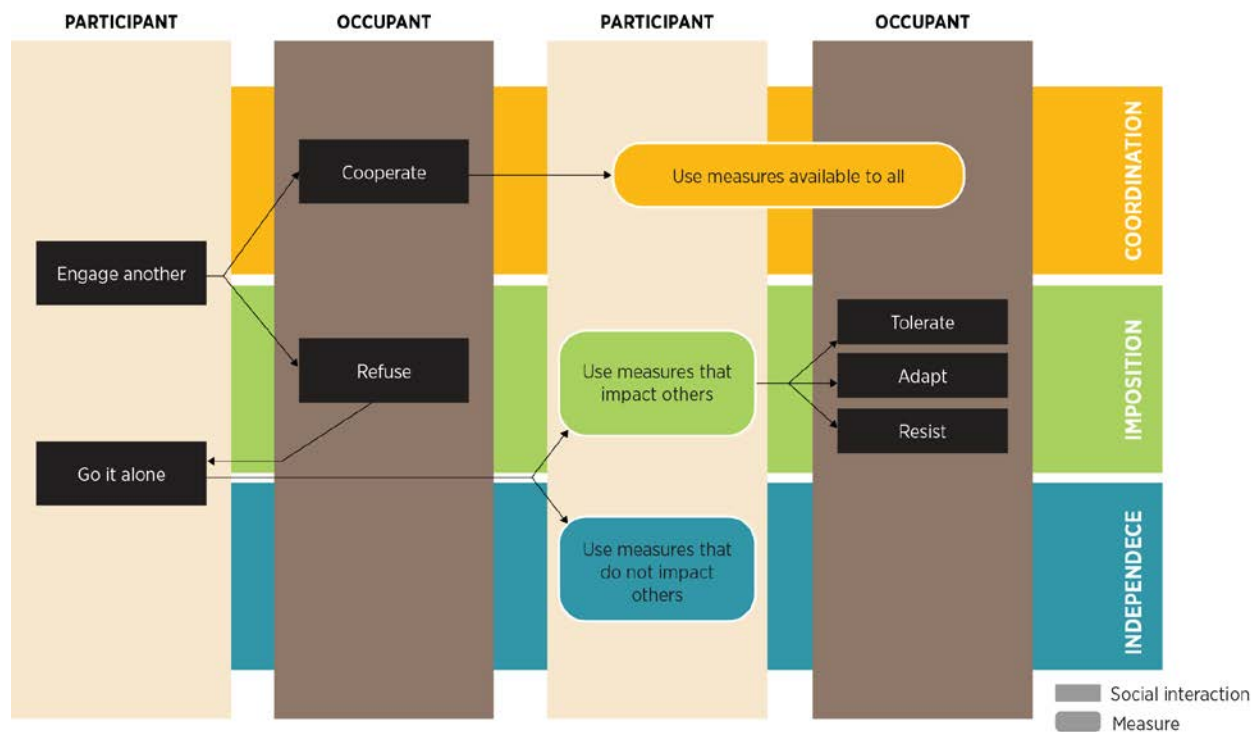


Figure 6. Social dynamics, measure attributes and pathways to the outcome

Although some measures may be more feasible with certain social dynamics than others, as Figure 6 illustrates, any given measure could be adopted under two different social dynamics (i.e., coordination or imposition for measures that impact others, and coordination or independence for measures that do not impact others). Given that, the reason an individual adopts a particular measure may be more indicative of the social dynamics in the household than the attributes of the adopted measure itself. For example, occupants may disperse to their respective bedrooms and use room A/Cs (E-Sogo) or ceiling fans (West Village) in pursuit of thermal comfort for two entirely different reasons. In the case of Independence, they are dispersed, not in response to the imposition of another’s cooling strategy in a communal space, but to pursue their own independent preferences (for thermal comfort, privacy, or other reasons). In that context, the occupants separately engage in cooling strategies, balancing their own comfort and energy goals (if any).

5. Implications and Conclusions

This work builds on the literature regarding energy behavior segmentation (Boudet et al., 2016; Karlin et al., 2014). Boudet et al. identified Family Style measures that all household members can engage in (as defined by the locus of decision). The present research suggests that whether an energy measure impacts multiple household members is another important

social attribute to consider. Utilities and energy program managers can use these behavior segmentation frameworks to guide selection of targeted measures for a given audience, or vice versa. For example, households could be screened prior to an intervention to understand the relevant social dynamics, after which, the most appropriate measures to promote could be selected (e.g., Table 3). Adopting this approach would mitigate some of the problems encountered in the case studies presented.

Table 3. Tailoring targeted measures to prevailing household dynamics

	MEASURE DOES NOT AFFECT OTHERS	MEASURE AFFECTS OTHERS
COORDINATION DYNAMIC	Appropriate	Appropriate (with guidance)
IMPOSITION DYNAMIC	Appropriate	Not advised without careful guidance
INDEPENDENCE DYNAMIC	Appropriate	Not advised without careful guidance

This paper explores the intersection of two frameworks: the social attributes of various cooling measures (i.e., locus of decision and impact on others) and the prevailing social dynamics within a household. It finds that there are problems with utilizing established household engagement and behavior modification techniques. Specifically, interventions that utilize the same problematic approaches as the ones described in the case studies (i.e., targeting a single household member, promoting measures that impact other members, and failing to support coordination) can yield undesirable outcomes. Without coordination, occupants may adopt counterproductive strategies that lead to perverse energy outcomes. Failing to align the promoted strategies with the underlying social dynamics can lead to conflict and other relational difficulties among household members.

To illustrate, consider a household with an “Imposition” dynamic. A (hypothetical) study participant adopts measures that impact other occupant(s), who, in turn, may: 1) resist the change, leading to overt conflict, 2) tolerate it, or 3) adapt, potentially creating bitterness (latent conflict). A study participant’s efforts to coordinate with other household members may also lead to conflict if the other members refuse to cooperate. These hypothetical outcomes could lead to unfavorable impacts on energy consumption and social relations with the household.

Interventions can avoid some of the problems described by including not only directions to coordinate when appropriate, but also *how to* productively coordinate (e.g., modelling and friendly competition rather than dictating and nagging) to mitigate potential implications for social disruption. Further research might productively explore how interventions could change the prevailing pattern of social dynamics (e.g., from independence to coordination).

Many energy-saving measures related to thermal comfort impact, and are available to, multiple household members. As a result, uptake of these measures in energy interventions is

strongly influenced, and in turn influences, household social dynamics. Future research is needed to develop best practices for engaging multiple household members, tailoring interventions to the prevailing social dynamics, and considering impacts across multiple household members. Ultimately, energy interventions that leverage an understanding of both the psychology of behavior change as well as the influence of relevant household dynamics will be both more socially valid and more effective at reducing household energy consumption.

Furthermore, this study illustrates the importance – and value – of investigating our failures as researchers. In fact, the problems with the traditional social science methods used in the interventions were pivotal in unlocking a deeper understanding of household energy practices. Examining the problems inspired the development of a new framework to understand how cooling practices and social dynamics intersect. In turn, we gained insight on how to address the complex nature of individual energy practices that are embedded within a household – making lemonade from lemons.

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