West Village
DAVIS, CALIFORNIA

E-Sogo
YOKOHAMA, JAPAN

CAN AC USE BE REDUCED?

Field experiments to encourage adoption of alternative cooling strategies in Japan and the U.S.

Prepared By Sarah Outcault, Ph.D., Kristin Heinemeier, Ph.D., Marco Pritoni, Jennifer Kutzleb, and Qiwei Wang

Western Cooling Efficiency Center
University of California, Davis

For: Tokyo Gas

January 30, 2015

Table of Contents

TABLE OF FIGURES

TABLE OF TABLES

ABBREVIATIONS & ACRONYMS

AC	Air conditioner
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CA	California
HH	Household
IRB	Institutional Review Board
kWh	Kilowatt hour
PV	Photovoltaic
WCEC	Western Cooling Efficiency Center
ZNE	Zero-net energy

I. RATIONALE

Zero-net energy (ZNE) homes have made great accomplishments in saving energy through efficient design features and high efficiency equipment. However, many ZNE communities fail to reach their stated goal because consumption exceeds the expected levels. In addition, consumption varies widely across otherwise similar homes. These issues are evident in both Tokyo Gas' E-Sogo apartment building and West Village.

In these communities, as with others, the driving force behind occupant consumption levels and variability is occupant behavior. Thus, research on promoting energy savings within the ZNE context must focus on the behavioral drivers of energy consumption. Furthermore, conducting parallel research at two sites, and drawing cross-cultural comparisons, can shed more light on the behavioral drivers of energy use than is possible with a single-site study. Thus, this study aims to leverage the research findings from each site, to reveal additional insights about the other.

II. OBJECTIVES

The behavioral research team at UC Davis' Western Cooling Efficiency Center (WCEC) was asked by the Tokyo Gas Company Ltd. to establish an ongoing research exchange focusing on two zero-net energy communities: E-Sogo in Yokohama, Japan and West Village in Davis, CA. The research focused on the impact of behavioral strategies and interventions on energy consumption in these two different communities. Interventions were designed for each community to understand the impacts of behavior on energy usage. The results from these different interventions are were then compared and used to develop recommendations for Tokyo Gas and future research studies on behavior's impact on energy usage.

III. BACKGROUND STATISTICS/CONTEXT

In this section a brief overview of energy use and the factors that drive it, in Japan and the U.S., are presented and compared. The intention is to provide some context for each of the experimental studies that are the main focus of this report. The discussion is organized in four parts covering the geographic and economic context, household and housing characteristics, energy use and costs, and thermal comfort and space conditioning.

GEOGRAPHIC & ECONOMIC CONTEXT

In both population and landmass, the United States is much larger than Japan, as Table 1 shows. However, the actual study locations differ in a way that deviates from the overall trend. Yokohama is a city of 3.7 million people and has a high population density. By contrast, Davis is a very small city of only 66,000 and a population density just one percent of Yokohama's.

In addition, although both Japan and California (and the U.S.) span great lengths of latitude, the precise latitude of the study locations also differs. Davis, CA is 3.2 degrees (roughly equivalent to 350 km) north of Yokohama. As a point of comparison, the Japanese city of Sendai is located at a latitude similar to Davis, CA.

Table 1. Geographic and population statistics

	Japan	Yokohama	US	CA	Davis
Population (in thousands)	128,067[1]	3,708[1]	318,350[2]	38,333[3]	66[3]
Land area (sq. km.)	362,223[4]	435[5]	9,147,592[6]	403,466[6]	26[7]
Latitude	31.0 - 45.5 N[8]	35.4 N[8]	25.1 - 49.4 N[8]	32.5 – 42 N[8]	38.6 N[8]
Population Density (ppl / sq. km.)	354	8,522	35	95	2,584
Percent Urbanized	91.3%[9]	100%	82.4%[9]	95%[10]	100%[11]

In addition, while Yokohama is a port city, Davis is located in the relatively hot and dry California Central Valley, approximately 35 kilometers inland from the coastline. Thus, the climates of the two cities vary substantially. As Figure 1 illustrates, despite being further North, Davis has hotter daytime temperatures than Yokohama, except in August when the average high converged around 33 degrees C. However, being more temperate, nighttime temperatures in Yokohama drop much less than in Davis (e.g., 7-8 degrees C in summer months compared to 18-21 degrees C, respectively). These patterns have significant implications on the potential for passive cooling, as study results reflect.

[1] "Chapter 2, Population and Household", Statistics Japan. Statistics Bureau, Ministry of Internal Affairs and Communication. http://www.stat.go.jp/data/nihon/pdf/n0200000.pdf.

[2] "U.S. and World Population Clock". United States Census Bureau. http://www.census.gov/popclock/.

[3] "Davis (city) QuickFacts". United States Census Bureau. http://quickfacts.census.gov/qfd/states/06/0618100.html.

[4] "Japan Statistical Yearbook 2010". Statistics Bureau. p. 17. http://www.stat.go.jp/data/nenkan/pdf/yhyou01.pdf.

[5] Population News of Major Cities. Statistical Information Division, Policy Bureau. http://www.city.yokohama.lg.jp/ex/stat/jinko/city/new-e.html.

[6] United States Summary: 2010, Population and Housing Unit Counts, 2010 Census of Population and Housing (PDF). United States Census Bureau. September 2012. pp. 41 (Tables 18). http://www.census.gov/prod/cen2010/cph-2-1.pdf.

[7] "State & County Quick Facts, Davis (city), California". US Census Bureau. http://quickfacts.census.gov/qfd/states/06/0618100.html.

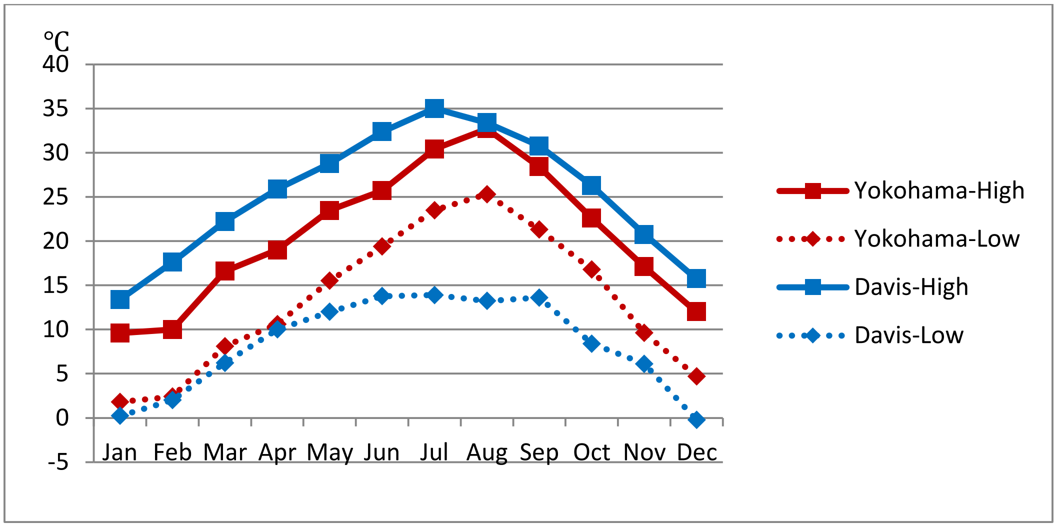
[8] Latitude obtained from Google Maps. http://maps.google.com

[9] Japan and United States Sections from The World Factbook. https://www.cia.gov/library/publications/the-world-factbook/

[10] California Percent Urbanized: " Growth in Urban Population Outpaces Rest of Nation, Census Bureau Reports. https://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html

[11] Noted as urban given that its population density exceeds the U.S. Census definition of urban, defined as at least 386 people per km^2.

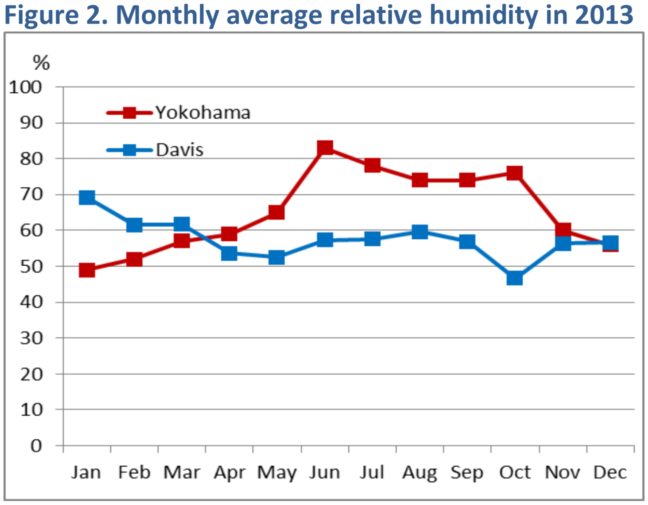
Figure 1. Monthly Average Temperatures in 2013



Sources: Japan: "Yokohama City; Monthly Values of Year 2013; Major Factors". Japan Meteorological Agency. http://www.data.jma.go.jp/obd/stats/etrn/view/monthly_s1.php?prec_no=46&block_no=47670&year=2013&month=&day=&view=. US: "Summary of Monthly Normals 1981 - 2010".U.S. Davis 2 WSW Experimental Farm, CA, US; National Environmental Satellite, Data, and Information Service, National Oceanic & Atmospheric Administration, U.S. Department of Commerce. http://www.ncdc.noaa.gov/cdo-web/datatools/normals.

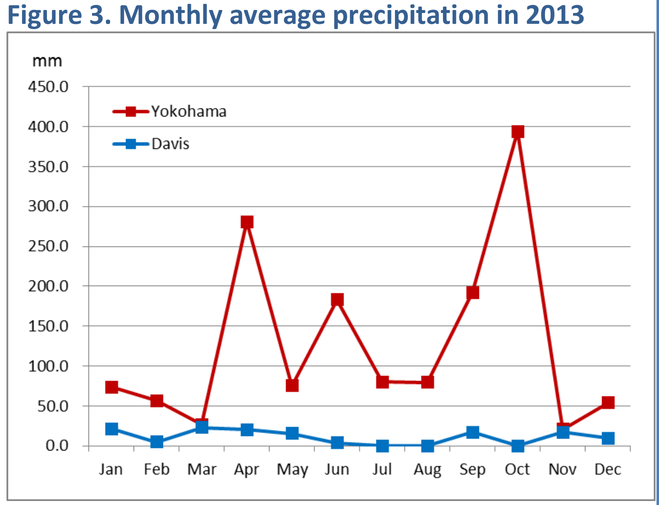
Another significant climatic difference between Yokohama and Davis is the humidity and precipitation. Yokohama summers have more rain and humidity, on average, than those in Davis, as the examples from 2013 in Figure 2 and Figure 3 show. These factors also have implications for the potential for passive cooling.

Figure 2. Monthly average relative humidity in 2013



Sources: Japan: "Yokohama City; Monthly Values of Year 2013; Major Factors". Japan Meteorological Agency. http://www.data.jma.go.jp/obd/stats/etrn/view/monthly_s1.php?prec_no=46&block_no=47670&year=2013&month=&day=&view=. US: "Retrieve daily data for DAVIS.A (CIMIS #6, Davis)", UCIPM online. http://www.ipm.ucdavis.edu/calludt.cgi/WXSTATIONDATA?MAP=yolo.html&STN=DAVIS.A&BACKUP=NONE&GETALL=0.

Figure 3. Monthly average precipitation in 2013



Sources: Japan: "Yokohama City; Monthly Values of Year 2013; Major Factors". Japan Meteorological Agency. http://www.data.jma.go.jp/obd/stats/etrn/view/monthly_s1.php?prec_no=46&block_no=47670&year=2013&month=&day=&view=. US: "Summary of Monthly Normals 1981 - 2010".U.S. Davis 2 WSW Experimental Farm, CA, US; National Environmental Satellite, Data, and Information Service, National Oceanic & Atmospheric Administration, U.S. Department of Commerce. Retrieved June 30, 2014. http://www.ncdc.noaa.gov/cdo-web/datatools/normals.

Economic conditions are different in the two countries, as well. In 2013, the per capita GDP of Japan was estimated to be ¥4.4 million, ranking 36th in the world. By contrast, United States ranked 14th in the world with a per capita GDP of approximately ¥6.3 million.[12]

Both study locations (i.e., E-Sogo and West Village) are inhabited by residents who are relatively wealthier than average. The Tokyo Gas employees who live in E-Sogo earn higher-than-average salaries. Similarly, the rental rates at West Village are on the higher end of student housing, suggesting that the residents (or their families who may pay for their schooling) are also wealthier than average, in general. The potential implications of this are discussed in Part C: Comparison of key findings.

HOUSEHOLD & HOUSING CHARACTERISTICS

The average household size in the U.S. and Japan is remarkably similar, 2.58 and 2.55, respectively.[13] It should be noted, however, that differences in the age structure and housing patterns in the two countries suggest that the age and relationship between household members may be significantly different, even within similarly sized households. American households, for example, are on average younger and more likely to include members without familial ties, than Japanese households. The study locations are an extreme example of this pattern, as is described in later sections. For now, it is sufficient to note that the age and relationship of household members can have implications on the cooling needs of a home based on occupancy patterns and physiological characteristics.

Japanese and American housing differs significantly, too. In Japan, 55.3% of households live in a single family home, whereas 69.2% in the U.S. do. Not surprisingly, then, the average Japanese home is much smaller than that in the U.S. (a trend driven in part by the greater urbanization in Japan, too). Japan homes provide, on average, 1.9 m^2 per person, whereas American homes are more than 3 times larger, with 6.5 m^2 per person on average.[14] Larger homes translate to greater energy needs for space conditioning, which is borne out by the data in the next section.

ENERGY USE & COSTS

Not surprisingly, given the differences in average housing size, American households (and those in the Western region, which includes California) consume twice the amount of electricity as Japanese households, whether among single family homes or multi-family homes, as illustrated in Figure 4.

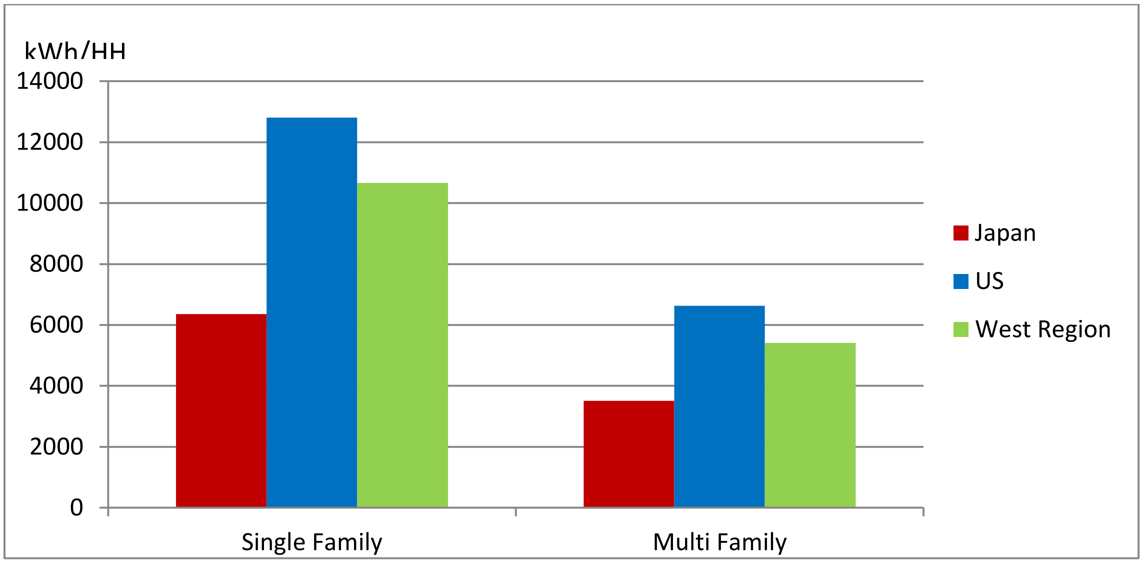
---

[12] The World Factbook 2013-14. Washington, DC: Central Intelligence Agency, 2013. https://www.cia.gov/library/publications/the-world-factbook/index.html. Currency converted using www.oanda.com on January 12, 2015.

[13] US: United States: 2010 Summary Population and Housing Characteristics, United States Census Bureau. https://www.census.gov/prod/cen2010/cph-1-1.pdf. Japan: Appendix of 2008 Household and Land Census, Statistics Japan. http://www.stat.go.jp/data/jyutaku/2008/pdf/kgiy11.pdf.

[14] Japan: Appendix of 2008 Household and Land Census, Statistics Japan. http://www.stat.go.jp/data/jyutaku/2008/pdf/kgiy11.pdf. US: American Housing Survey for the United States: 2011, United States Census Bureau. https://www.census.gov/content/dam/Census/programs-surveys/ahs/data/2011/h150-11.pdf.

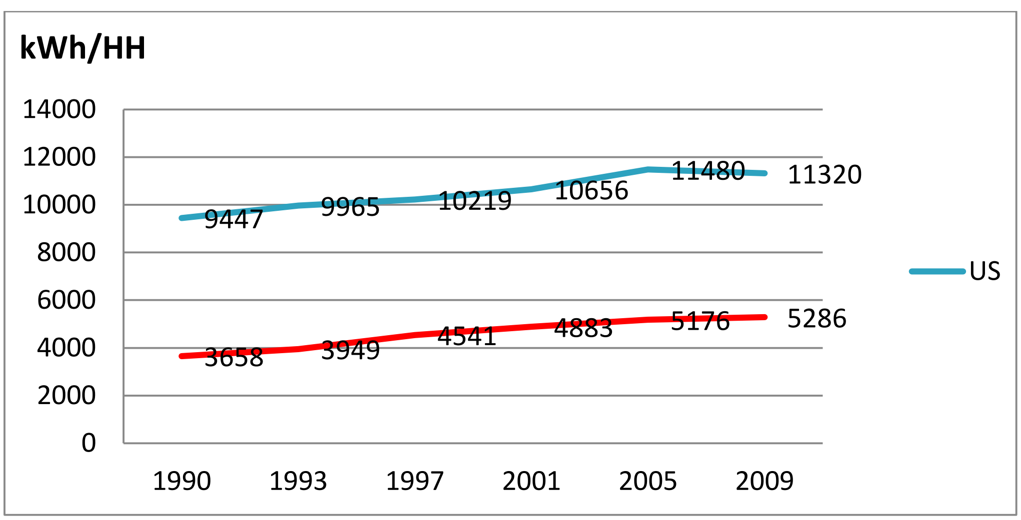
Figure 4. Annual household electricity use, by housing type



Sources: Japan: "2012 Annual Research on Energy Consumption". Agency for Natural Resources and Energy. http://www.meti.go.jp/meti_lib/report/2013fy/E003078.pdf. Retrieved June 30, 2014. U.S.: "Residential Energy Consumption Survey". Energy Information Administration. http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#fuel-consumption. Retrieved June 30, 2014.

The cross-country differential in household electricity use has persisted for decades, as Figure 5 shows, although the gap is narrowing, in relative terms. It is due to the fact that electricity use has grown faster among Japanese households than American ones. From 1990 to 2009, the average amount of electricity used rose 45% in Japan, compared to 20% in the U.S.

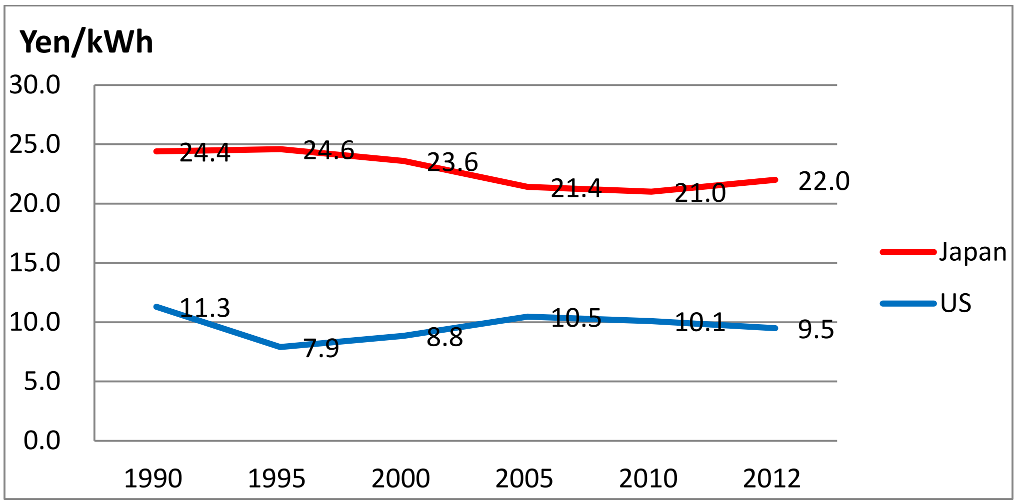
Figure 5. Historical trend in household electricity use



Sources: Japan: 2014 Household Energy Handbook. US: "Residential Energy Consumption Survey". Energy Information Administration. 2009 RECS Survey Data, CE2.1; 2005 RECS Survey Data, US8; 2001 RECS Survey Data, Table 3; 1997 RECS Survey Data, Table 3; 1993 RECS Survey Data, Table 5.4; RECS Archive, year 1990, Consumption & Expenditure Tables, National, Table 2. http://www.eia.gov/consumption/residential/data/2009/.

Another factor that may contribute to higher electricity consumption among American homes, is the lower residential electricity prices they have faced, relative to their Japanese counterparts. Since 1990, American households have paid less than half what Japanese households pay per kWh, as shown in Figure 6. Overall, electricity prices have declined in Japan, although that trend has reversed in recent years. One significant contributor to these price increases was the magnitude 9.0 earthquake and resulting tsunami that hit Japan's coast and the Fukushima Nuclear Power Plant in 2011. Because of the wreckage of the power plant, and environmental threats from its ongoing leakage of radiation, Japan has since closed down all of its nuclear power plants. Without nuclear sources, Japan must rely on imported fossil fuels to generate electricity, and the cost has increased dramatically.

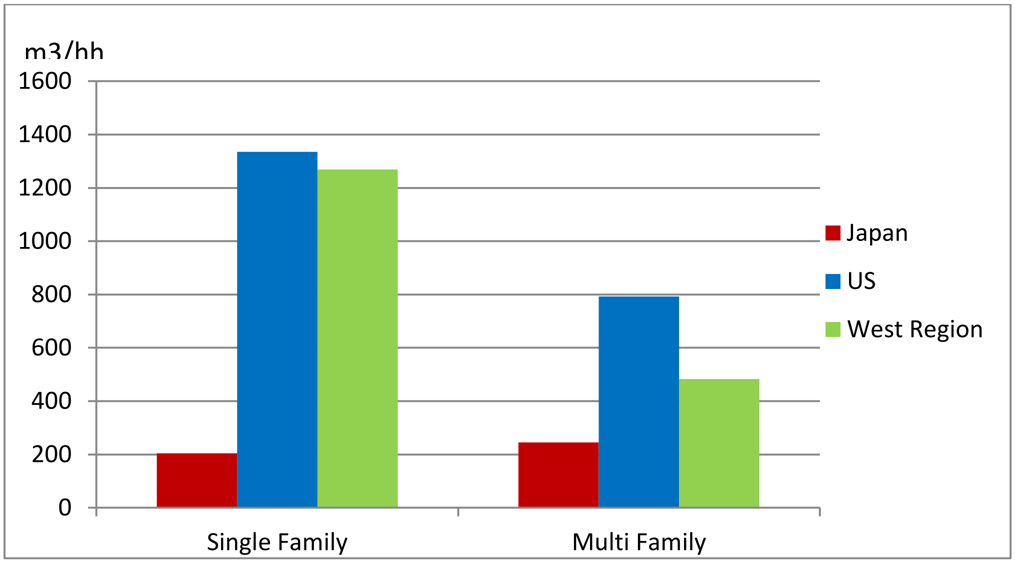
Figure 6. Historical trend in residential electricity prices



Sources: Japan: 2014 Household Energy Handbook. U.S.: Form EIA-861, "Average price by state by provider, back to 1990". U.S. Energy Information Administration. Dollar-Yen exchange rate: www.oanda.com.

The patterns among residential gas use also reveal higher consumption among American households. As Figure 7 illustrates, American households use three to six times as much as Japanese households. This is likely driven in large part by differences in heating sources.

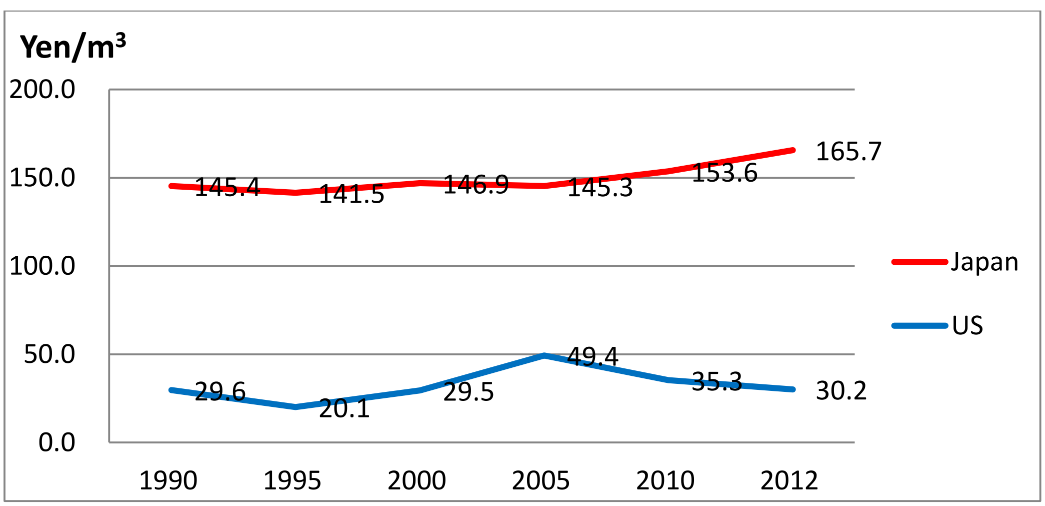
Figure 7. Annual household gas use, by housing type



Sources: Japan: "2012 Annual Research on Energy Consumption". Agency for Natural Resources and Energy. http://www.meti.go.jp/meti_lib/report/2013fy/E003078.pdf. Retrieved June 30, 2014. U.S.: "Residential Energy Consumption Survey". Energy Information Administration. http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#fuel-consumption. Retrieved June 30, 2014.

A cross-country differential in residential gas prices has persisted for decades, as Figure 8 shows. From 1990 to 2009, American households have paid just one-fifth the price per cubic meters for gas as Japanese households. In addition to being higher, the residential gas prices have grown more in Japan, too. It should be noted that the United States has domestic sources of natural gas, while Japan must import its natural gas from neighboring countries, such as Malaysia and Australia.

Figure 8. Historical trend in household gas prices



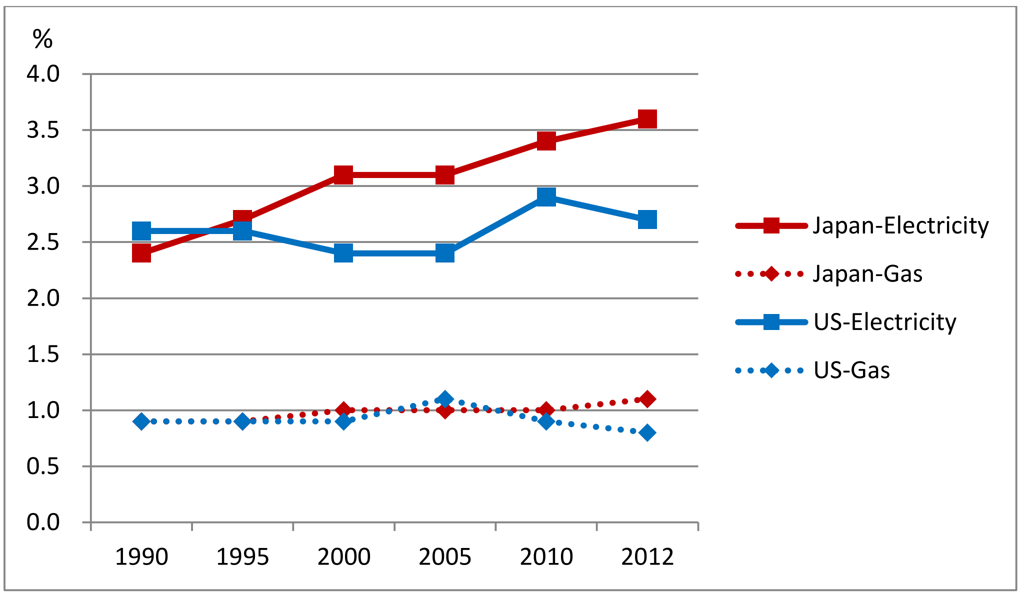
Sources: Japan: 2014 Household Energy Handbook. U.S.: Form EIA-861, "Average price by state by provider, back to 1990". U.S. Energy Information Administration. Dollar-Yen exchange rate: www.oanda.com.

Looking at consumption and prices together provides another perspective. As a percentage of total household expenditure, the amount spent on gas has been roughly the same in Japan and the U.S., hovering around 1%, as illustrated in Figure 9. In recent years, this trend has changed as prices have dropped in the U.S. and risen in Japan.

By contrast, while household spending on electricity was similar in the 1990s (i.e., around 2.5%), Japanese households have spent a greater share of their household expenditures on electricity since then, rising to a high of 3.6% in 2012. This trend is largely driven by increase consumption, as prices have actually declined over that period.

Overall, the proportion of household expenditures devoted to electricity has risen in the U.S., too, although not to the same extent. This is in part due to falling prices.

Figure 9. Historical energy expenditure, as % of total household expenditure



Sources: Japan: 2014 Household Energy Handbook. US: "Average Annual Expenditures of All Consumer Units by Selected Major Types of Expenditure: 1990 to 2009". United States Census Bureau. https://www.census.gov/compendia/statab/2012/tables/12s0684.pdf. "Average Annual Expenditures by Major Category of All Consumer Units and Percent Changes, Consumer Expenditure Survey, 2009-2012", pg. 2, BLS Reports. U.S. Bureau of Labor Statistics. http://www.bls.gov/cex/csxann12.pdf. "Residential Sector Energy Consumption". U.S. Energy Information Administration. http://www.eia.gov/totalenergy/data/monthly/pdf/sec2_5.pdf.

THERMAL COMFORT & SPACE CONDITIONING

Thermal comfort is a subjective evaluation of one's satisfaction with the thermal environment. Comfort roughly equates to thermal neutrality, whereby occupants are neither losing nor gaining heat from their environment, but instead, are able to maintain equilibrium with the ambient conditions. In essence, with thermal neutrality, the body does not have to expend energy to stay warm or to cool off. Thermal comfort is important because it affects occupants' health, happiness, and productivity.

Providing thermal comfort to occupants is the primary objective of conditioning indoor spaces. A widely accepted guideline for doing so in the U.S. and abroad is provided by ASHRAE Standard 55, produced by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers. The stated purpose of ASHRAE Standard 55 is "to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within the space".[15] Thus, many of the specific details on how thermal comfort is measured and what influences it are derived from ASHRAE Standard 55.

There are many factors that drive thermal comfort. They can be broadly categorized as either environmental or personal factors. Environmental factors influencing thermal comfort include air temperature, mean radiant temperature (derived from heat transferred from a surrounding surface), air speed and humidity. In general, humans feel relatively warmer as air temperature, radiant temperature and humidity increases, and as air speed decreases.

The typical personal factors considered include individuals' metabolic rate and clothing level. The metabolic rate is a function of human physiology (which includes elements such as age, gender, body mass, metabolism, and dietary intake) and activity level. The metabolic rate is expressed in units of "met", where 1 met = 58.2 W/m^2 (or 18.4 $Btu/h \cdot ft^2$). ASHRAE provides estimates for the met value of various activity levels (e.g., 1.0 met for reading or writing while seated, 1.2 for standing relaxed, 1.7 for walking about) undertaken by an "average person".[16]

The insulation humans receive from clothing also affects thermal comfort by preventing heat loss. The insulation provided by clothing is measured in a unit called a "clo" value, where 1 clo = 0.155 $m^2 \bullet °C/W$ (or 0.88 $ft^2 \bullet h \bullet °F/Btu$). This is equivalent to the insulation provided by trousers, a long sleeved shirt, and a jacket, according to ASHRAE Standard 55. Clo values typically vary between summer and winter, so the conditioning requirements to provide comfort are also different.

There is also evidence that assessments of thermal comfort have a psychological component. The human body is highly adaptable,[17] and comfort can be measured (and interpreted) in absolute terms or in relative or conditional terms. For example, there is evidence that expectations influence one's reporting of thermal comfort. Thus, seasonal outdoor temperature shifts often affect occupants' expectations of indoor conditions such that thermal comfort, as they assess it, is associated with slightly higher or lower indoor temperatures throughout the year, and even throughout the day.[18]

Numerous studies have also demonstrated that occupants' control (or perceived control) over indoor conditions can also affect occupants' assessment of thermal comfort. For example, Karjalainen (2009) found a strong correlation between satisfaction with room temperature and the perceived level of control over room temperature. This finding was statistically significant in both home and office environments.

[15] ASHRAE, 2010.
[16] ASHRAE, 2013.
[17] Mishra & Ramgopal, 2013.
[18] Ibid.

Although norms about spacing conditioning differ substantially around the world, it is generally accepted that significant cultural differences in absolute thermal comfort do not exist. Indeed, intra-group differences typically exceed inter-group differences. There is evidence, though, that the human body has evolved and adapted to the surrounding climatic characteristics resulting in differences in sweating, for example, between Japanese and (Caucasian) Americans.[19] In addition, there are cultural differences in the social norms governing factors such as clothing, body mass, and nutritional intake, which in turn affect thermal comfort.

While many factors influence thermal comfort, as described above, measuring thermal comfort is fairly straightforward. Typically, at least two dimensions of thermal comfort are measured: thermal sensation and comfort. ASHRAE's thermal sensation measure, for example, is a 7-point scale where -3 = cold, -2 = cool, -1 = slightly cool, 0 = neutral, +1 = slightly warm, +2 = warm, and +3 = hot. This scale has been used by many empirical studies of thermal comfort around the world, although it is by no means the only one.[20]

Separate from thermal sensation, individuals are often asked to assess their comfort. ASHRAE's 9-point scale ranges from −4 (intolerably cold) to +4 (intolerably hot). Other comfort scales ask about satisfaction with,[21] or the acceptability, comfort[22] or tolerability of, the indoor temperature, without reference to the thermal sensation. Such acceptability scales explicitly acknowledge the fact that thermal comfort is different from thermal sensation.

The acceptability of a given indoor temperature can depend in part on the other parameters over which an occupant is attempting to maximize utility, i.e., balancing comfort with energy cost or environmental impact of energy use. There is some evidence to suggest that individuals are willing to extend their normal boundaries of acceptability to make allowances when thermal comfort is delivered in more environmentally benign manners (e.g., natural ventilation, solar-powered air conditioning), as the results of this study will show.

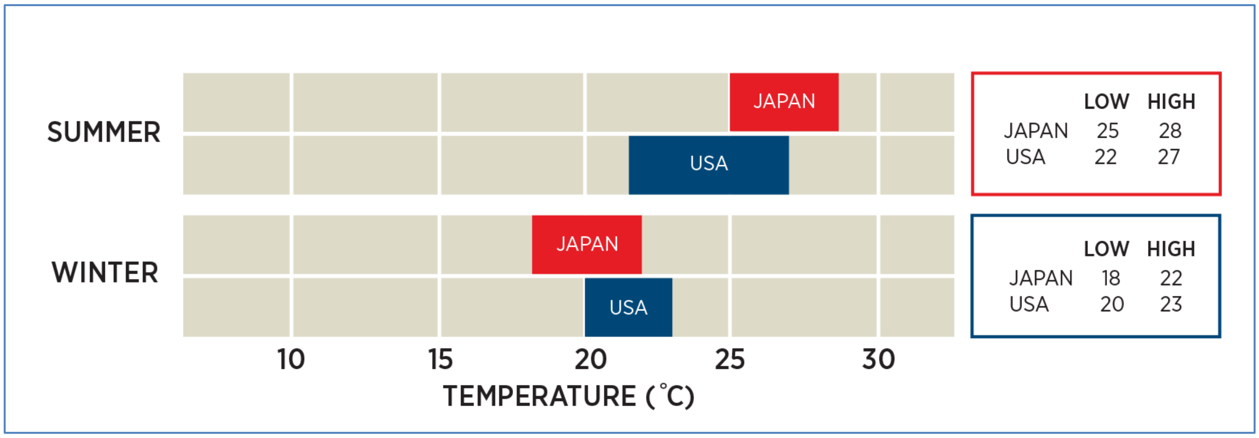
Cultural norms and expectations play a significant role in determining the acceptable range of thermal comfort, and in turn the energy consumption derived from space conditioning. For example, in the U.S., ASHRAE Standard 55 effectively drives decisions about the provision of building materials, heating and cooling technologies, and temperature controls, which aim to provide an acceptable level of comfort for a maximum number of people (although the standard is not typically cited when building *operations* are considered). This establishes norms, thereby influencing expectations of the acceptable range of indoor temperatures.

Figure 10 illustrates the thermal comfort ranges utilized by ASHRAE and a Japanese manufacturer. They indicate what may be considered acceptable comfort ranges in the U.S. and Japan, during summer and winter. There are two key differences to note. The first is that the comfort ranges of the two seasons

[19] Tanabe & Kimura, 1989.
[20] See, for example Zhang, 2003.
[21] Hoyt, et al., 2013.
[22] Zhang, 2013.

overlap in the U.S., whereas they do not in Japan, suggesting the Japanese expect (or at least accept) seasonal differences in thermal comfort. The result is that the overall thermal comfort range is much narrower in the U.S. than in Japan, at least according to the particular sources cited. The second observation is that the comfort range in the U.S. is relatively cooler in the summer and warmer in the winter, relative to Japan. All else equal, this drives up energy use in the U.S., compared to a set of more conservative ranges in Japan.

Figure 10. Industry's thermal comfort range



Sources: Japan: http://www.crecer.jp/Q-A/HTML/A-11.html; US: ASHRAE guidelines

Survey data from the United States corroborates the notion that American homes tended to be cooled to lower temperatures in the summer than Japanese homes. Among those that utilize a programmable thermostat, nearly eighty percent of households in the U.S. (and 68% in California) maintain temperatures below 25 degrees C when someone is home during the day, as Figure 11 shows. (Note that 25 is the lower end of the cooling range presented in the graph above, and still significantly cooler than the 28 degrees C that is now recommended by the Japanese government to conserve energy and maintain system reliability during summer.[23]) The percentages are similar for nighttime cooling, too, with 80% of homes in the U.S. and 73% of homes in California setting their thermostats below 25 degrees C at night, as shown in Figure 13. Even when no one is home, two-thirds of American homes and one-third of California homes were cooled to below 25 degrees C, as Figure 12 indicates.

[23] *Household Energy-Saving Handbook*. Tokyo Metropolitan Governments. http://www.tokyo-co2down.jp/ecology/home/.

Figure 11. Indoor air temperature with central AC (F): Daytime, Someone home

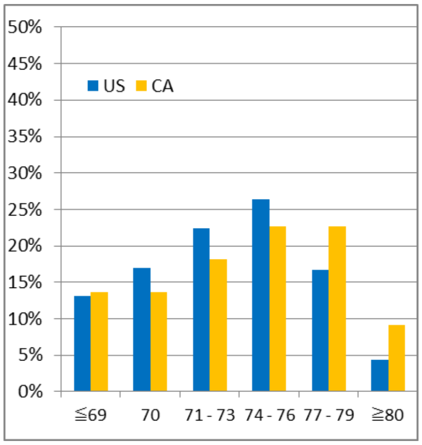


Figure 12. Indoor air temperature with central AC (F): Daytime, No one home

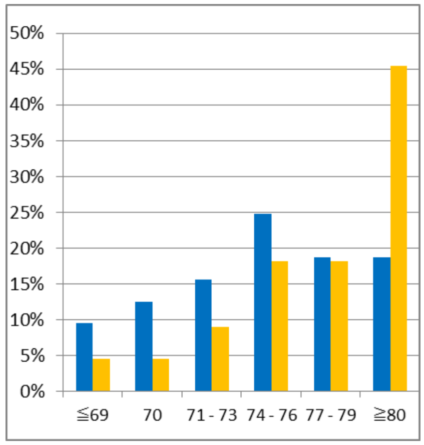
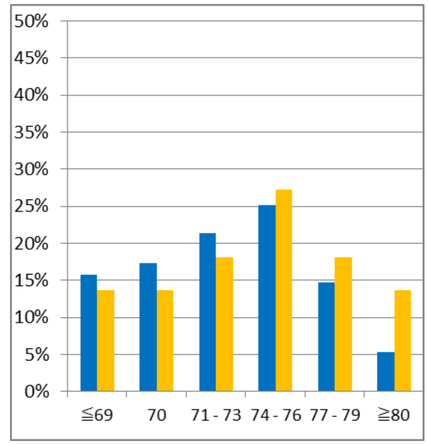


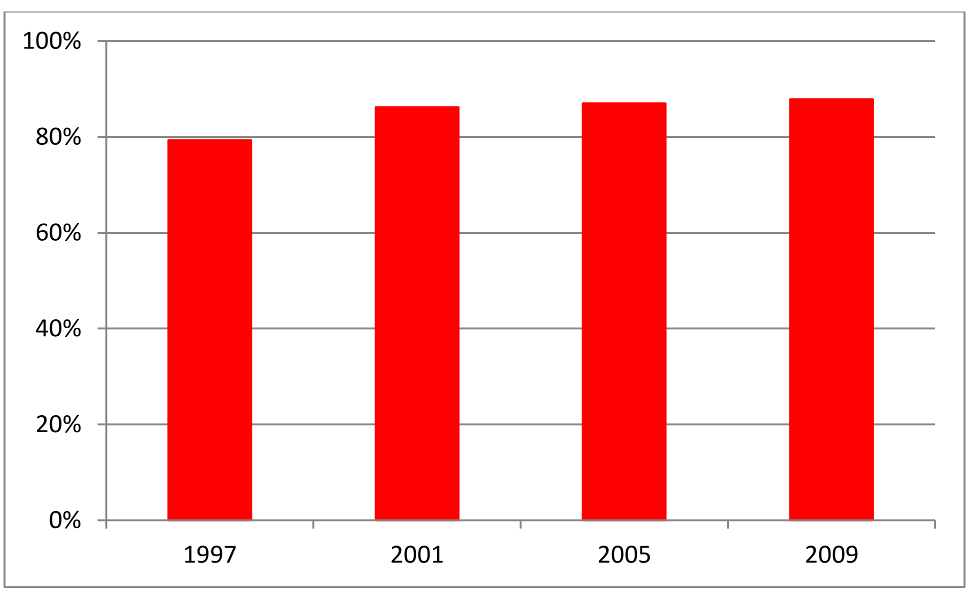
Figure 13. Indoor air temperature with central AC (F): Nighttime



Source: HC 7.11, "2009 RECS (Residential Energy Consumption Survey) Survey Data," U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/2009/xls/HC7.11%20Air%20Conditioning%20in%20West%20Region.xls.

Another significant difference between Japan and the U.S. is the manner in which households typically cool their homes. The predominant source of mechanical cooling in Japanese homes is room air conditioners ("ACs"). Note that Japanese homes typically use mini-split heat pump systems with one or more indoor units for different rooms, to provide both summer cooling and winter heating. Thus "AC" refers to both heating and cooling, while in the United States, AC refers only to cooling). In fact, by 2009, 88% of households in Japan owned one or more room AC units, as Figure 14 illustrates.

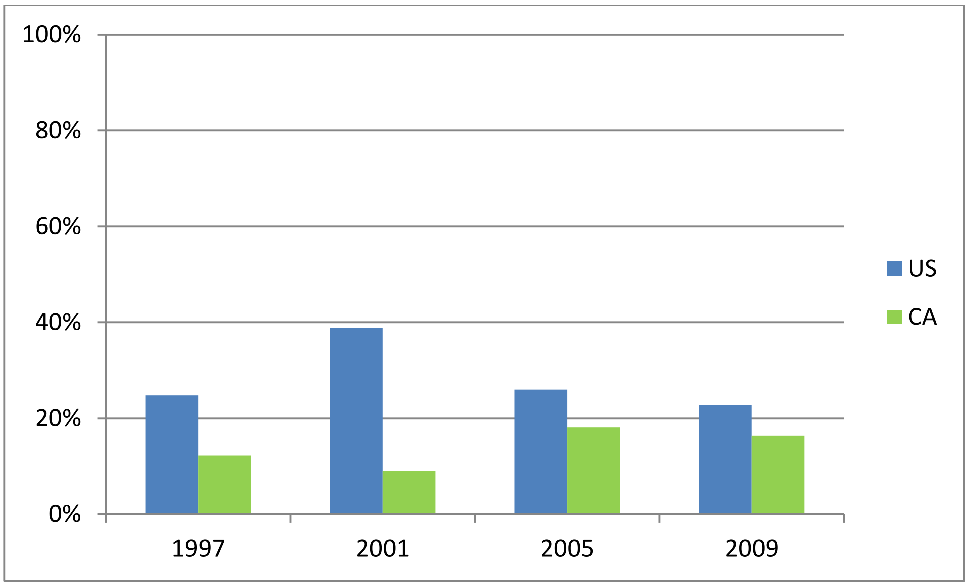
Figure 14. Historical trend in room AC ownership, Japan



Source: "Monthly and Annual Consumer Behavior Survey", pg.16. Economic and Social Research Institute, Cabinet Office. http://www.esri.cao.go.jp/jp/stat/shouhi/2012/1203honbun.pdf#page=15.

In the U.S., "room AC" refers to window-units: very small air conditioners (cooling only), which combine the evaporator and condenser in one box. Ownership of room ACs is much less common in the United States, and even less so in California. American homes are much more likely to be cooled by central AC units, and the trend is growing, as Figure 15 illustrates.

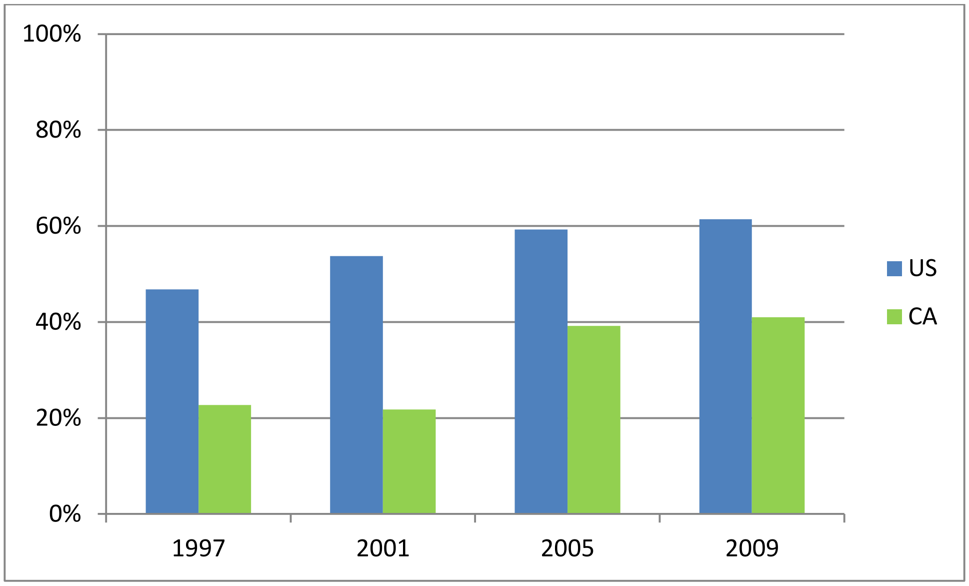
Figure 15. Historical trend in room AC ownership, United States and California



Sources: Table 3.1a, 3.2b, 3.14, 3.15, "1993 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/1993/. HC 5-7b, "1997 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/1997/. HC 1-7a, HC4-7a, "2001 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/2001/. HC 14.7, "2005 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/2005/. HC 7.11, "2009 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. Retrieved 1 July, 2014. http://www.eia.gov/consumption/residential/data/2009/.

Instead, central AC is the dominant (and growing) cooling technology used in both the U.S. and California, as Figure 16 illustrates. By 2009, more than 60% of American households and 40% of California households lived in homes with central AC.

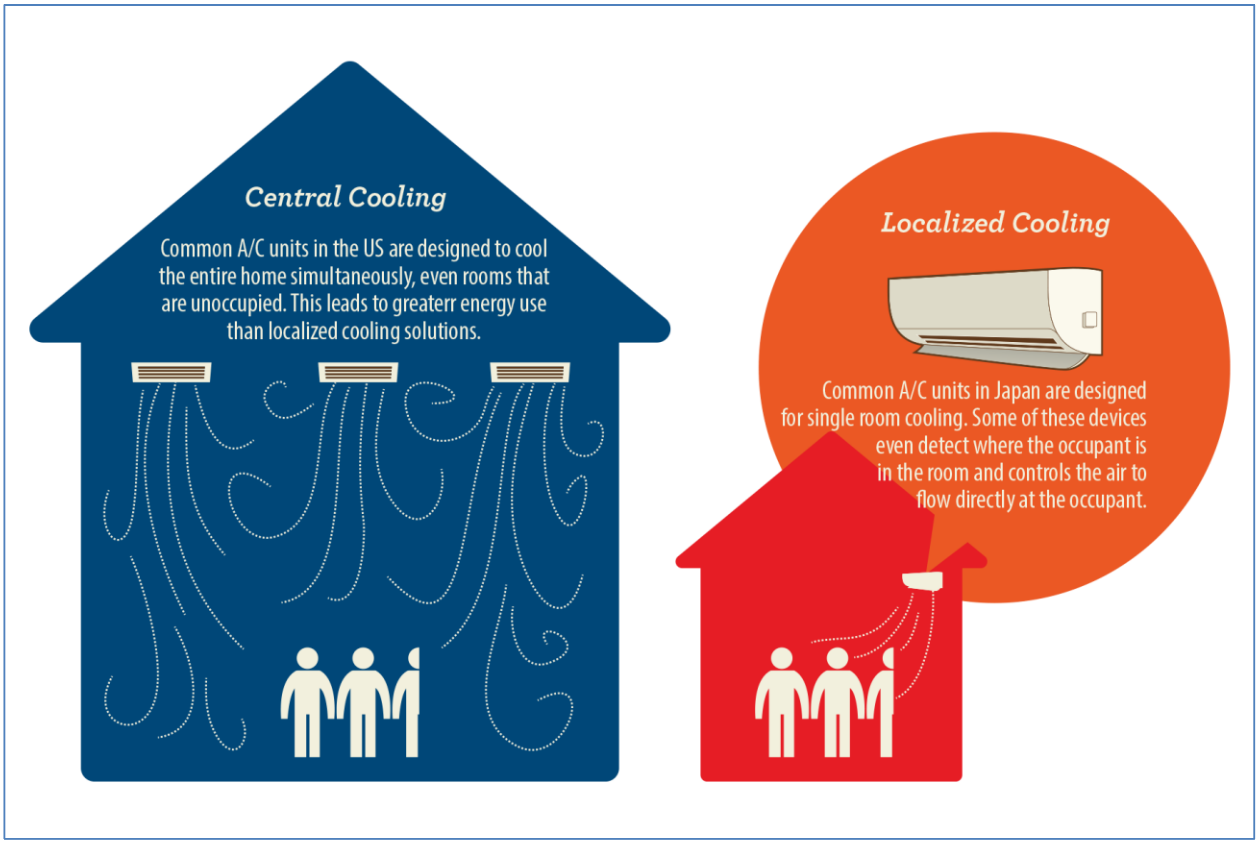
Figure 16. Historical trend in central AC ownership, United States and California



Sources: Table 3.1a, 3.2b, 3.14, 3.15, "1993 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/1993/. HC 5-7b, "1997 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/1997/. HC 1-7a, HC4-7a, "2001 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/2001/. HC 14.7, "2005 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/data/2005/. HC 7.11, "2009 RECS Survey Data", Residential Energy Consumption Survey. U.S. Energy Information Administration. Retrieved 1 July, 2014. http://www.eia.gov/consumption/residential/data/2009/.

There are many implications of this difference in equipment type, a full discussion of which is beyond the scope of this report, but several key observations are made. First, central AC typically cools the entire home, whereas room ACs deliver cooling to a particular room. This means that in general, central ACs cool more rooms than all the room ACs in a house combined, since the latter are rarely installed in every single room (e.g., bathrooms, kitchens). This difference is further exacerbated when comparing Japanese homes cooled with room ACs and American homes cooled with central ACs, since the latter tend to be much larger (i.e., three times larger). Figure 17 illustrates how these two patterns combined can contribute to higher cooling loads in American homes, relative to Japanese homes.

Figure 17. Graphical depiction of mechanical cooling strategy in American vs. Japanese homes



As the previous section demonstrates, there are substantial differences in the broader context in which the study locations are set. The geographic, climatic, and economic factors of Japan and the U.S., as well as Yokohama and Davis, differ, as do housing characteristics, energy use and costs, and thermal comfort norms and strategies. Despite these differences, the study locations have had some common experiences in their first few years of operation. Most notable among them, for this report, is that they share a similar challenge: how to urge occupants to consume less energy, particularly in cooling, in order to meet their ZNE goals.

IV. STUDY LOGISTICS

This section describes the project timeline, human subjects' protection activities, and language translation.

TIMELINE

Preparations for the study took place from March 2014 until July 2014. A series of kick-off meetings were held during the WCEC research team's visit to Japan April 7-11th. Subsequently, the team worked on the study design, IRB application, and development of data collection instruments.

For the E-Sogo portion of the study, recruitment, surveys and interviewing took place from July 2014 through September 2014. The resulting data was analyzed over the period from August through November 2014. For the West Village portion of the study, recruitment and survey implementation took place in August 2014. The resulting data was analyzed over the period from September through November 2014.

HUMAN SUBJECTS PROTECTION

UC Davis researchers engaged in research involving human subjects are required to have their study plan and materials reviewed by an Institutional Review Board (IRB). The job of the IRB is to ensure that human subjects and their sensitive information will be adequately protected throughout the course of the study and after. In compliance with this policy, the WCEC research team submitted an application, which included a draft of all study materials (e.g., a study protocol, informed consent forms, survey and interview protocols), to the IRB. The study was found to present minimal risk to research subjects and was deemed “Expedited”. Upon completion of the review, the research was approved to proceed.

TRANSLATION

The cross-national nature of this two-part study posed unique challenges both linguistically and, to a lesser extent, culturally. To facilitate in-depth research and communication, the WCEC research team hired a Japanese-speaking research assistant. This allowed the team to collect data from Japanese-only websites, input and interpret the survey data from E-Sogo, and create preliminary versions of the Japanese study materials (e.g., surveys, energy report, reminders).

On the three occasions that WCEC researchers traveled to Japan to work on this study, Tokyo Gas provided a professional interpreter to facilitate bi-partite meetings and interviews with respondents.

PART A: E-SOGO HOUSE

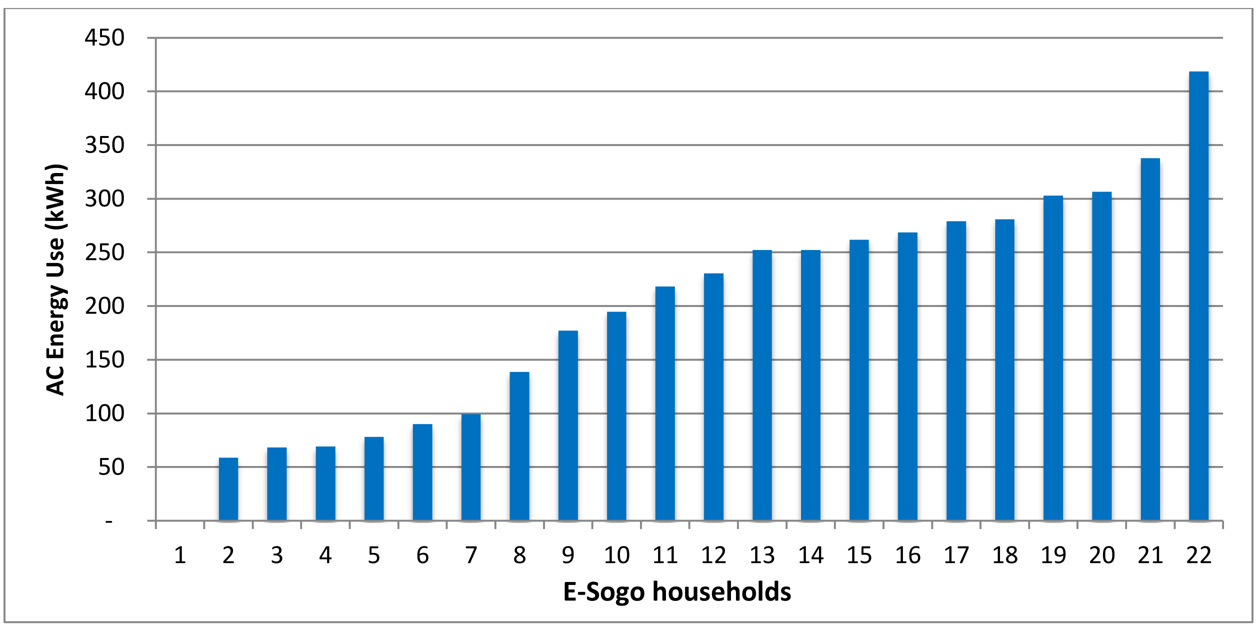
I. OVERVIEW

The E-Sogo apartment building was built in March 2012 as a zero-net energy demonstration project for Tokyo Gas, and the Japanese Government. It has 24 housing units, 22 of which are occupied by Tokyo Gas employee and their families, while the other two remain open for tours. E-Sogo is one of many company-sponsored apartment buildings in which Tokyo Gas employees live. Those invited to live at E-Sogo must grant permission to have their energy usage data monitored. They are asked to cooperate with on-going studies at E-Sogo, but participation is entirely voluntary.

The E-Sogo apartment building was designed to be energy efficient, with a state-of-the-art thermal envelope and specialized doors and windows designed to capture breezes for natural ventilation and cooling. The E-Sogo apartment building has a complex on-site energy system, including 140 solar photovoltaic (PV) panels, solar thermal panels for a solar-hot water system, cogenerating fuel cells that produce electricity as well as hot water, and conventional (high efficiency) natural gas boilers. The end use equipment was similarly sophisticated, including room ACs in the living rooms and bedrooms, radiant (hot water) floors, hookups for gas space heaters, domestic hot water from the fuel cells, solar-thermal system and gas-fired boiler, a “misty” sauna in each bathroom, which uses water heated locally, and electric-car charging stations. Any excess electricity generated is used in the neighboring conventional apartment building, also owned by Tokyo Gas Company.

Currently, the ZNE goal for E-Sogo has not quite been met. Tokyo Gas estimates that E-Sogo uses 30% less energy than comparable conventional buildings. However, to meet the ZNE goal, it is estimated that occupants must reduce total energy consumption by about an additional 10%. Numerous programs and experiments have been conducted to try to encourage energy conservation, but consumption remains higher than anticipated. Furthermore, consumption varies widely across households, especially for summertime AC usage, as the graph below illustrates. In fact, the highest AC user consumed 87% more than the median user in the summer of 2013 and 611% more than the lowest user (excluding the household with no AC consumption).

Figure 18. Total AC usage June-September 2013 (kWh)



It was agreed that the WCEC behavioral research team would design an intervention to try to encourage E-Sogo residents to reduce electricity consumption from AC usage, using several behavioral techniques, some of which had not been utilized in previous experiments at E-Sogo.

II. METHODOLOGY

In this section we describe the study design, recruitment method, data collection efforts and analytic approach.

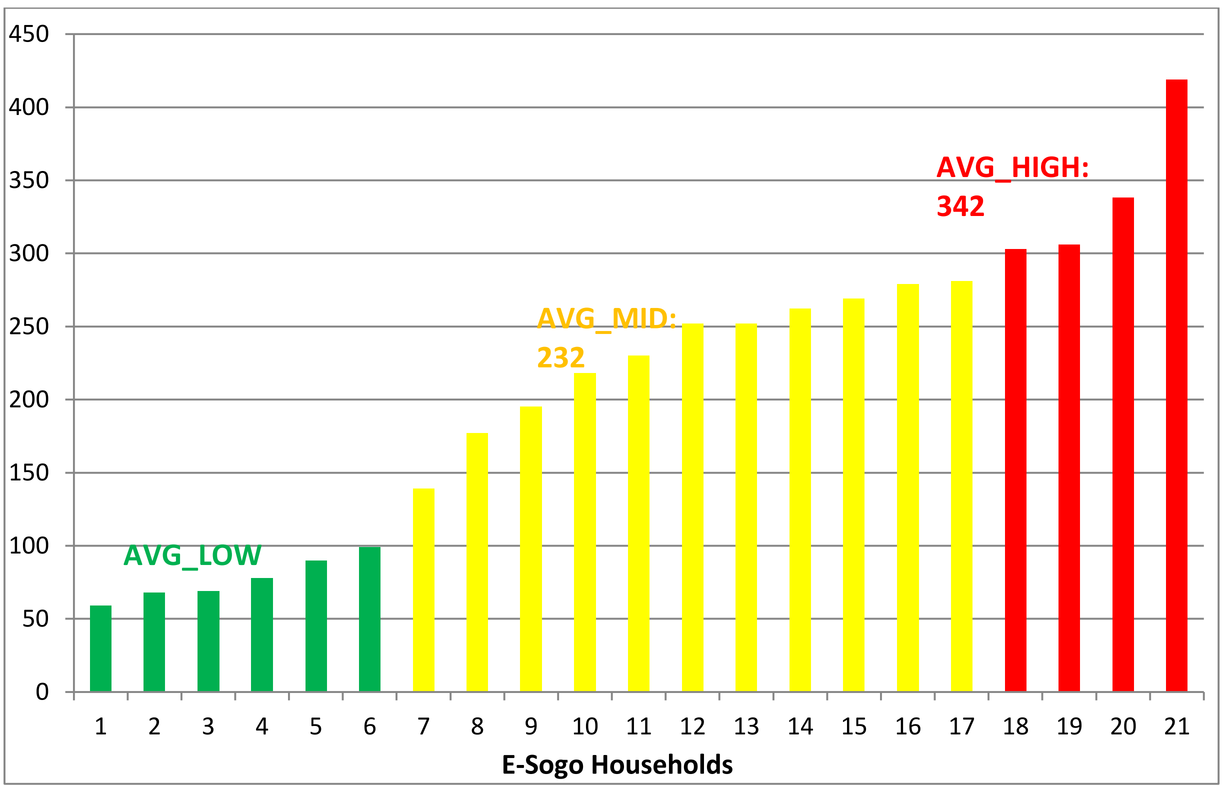
A. STUDY DESIGN

The E-Sogo study compares a treatment group's behavior and energy use, before and after the intervention, to measure the effect of the energy-saving intervention. This is a standard pre-/post-analysis.

GROUP ASSIGNMENT

Assignment to the treatment and non-treatment[24] groups was determined by energy use from AC in the summer of 2013. Each household was ranked from lowest to highest. The 15 households with the highest AC use were assigned to the treatment group (and noted as medium or high users as in Figure 19) and were all asked to participate in the passive cooling intervention. Although assignment was determined at the household level, adult household members themselves determined who among them would complete the survey, which in essence constituted participation in the intervention.

Figure 19. Total AC usage June-September 2013 (kWh), by low, medium and high users



The remaining 7 households with the lowest AC use were assigned to the non-treatment group (including one not shown in the above graph because it had zero energy use from AC), as it was

[24] The term "non-treatment group" is utilized in the E-Sogo context because the members do not constitute a control group, per se, as their behavior is not directly compared to that of the treatment group.

reasoned that there was very little potential energy savings by reducing their consumption further. The lowest AC users did not participate in the intervention, but instead were asked to participate in an interview to discuss why they use so little AC and how they cope with the summer heat and humidity. Results of those findings are presented in Section III.**Error! Reference source not found.** below.

DESCRIPTION OF INTERVENTION

The intervention involved several components including a pre-intervention survey, a mid-intervention reminder, a post-intervention interview, and a post-intervention survey.

Survey

The 10-page hardcopy pre-intervention surveys had multiple components, each with a different objective. The complete survey is included in Appendix C, but the following provides an overview and explanation.

The survey is prefaced with a description of the study and informed consent language to inform respondents of their rights and protections as study participants. Respondents were assured their responses would be anonymous to anyone outside the WCEC research team, as per the IRB application.

The first module of questions identified baseline AC usage patterns, and the motivations and strategies driving them. It included questions that target how, when and why residents use their AC in the summer in various rooms within their apartment.

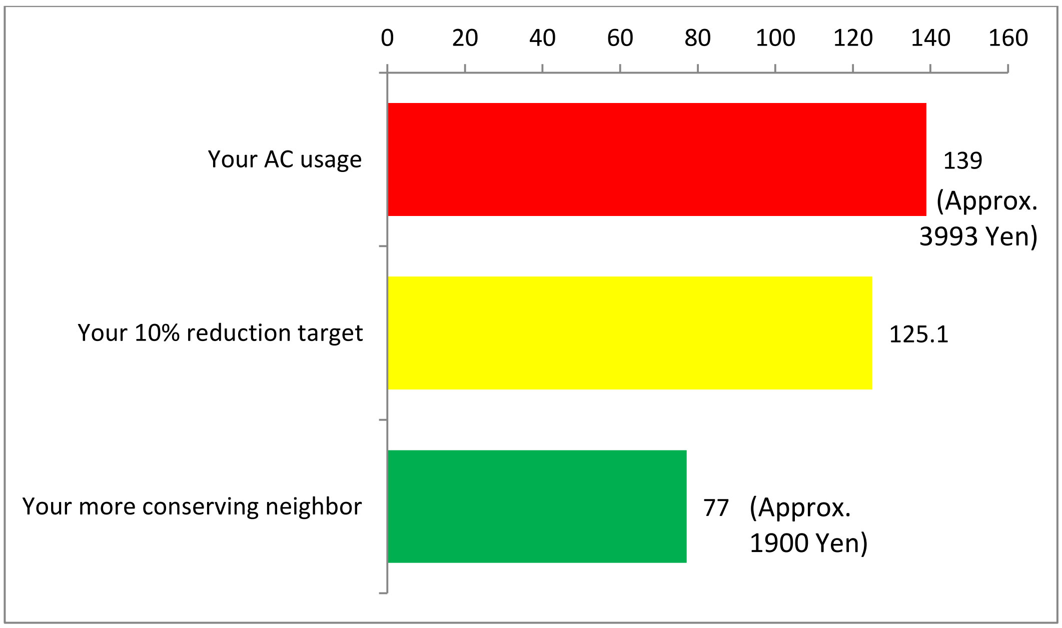
The second module contained a highly targeted energy report. Below is an example.

Figure 20. Sample energy report (in English)

Your Summer AC Energy Report

Here's how much energy you used running your AC last summer compared with your neighbors. Do you think you could achieve the 10% reduction target this year?

Summer (4 Months) AC Energy Usage in kwh



Note: Yen values in the graph are estimates only. (目安です)

Accept the challenge try to conserve energy this summer by reducing your AC usage by as much as 10% through behavior changes. This will help you save money and help fight global warming.

The bar representing the more conserving neighbor's AC use was always less than the respondent's, but was one of two values, depending on the respondent's AC use. The reference values were determined by splitting the treatment group into two tiers of AC use – high and medium (See Figure 19 above for the details). The high users' households were given the average of the medium users' AC use as a comparison, while the medium users' households were given the low users' (non-treatment group) AC use as a comparison.[25]

In the third module of the survey, respondents were asked if they would be willing to commit to trying a range of energy saving techniques to reduce AC usage during the study period (July 30 to September 22). Respondents were asked to report how often they typically utilize 14 different strategies to reduce AC use and stay cool in the summer, and to commit to increasing the frequency of each strategy listed. They are listed below.

<u>During the day</u>

- Closing windows and blinds as the outside temperature starts to rise in the morning.
- Trying not to turn on the AC unless it is uncomfortably hot. Turning it off as soon as it cools down outside.
- Turning the AC off and turning on a fan
- Cooling only rooms that are occupied and closing doors to rooms that are unoccupied
- Changing to lighter clothing
- Placing a cooling towel or pillow on the back of your neck
- Running errands (at cool shops) during the hottest part of the day
- Using the AC's "Cool" setting instead of "Dry" setting. [It was explained that the "Cool" setting uses less energy.]

<u>During the night</u>

- Running the AC for a short amount of time before bedtime, to dehumidify the air, with the door closed. Then shutting off the AC when going to bed.
- Turning the AC on when going to bed, but setting a timer to turn it off after a short amount of time.
- Turning the AC off and turn on a fan
- Using the AC's "Cool" setting instead of "Dry" setting. [It was explained that the "Cool" setting uses less energy.]
- Placing a cooling towel or pillow on the back of your neck
- Opening windows in the evening as soon as it becomes cooler outside than inside. Keeping the windows open all night.

The survey content was created by the WCEC research team, with input from the Tokyo Gas research staff. Once a final agreement was reached on the English version of the survey, WCEC research staff created a preliminary version of the Japanese version of the survey. Refinements to the survey language were made by Tokyo Gas staff and its advisors.

[25] See further discussion of the rationale behind this in a subsequent section on the Behavioral Principles Utilized.

Learning from Low AC Energy Users

In parallel with the interventions with the treatment group households, we aimed to learn from the low AC using households how they managed to get by with only very minimal use of the AC. In-person Interviews with members of the non-treatment group were conducted by Dr. Kristin Heinemeier, with the assistance of a professional interpreter. The interviews took place in the community room at E-Sogo during the days of July 29, 2014 and August 1, 2014. Each interview took approximately an hour, and six respondents participated in the interviews.

The low users' interviews focused on energy usage habits, values, priorities, motivations, strategies, and coping methods. The discussion was guided by questions outlined in an interview protocol, but deviated, as appropriate in accordance with a semi-structured interview style. A copy of the complete protocol is included in Appendix G.

Reminders

Halfway through the intervention, on August 25th, reminders were sent to treatment group members via hardcopy delivered to their mailboxes. These reminders served a dual purpose. First, it reminded the participants of the study, and kept it fresh in their minds. Second, it gave them feedback on the commitments they had made. Our intent was that it would be a concise format suitable for posting on a refrigerator, for example, as an ongoing reminder. The reminders highlighted the commitments that participants had promised to try for the month of August. A copy of the reminder is included in Appendix D.

Post Intervention Surveys

At the conclusion of the study period, members of the treatment group were asked to participate in an in-person interview with Dr. Sarah Outcault (through a professional interpreter). These interviews were held between September 22 and 25, 2014. The interviews focused on their experiences during the intervention, and motivations to engage in energy reducing behaviors and energy-related behaviors in general. The discussion was guided by questions outlined in an interview protocol, but deviated, as appropriate in accordance with a semi-structured interview style. A copy of the complete protocol is included in Appendix F.

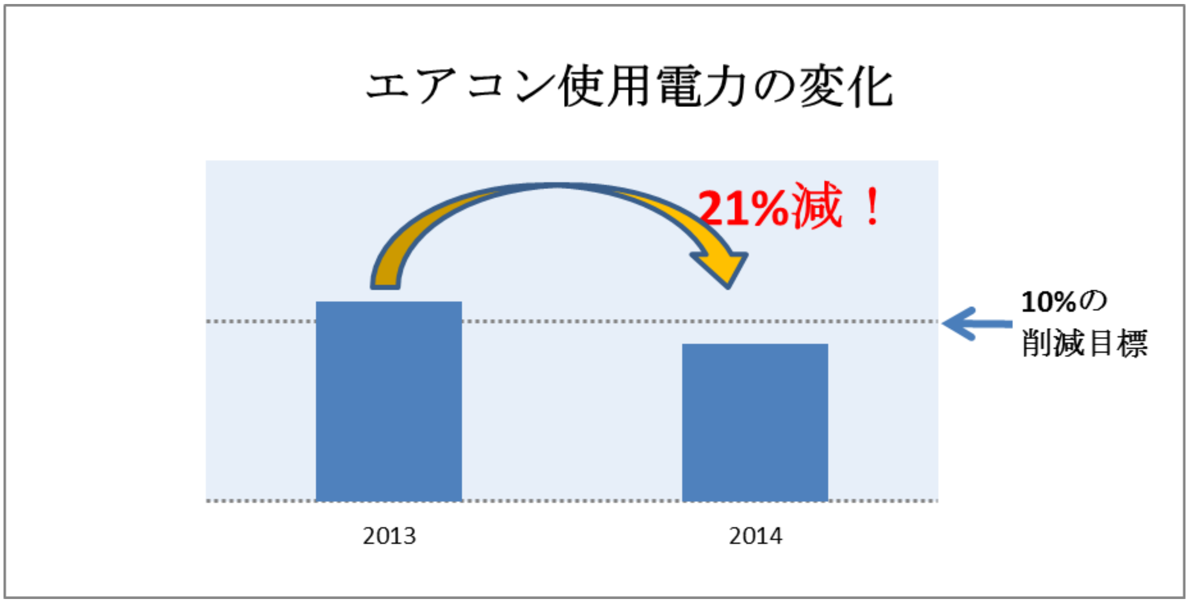
A post-intervention survey was implemented to: 1) measure the self-reported change in behavior due to the intervention, and 2) learn about respondents' experience during the intervention. The former was estimated by asking respondents whether they had increased the frequency with which they used each of the 14 strategies listed during the intervention period. The latter focused on identifying particular challenges respondents faced when trying to reduce AC usage, including comfort, convenience and coordination with other family members.

Respondents were also asked by how much they tried to reduce energy usage from AC, and how much they thought they actually were able to reduce energy usage from AC.

In addition, the post-intervention survey included another household-level energy report identifying the results of their energy-saving efforts. Energy reports were provided in a separate, sealed envelope, to ensure that responses to previous questions were not biased by viewing the results of their energy report.

The reports detailed how much the household reduced energy consumption from AC relative to: the previous year, the 10% target, and the average of all treatment group households, as illustrated in Figure 21.

Figure 21. Sample graph from post-intervention energy report



Respondents were asked to report how the results made them feel about their household's energy savings, and that of the treatment group members as a whole.

BEHAVIORAL PRINCIPLES UTILIZED

The study design leveraged several behavioral principles to encourage, both directly and indirectly, reductions in AC usage and utilization of passive cooling techniques.

The individualized energy report embedded in the initial survey was intended to leverage the power of social norms. Studies from the field of behavioral economics have found that describing the social norm can be a powerful motivator for behavioral change.[26] OPower has proven to be somewhat effective at

[26] For an overview, see http://www.ideas42.org/social-norms/ and http://www.ideas42.org/social-norms-and-energy-conservation/. For social norms to promote energy conservation, see for example Schultz, et al, 2007;

stimulating energy conservation by making social comparisons of energy use among neighbors, yielding energy savings of 1.1-2.8 percent.[27]

However, making the right social comparison is important. Describing the cases that illustrate the extremes (such as the lowest energy users at E-Sogo) is likely to be less effective. This is in part because the gap is too great, but also because individuals respond more favorably to information that is highly relevant to themselves.[28] Extremely low AC users are, by definition, very different than other E-Sogo residents, and thus their behavior (and energy use) was unlikely to motivate higher AC users. Thus, WCEC researchers concluded that comparing each household's AC use with the average of the adjacent tier's AC use would motivate, rather than alienate, respondents to save energy.

Commitments have been shown to be effective in stimulating behavioral change.[29] Thus, the survey asked respondents to make a commitment to increase the frequency with which they utilized various lower energy intensity strategies to stay cool during the summer, in an effort to try to reduce energy use from AC by 10%. The subsequent reminder sent out during the middle of the intervention recalled the commitment they made to reinforce it.

Reminders are known to be potentially powerful behavioral levers, as they help to overcome the problem of limited attention.[30] For respondents who were not actively engaged with the study on a daily basis, their commitment and the study could have be easily forgotten. Thus, the mid-intervention reminder was intended to draw respondents' attention back to the study. Furthermore, residents were requested to hang the reminder in a very visible place, such as on the refrigerator, to ensure that the reminders had a sustained impact.

To motivate behavioral change, the study appealed to the intrinsic motivations to save energy. Respondents were urged to reduce AC use and conserve energy to "(save money,) conserve energy and help fight global warming". The only extrinsic motivation leveraged in the study was the indirect benefit of saving money on one's electricity bill by saving energy.

B. RECRUITMENT

Recruitment for the pre-intervention and post-intervention surveys was conducted by Tokyo Gas research staff, on behalf of the WCEC research team. The approach was agreed upon because E-Sogo residents are familiar with Tokyo Gas researchers, and it is more convenient for them to have a single point of contact for all ongoing research at E-Sogo.

Prior to the study, treatment group households were contacted by Tokyo Gas research staff to inform them of the upcoming study by WCEC. Hard copies of the survey forms were hand-delivered to each household. (A similar approach was used to recruit respondents for the post-intervention survey.) The

[27] Allcott, 2011.
[28] See Lehrer, D., J. Vasudev and S. Kaam, 2014.
[29] See Ashraf, N., D. Karlan, et al. (2006); Thaler and Benartzi, 2004.
[30] For an overview, see http://www.ideas42.org/limited-attention/ and http://www.ideas42.org/procrastination/.

cover sheet of the survey requested that it be completed by the person who is primarily in charge of controlling the AC in the household (especially the living room). It was noted that only adult members of the household were eligible to participate. A request was also made that the same person makes him or herself available to complete the post-intervention survey.

For interviews with the adult members of both the low AC user group households and the treatment group households after the intervention, Tokyo Gas contacted occupants via email and phone to request their participation in an interview. A copy of the informed consent document was provided to respondents in advance of the interview, and written consent was obtained from interview participants at the beginning of each interview.

No incentives were offered to participate in any portion of the E-Sogo study.

C. DATA COLLECTION

Pre-intervention surveys (in Japanese) were sent by Tokyo Gas to treatment group members on July 30th via hardcopy delivered to their apartment mailbox. Respondents were requested to return the surveys within 1 week. Respondents returned completed surveys in sealed envelopes to a designated spot in the communal area of E-Sogo. Completed surveys from all 15 treatment group households (100%) were collected by Tokyo Gas staff throughout the month of August. To protect respondents' anonymity, a non-staff member of the Tokyo Gas team (i.e., an American student intern) opened each of the sealed envelopes containing the completed surveys and scanned and emailed them to the WCEC researchers. Later, the original hard copies were delivered to the WCEC. Data from the hard copies were input into Excel by WCEC research staff. None of the collected data were retained by staff or non-staff members of the Tokyo Gas team.

Sixty percent of respondents were female. The median age of respondents was 39. Three of them lived in a 2-person household, 7 in a 3-person household, 4 in a 4-person household, and 1 in a 5-person household. Twelve out of the 15 treatment group households contained children. Of those, three had at least one child under 6 years old, five had school age children between 6 and 18, and two had children over 18 years old. The remaining two households with children did not report their ages. In ten of the households, at least one person typically stayed home during the weekdays.

It is important to note that since assignment to the treatment group was determined at the household level, but only a single adult household members participation in the intervention, the data collected take several forms: individual-level responses and household-level responses submitted by the respondent on behalf of the family, as well as household-level energy data generated by the sensor equipment.

Post-intervention interviews were conducted with members of the treatment group from September 22-25, 2014. The interviews were conducted in person in Japanese by Dr. Sarah Outcault, through a professional interpreter. The interviews took place in the communal room at E-Sogo. Each interview took approximately 1 hour.

Twelve respondents participated in the interviews from among the 15 treatment group households (80% response). However, requests to participate in the interviews were made at the household level, and in numerous cases the interviewee was different than the household member who had completed the pre-intervention survey. This compromised our data collection about the respondents' experience during the intervention, but still yielded valuable findings.

The English portion of the interviews was transcribed by a WCEC researcher.

Post-intervention surveys were sent by Tokyo Gas to treatment group members on October 9th via hardcopy delivered to their apartment mailbox. Respondents hand-delivered completed survey forms in sealed envelopes to a designated spot in the communal area of E-Sogo. Completed surveys from 11 (out of 15, or 73%, corresponding to an attrition rate of 27% from the baseline survey) treatment group households were collected by Tokyo Gas staff between October 21st and November 4th. Tokyo Gas research staff scanned the completed surveys and emailed them to the WCEC researchers. Data from the hard copies were input into Excel by WCEC research staff.

Again, since assignment to the treatment group was determined at the household level, but only a single adult household members participation in the intervention, the data collected includes individual-level responses and household-level responses submitted by the respondent.

D. ANALYTIC APPROACH

The impact of the intervention was assessed along two dimensions: behavioral change and energy savings. The former relies on self-reported frequency of alternative cooling strategies utilized before and after the intervention. The impact such actions had on energy usage from air conditioning units is estimated using statistical analysis techniques. The latter relies on data generated by the monitoring devices installed in the E-Sogo apartments as part of the ongoing research efforts there. With permission from the occupants, such data was already being collected by Tokyo Gas as a matter of course prior to this study. The precise methods used to estimate energy savings are described in Section III.C1.2 below.

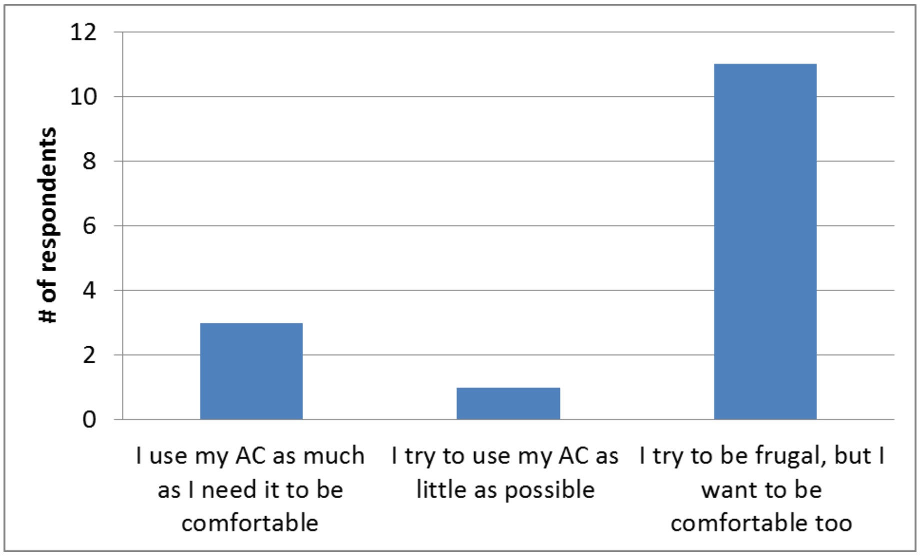
III. KEY FINDINGS

In this section the key findings are presented. The discussion is organized in four sections: baseline activity, willingness to change, effects of the intervention, and findings from the low AC users. The intervention effects analysis covers both the behavioral changes reported and the energy savings observed.

A. BASELINE ACTIVITY

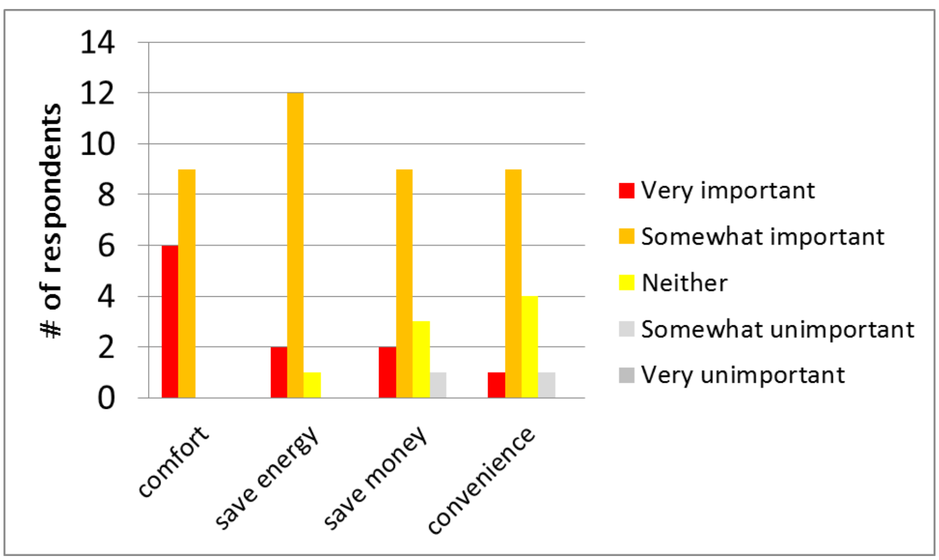
As a starting point, it was important to understand how and why respondents manage the summer heat, and in particular how they use their air conditioners and other cooling strategies. When asked about the reasons for using AC, most respondents (11 out of 15) reported striking a balance between frugality and comfort, as the figure below illustrates.

Figure 22. Reasons for using air conditioner (N=15)



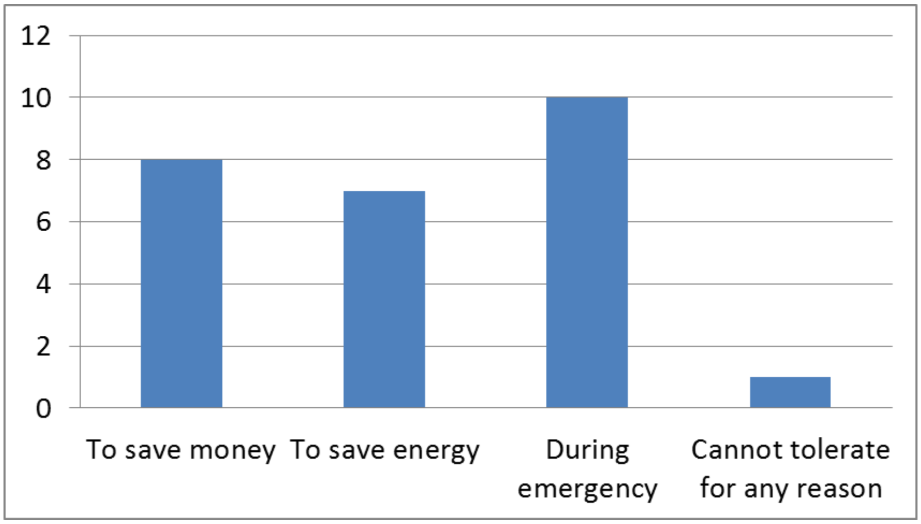
When asked about the importance of various goals when cooling their apartment, respondents generally agreed that comfort, saving energy, saving money and convenience were all important.

Figure 23. Importance of goals when cooling apartment (N=15)



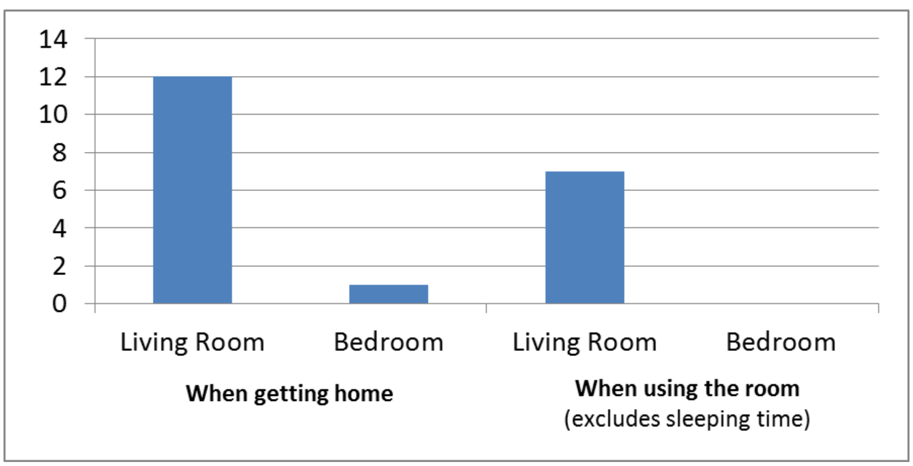
However, when asked under which conditions they would actually be willing to tolerate higher indoor temperatures, only half said they would do so to save money or energy. Slightly more were willing to sacrifice comfort during an earthquake or other emergency, but 5 out of 15 were not, even under those dire circumstances.

Figure 24. Conditions under which respondents can tolerate a relatively higher temperature (N=15)



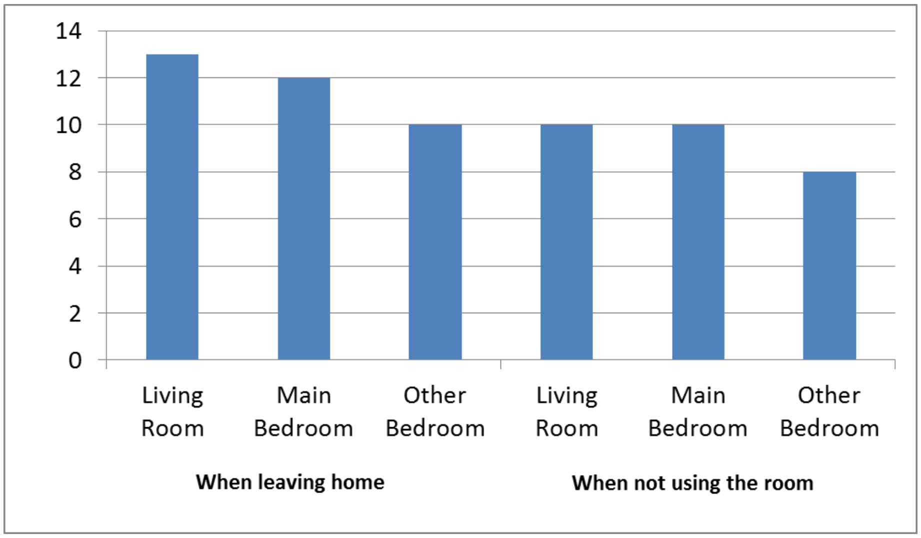
Next, respondents were asked detailed questions about when and how they use their ACs. Twelve out of 15 respondents reported routinely turned the living room AC on when returning home, and 7 did so when using the room. Neither was commonly the case for the bedroom AC, when bedtime was excluded. The underlying assumption with these questions, which was confirmed through a different set of questions (and illustrated in Figure 25 below), was that ACs were not otherwise on, that is, when the room or home was unoccupied. While in Japan this is not a remarkable finding, it is in notable contrast to how Americans typically cool their homes, especially given the prevalence of central air conditioning.

Figure 25. Number of respondents who turn AC on at given times, by room (N=15)



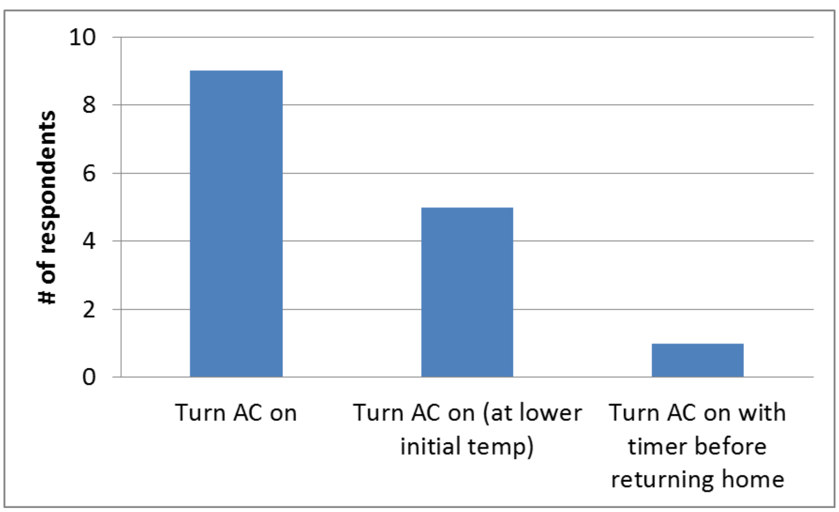
As Figure 26 below shows, even relatively high AC use residents of E-Sogo actively manage their AC use. Shutting ACs completely off when leaving the home was nearly universal. Nine or ten out of 15 shut them off even when no longer using a particular room. Further evidence of this relatively active cooling strategy is the fact that 13 out of 15 E-Sogo residents reported closing the doors to unoccupied rooms when cooling occupied rooms. Again, this is in marked contrast to the typical cooling strategy employed in West Village, as is described in Part B of this report.

Figure 26. Number of respondents who turn AC off at given times, by room (N=15)



Another way to learn how resident use their AC to explore what they do in specific situations (as opposed to the conditions under which they turn the AC on or off). For example, upon returning home, nine out of 15 reported that they turn on their AC.[31] Five do so, and set the temperature lower than the normal setting for an initial period to try to achieve cooling faster. One respondent reported setting the timer to have the AC turn on and begin cooling before the expected time of return. Note that all 15 respondents reported that they turn their AC on when returning home, in one manner or another.

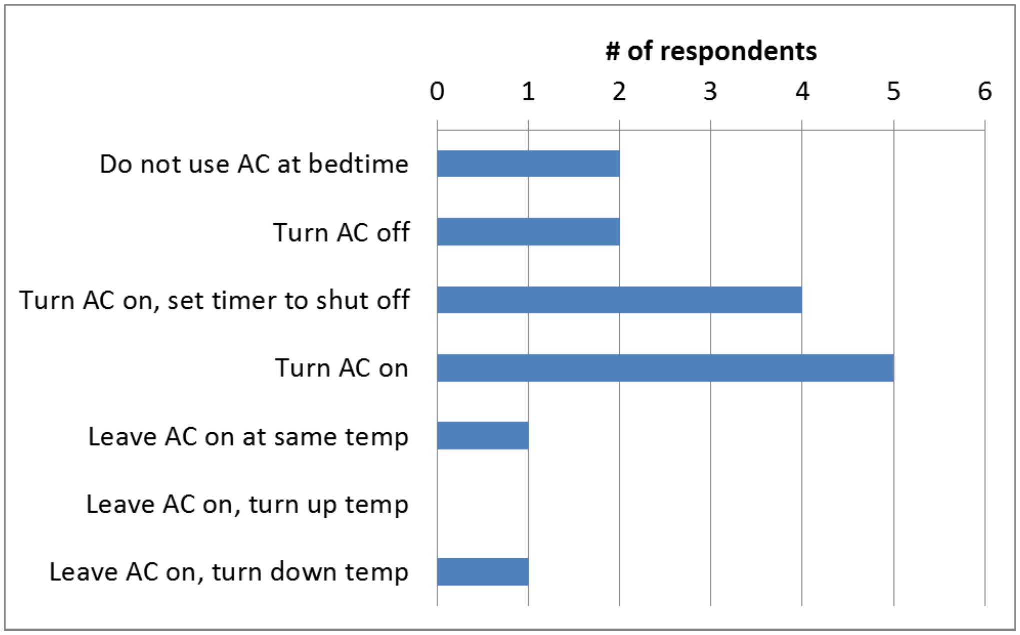
Figure 27. AC action upon returning home (N=15)



[31] This statistic is close, but not identical, to the one in a previous graph because the question was asked multiple times in slightly different ways.

By contrast, AC use upon going to bed is more varied. Seven different scenarios were posed, and of those, six reportedly described how respondents utilized their AC while sleeping. Eight out of 15 said they did not use AC after going to bed (including having it shut off by timer). The other seven reported using the AC throughout the night while sleeping, although interestingly only two of these households were among the highest AC energy users at E-Sogo. This illustrates that even among treatment group members there was a lot of variation in baseline AC use patterns, which is evident in the consumption levels, as shown in Figure 19 above.

Figure 28. AC action when going to bed (N=15)



The median temperature setting respondents reported was 26°C (79°F) on the living room AC and 27°C (81°F) on the main bedroom AC.

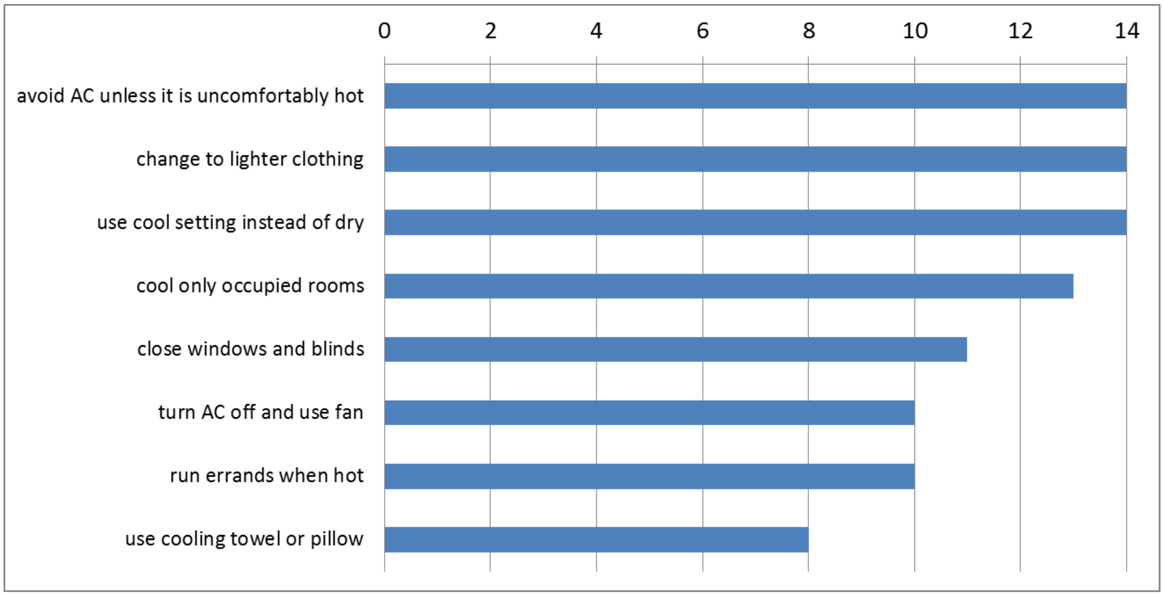
B. WILLINGNESS TO CHANGE

One respondent abstained from the section of the survey requesting a commitment to try alternative cooling strategies. Thus, in this section, the results are presented for the 14 respondents who did provide responses.

One hundred percent of these respondents agreed to commit to increasing the frequency with which they utilized at least one of the 14 lower energy-intensity cooling strategies suggested. On average, respondents committed to trying more frequently 6.7 out of 8 daytime strategies and 4.6 out of 6 nighttime strategies (for a total of 11.3 out of 14).

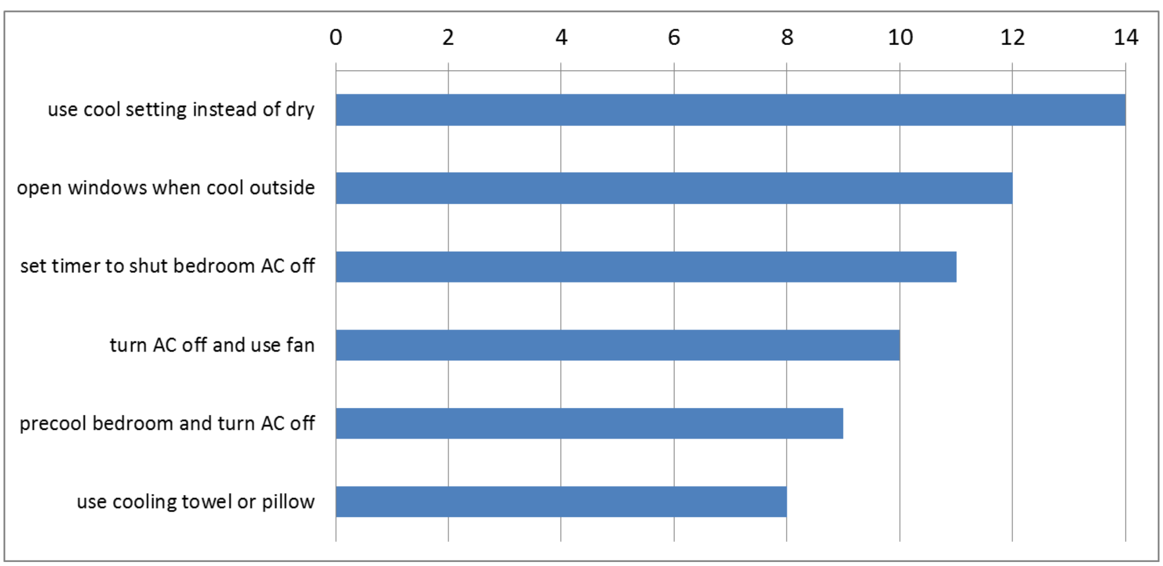
Between 8 and 14 out of 14 respondents committed to trying each of the daytime strategies more often. Everyone agreed to try avoiding AC, wearing lighter clothing and using the “cool” setting more frequently (as opposed to the "dry" setting, which many occupants believe is a lower energy use setting, although the dehumidification effect actually uses more energy). Using a cooling towel or pillow, running errands when it's hot and using a fan received the fewest commitments.

Figure 29. Number of respondents who committed to increase frequency of daytime cooling strategy (N=14)



Between 8 and 14 out of 14 respondents committed to trying each of the nighttime strategies more often. Everyone agreed to try using the "cool" setting more frequently. Using a cooling towel or pillow and precooling the bedroom then shutting off the AC at night received the fewest commitments.

Figure 30. Number of respondents who committed to increase frequency of nighttime cooling strategy (N=14)



Further analysis was conducted to investigate possible explanations for the differences in commitments. To do this, sub-groups were defined based on four characteristics reported in the baseline survey, which, based on the survey and interview findings, seemed plausible drivers of differences in behaviors and attitudes. Thus, we compared households with high (n= 3) and medium (n=11) energy consumption from AC (defined using the categories identified in Figure 19); households with (n=9) and without (n=5) someone home during the day; households with (n=11) and without (n=3) children; and households with the highest use of the recommended strategies prior to the intervention (n=3), and those with less frequent prior use (n=11). "Very frequent" prior use was defined as having used 10 or more strategies used 75 or 100% of the time.[32]

As Table 2 shows, there do not appear to be significant differences in the number of strategies to which households committed based on prior AC consumption levels or daytime home occupancy. However, on average, households without children committed to two fewer strategies than those with children. As is shown in the later discussion of behavior change, although interview respondents reported that their children made it difficult to adopt alternative cooling strategies with more frequency the results indicate that households with children were able to increase strategy use and yield higher energy savings compared to (their admittedly small number of) childless counterparts. Interestingly, households with relatively higher prior use of the efficient strategies committed to, on average, two fewer strategies than those with lower prior use.

Table 2. Comparison of commitment level by sub-group

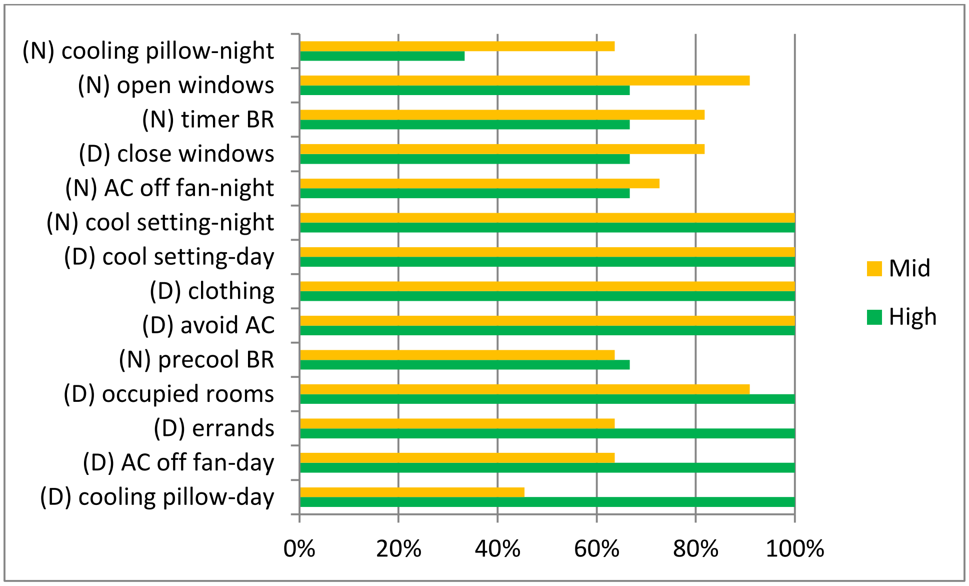
Category	Average # of strategies committed to increasing
High prior AC consumption	11.7
Medium prior AC consumption	11.2
Someone home during day	11.3
Nobody home during day	11.2
Has children	11.7
Doesn't have children	9.7
High prior strategy frequency	9.7
Low prior strategy frequency	11.7

In addition to the number of strategies each sub-group committed to, we also explored the types of strategies they committed to in order to determine whether there were apparent differences that may be associated with various sub-group characteristics. Again, caution is advised when reviewing these results since the sub-group sizes are small and unbalanced. However, though imperfect, they do shed some light on who is most likely to adopt particular strategies, and who is not.

[32] This cutoff was determined by patterns in the data, but is completely subjective. A different definition would yield a different categorization. However, cutoff was chosen because it was the only place where a discrete difference was observed.

Error! Reference source not found. Figure 31 illustrates the patterns by prior AC energy consumption. One hundred percent of both groups committed to using the cool setting, wearing light clothing and avoiding AC when possible, as was true of the respondents as a whole. High AC users were more likely to commit to using cooling pillows and fans during the day, or running errands when it was hot. By contrast, mid-level AC users were more likely to commit to using a cooling pillow or opening the windows at night.

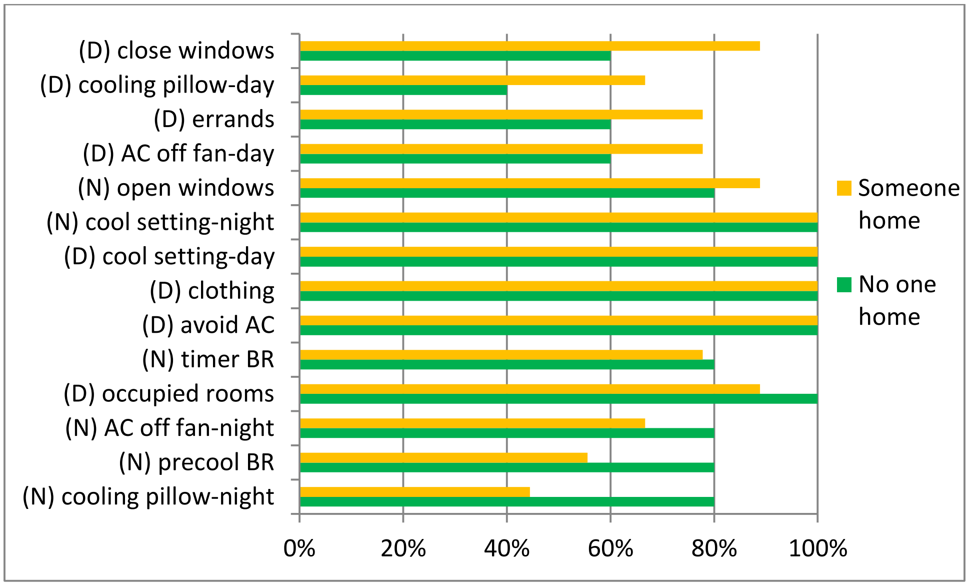
Figure 31. Percent of respondent who committed to individual strategies, by AC energy consumption



Note: "BR" is shorthand for bedroom.

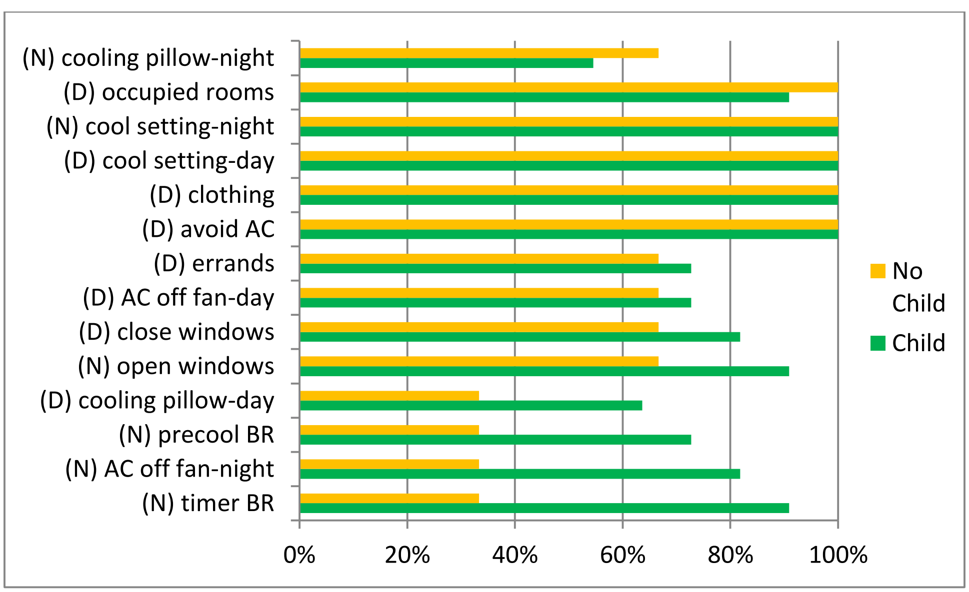
Error! Reference source not found. Figure 32 illustrates the patterns by daytime occupancy. Households with someone home during the day were more likely to commit to daytime strategies (e.g., closing windows, using cooling pillows, running errands), while households that were unoccupied during the day were more likely to commit to nighttime strategies (e.g., using cooling pillows, pre-cooling the bedrooms). This makes sense, given that the latter group would have a difficult time implementing many of the daytime strategies. Although there is nothing precluding individuals who are home during the day from adopting nighttime strategies, perhaps respondents (consciously or unconsciously) opt to commit only to a subset of activities, and prioritize accordingly. If so, this would suggest that respondents view these as substitutes for one another.

Figure 32. Percent of respondent who committed to individual strategies, by daytime occupancy



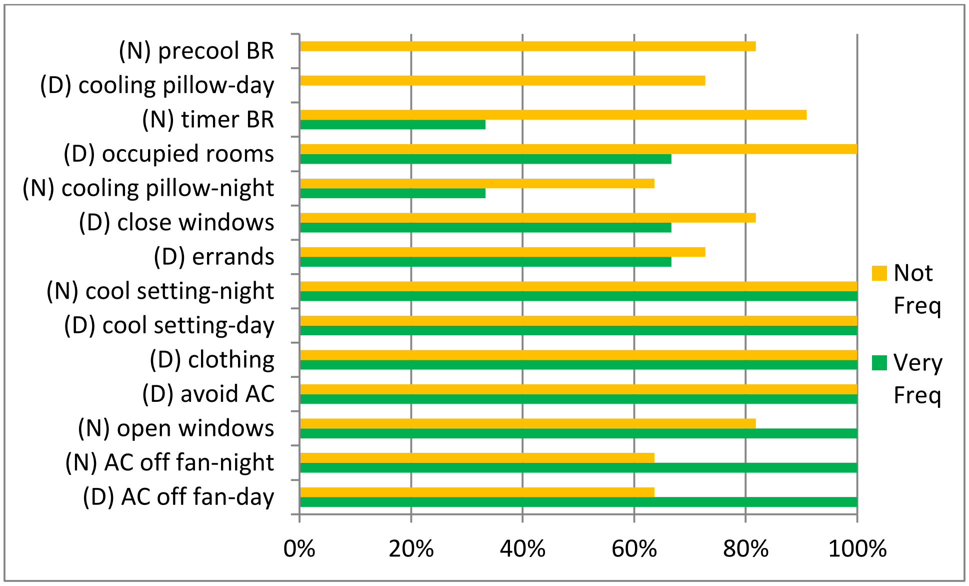
In general respondents with children were much more likely to commit to the strategies requested, as shown in Figure 33. This was particularly true for nighttime cooling options, which involved shutting off the AC. The interview findings can shed some light on this pattern. Although many respondents mentioned concern for their children's health due to the heat, they also mentioned that having their sleep interrupted due to the heat was unacceptable. Perhaps the concern for lack of sleep is particularly true of respondents without children. Again, though, with only 3 households having no children, caution should be taken in over-interpreting these results.

Figure 33. Percent of respondent who committed to individual strategies, by family structure



Finally, households with the highest prior use of strategies were compared with the others. The former were more likely to commit to the strategies overall, and especially for fan use during the day and night. Households that utilized the strategies relatively less often at the baseline were more likely to commit to precooling the bedroom, using a cooling pillow during the day, and setting a timer to shut the AC off at night. No respondents with very high prior use committed to the former two strategies, but since there are only 3 such households, caution is urged in drawing conclusions on this alone.

Figure 34. Percent of respondent who committed to individual strategies, by prior strategy use level



In general, respondents reported a fairly high degree of willingness to change (i.e., try the various cooling strategies with greater frequency). However, as the next section reveals, their ability to do so was somewhat limited.

C. EFFECTS OF INTERVENTION

Effects of the intervention were assessed through self-reported behavior change (through the survey and interviews) and energy savings analysis.

1. BEHAVIOR CHANGE

Survey results

In the post-intervention survey respondents were asked to report on various ways they might have used their ACs during the study period, including the frequency of those actions and the comfort level they yielded. The table below presents an overview of some of the findings. Note that most respondents reported no change in the frequency with which they took the specified energy saving actions (i.e., turning their AC off, down or to “cool” mode). This is not particularly surprising as the intervention emphasized the list of 14 strategies more than these ones (except for the “cool” mode recommendation which was included on the list of encouraged strategies). Furthermore, the baseline survey revealed that respondents already routinely turned their AC off when leaving for the day. As later results will show, however, encouraging respondents to turn their AC off when going to bed was much more difficult.

Table 3. Energy saving AC actions taken during intervention (N=11)

		Q1: leave for the day			Q2: went to bed			Q3: get out of bed		
		Living Room	Main Bedroom	Other Bedroom	Living Room	Main Bedroom	Other Bedroom	Living Room	Main Bedroom	Other Bedroom
		N	N	N	N	N	N	N	N	N
Turn the AC OFF.		10	10	7	8	4	5	4	7	5
Turn the AC temperature to a warmer setting.		1	0	0	1	1	0	1	0	0
Use the “Cool” setting on your remote control instead of “Dry” setting.					2	4	2	5	2	1
None of these.		0	1	3	0	1	4	1	2	5
On a daily basis, how often did you do the above actions that you checked? (Circle one):	100%	5	6	5	6	5	3	2	6	3
	75%	5	3	2	4	3	3	7	3	2
	50%	1	1	1	1	1	1	0	0	1
	25%	0	0	0	0	1	0	1	0	0
Did you find using the above energy saving action comfortable or uncomfortable? (Circle one):	Very Comfortable	0	0	0	1	0	0	1	0	0
	Comfortable	3	5	2	3	4	1	4	3	1
	Somewhat Comfortable	2	2	2	3	2	3	2	3	3
	Somewhat Uncomfortable	3	3	3	4	4	3	3	3	2
	Uncomfortable	2	0	1	0	0	0	0	0	0
	Very Uncomfortable	0	0	0	0	0	0	0	0	0
Was this an action you committed to try in order to reduce your energy usage by 10%? (Circle one):	Yes	9	8	7	10	9	7	9	8	6
	No	1	2	1	0	1	0	0	1	0
Was that more or less often than you did in July?	More Often	1	0	1	1	0	1	2	1	1
	Less Often	2	1	1	1	0	0	2	1	2
	Same	8	9	6	9	10	6	6	7	3

The post-intervention survey also asked respondents to report on their utilization of the 14 different cooling strategies promoted during the intervention. Only 50% of respondents (n=5) increased the frequency of at least one passive cooling technique during the experiment, the remainder estimated they had used all the strategies with the same frequency or less than before the intervention.[33] Among those that had increased the frequency of use of at least one strategy, they did so with 4.4 techniques, on average, with the actual number ranging from 1 to 9. On average, each technique was used more often by only 1-2 respondents.

[33] One respondent abstained from providing answers to the questions regarding the commitment requested during the intervention.

The table below presents an overview of the frequency with which respondents tried the specific daytime strategies, whether frequency increased, whether the action was one the respondent committed to (based on respondent recall) and the comfort level each strategy yielded.

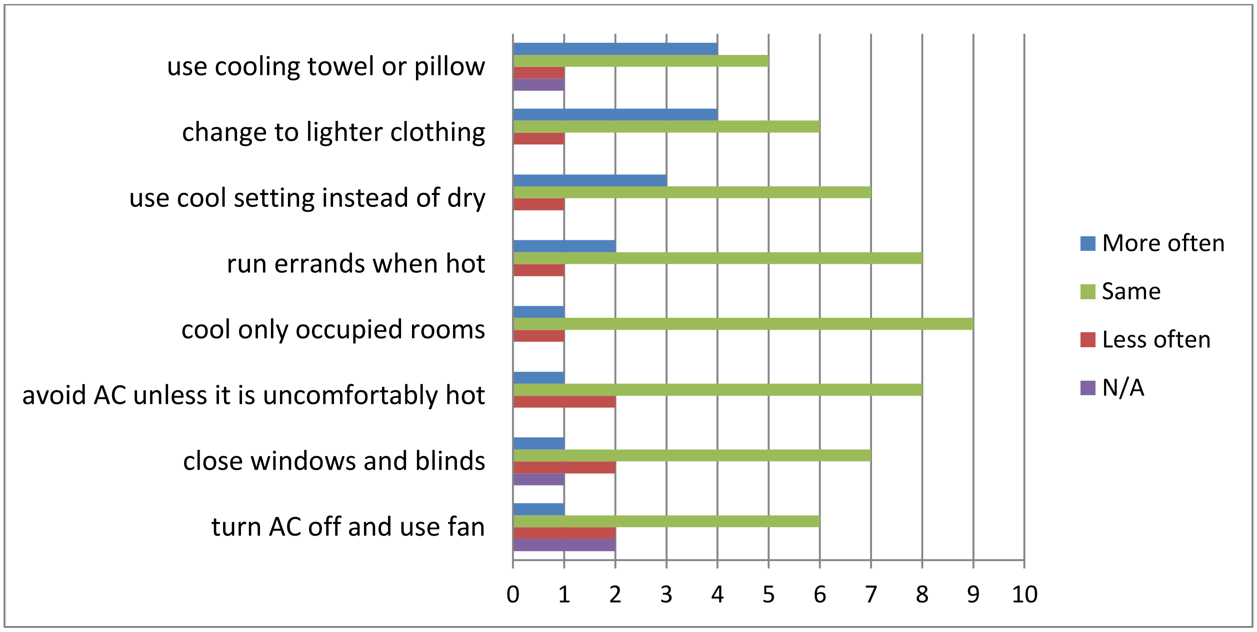
Table 4. Daytime energy saving cooling strategies utilized during intervention (N=11)

		4. Turned AC off and turned on a fan	5. Closed windows and blinds as the outside temperature started to rise in the morning	6. Tried not to turn on the AC unless it was uncomfortably hot. Turned the AC off as soon as it cooled down outside	7. Cooled only rooms that were occupied and closed doors to rooms that were unoccupied	8. Changed to lighter clothing	9. Placed a cooling towel or pillow on the back of your neck	10. Ran errands (at cool shops) during the hottest part of the day	11. Used AC's "Cool" setting instead of "Dry" setting. The "Cool" setting uses less energy
On a daily basis, how often did you do the above action?	100%	0	1	1	8	8	0	1	5
	75%	3	4	5	1	3	4	2	4
	50%	4	3	3	1	0	2	3	2
	25%	1	2	1	1	0	2	4	0
	0%	3	1	1	0	0	3	1	0
Was that more or less often than you did in July?	More Often	1	1	1	1	4	4	2	3
	Less Often	2	2	2	1	1	1	1	1
	Same	6	7	8	9	6	5	8	7
Did you find using the above energy saving action comfortable or uncomfortable?	Very Comfortable	0	0	0	0	0	0	1	0
	Comfortable	3	2	6	8	7	5	7	7
	Somewhat	4	6	3	1	3	3	1	3
	Somewhat	1	2	1	2	1	1	2	1
	Uncomfortable	0	0	0	0	0	0	0	0
	Very	1	0	1	0	0	1	0	0
Was this an action you committed to try in order to reduce your energy usage by 10%?	Yes	7	8	8	10	8	8	9	10
	No	2	2	2	0	0	1	1	0

Despite high levels of commitment to try various daytime cooling strategies more often during the intervention, less than half of all respondents reported having actually achieved this for any of the strategies, as shown in Figure 35. In the interviews, many respondents complained that August had been very hot, and they had not been able to follow through on their commitments. In addition, many had trouble recalling their commitments, or even the study itself. Thus, it is not surprising that few respondents actually changed their behavior as a result of the intervention. Finally, it is worth noting that self-reported behavior change can be flawed. Respondents may feel compelled to report the result they think researchers want to hear, or the social norms of modesty may compel them to underestimate their efforts. The energy savings yielded by the intervention suggests that the latter may have been a factor.

However, four respondents (out of 10) reported using a cooling towel or pillow and wearing lighter clothing "more often" than before the intervention, while only one did for four of the other strategies. It is notable that it was the personal cooling strategies that attracted the most behavior change. Several interview respondents noting having forgotten about cooling pillows. It is very possible that the baseline survey reminded them of this option for summer cooling. Furthermore, there have been significant improvements in the products available for personal cooling, including cooling pillows and specially designed clothing. One respondent complained in the interview that the cooling pillows he had tried in the past had left his shirt wet and him uncomfortable. It is possible other respondents had had similar experiences, but when reminded of the cooling pillow (and clothing) option, decided to give the new technology a chance. Further research would be required to verify this interpretation, however.

Figure 35. Number of respondents who reported changing frequency of daytime strategies during the intervention (N=9-11)



In the vast majority of cases, the few respondents who were able to increase the frequency of use of particular strategies were the individuals who had committed to doing so, as Table 5 reveals. Thus, it appears that the commitment device was effective, to a certain degree. In general, it increased the likelihood that an individual would carry out the specified action.

Table 5. Change in frequency of daytime strategy use, by prior commitment

	4. Turned AC off and turned on a fan		5. Closed windows and blinds as the outside temperature started to rise in the morning		6. Tried not to turn on the AC unless it was uncomfortably hot. Turned the AC off as soon as it cooled down outside		7. Cooled only rooms that were occupied and closed doors to rooms that were unoccupied		8. Changed to lighter clothing		9. Placed a cooling towel or pillow on the back of your neck		10. Ran errands (at cool shops) during the hottest part of the day		11. Used AC's "Cool" setting instead of "Dry" setting. The "Cool" setting uses less energy	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
More	1	0	1	0	0	1	1	0	4	0	4	0	2	0	3	0
Less	2	0	2	0	2	0	1	0	1	0	1	0	1	0	1	0
Same	4	1	5	1	6	1	8	0	4	0	3	1	6	1	6	0
NA	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0

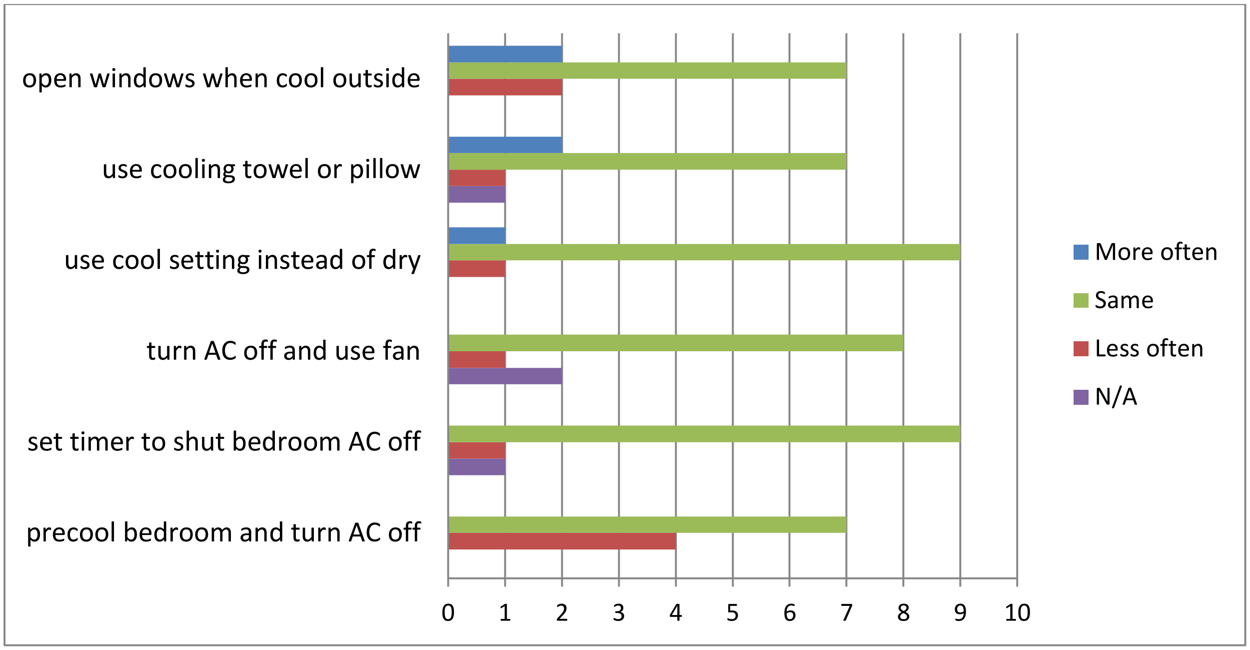
The table below presents an overview of the frequency with which respondents tried the *nighttime* strategies, whether frequency increased, whether the action was one the respondent committed to (based on respondent recall) and the comfort level each strategy yielded.

Table 6. Nighttime energy saving cooling strategies utilized during intervention (N=11)

		12. Ran the AC about for a short amount of time before bedtime, to dehumidify the air, with the door closed. Then shut off the AC when going to bed	13. Turned AC on when going to bed, but set timer to turn it off after a short amount of time	14. Turned AC off and turned on a fan	15. Used AC's "Cool" setting instead of "Dry" setting. The "Cool" setting uses less energy	16. Placed a cooling towel or pillow on the back of your neck	17. Opened windows in the evening as soon as it became cooler outside than inside, and kept the windows open all night
On a daily basis, how often did you do the above action?	100%	2	2	1	6	1	2
	75%	1	1	0	4	3	3
	50%	6	3	5	1	0	4
	25%	2	3	2	0	5	1
	0%	0	2	3	0	2	1
Was that more or less often than you did in July?	More Often	0	0	0	1	2	2
	Less Often	4	1	1	1	1	2
	Same	7	9	8	9	7	7
Did you find using the above energy saving action comfortable or uncomfortable?	Very Comfortable	0	0	0	1	0	0
	Comfortable	6	6	5	5	5	6
	Somewhat	3	2	2	3	2	3
	Somewhat	2	1	1	2	2	2
	Uncomfortable	0	1	0	0	0	0
	Very	0	0	1	0	1	0
Was this an action you committed to try in order to reduce your energy usage by 10%?	Yes	10	9	7	10	6	10
	No	0	1	2	0	3	0

Despite relatively high levels of commitment to try various nighttime cooling strategies more often during the intervention, very few respondents (a maximum of 2) reported having actually achieved this for any of the strategies, as shown in Figure 36. In fact, for three of the nighttime strategies, none of the respondents were able to do them more often. Interestingly, all of those strategies involved turning off the AC at night. In fact, many respondents were able to use these cooling strategies "less often" than they did before. As mentioned before, the discomfort of sleeping without AC was mentioned by many respondents in the interviews. Several complained they wake up multiple times throughout the night if their bedroom is too hot. Some mentioned that it is difficult to function at work the next day when they have had a bad night's sleep due to the heat.

Figure 36. Number of respondents who reported changing frequency of nighttime strategies during the intervention (N=9-11)



Another common theme in the interviews was the tendency to blame other members of the household for high AC use and low utilization of alternative strategies. Children (both old and young), spouses, and even pets were cited as the reason they could not reduce AC usage further. Again, health concerns were cited, but comfort was, too. In several cases, the interview subject pointedly referred to his or her own ability to sacrifice comfort. This was attributed to a frugal personality, environmental concerns, and the stoic characteristics inherited from Samurai lineage. However, in each of these cases, the respondent reported deferring to family members with greater inclination to want or use AC.

In the case of nighttime strategies, the link between commitment and increased the frequency of use was weaker than it was for daytime strategies, as Table 7 reveals. Only five individuals increased the frequency with which they used a particular strategy at night, and only three of those had committed to doing so. Thus, in the case of nighttime strategies, a commitment did not increase the likelihood of more frequent strategy use. This is not surprising given that fewer respondents committed to nighttime cooling strategies, and during the interviews, many reported significant (and unacceptable) discomfort while trying to sleep without AC.

Table 7. Change in frequency of nighttime strategy use, by prior commitment

	12. Ran the AC about for a short amount of time before bedtime, to dehumidify the air, with the door closed. Then shut		13. Turned AC on when going to bed, but set timer to turn it off after a short amount of time		14. Turned AC off and turned on a fan		15. Used AC's "Cool" setting instead of "Dry" setting. The "Cool" setting uses less energy		16. Placed a cooling towel or pillow on the back of your neck		17. Opened windows in the evening as soon as it became cooler outside than inside, and kept the windows open all	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
More	0	0	0	0	0	0	1	0	0	2	2	0
Less	4	0	1	0	1	0	1	0	1	0	2	0
Same	6	0	8	0	6	1	8	0	5	1	6	0
NA	0	0	0	1	0	1	0	0	0	0	0	0

Above we observed that there were some differences in the number of strategies to which respondents committed, based on four characteristics defined (i.e., prior AC consumption level, daytime occupancy, children, and prior strategy use). Table 8 presents the average number of strategies which respondents reported having increased the frequency of, broken out by the same four characteristics. The number of strategies which respondents increased the use of was higher among high AC users, households occupied during the day, households with children, and households with high prior strategy use, relative to each of their counterparts. Among other things, this suggests that the willingness to change is high among those who already exhibit the desired behavior (i.e., strategy use), and that children do not appear to be the impediment to change that many respondents suggested in the interviews. It is likely the case that although children pose a challenge to adopting alternative cooling strategies, households without children face other challenges which resulted in them adopting fewer changes.

Table 8. Number of strategies increased by sub-group

Category	**Average # of strategies increased**
High prior AC consumption	3
Medium prior AC consumption	1.6
Someone home during day	2.3
Nobody home during day	1.5
Has children	2.3
Doesn't have children	0.5
High prior strategy frequency	4.3
Low prior strategy frequency	1.3

The above discussion illustrates the modest success the intervention had in changing E-Sogo residents' behavior with respect to the use of their AC and alternative cooling strategies. In the next section, the impact these changes had on energy savings is presented.

2. ENERGY SAVINGS

To evaluate energy savings for the intervention, we utilized an analytic methodology that follows industry best practices, as described in detail in Appendix B. These internationally-accepted measurement and verification protocols ensure that reported outcomes are valid and verifiable. They grant rigor and transparency of how the energy performance is measured.

The approach selected is referred to as "retrofit isolation", which measures the energy use of a specific system during a baseline period, and again after an intervention is implemented. The raw savings were adjusted to account for factors such as differences in weather. In this case, as Table 9 shows, the temperature was higher in the post period than in the pre period, as defined for the purposes of the energy analysis.[34] Given that, the energy analysis techniques utilized attempt to explain the results of the intervention, netting out the expected positive effect of increased temperatures.

Table 9. Average temperature in pre- and post- intervention period

Period	Average temperature (°C)
"Pre", i.e., June-September 2013	25.3
"Post, i.e., August 2014	26.8

Estimated savings, calculated using the technique described, are shown for each household in Table 10. The adjusted difference between pre and post is the savings we assumed was attributable to the intervention. We found that 10 households were able to reduce energy consumption from AC use (i.e., generating energy savings), while 5 households increased their consumption (i.e., yielded negative energy savings). On average, households who saved energy reduced consumption by 27%, while those that had negative energy savings averaged -32%.

Table 10. Estimated energy use and savings from intervention, by household (kWh in August 2014)

Apartment	Projected	Actual Post	Savings	Savings (%)
I11	83	79	5	6%
I12	87	105	-18	-21%
I13	141	276	-135	-96%
I21	79	94	-14	-18%
I22	109	113	-5	-4%
I23	82	65	17	21%

[34] Note that from the respondents' perspective, the pre-intervention period was loosely defined as Summer 2013 and June/July 2014. The survey and interview questions specified the comparison period differently in various instances.

I31	86	48	38	44%
I34	79	97	-18	-23%
I41	90	71	19	21%
I43	70	45	25	36%
I44	109	81	28	26%
I51	92	50	42	46%
I52	63	55	8	13%
I53	50	41	9	17%
I54	92	58	34	37%

The estimated the effect of the intervention on the treatment group was calculated in two ways, as shown in Table 11. The average of each household's energy savings (i.e., the simple arithmetic average) was 7%. In addition, the weighted average of energy savings among the treatment group as a whole was calculated, and found to be 3%. The discrepancy between the simple and weighted average indicates that the households that achieved relatively higher savings rates had lower AC energy use, on average, than the households with lower savings rates. Essentially, the lower users were able to curtail their energy use more than the higher users.

Table 11. Average estimated energy savings from intervention, Treatment group

	Projected kWh in August 2014 without Intervention	**Actual kWh Observed in August 2014**	**Savings (kWh in August 2014)**	**Savings (%)**
Household level (arithmetic average)	87.5	85.1	2.3	7%
Group level (totals)	1,312	1,277	35.0	3%

To gain insight into what might be driving the differences observed in savings rates, sub-group analysis of the savings was conducted. Table 12 below presents the unweighted sub-group averages, for sub-groups of the Treatment group defined by the characteristic listed. For example, households categorized as "high users" in the pre-intervention period had negative savings, on average, while those with mid-range consumption were able to cut consumption by 12%. This finding suggests that high users may be more difficult to influence than medium-level AC users.

Households with no one home during the day or that does not have children were able to saving more energy than their counterparts with someone home or with children as part of the family. The interview findings corroborated this, as numerous respondents cited being home all day as posing a challenge to cutting AC usage. Children, both school age and younger, were also frequently cited as a reason respondent experienced difficulty reducing AC usage. In both case, respondent often cited health concerns from restricting AC use too much, and heat stroke in particular.

We also compared the energy savings among the households based on the level of use of the recommended strategies prior to the intervention, as defined above. The results reveal that households with relatively high prior use of strategies were able to save more energy than those with relatively lower prior use of strategies.

Table 12. Comparison of energy savings rates by sub-group

Category	Average energy savings
High prior AC consumption	-7%
Medium prior AC consumption	12%
Someone home during day	6%
Nobody home during day	9%
Has children	2%
Doesn't have children	25%
High prior strategy frequency	18%
Low prior strategy frequency	13%

As mentioned above, one-third of households experienced negative energy savings (averaging 32%). Again, we explored the patterns by sub-group to determine whether certain defining characteristics might be associated with negative energy savings. Table 13 presents various characteristics of positive and negative energy savers. Immediately the association between prior energy use and energy savings is apparent. Households with negative energy savings consumed twenty percent more energy from AC in the baseline period than households with positive energy savings. Since the former have a greater capacity to save energy, this finding suggests that preferences may be more fixed among higher AC users.

Perhaps not surprisingly, households that had positive energy savings had committed to 1 more strategy than those with negative energy savings. Between positive and negative energy savers, there was not a significant difference in the percent whose homes were occupied during the day or had high prior strategy use. Although it appears that positive energy savers are more likely to have children, the sub-group without children is so small (n=3) in this sample, that it would be unwise to draw conclusions from that finding alone.

Table 13. Sub-group analysis of positive and negative energy savers

Category	Negative energy savings	Positive energy savings
Average prior AC consumption (Summer 2013)	293 kWh	245 kWh
Average # of strategies committed to	10.5	11.6
Someone home during day	70%	60%
Has children	70%	100%
High prior strategy frequency	20%	20%

With such a small sample size, it is difficult to pinpoint exactly which factors are associated with negative energy savings. Certainly it seems that higher AC use prior to the intervention may be significant. It is important to not, however, that there are lifestyle factors that play a significant role in driving AC use. In the interviews, respondents mentioned numerous events that may have affected their energy use, including taking vacations, becoming employed, having a baby, and children entering school. All of these factors can significantly impact occupancy of the home. Given how closely tied AC use is to occupancy (especially in Japan), such life events likely affect energy use in a substantial way. Further research should be conducted to explore the differences in energy use when the effect of occupancy is more closely accounted for.

As a point of comparison, energy savings among the non-treatment group was analyzed, too. They had slightly higher energy use from their ACs this summer, relative to the projection. As a result, the energy savings was negative among the non-treatment group on average, as shown in Table 14. This is not surprising given that these households already had very low energy consumption. As consumption is constrained by a lower bound of zero, an increase is statistically more likely than a decrease.

Table 14. Average estimated energy savings from Non-treatment group

	Projected kWh in August 2014 without Intervention	Actual kWh Observed in August 2014	Savings (kWh in August 2014)	Savings (%)
Household level (arithmetic average)	23.7	36.1	-12.4	-46%
Group level (total, weighted average)	165.8	252.4	-86.6	-52%

D. INSIGHTS FROM THE LOW AC USERS

The findings from the interviews with the low AC users were quite informative. One finding is that we were able to confirm that the low AC usage was in fact due to behavioral factors, and not an artifact of looking at different types of households. For example, we suspected that their low usage might be attributable to being a childless couple who did not occupy the apartment at all during the day. We found, however, that with only one exception, the households included housewives who stayed at home with their children during the day.

Mostly, these households did not intend to use AC, and if they did use the AC, it was just for a short time, and they always turned it off when they left the room. Thus, their use of the AC was very much focused on only the times and places where they needed cooling. They also actively pursued alternative strategies, such as opening windows, and using fans.

Another interesting finding was that the respondents for the most part did not select these remarkably frugal strategies in order to reduce energy costs, or directly to achieve environmental objectives (two reasonable hypotheses). The predominant value that was expressed was "eliminating waste", in whatever form it is found.

> *"Rather than the amount of energy we use, we are more conscious about not wasting energy."*

> *"…our personality is directly related to our energy efficient habits in our daily life, our personality is that we do not like to use something useless, and we want to save what we do not have to use, that kind of personality is reflected in our energy efficient practice."*

We found that by redefining the problem as one of "avoiding waste" rather than "reducing consumption," residents are able to find ways to avoid wasting energy (for example, by making sure that consumption patterns match occupancy patterns closely) and to consider alternatives before resorting to the use of AC.

One final finding was that while most of these low-consumers "coping" without air conditioning reported being uncomfortable, they also reported that this was very acceptable. This is a startling finding, because in the US and many other western cultures, "uncomfortable" and "unacceptable" are considered to be synonymous. One response in particular, after being informed that Americans tend to find uncomfortable conditions to be unacceptable, noted the following:

> *"You don't have the culture of enjoying something that is not comfortable? Having to put up with something can be quite fun. For example, when you're a student doing sports, pushing yourself to the limits, having to put up with all that, can be quite fun. In another example, When it's very hot, and I'm wiping the floor, and I can see my sweat dripping to the floor, it gives me something like a sense of achievement that I've done so much."*

> *"I guess that means that [Americans] are living a lifestyle that doesn't require them to be tolerant."*

Clearly, this reveals a very significantly different attitude about cooling that, as we see, can result in quite low energy use.

Note that interview subjects in the low AC user group did not experience the summer heat in a significantly different manner than the others. Just as the study participants interviewed after the intervention, the low users agreed the summer was hot and it was uncomfortable. The difference stemmed largely from their acceptance of these facts. As described in the introductory discussion on thermal comfort, acceptance is a key driver of differences in attitudes and cooling strategies.

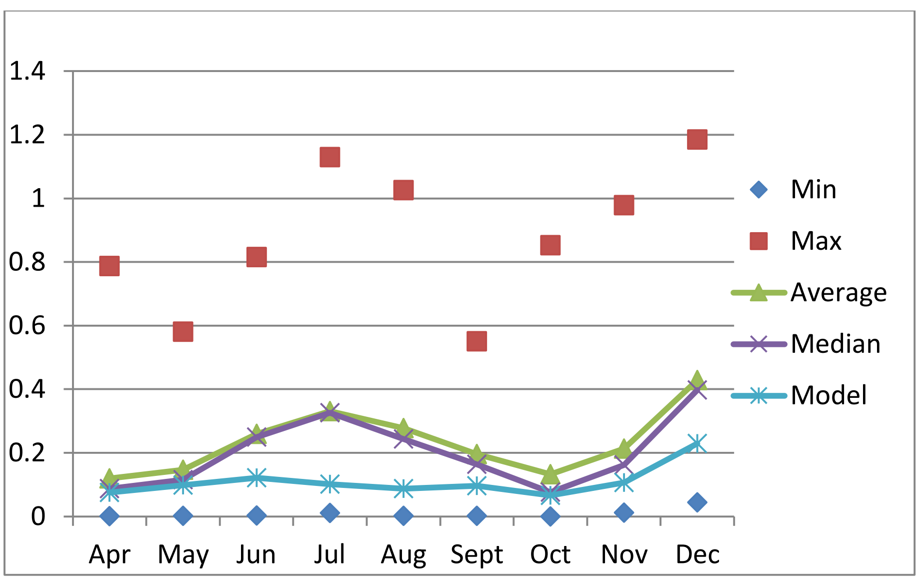
PART B: WEST VILLAGE

I. OVERVIEW

West Village is a mixed-use complex at the University of California-Davis (in central, Northern CA). It currently houses 2000 students, faculty and staff, as well as commercial space (including the WCEC offices), although the latter is not included in the ZNE goal. Apartments in West Village are spacious, modern, and high-end. Electricity (which powers all of the heating and cooling demands, among other things) is included in student rents, and although there is an electricity quota, it is not enforced for a variety of reasons.

As a result, West Village has failed to meet its ZNE goals. Consumption exceeds the predicted levels by 15% overall, and by 118% for heating and cooling. In addition, there is wide variability in consumption from AC for cooling across apartments, even adjusting for square footage. As the graph below illustrates, the highest AC users consumed 3 to nearly 4 times more than the average West Village resident in the summer of 2013.

Figure 37. Distribution of monthly HVAC energy use in 2013 (kWh/sqft)



Source: NORESCO Report, 2014

A number of interventions have been implemented to try to curb energy use. For this study, the intervention targeted energy use from AC units.

West Village was designed to utilize passive cooling techniques, through the positioning and shading of windows, and installation of ceiling fans in every room. Furthermore, Davis, where West Village is located, while very hot during the day in summer, experiences significant drops in temperatures during the evening, by as much as 22 degrees (C). It is certainly cool enough to shut off the AC and open the windows at night, but anecdotally the research team learned that many student residents at West Village instead run their AC all night.

Thus, it was agreed that the WCEC behavioral research team would design an intervention to try to encourage West Village residents to reduce electricity consumption from AC usage, by utilizing passive cooling techniques, and leveraging behavioral drivers that had not yet been utilized in previous interventions at West Village.

II. METHODOLOGY

In this section we describe the study design, sampling plan, recruitment method, data collection efforts and analytic approach.

A. STUDY DESIGN

The West Village study utilizes pre-/post- comparisons behavior, and pre-/post-, Treatment vs. Control group comparisons of energy use, to determine the effect of the intervention relative to the baseline, and across treatment groups.

To create a targeted intervention, we first conducted a focus group with five West Village residents to gain their feedback on the educational flier we planned to use. In addition, the focus group participants were able to field questions to make sure our survey targeted the right issues, behaviors, motivations and knowledge that respondents might have.

Focus group participants agreed that they liked an educational flier that highlighted using “natural” cooling strategies to address climate change and save the environment. They also agreed that they would like to get feedback in how they are doing if they tried these strategies, for example, how much energy did they save or what kind of environmental impact did their actions have?

Feedback from the focus group also allowed us to understand possible problems study participants might have in implementing “natural” cooling strategies. For example, some focus group participants said that opening their windows at night was difficult because of noise issues or for security reasons.

We also learned that many West Village residents do not coordinate AC use with their roommates. Thus, if one roommate decided to open their bedroom window, another roommate may still decide to run the AC within the apartment, making it difficult to use “natural” cooling strategies to save energy.

GROUP ASSIGNMENT

Assignment to treatment and control groups was determined as follows. First, eligibility for the study was contingent on living in one of 100 households in which energy data monitoring devices were already installed (as part of a different effort by another research team), which are all located in the Rambles collection of buildings within West Village. Of the households that remained eligible for the treatment group, 75 (75%) were randomly assigned to our treatment group, and 25 (25%) were assigned to our control group.

Although assignment was determined at the household level, each household member in a treatment group household was invited to participate in the study for a total of 239 individuals.

DESCRIPTION OF INTERVENTION

The intervention involved several components including distribution of an informational flyer, a pre-intervention survey, mid-intervention reminders and surveys, and a post-intervention survey.

The base level treatment was receipt of an informational flyer on how to use passive (or “natural”) cooling techniques (See Appendix I for a copy of the flyer.) The flyers were intended to inform and motivate residents to try passive cooling. They urged residents to set their thermostat to 80 F (27C), use their ceiling fans, and open their windows from 9 PM to 9 AM to capture cool night air. The flyers were developed and designed by WCEC research staff, incorporating some of the findings from the focus group discussions.

Flyers were hand-delivered to 75 households (i.e., 19 2-bedroom apartments, 23 3-bedroom apartments, and 33 4-bedroom apartments) along with a note that requested the residents mount them near their thermostat. Proximity to the thermostat was intended to remind residents to try passive cooling. Thermostats are centrally located in the living room of each apartment, in a highly visible place. An additional aim was to prompt users to by-pass the AC in favor of passive cooling, when they were otherwise about to engage with their thermostat.

The laminated flyers came with double-sided tape attached to the back to facilitate easy of mounting (intended to overcome the common behavioral barrier of procrastination).

Pre-intervention surveys were then implemented online through a program called Qualtrics. Pre-intervention surveys had multiple components, each with a different objective. A copy of the pre-intervention survey form is included in Appendix H, but the following provides an overview and explanation.

The survey is prefaced with a description of the study and informed consent language to inform respondents of their rights and protections as study participants. Respondents were assured their responses would be anonymous to anyone outside the WCEC research team, as per the IRB application submitted.

To establish a baseline for this intervention study, first module of the pre-intervention survey asked a number of key questions to measure participants' energy use and passive cooling habits. The baseline questions targeted the following areas:

- Energy Use
  - How they and their roommates use and control their AC
  - What temperature they and their roommates felt was comfortable
- Behaviors
  - When and how often they opened their windows in bedrooms and living areas
  - When and how they used ceiling fans
- Motivation
  - What motivated them when cooling their apartment: comfort, energy saving, saving money, convenience
  - What motivated for opening windows and using ceiling fans
  - What prevented participants from opening windows and using ceiling fans
- Knowledge
  - If they knew about nighttime temperature drops

Second module focused specifically on passive cooling. It gauged respondents' awareness of and interest in it, and asked respondents to make a commitment to try "natural" cooling techniques for the month of August.

To keep survey respondents engaged and reminded of their commitment to try passive cooling, mid-intervention reminders and surveys were emailed to participants who had agreed to participate and made a commitment to energy saving strategies to reduce energy usage from air conditioning (as determined in the initial survey). They received 3 reminder emails and a request to complete a short online survey that allowed them to "check-in" with the research team on how they were doing.

After the initial survey was conducted to establish a baseline, participants (who were part of the treatment group) were introduced to a number of "natural cooling" strategies to try at home for the month of August. These strategies were visually presented on a laminated card that participants were asked to place near their thermostat to remind them of the strategies and to encourage them to change their energy use behaviors.

Post-intervention surveys were implemented online through a program called Qualtrics. A copy of the post-intervention survey form is included in Appendix J. The questions covered whether respondents engaged in alternative cooling strategies, how frequently, what the experience was like, and any challenges they faced.

Based upon voluntary participation in the pre-intervention survey and control group assignment, there were essentially three tiers of participation within the treatment group and one control group, totaling 4 sub-groups, namely:

- Treatment group 1 - Received flyer, completed survey and commitment
- Treatment group 2 - Received flyer, completed survey not commitment
- Treatment group 3 - Received flyer, did not complete survey or commitment
- Control group

BEHAVIORAL LEVERS UTILIZED

The study design leveraged several behavioral principles to encourage utilization of passive cooling techniques, both directly and indirectly.

Residents were requested to mount the informational flyers in a highly visible place, near their thermostats in order to provide relevant information at an appropriate time and nudge individuals towards the desired outcome. Individuals have limited attention. Providing well-placed and well-timed reminders can help to overcome that behavioral barrier. Furthermore, the laminated flyers came with double-sided tape attached to the back to facilitate easy of mounting (intended to overcome the common behavioral barrier of procrastination).

The survey requested respondents make a commitment to try passive cooling for the month of August, and subsequent communications reminded them of the commitment they made. Commitments have been shown to be effective motivators for behavioral change (see citations above).

The mid-intervention reminder emails were intended to overcome the common barrier of limited attention (see citations above). If respondents were not actively engaged with the study, they ran the risk of forgetting about it altogether. Thus, reminders were issued to call respondents' attention back to the study.

To motivate behavioral change, both intrinsic and extrinsic incentives were offered. Small monetary gifts (extrinsic motivators) were offered for participating in the surveys, while intrinsic motivation was stimulated by stressing the environmental benefits of the utilizing passive cooling techniques. The laminated flyers urged respondents to reduce AC use and save energy for the benefit of a "Happy Planet", and to "Do it for your Mother (Earth)".

To make the environmental benefits more concrete, the mid-intervention surveys gave respondents feedback on their efforts. Specifically, it provided an example of an activity with equivalent energy saving potential to avoiding AC for a given number of nights (e.g., riding one's bicycle instead of driving to the local grocery store). The secondary intent was to highlight the minimal effort required to save energy through passive cooling, relative to other energy-saving activities.

B. RECRUITMENT

Other than delivery of the laminated flyers, there was no recruitment to the base level treatment group, per se. However, every member of the treatment group households (75 units) that received the flyer also received a request, via email, to participate in pre-intervention survey. The email described the study (and outlining the pre-intervention survey, request to try passive cooling, post- intervention survey). It also provided a link to an online survey. The emails offered participants the chance to win a $10 gift card, which was offered as an incentive to participate.

Requests to participate in the mid-intervention surveys were sent to all members who agreed to participate in the study and try natural cooling strategies, via email. The emails offered participants the chance to win a $10 gift card, which was offered as an incentive to participate. In addition, participation was encouraged by promising to provide feedback on the environmental impact of their efforts during the previous week.

Similarly, requests to participate in post-intervention surveys were emailed to all members who agreed to participate in the study and try natural cooling strategies. The email described the post-intervention survey and provided a link to an online survey. A small monetary incentive was offered to every participant who completed the survey.

C. DATA COLLECTION

Assignment to the treatment group was determined at the household level, but participation was not limited to a single household member. However, in practice, only a one household member from each of the participating households responded to the survey. Thus, the data collected take several forms: individual-level responses, household-level responses submitted by the respondent on behalf of the household, and household-level energy data generated by the installed sub-meters.

Emails requesting participation in the initial survey were sent to 239 individuals who resided in the 75 the treatment group apartments on August 4, 2014. Survey responses were collected from 18 respondents (13.3%) from August 4-13, 2014.[35] Respondents were 56% female and 44% male. Participants were 18 years of age or older, but typically younger than 23. Two respondents lived in 2-person households, two lived in 3-person households, and 12 lived in 4-person households. One survey respondent had lived in West Village for 0-6 months, ten lived at the apartment for 7-12 months, and eight lived at the apartment for more than 1 year.

Emails reminding participants about the study and requesting participation in the mid-intervention surveys were sent to 11 respondents on August 15, August 21, and August 29. Survey responses were collected from 4 participants between August 15 and August 30.

Emails requesting participation in the post-intervention survey were sent to 15 respondents on September 11th and a reminder email was sent on September 16th. Survey responses were collected from 7 respondents between September 11th and 16th (representing 39% of the baseline sample, and corresponding to an attrition rate of 61% from the baseline). Respondents were 71% female and 29% male.

[35] Twenty-four respondents initiated the pre-intervention survey, but 8 of them were ineligible to take the survey because they were not planning to remain at their apartment in West Village for the duration of the study period (August 2014).

Similar to previous studies conducted at West Village, this study suffered from very low response rates:

- 7% (n=18) for the initial survey
- 22% (n=4) of the baseline (or 1.7% of the total sample) for the mid-intervention surveys
- 39% (n=7) of the baseline (or 2.9% of the total sample) for the post-intervention survey.

The students proved to be a difficult-to-reach population, especially while attending summer session classes. The research team anticipated that getting their attention via email would be challenging. However, alternatives suggested by the focus group participants, such as Facebook, were not feasible without contaminating the control group.

D. ANALYTIC APPROACH

The impact of the intervention is assessed based upon the self-reported frequency of alternative cooling strategies utilized before and after the intervention. The impact such actions had on energy usage from air conditioning units, relative to control apartments, will also be measured (i.e., constituting a pre/post, treatment control analysis). The latter will rely on data generated by the pre-existing monitoring devices installed in the treatment and control group apartments, to which the residents have already granted permission for continuous access. The devices were installed and are monitored by Architectural Energy Group, on behalf of the Carmel Properties, the owner/operator of West Village. The UC Davis research team was not provided access to the raw data, but rather submitted requests for aggregated and de-identified data. Care was taken to ensure that group assignment was preserved with the de-identified data, to facilitate appropriate sub-group analysis.

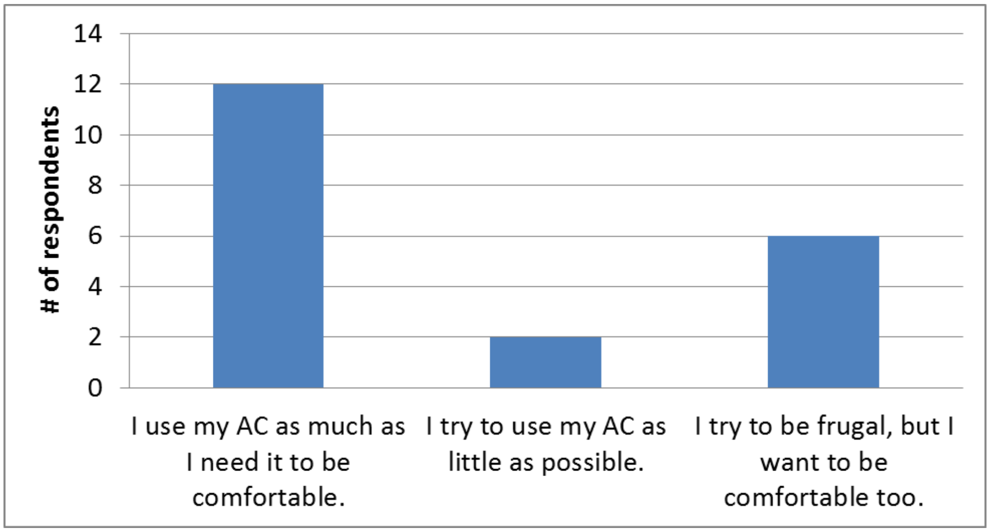
III. KEY FINDINGS

In this section the key findings are presented. The discussion is organized in three sections: baseline activity, willingness to change, and effects of the intervention. The latter covers both the behavioral changes reported and the energy savings observed.

A. BASELINE ACTIVITY

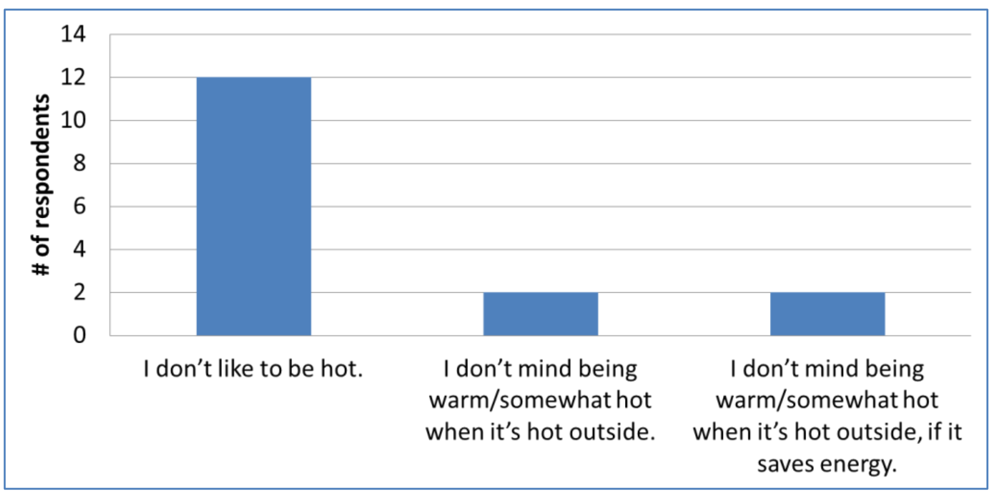
To establish a baseline for this intervention study, we asked a number of key questions to measure how and why respondents manage the summer heat, and in particular how they use their air conditioners and other cooling strategies. When asked about the reasons for using AC, most respondents (12 out of 18) reported using their AC as much as needed to stay comfortable, as the figure below illustrates.

Figure 38. Reasons for using air conditioner (N=20)



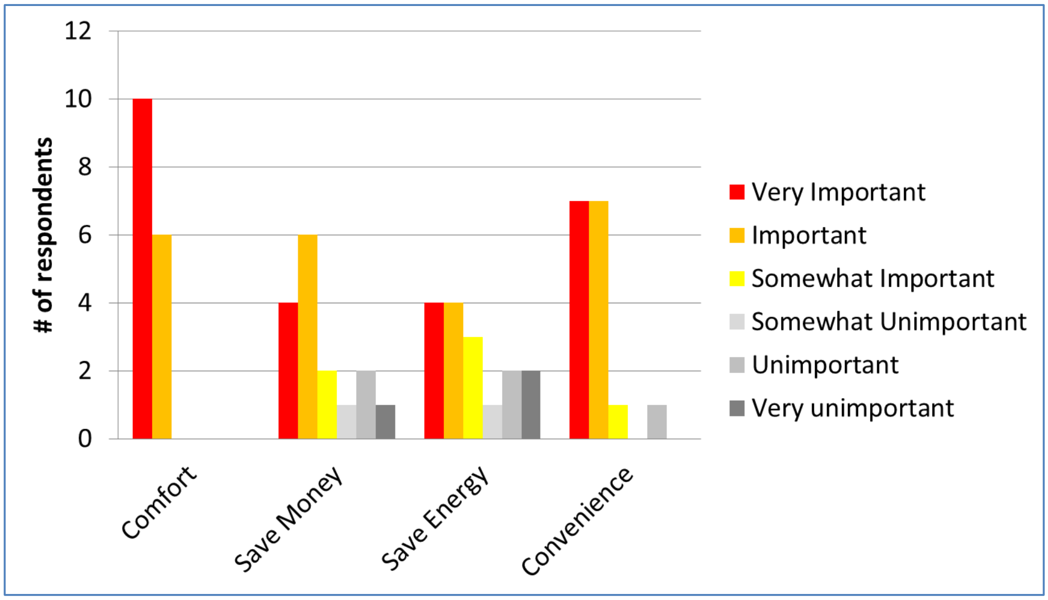
When asked about their sensitivity to heat on hot days, most respondents (12 out of 16) reported they did not like feeling hot. Only a few demonstrated flexibility in thermal comfort in relation to the outdoor temperature or the energy-intensity to deliver cooling.

Figure 39. Sensitivity to heat on hot days (N=16)



When asked about the importance of various goals when cooling their apartment, most respondents agreed comfort and convenience were important. Responses about goals like saving energy and saving money showed some respondents (4 to 5) found these to be unimportant goals when cooling their apartment. This is likely driven to a large extent by the fact that West Village residents do not pay for their energy use directly.

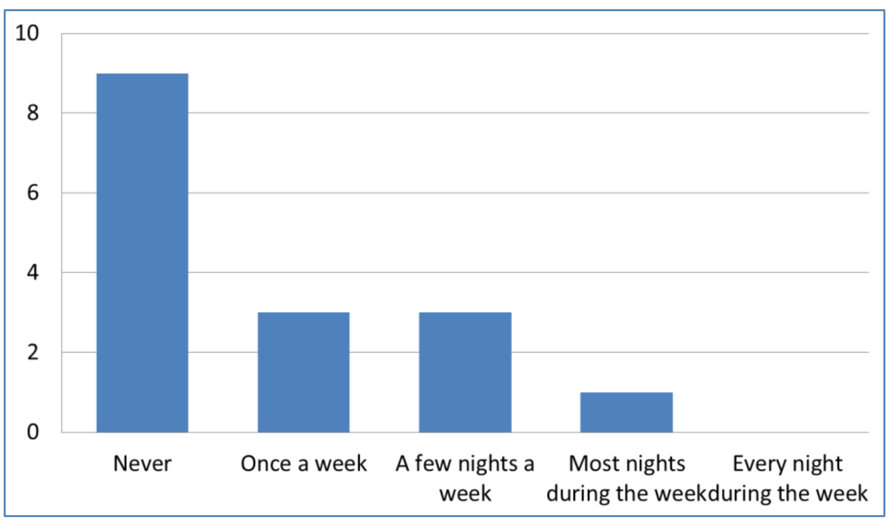
Figure 40. Importance of goals when cooling apartment (N=16)



The primacy of comfort was evidenced in the typical thermostat setting in respondents' households, too. The highest acceptable temperature setting on the central AC was reported to be between 21°C (70°F) and 26.7°C (80°F), with the majority reporting 24.4°C (76°F).

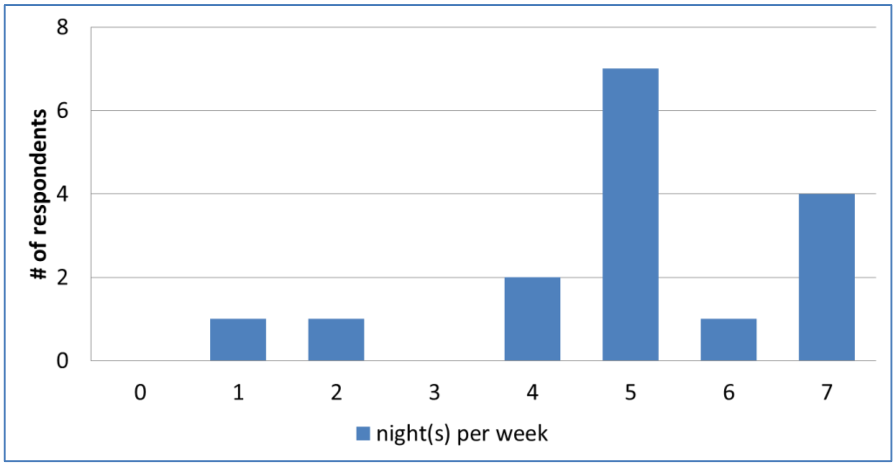
When asked about alternative cooling strategies, like opening windows at night, many respondents (9 out of 16) said they never left their window open at night while only 1 respondent said they left their window open most nights during the week.

Figure 41. Number of nights per week respondents' household leaves windows open (N=16)



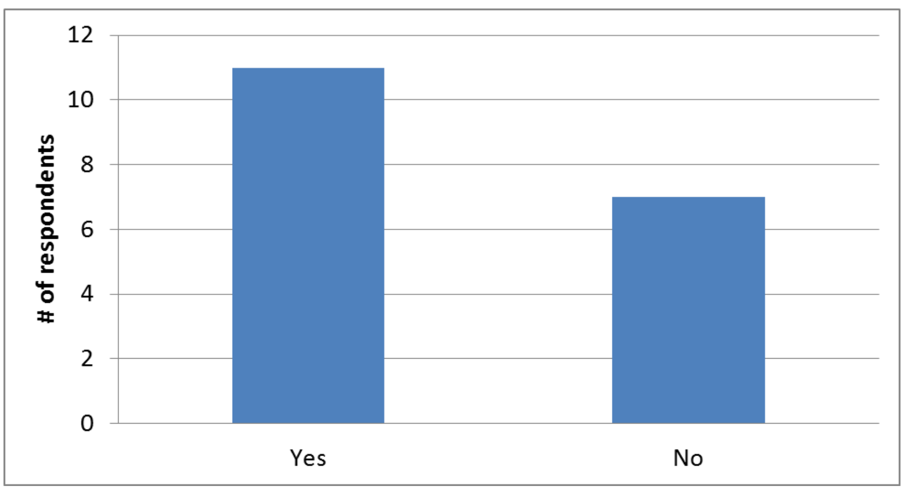
Not surprisingly, most respondents reported leaving their AC on during the night to stay cool. Most respondents left their AC on for 4 or more nights a week.

Figure 42. Number of nights per week respondents' household leaves AC on



Low levels of utilization of passive cooling techniques prior to the intervention may have been due in part to lack of awareness about nighttime temperature shifts. Although daytime temperatures in Davis are quite high, 33°C (91°F) on average, nighttime temperatures average only 13°C (55°F) in August, well below the average thermostat setting in West Village apartments. Indeed, the survey revealed that 7 out of 16 respondents were unaware of the 20°C drop in nighttime temperatures which present ample opportunity for passive cooling.

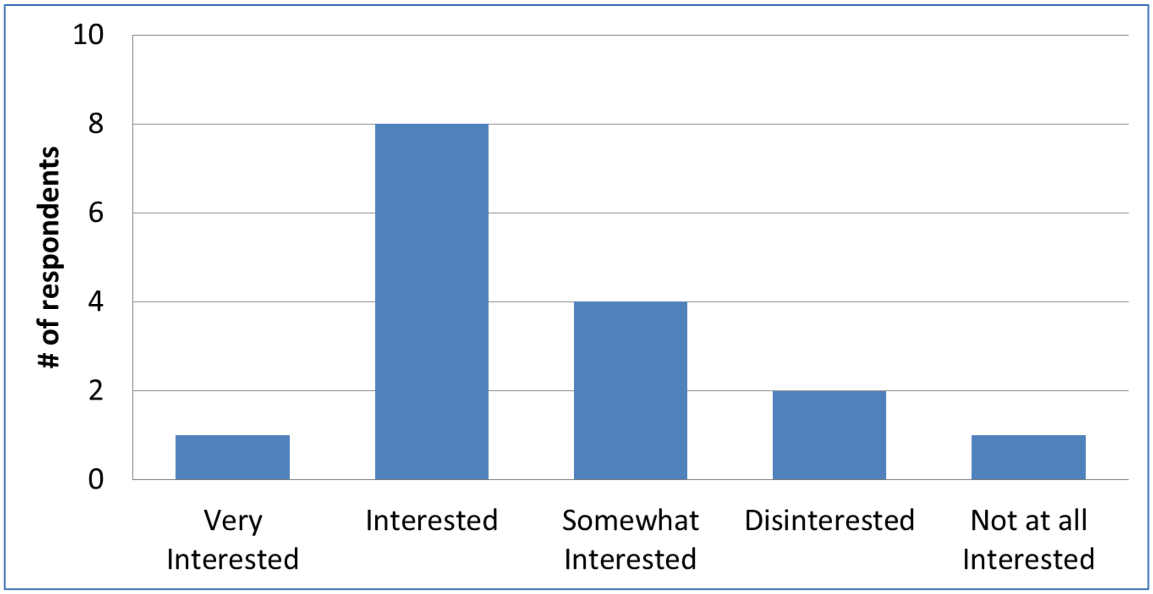
Figure 43. Awareness of steep drop in nighttime temperatures (N=16)



B. WILLINGNESS TO CHANGE

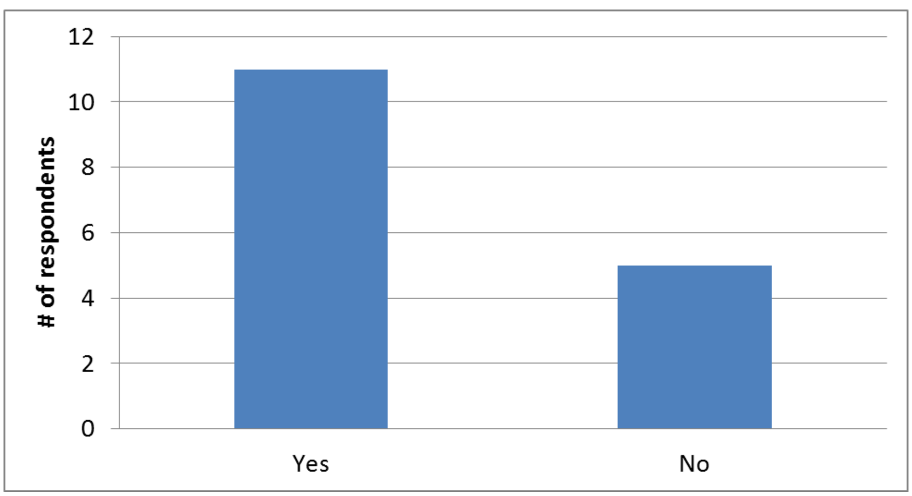
In the initial survey, 13 out of 16 respondents were interested in trying "natural" cooling strategies during the intervention period (August 2014).

Figure 44. Respondents' level of interest in trying "natural" cooling in August (N=16)



When asked to commit to trying "natural" cooling strategies for the month of August, eleven out of 16 survey respondents reported a willingness to try the passive cooling strategies described in the survey (and on the laminated card) during for the month.

Figure 45. Number of survey respondent willing to try "natural" cooling in August (N=16)



There are numerous reasons why West Village residents may have been unwilling to try natural cooling (or participate in our survey, for that matter). There is a general perception that West Village rents are high, and occupants feel entitled to utilize as much electricity as they wish. This attitude is not discouraged by the building management who fail to enforce the electricity quota to which each apartment is contractually obligated.

Another, perhaps more subtle factor that may be at work is the perverse incentives that renewable generation introduces, for some residents. As with many eco-friendly options, many who consume energy produced by renewable sources view their one-time investment in the procurement of that source as their environmental contribution, and pay little attention to subsequent consumption on the grounds that it is not detrimental to the environment. One respondent's comment reflected this attitude when asked whether s/he would be willing to curtail AC use: "Energy [i]s free and plent[iful] at West Village. Why would I open my windows when I can use the AC to my heart's content and maintain a controlled temperature?" It is not known how widespread such an attitude is among West Village residents, but there is evidence to suggest it may be driving the behavior of at least some.

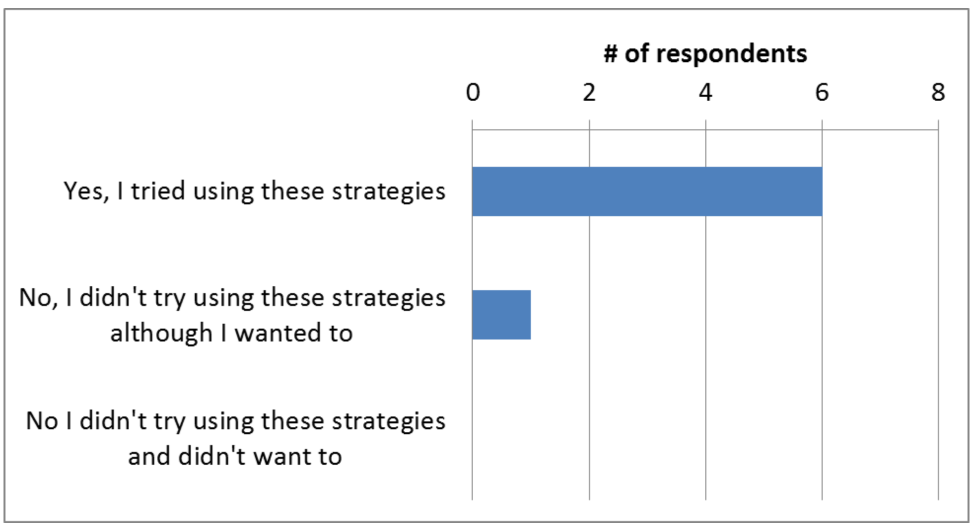
C. EFFECTS OF INTERVENTION

Effects of the intervention were assessed through self-reported behavior change and energy savings analysis.

1. BEHAVIOR CHANGE

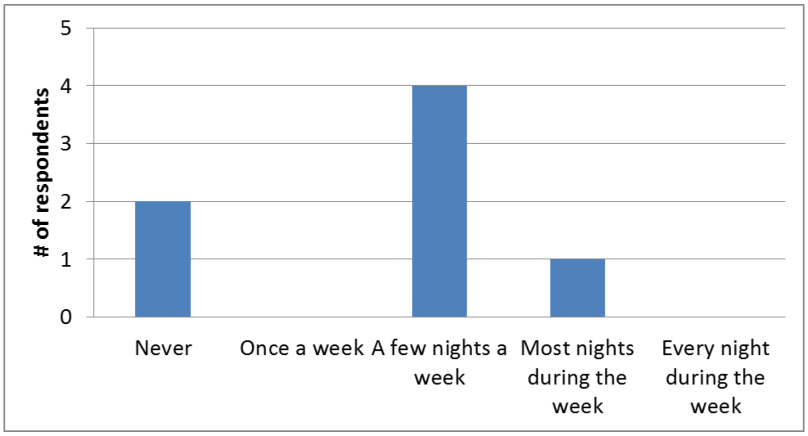
Following up with respondents after the end of the study, we found that most (6 out of the 7 who took the post-intervention survey) had tried using some of the "natural" cooling strategies in the month of August.

Figure 46. Number of respondents who tried passive cooling strategies during intervention (N=7)



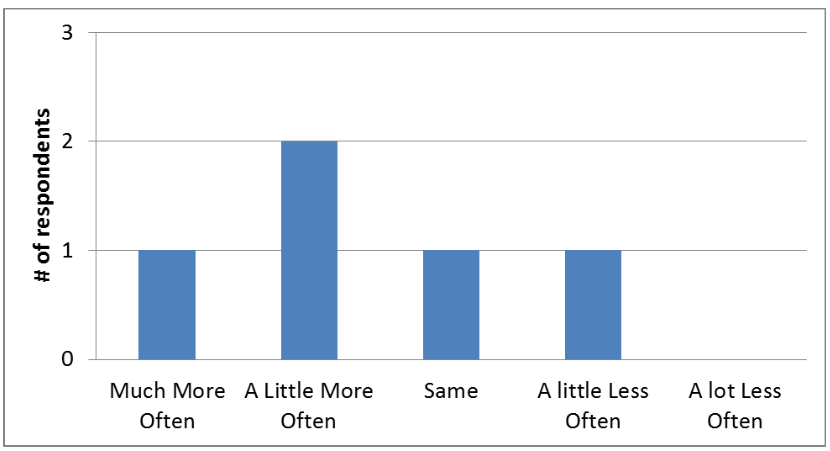
Most respondents (5 out of 7) had opened their windows at night. Still, the frequency of opening windows remained low, at only a few nights per week for most respondents.

Figure 47. Average nights per week respondents left the window(s) open at night during intervention (N=7)



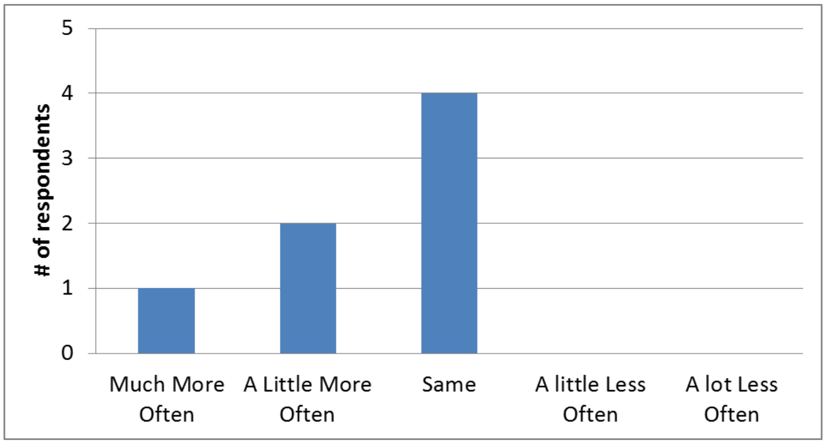
Despite the infrequency of opening windows at night, three respondents reported an increase relative to before the intervention.

Figure 48. Frequency of leaving window(s) open at night during intervention, relative to July (N=7)



Respondents were also asked about their use of ceiling fans to stay cool during the intervention. Three out of 7 had used their ceiling fans more often to stay cool during the month of August while the rest of the respondents (4 out of 7) reported using their ceiling fans the same amount as in July.

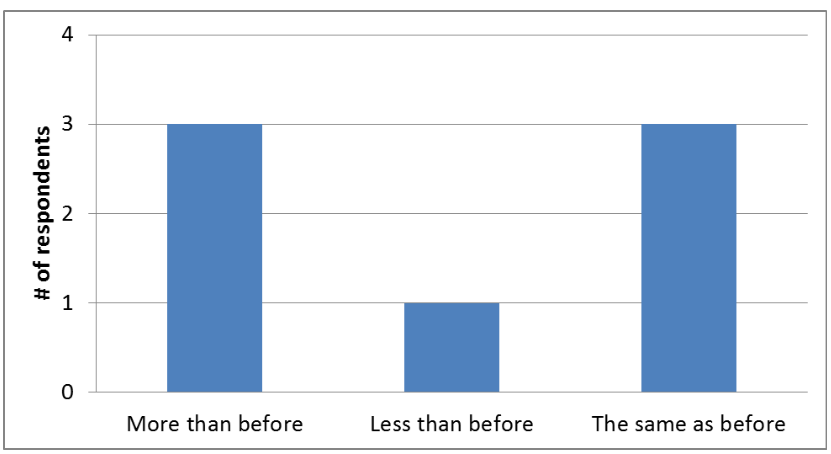
Figure 49. Frequency of ceiling fan use during intervention, relative to July (N=7)



When asked why they had opened their windows at night or increased the frequency of ceiling fan use, several respondents reported that the laminated card had influenced them, either because it reminded them or because they "tried to listen to the card". Not all respondents were so positively influenced. When asked to described their motivation for behavior change one respondent said: "Who would be convinced to alter their habits based on a piece of paper?". Clearly, behavioral levers that are effective for some are not for others.

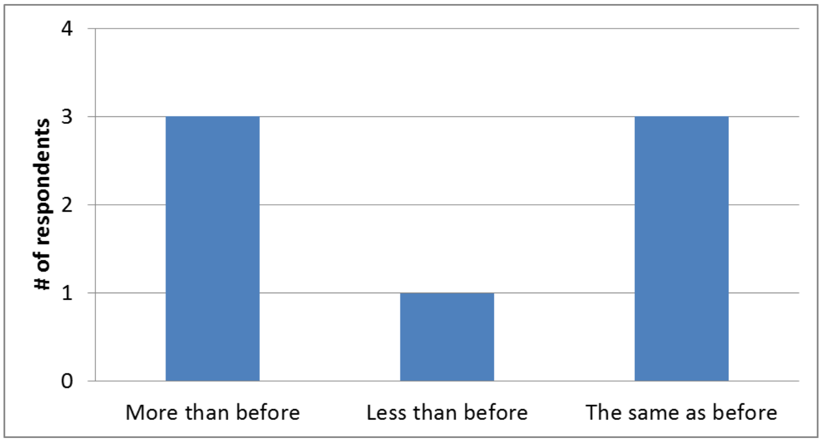
Finally, when respondents were asked about their willingness and plans to use "natural" cooling strategies in the future, many said they would continue using these strategies in order to avoid using their AC. For example, three respondents reported they would use their ceiling fan "more than before."

Figure 50. Expected use of open windows at night to avoid or delay AC use in the future, relative to pre-intervention (N=7)



When asked about opening their windows at night to avoid using AC, three reported they would open their windows at night "more than before." The reason cited was to "save energy". One respondent clarified his/her motivation thusly: “Now that I am living in a place that charges for electricity, we rely more on natural cooling.”

Figure 51. Expected use of ceiling fans to avoid or delay AC use in the future, relative to pre-intervention (N=7)



While the sample size for both surveys extremely low side, these findings are not statistically significant. However, they provide indicative evidence that it may be possible to motivate people (even disengaged students who do not pay their electricity bill) to use alternative methods to cool their homes during the hottest parts of the year.

2. ENERGY SAVINGS

Several analytic techniques were employed to calculate whether the treatment groups’ energy consumption dropped as a result of the intervention. Again, small sample sizes limit the statistical significance of the findings, but the results provide some indication of the impact, however approximate.

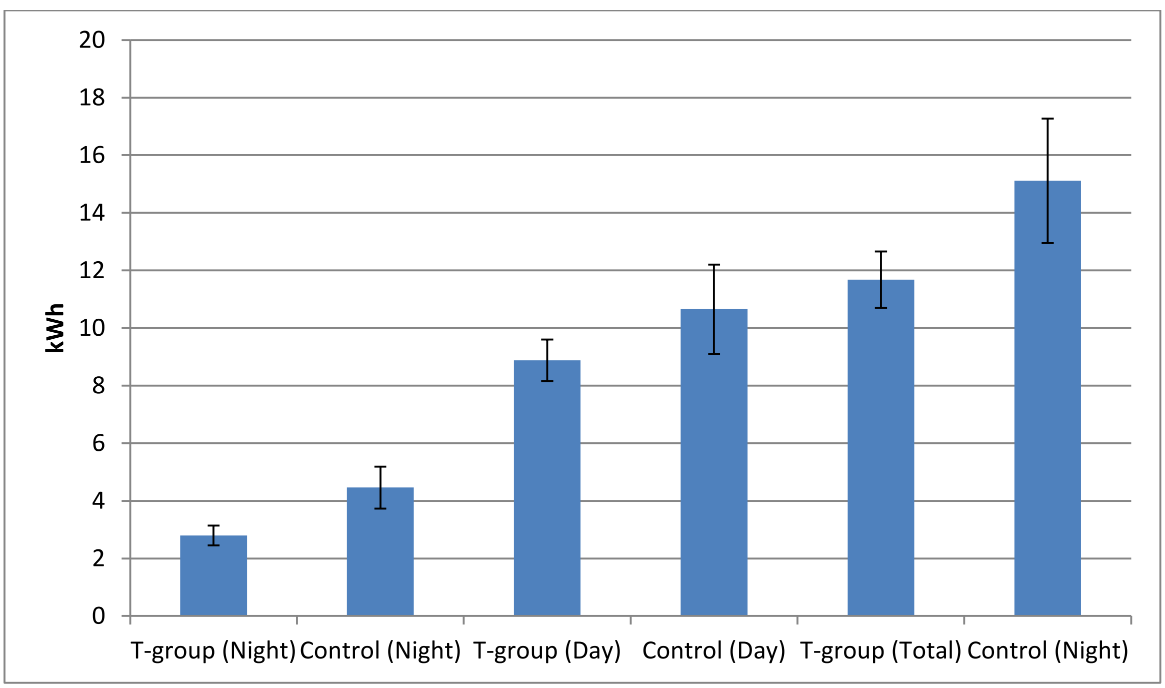
Unfortunately, energy data was available for only 62 of the 100 households in our study. While the initial 100 households in the treatment and control groups (i.e., 75 and 25 households, respectively) were part of an ongoing monitoring effort by another research organization, during the course of the study their monitoring efforts were scaled back and many households’ data takers were removed. Thirty-eight of those removed were households in this study. Thus, the energy analysis can only be completed on the remaining 62 households for which data is available. The following table contains the precise sample sizes. Note that in addition to the specific three treatment groups, an aggregate treatment group has been specified. This was done to address the very small numbers of Treatment groups 1 and 2 (who took the survey). All Treatment group members received the passive cooling flyer, at a minimum.

Table 15. Energy analysis sample descriptions and sizes

Treatment group	**Description**	**No. for which energy data is available**
Treatment group 1	Received flyer, completed survey and commitment	4
Treatment group 2	Received flyer, completed survey, not commitment	3
Treatment group 3	Received flyer, did not complete survey or commitment	39
Treatment group (any)	Belong to Treatment groups 1, 2 or 3	**46**
Control group	Received no intervention	**16**
Total		**62**

The first step of the energy analysis was to determine whether the treatment and control groups had comparable energy use from AC before the intervention. If randomization was done correctly, this should be the case. As Figure 52 illustrates, that is not universally the case. Average nighttime and total energy use per day differed significantly between the two groups (indicated by the non-overlapping error bars) prior to the intervention, i.e., in July 2014, with the Treatment group having consistently lower energy use in all periods defined (i.e., day, night, total)[36]. This finding is not surprising, given the small number of Control group households (i.e., 16), since small sample sizes can lead to anomalous results.

Figure 52. Mean daily energy consumption from AC pre-intervention and standard error of the mean, by Treatment Group (July 2014)



[36] Day is defined as 9am to 8:59pm. Night is defined as 9pm-8:59am. The "total" is calculated over a 24-hour period from 12am to 11:59pm.

In comparing pre- and post-intervention energy use, it is important to account for outdoor air temperature. Although both treatment and control groups were subject to the same conditions, it is important to understand the other factors besides the intervention that may be driving any changes observed. All else equal, we would expect higher temperatures to be associated with higher AC consumption.

In fact what we find is that the average daytime and nighttime temperatures were lower in August (the "post" period) than in July (the "pre" period), as Table 16 shows. Thus, even in the absence of the intervention, we would expect AC use to decline among both treatment and control group households.

Table 16. Monthly average temperature, Celsius (F)

	July 2014		August 2014	
	°C	°F	°C	°F
Daytime (9am to 9pm)	30.0	86.0	28.6	83.4
Nighttime (9pm to 9am)	19.1	66.3	17.8	64.1
Total monthly average	24.6	76.2	23.2	73.8

As Table 17 shows, that is in fact what we observe. Average AC energy use per day dropped among both Treatment and Control group households during the day, night and overall. One of the benefits of having a Treatment-Control group study design is the ability to net out the effect of mitigating factors that affect both groups during the course of the study. In this case, the Control group illustrates the effect of lower temperatures in August. All else equal, we would expect the Treatment group to have lowered their consumption by more than the Control group. In a Pre-Post, Treatment-Control group comparison such as this we estimate the effect of the intervention to be:

$$Effect\ of\ Intervention = Change\ in\ Energy\ Use_{Treatment} - Change\ in\ Energy\ Use_{Control}$$

By this measure, we can estimate that daytime AC consumption dropped by 8.3 percentage points more among the Treatment group than the Control group. This is a very rough indication of the treatment effect, given the small sample sizes and difference in energy use at the baseline. Although the intervention requested that households use passive cooling at night, in lieu of AC, it is not surprising that *daytime* AC consumption dropped. With relatively low nighttime temperatures in Davis running the AC at night does not require a lot of energy to maintain the temperature at 72 degrees, for example. The real energy savings comes from pre-cooling the space with outside air at night such that the indoor temperature is closer to the nighttime average, say 65 degrees, before the temperature starts to rise in the late morning.

Table 17. Difference in daily AC energy use: Pre-post, Treatment vs. Control (kWh)

	Average			
	Pre	Post		Change in kWh
Night				
Treatment	2.8	2.2	-0.6	-19.9%
Control	4.5	2.7	-1.8	-40.2%
Difference (T-C)/C	-37.3%	-16.0%		
Day				
Treatment	8.9	6.5	-2.4	-26.5%
Control	10.7	8.7	-1.9	-18.2%
Difference (T-C)/C	-16.7%	-25.1%		
Total				
Treatment	11.7	8.8	-2.9	-24.9%
Control	15.1	11.4	-3.7	-24.7%
Difference (T-C)/C	29.4%	29.8%		

Perhaps the more surprising finding is that average nighttime energy consumption declined more among the Control group than the treatment group, even in relative terms. One explanation for this is simply that it is an odd result generated by small and non-comparable samples. Another is that plausible explanation is that since energy consumption has a lower bound of zero, the potential to decrease consumption declines as consumption approaches zero. Given that, even if AC usage remained unchanged between July and August, say, in the absence of the intervention, lower temperatures in August would have decreased the Control group's energy consumption more than the Treatment group's, all else equal.

Figure 53 shows that unlike in July, in August, the daytime energy used was significantly different among the Treatment and Control groups, with the latter using 2.2 kWh less per day, on average. By contrast, the difference in nighttime average AC use between the two groups is not statistically significant, as the error bars overlap.

Figure 53. Mean daily energy consumption from AC post-intervention, by Treatment Group (August 2014)

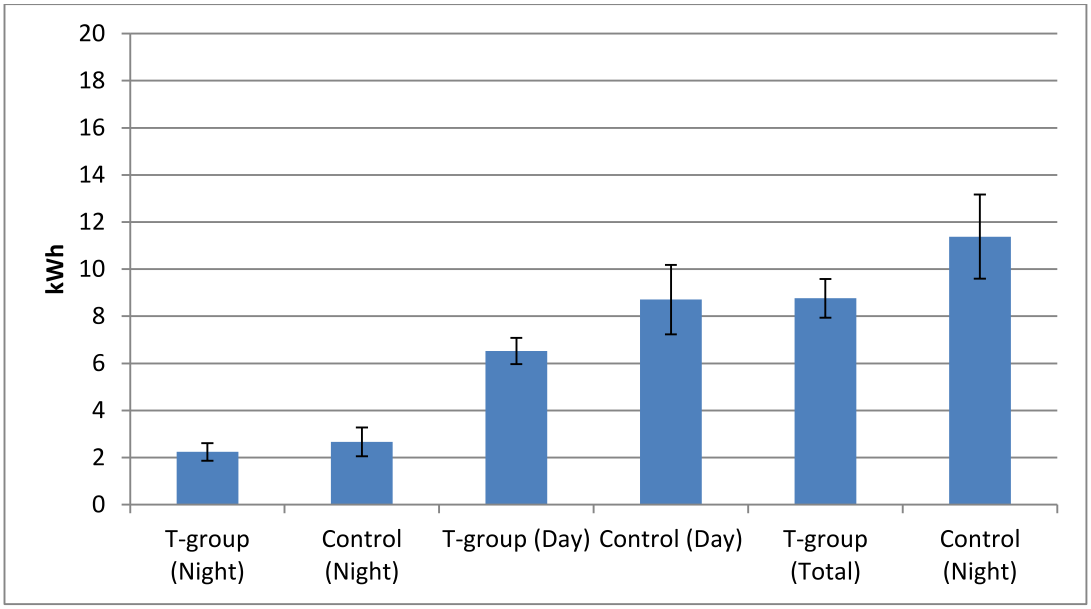


Table 18 presents a more comprehensive breakdown of the results, including the results by specific Treatment group categorization (i.e., 1-3). Such small sample sizes do not merit a lot of discussion of these results. However, it is worthwhile to note that in general, Treatment group 1, the most engaged of the study participants (i.e., who received the flyer, completed the survey and committed to trying passive cooling), had the lowest energy use from AC in the baseline period. This suggests that the study attracted greater participation from individuals who already had relatively low energy consumption from AC. This is a form of self-selection bias, which is common among many such studies, and is important to keep in mind when interpreting the results.

Table 18. Summary statistics of energy use from AC pre- and post-intervention (kWh), by time of day

	July 2014			August 2014		
Nighttime						
	Mean	95% Conf. Int		Mean	95% Conf. Int	
Treatment group 1	2.9	*2.5*	*3.3*	2.5	*2.1*	*2.8*
Treatment group 2	3.4	*2.8*	*4.1*	1.7	*1.3*	*2.1*
Treatment group 3	2.8	*2.6*	*3.0*	2.3	*2.1*	*2.5*
Treatment group	2.8	*2.7*	*3.0*	2.2	*2.1*	*2.4*
Control group	4.3	*3.9*	*4.6*	2.7	*2.4*	*3.0*

Daytime						
	Mean	95% Conf. Int		Mean	95% Conf. Int	
Treatment group 1	7.7	*6.9*	*8.4*	5.8	*5.0*	*6.5*
Treatment group 2	9.3	*8.6*	*10.0*	6.7	*6.0*	*7.5*
Treatment group 3	9.1	*8.7*	*9.4*	6.6	*6.3*	*6.9*
Treatment group	9.0	*8.6*	*9.3*	6.5	*6.2*	*6.8*
Control group	10.4	*9.7*	*11.0*	8.7	*8.1*	*9.3*
Total						
	Mean	95% Conf. Int		Mean	95% Conf. Int	
Treatment group 1	10.6	*9.5*	*11.6*	8.2	*7.2*	*9.2*
Treatment group 2	12.8	*11.6*	*14.0*	8.4	*7.5*	*9.4*
Treatment group 3	11.9	*11.3*	*12.4*	8.8	*8.4*	*9.3*
Treatment group	11.8	*11.3*	*12.3*	8.8	*8.4*	*9.2*
Control group	14.6	*13.7*	*15.5*	11.4	*10.6*	*12.1*

Overall, there is some evidence that the passive cooling intervention at West Village did reduce energy consumption from AC, although the evidence is weak given the study's shortcomings as described above.

PART C: COMPARISON OF KEY FINDINGS

There are numerous significant differences about the context in which the E-Sogo and West Village studies took place, as well as the studies themselves. As a result, caution should be exercised when comparing the findings. However, there are advantages to running similar studies in parallel, and drawing contrast from the two. In this section, comparisons between the two studies are made to highlight the similarities and differences in the baseline conditions, the interventions, respondents' willingness to change, and the effects of the interventions in terms of behavior change and energy savings. Again, caution is urged when reviewing these comparative findings.

Before moving to the discussion of findings, it is important to highlight a few important factors about the context in which these studies took place. First, there are significant climatic differences, as discussed in Section III above. Although daytime temperatures are hotter in summer, on average, in Davis, the lower nighttime temperatures and overall humidity level mitigates that to a large extent. For large portions of the day, Yokohama may "feel" hotter than Davis.

Second, both studies took place in ZNE communities. They are modern and designed to be energy efficient. Certainly, this attracts a certain type of resident (e.g., environmentally conscious, young). In addition, the communities are inhabited by residents who are relatively wealthier than average. By virtue of their wealth, residents of E-Sogo and West Village have less (economic) incentive to reduce their energy consumption (and perhaps none in the case of West Village since electricity is included in the rent). In these ways, they do not represent the Davis and Yokohama communities at large, let alone the U.S. and Japan.

Despite these similarities, one important difference to note is that E-Sogo apartments are inhabited by families, while West Village apartments are inhabited by students. At E-Sogo, the typical households were families, with from zero to three children. At West Village, the typical households were 2-4 unrelated "roommates", who each had their own bedroom and bathroom, and who shared a communal kitchen and living room (although most students spent relaxation time in their private rooms, and many eat in their private rooms). They may or may not have been friends prior to moving to West Village, and they may or may not have developed close friendship ties since moving there, but their cohesion and sense of common cause is clearly much less than in a family.

From a behavioral perspective, the implication is that E-Sogo households operate as a single decision-making unit. Although there may be significant differences in preferences and values among the family members, as the interviews confirmed, ultimately a family tends to coordinate household decisions, at least to some extent. By contrast, students living in shared apartments each constitute their own household within a shared housing unit. This affects how and why they make decisions in a way that differs from family members who share a home.

In the course of conducting this study, we observed several important differences in the cooling strategies and factors that drive them between E-Sogo and West Village residents, and the Japanese and Americans more broadly.

First, the scope of cooling strategies varies substantially between the U.S. and Japan, broadly speaking. In the U.S., cooling is largely delivered in a generalized manner through central AC. By contrast, localized, "task" cooling is much more prevalent in Japan. As the diagram in Figure 17 shows, Japanese room ACs target specific rooms, and even specific areas of rooms. Some manufacturers boast that their latest technologies can detect where in the room occupants are located and direct the cool air towards them. Similarly, the use of personal cooling devices (e.g., cooling towels or pillows, specialized clothing) is much more common in Japan than the U.S. By narrowing the scope of the cooling target – to a single room, a person within a room, or a particular body part – Japanese cooling strategies demand much less energy to deliver thermal comfort, relative to conditioning an entire house, as is common in the U.S.

Second, the Japanese cooling strategy, in general, seems to be characterized by more active engagement. E-Sogo survey and interview respondents confirmed this by reporting that they routinely turn off their AC when they leave the room (and the house). By contrast, the American cooling is predominated by setting and forgetting a thermostat that controls a central AC. If the occupants have taken the time to program the thermostat, which research suggests many have not,[37] and programmed it correctly, then temperature setbacks are administered, simulating the Japanese strategy, without the continuous engagement. However, as this does not appear to be the norm, it seems fair to say that the American cooling strategy is typically an unresponsive one, in which energy for cooling the air is not closely tailored to the instantaneous needs of the occupants.

Finally, there appear to be important cultural differences in the acceptability of thermal comfort, as described in an earlier section. From the surveys and interviews with E-Sogo residents, it was apparent that many conceived of thermal comfort in conditional or relative terms. Their expectations about thermal comfort seemed to be influenced by the weather conditions, energy costs, environmental impact of AC use, and even self-conceptions of frugality, stoicism and personal responsibility. Thus, their prioritization of thermal comfort was typically weighed in relation to other values.

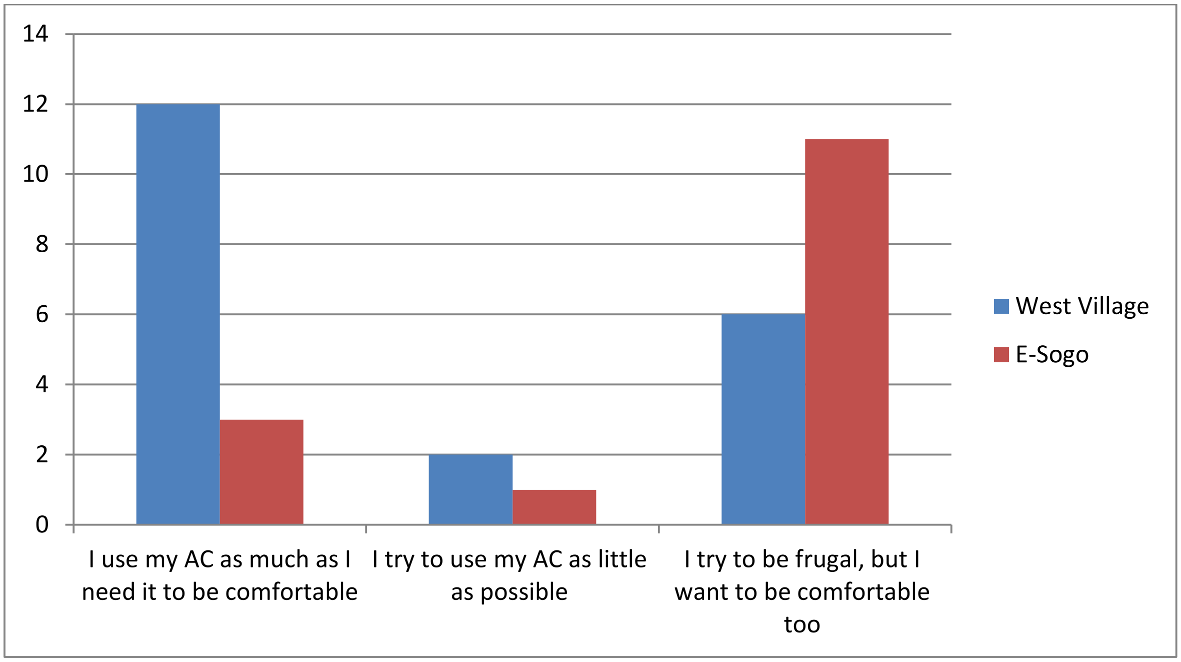
Without having conducted in-depth interviews at West Village the data available to make a similar assessment of the American study participants is limited. What little evidence we have (including Figure 54 below and comments provided in the survey) suggests that West Village respondents conceive of thermal comfort in more unconditional or absolute terms. Alternatively, they may simply prioritize it more highly than E-Sogo residents do. Further research is required to understand these differences more thoroughly. However, prior work with U.S. air conditioning manufacturers indicates that they clearly perceive their prime directive to be to provide optimal comfort whenever it is needed, which requires as stable conditions as possible, and to err on the side of being prepared to provide more cooling or heating than may be called for.

I. BASELINE ACTIVITY

Within the context described above, residents of E-Sogo and West Village used their ACs to deliver mechanical cooling during the summer. Respondents' strategies, values, knowledge and habits were assessed using baseline surveys relying on self-reports of the former. As Figure 54 illustrates, West Village residents were much more likely to report using their AC as much as they need to be comfortable, while E-Sogo residents were more likely to balance the desire for comfort with the desire to be frugal.

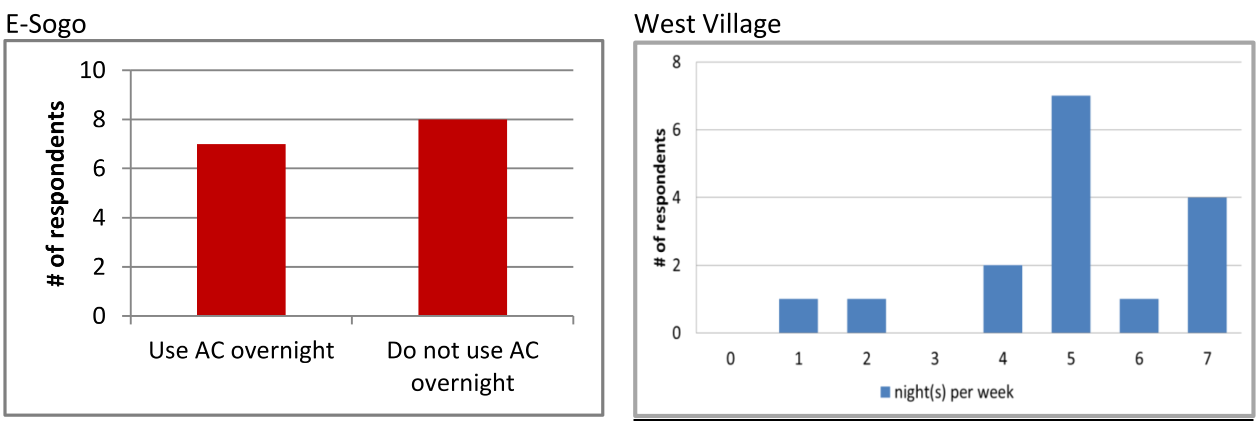
[37] See, for example, Archacki in Peffer et al., 2011 and Meier et al., 2011.

Figure 54. Prioritization of AC use



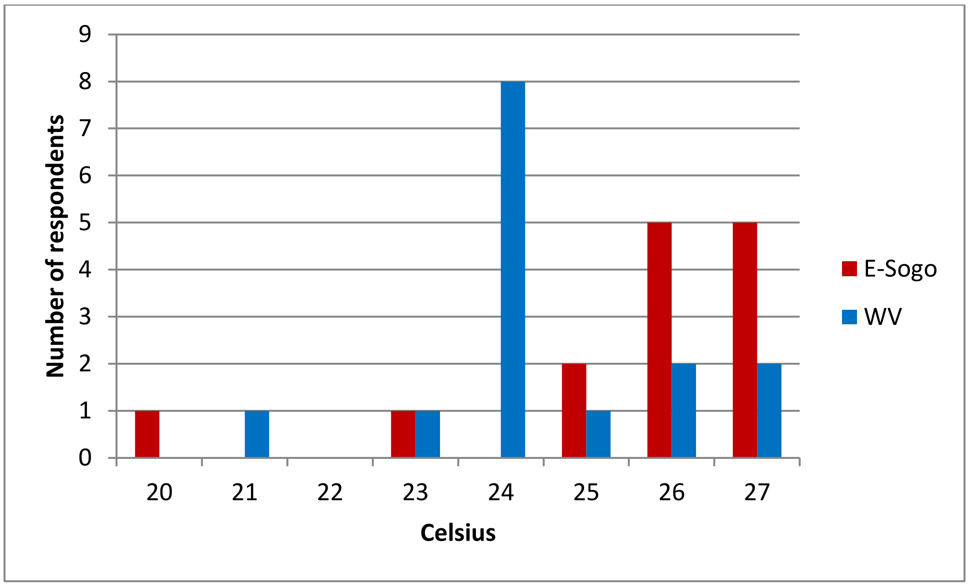
The frequency with which E-Sogo and West Village residents used their AC at night differed. The survey questions were worded differently, making direct comparisons impossible. Specifically, E-Sogo residents were asked to report what they typically did at night, while West Village residents were asked to report the number of nights per week they use the AC. However, as the graphs below indicate, we can get a general sense for comparing the two, which gives the impression that nighttime AC use is more common among West Village residents, despite cool evening temperatures.

Figure 55. Overnight AC use among E-Sogo and West Village respondents



In addition, both baseline surveys asked respondents about the temperature settings on their (living room) ACs. The differences are striking. Figure 56 is a histogram plotting the number of respondents who reported a particular temperature setting (or the nearest equivalent after converting the response from West Village to Celsius). In general, West Village respondents set their ACs lower than E-Sogo residents. Note that the result is even more extreme considering the differences in the precise wording of the survey questions. E-Sogo residents were asked to report the actual temperature setting on their living room ACs. Among E-Sogo treatment group households (which excluded the lowest AC users at E-Sogo), the median was 26°C (79°F). By contrast, on average West Village respondents reported that the highest acceptable indoor air temperature in their apartment was 24.4°C (76°F). These differences reflect the general trend reported in the thermal comfort section of the Background chapter.

Figure 56. Living room temperature settings among E-Sogo and West Village participants

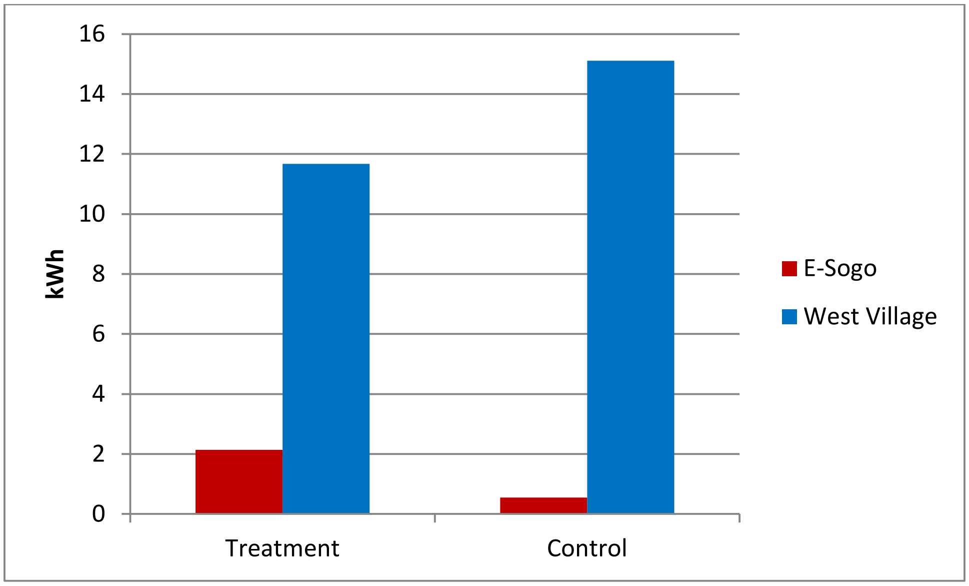


The baseline energy use for AC in the two communities is shown in Figure 57. As the graph indicates, E-Sogo residents used far less energy for AC than West Village residents in the baseline period (i.e., June-September 2013 for E-Sogo and July 2014 for West Village). This is in keeping with the overall difference in electricity consumption between Japan and the U.S., shown earlier in Figure 4.

Several other factors more specific to E-Sogo and West Village may have also contributed to this pattern. Some of the difference is likely driven by the larger size of West Village apartments compared to those at E-Sogo. Another factor is certainly attributable to the difference consumption rates of central versus localized AC equipment. Another factor may be that a larger proportion of the apartments were occupied during the day at West Village, given their erratic schedule compared to families at E-Sogo.

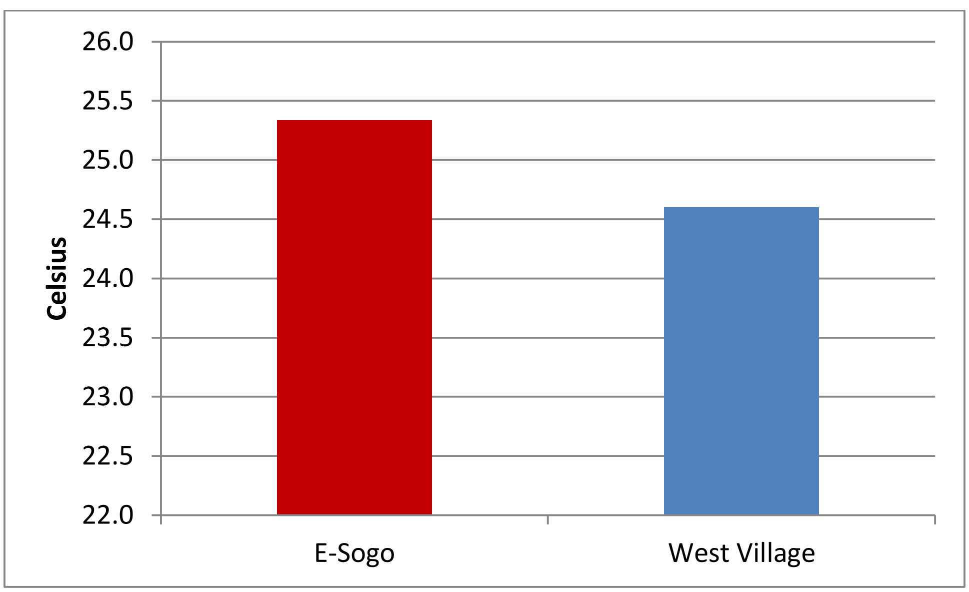
Another interesting difference in the energy use at the baseline is that at E-Sogo, the “control” or non-treatment group had lower consumption than the treatment group, by design. By contrast, although the energy use was expected to be the same among treatment and control groups in West Village, in fact the latter had higher consumption at the baseline.

Figure 57. Baseline daily average energy use for AC, E-Sogo vs. West Village



Another critical factor to keep in mind in interpreting the graph above is the differences in the weather. In the pre-intervention period (i.e., Summer 2013 for E-Sogo and July 2014 for West Village), the average daily temperature was slightly higher in Yokohama. In addition, humidity and nighttime temperatures tend to be higher in Yokohama than in Davis. However, cooling loads were much lower, despite those factors. This highlights the critical role that differences in cooling strategies and preferences play in driving energy consumption.

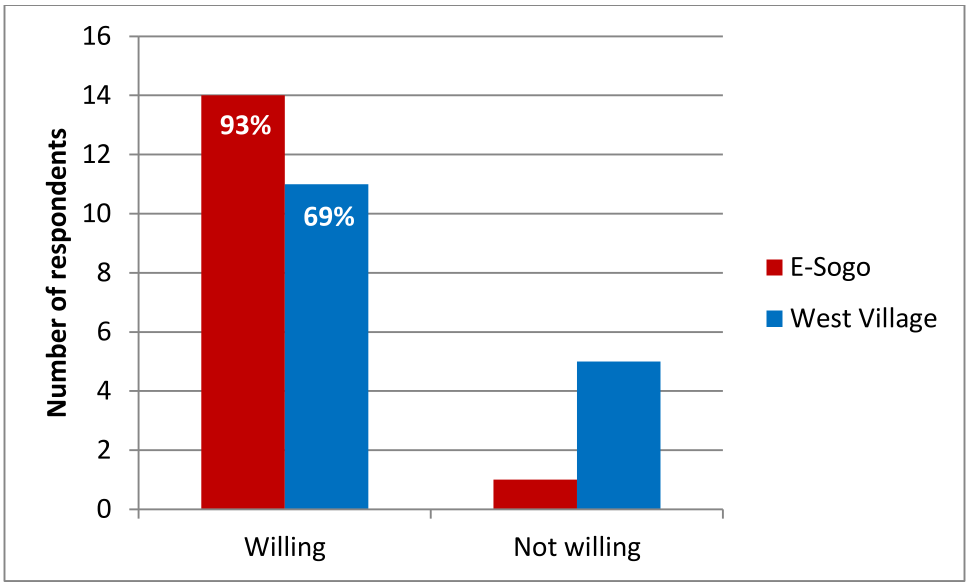
Figure 58. Average outdoor air temperature in the pre-intervention period



II. WILLINGNESS TO CHANGE

Ninety-three percent of E-Sogo respondents agreed to commit to increasing the frequency with which they utilized at least one of the 14 lower energy-intensity cooling strategies suggested. By contrast, 69% of West Village survey respondents reported a willingness to try the "natural" cooling strategy encouraged by the intervention.

Figure 59. Willingness to commit to passive cooling strategies urged by intervention



Note that the commitment we asked for was not identical in each case. E-Sogo residents were provided with many independent options to which to commit, whereas West Village respondents were asked to commit to a single strategy with three key components: raising the thermostat setting, using passive cooling to pre-cool the apartment at night, and using ceiling fans and/or lighter clothing to cope with modest discomfort, as listed in Table 19. With more flexibility across 14 specific strategies from which to choose, it is not surprising that a higher percentage of residents at E-Sogo were willing to make a commitment to engage with the activities encouraged.

Table 19. Comparison of strategies to which study participants were asked to commit

E-Sogo	**West Village**
Daytime	Set thermostat to 80°F (26.7°C)
Close windows and blinds as the outside temperature starts to rise in the morning.	Use ceiling fans
Try not to turn on the AC unless it is uncomfortably hot. Turn it off as soon as it cools down outside.	Open windows from 9pm-9am
Turn AC off and turn on a fan	Close windows from 9am-9pm
Cool only rooms that are occupied and close doors	Wear light clothing

to rooms that are unoccupied	
Change to lighter clothing	
Place a cooling towel or pillow on the back of your neck	
Run errands (at cool shops) during the hottest part of the day	
Use AC's "Cool" setting instead of "Dry" setting. The "Cool" setting uses less energy.	
Nighttime	
Run the AC for a short amount of time before bedtime, to dehumidify the air, with the door closed. Then shut off the AC when going to bed.	
Turn AC on when going to bed, but set timer to turn it off after a short amount of time.	
Turn AC off and turn on a fan	
Use AC's "Cool" setting instead of "Dry" setting. The "Cool" setting uses less energy.	
Place a cooling towel or pillow on the back of your neck	
Open windows in the evening as soon as it becomes cooler outside than inside. Keep windows open all night.	

The difference in the interventions, and the commitments requested, means that the studies are not strictly speaking, comparable. Thus, caution should be exercised when comparing the effects of the interventions.

III. EFFECTS OF INTERVENTIONS

The effects of the interventions are compared both in terms of behavior change and energy savings. Again, the caveats provided earlier apply. Caution should be taken in drawing direct comparisons as the studies differed in many ways.

A. BEHAVIOR CHANGE

Given that the behavior change requested of E-Sogo and West Village study participants was different, there are not many comparisons that can be made regarding behavior change. The surveys did capture perhaps the most important one, however, the change in frequency of the usage of the passive cooling strategies encouraged. As Figure 60 illustrates, both interventions were successful in inducing respondents to use at least one passive cooling strategy more often.[38] However, while more than half of West Village respondents reported doing so, only a third of E-Sogo residents did.

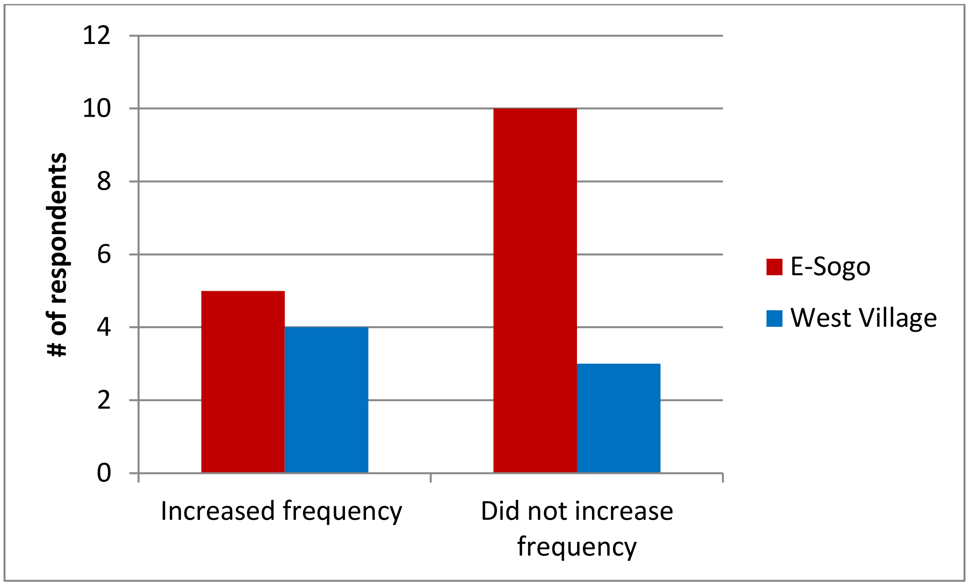
It is impossible to know exactly why the West Village was more successful in yielding behavior change, but there are several plausible explanations. First, the frequency with which E-Sogo residents already utilized passive cooling strategies during the baseline was already fairly high making it difficult to increase them further. That was not the case with West Village.

Second, the West Village intervention was more straightforward. Respondents were asked to do one specific set of activities – which comprised an overall passive cooling strategy – at specific times and in specific ways. This was possible largely because of the cool nighttime breezes, which the strategy was designed to leverage. Respondents were provided with visual reminder cards (i.e., laminated flyers) to promote awareness throughout the study.

By contrast, the E-Sogo residents were urged to do 14 different strategies more often than they did before. Many were complementary, but they were not presented as a cohesive strategy, as was the case with West Village. It may be harder to remember to execute many disparate actions than a single cohesive strategy with a few components. This seems to have been the case. Although respondents were provided with a reminder midway through the study, it seems from the interview responses that many respondents had forgotten about the study altogether. Furthermore, it may be difficult to recall whether one did each of many small actions more or less often than before. Modesty would urge an underestimate in such a case, which may have also played a role. However, the interviews did confirm that many respondents found it very difficult to increase the frequency with which they utilized the strategies encouraged, thus corroborating the survey findings.

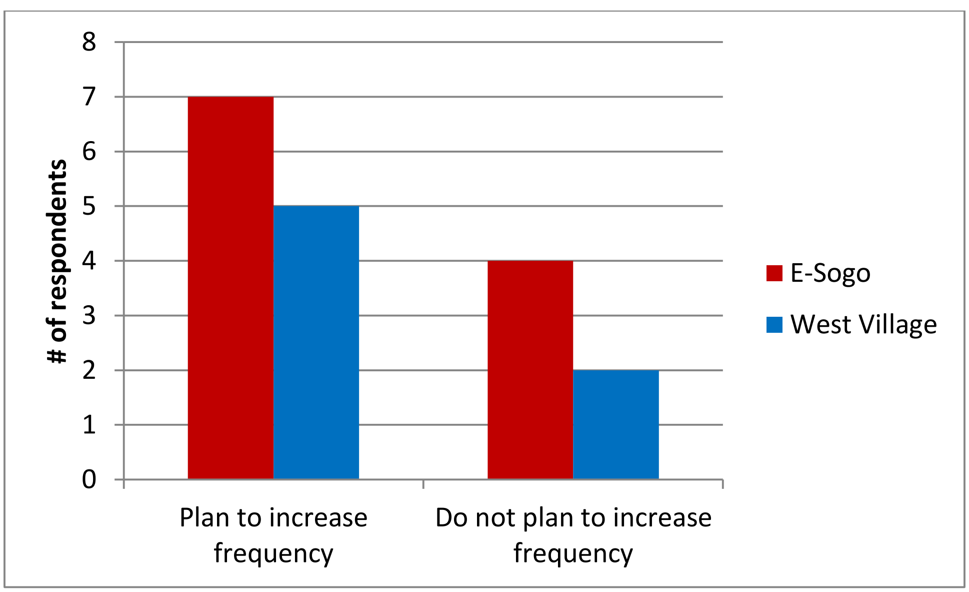
[38] For E-Sogo residents this was indicated by an increase in any one of the 14 strategies encouraged by the study. West Village residents were asked only about two strategies: opening windows at night and using ceiling fans.

Figure 60. Reported change in frequency of passive cooling strategy usage



Another indicator measured in both surveys was the intent to continue to utilize the passive cooling strategies the intervention promoted more often than previously. As Figure 61 shows, in both studies, more respondents intended to maintain a higher frequency of use than before. Although the studies did not incorporate a way to verify whether that occurred or not, intent is a necessary pre-condition for action. In that respect, it is another positive outcome of the interventions.

Figure 61. Respondents' intended frequency of passive cooling strategies in future



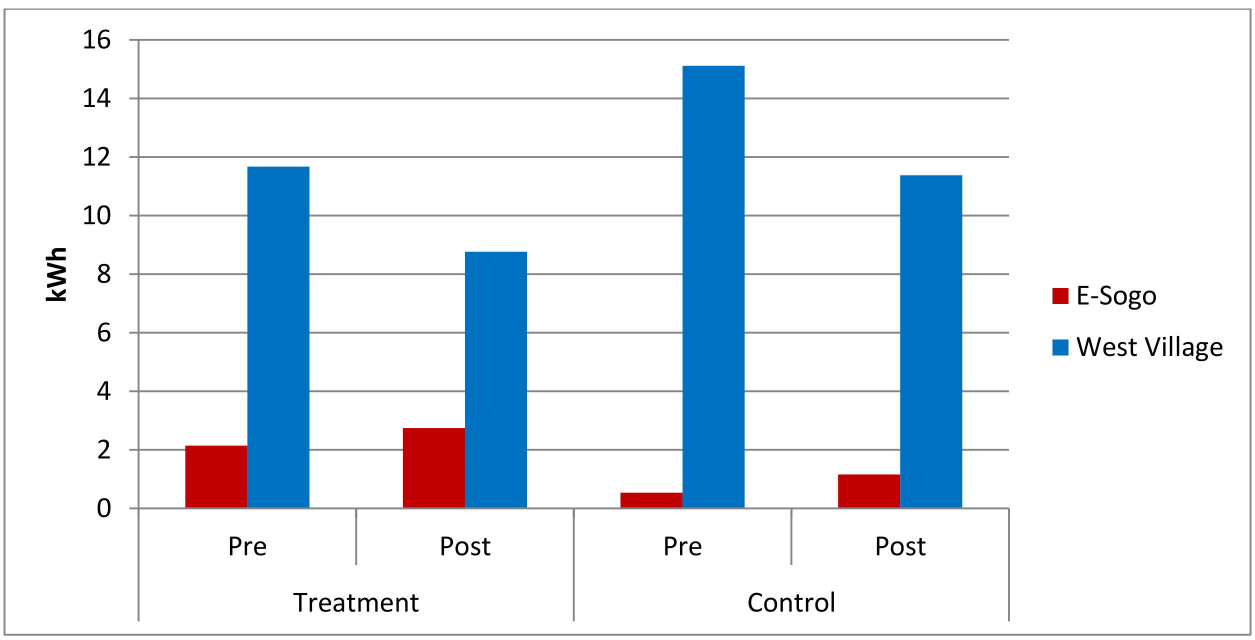
Despite lackluster findings related to behavioral change, there was some evidence that the changes that were made, however small, did result in some energy savings in both study locations, as discussed below.

B. ENERGY SAVINGS

Figure 62 shows the *unadjusted* comparison of daily average energy use from AC in the pre- and post-periods for the Treatment and Control groups from both E-Sogo and West Village. There are two distinct differences between the two experiences that are apparent from this graph. First, at E-Sogo, energy use was higher in the post period (defined as August 2014) among both the Treatment and non-treatment groups, while the reverse was true for West Village. The reasons for this are discussed above. Also, it is important to note that when accounting for weather, the E-Sogo treatment group did exhibit a decrease in energy use after the intervention, as did the West Village treatment group.[39]

Another notable distinction between the two experiments is the relative values of the Treatment versus Control groups. At West Village, the Control group had relatively higher consumption than the Treatment group in both periods. As mentioned before, this was an unexpected finding and potential source of bias in the study. By contrast, consumption among the non-treatment at E-Sogo was lower than the Treatment group, in that case by design, as the study aimed to target the medium to high users.

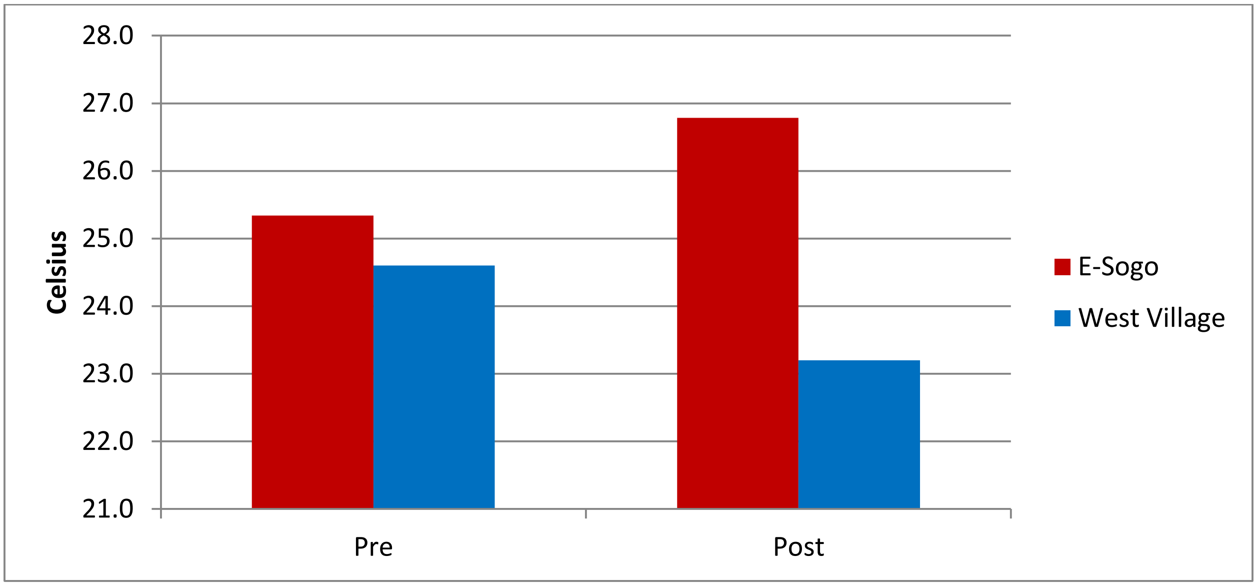
Figure 62. Pre-post, Treatment-Control comparison of daily average energy use from AC



[39] Note that weather normalization was conducted differently in the two cases. The E-Sogo data was analyzed using regression techniques to adjust for weather, while the West Village data utilized the change exhibited among the Control group as a means of netting out the effect of weather.

Note that the weather patterns were reversed in the two study locations. That is, the average temperature was higher in the post-intervention period at E-Sogo, and lower at West Village, relative to their respective pre-intervention periods, as Figure 63 illustrates. Thus, the analysis required to net out the effect of outdoor air temperatures make the adjustments to the results in opposite directions for the two studies.

Figure 63. Outdoor air temperatures in pre- and post-intervention periods



Recapping the weather-adjusted results presented above, the interventions yielded approximately 7% energy savings among Treatment group households at E-Sogo, and approximately 8% energy savings among Treatment group households at West Village. While there are significant caveats associated with those findings (e.g., small samples, self-selection bias, short post-intervention periods, limited accounting for the effect of weather in the case of West Village), the results are promising. They suggest that interventions that utilize multiple behavioral levers - which, for example, raise awareness, provide social comparisons, request commitments, and serve as reminders – can be effective in getting residents of ZNE communities to lower their AC use by adopting alternative cooling strategies, including passive cooling.

CONCLUSIONS

In this study, WCEC researchers attempted to encourage residents of two very high-efficiency apartment buildings—one in Yokohama, Japan and one in Davis, CA—to reduce their consumption of energy for summertime cooling. The approach was to identify a set of strategies that the residents could employ, and to get commitments from the residents to implement those strategies.

The strategies that were recommended were different for the two buildings, but they consisted of "passive cooling" techniques, such as opening and closing windows at the appropriate times, using fans, and other alternative strategies to substitute for mechanical cooling, and managing the temperature setpoints.

The mechanisms or principles utilized to encourage changes in behavior included:

- Education & awareness
- Feedback
- Social norms and comparisons
- Commitment
- Reminders
- Environmental altruism (as an intrinsic motivation).

Of these, it is estimated that the feedback and social comparisons provided were the most effective at stimulating behavior change. Both elicited strong reactions during the interviews, and respondents were eager to learn how their energy use was affected by their actions. Future experiments to encourage energy conservation would be wise to ensure that participants will be given information about their impact, in absolute terms and relative to others, when appropriate.

It should be noted, however, that social comparisons do pose a risk. Occupants have more information about their particular circumstances, and sometimes those of their neighbors. Drawing comparisons with households that study participants (or customers) do not believe are comparable can backfire, as OPower has learned. This study, too, yielded evidence of that as many E-Sogo residents questioned the fairness of the comparison. They wanted to know whether their neighbors had the same mitigating circumstances as they (e.g., children, pets, someone at home all day). There is ample research to show that social comparisons must, to the extent possible, be made only among comparable households lest the targets use the differences as a rationale for their own high consumption rather than a motivation to lower it.

In both study locales, self-reported changes in behavior did occur, illustrating the potential for behavioral initiatives that educate, motivate, and remind consumers to try alternative adaptations before using the AC. Furthermore, a notable 7-8% reduction in energy consumption from AC use was achieved. This was a very encouraging finding of the study.

The studies were not without significant challenges, however. Over the course of the research, evidence was gathered regarding the factors that limit the potential to encourage conservation through passive cooling. These challenges included:

- Low levels of participant engagement with the studies (in terms of recruitment at West Village and ongoing participation at E-Sogo) limited behavior change.
- Japanese cooling energy use is already quite low, and space temperatures are already much higher, so there may be little potential for conservation remaining.
- Discomfort with summer heat and humidity negatively affects residents, especially at night.
- There are few desirable alternatives to nighttime AC unless outdoor air temperatures drop significantly, as they do in Davis.
- Concern over heat stroke is a commonly cited barrier to passive cooling at E-Sogo.

- Although many E-Sogo residents were quite frugal, they reported that the younger generations of Japanese do not have the same ethic of avoiding waste, so conservation measures may become more difficult in the future.
- Discomfort, noise and safety concerns with open windows were cited as barriers at West Village. Although this was not a problem at E-Sogo, it could be for other Tokyo Gas customers.
- Housing design (and/or occupants' preference for privacy) may limit the potential for cross ventilation. Again, this was not a problem at E-Sogo, but it could be for other Tokyo Gas customers.
- Household members, whether related or not, may have significantly different thermal preferences and cooling habits. Passive cooling requires some degree of coordination among occupants. The extent to which that is possible varies across households.
- The impact on energy use of effectively free electricity at West Village cannot be estimated from this study. While behavioral research aims to look beyond the classical financial drivers, they should not be neglected, and it is possible that this factor could be one of the primary drivers.

Numerous factors related to the context in which these studies were conducted may have had a significant role in determining the outcomes observed. Various similarities and differences between the communities and participants were discussed in an earlier section. The broader national differences are perhaps worth reiterating here, however. Among Japanese and Americans, several important differences were observed in the cooling strategies and the factors that drive them. Japanese cooling techniques are more narrowly targeted at the room or person that desires cooling, while Americans tend to have a more generalized approach, conditioning an entire home. As a result, the Japanese cooling strategy often has multiple components. In addition, it seems to be characterized by more active engagement (e.g., turning AC on and off) relative to Americans' set-it-and-forget-it approach. Finally, there appear to be important cultural differences in the acceptability of thermal comfort. Japanese appear to assess thermal comfort, and its acceptability, relative to other priorities (e.g., energy cost, environmental impact).

It is very clear that, between Japan and the U.S., there are fundamental differences in attitudes about cooling, strategies for cooling, and the range of solutions that are considered possible. Such differences exist within national populations, too. As this research illustrates, understanding the strategies and motivations driving behavior is vital to designing interventions that will be successful in encouraging the adoption of alternative cooling strategies.

RECOMMENDATIONS

The potential for energy savings from behavioral methods to encourage passive cooling behaviors and strategies is significant. Based on the results of the two studies described in this report, it seems that the most promising strategies to pursue in Japan would include:

- Increasing awareness of the energy implications of "dry" modes;
- Reminding or informing individuals about improved cooling pillows/towels;
- Encouraging coping mechanisms while sleeping (e.g., cooling pajamas, cooling bedding, fans);

- Encouraging other personal cooling options (e.g., clothing designed for heat); and
- Developing control paradigms to ensure that the use of alternative strategies is integrated with the AC.

Another implication of this study is that the design of AC systems and controls in the future may be very different from current systems, both in Japan and the U.S. Controls should respond as closely as possible to the individual's instantaneous cooling requirements and preferences, while defaulting to an energy conserving mode. This would require behavioral research to identify the range of cooling strategies, and the best way to enable and encourage them.

Hopefully, manufacturers will take into account these findings as they design their new products. AC systems are marketed very heavily on features in Japan, including the presence of an "Eco" mode. The younger generation in Japan constitutes a growing part of the AC market. Respondents reported that this generation has not been instilled with the conservation ethic that their parents possess. AC designs that cater to their higher demand for comfort must not take the energy-intensive path of the American central AC with comfort as the prime directive. Rather, manufacturers can use framing described in this study to develop different modes or features for different "types" of consumers, to support those who choose to use as little energy as possible. These concepts—which represent a more radical change to the dominant AC paradigms in the U.S.—should be promoted there as well.

One example of the functionality that should be developed is a mechanism to mediate the different needs and preferences of the different residents of a home. Significant research on household social structures would be required to identify the best methods of setting and implementing strategies for collaboration.

If we accept that "comfort" can be a relative thing that is influenced by culture and attitudes, as well as personality, habit, and individual preferences, technologists in both Japan and the U.S. can explore new and previously unthinkable ways to provide appropriate conditions to occupants using the least possible amount of energy.

The outcomes of this study suggest that there may be other fruitful areas of behavioral research to reduce energy consumption in Japan. For example, heating energy use has many similarities with cooling, although it is more complex because there are a larger number of both mechanical and adaptive options for finding comfort, e.g., AC, gas space heater, gas-fired boiler, fuel-cell, solar thermal, passive solar (greenhouses and increased thermal mass), floor based radiant heating, electric resistance space heaters, "kotatsu" (traditional Japanese under-table heaters), using baths to warm up before bed.

It can be expected that there will be many cultural and behavioral factors that drive occupants to use one technology or another for comfort in winter. However, occupants typically do not know which technology will yield the lowest energy use. In fact, at this point researchers do not have enough information to make that determination either. Research should be done on the building-science and behavioral factors involved in heating choices. Since more energy is consumed for heating than cooling in Japan, and there may still be more room for improvement, this area of research is highly recommended.

Broader programs throughout Tokyo Gas territory or nationwide, focused on social means to encourage specific energy conservation behaviors may be warranted. Before implementing such programs, however, Tokyo Gas may want to evaluate and carefully design the materials used for obtaining commitments, reminders, etc…, in accordance with the results and lessons provided in this report.

Pilot studies in conventional homes should be implemented to assess the generalizability of results, as the savings in this study were realized for a small sample of households living in non-typical apartments. A broader program would likely have different savings (higher or lower), and it is important to consider that a broader implementation could also have impacts on both participants and non-participants, as it becomes more standard practice.

WCEC, through its HVAC Behavioral Research Initiative, intends to pursue more research in this vein. At West Village and other residential and commercial sites, we will continue our research to promote other energy saving behaviors, to learn more about how and why people use their technologies, and to find out the best ways to encourage conservation. More than ever before, it is critical to look not just at technical specifications of building technologies, but at their potential for working well within the human and social system. Tokyo Gas Company is encouraged to continue their ground-breaking work in this area.

REFERENCES

Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics*, *95*(9), 1082-1095.

American Housing Survey for the United States: 2011, United States Census Bureau. https://www.census.gov/content/dam/Census/programs-surveys/ahs/data/2011/h150-11.pdf.

"2012 Annual Research on Energy Consumption". Agency for Natural Resources and Energy. http://www.meti.go.jp/meti_lib/report/2013fy/E003078.pdf. Retrieved June 30, 2014.

Appendix of 2008 Household and Land Census, Statistics Japan. http://www.stat.go.jp/data/jyutaku/2008/pdf/kgiy11.pdf.

ASHRAE. (2010). " Standard 55: Thermal Environmental Conditions for Human Occupancy".

ASHRAE. (2013). "ANSI/ASHRAE Addendum g to ANSI/ASHRAE Standard 55-2010".

Ashraf, N., D. Karlan, et al. (2006). "Tying Odysseus to the Mast: Evidence from a Commitment Savings Product in the Philippines." *Quarterly Journal of Economics* 121(2): 635-672.

"Average Annual Expenditures by Major Category of All Consumer Units and Percent Changes, Consumer Expenditure Survey, 2009-2012", BLS Reports. U.S. Bureau of Labor Statistics. http://www.bls.gov/cex/csxann12.pdf.

"Average Annual Expenditures of All Consumer Units by Selected Major Types of Expenditure: 1990 to 2009". United States Census Bureau. https://www.census.gov/compendia/statab/2012/tables/12s0684.pdf.

"Average price by state by provider, back to 1990". U.S. Energy Information Administration.

"Chapter 2, Population and Household", Statistics Japan. Statistics Bureau, Ministry of Internal Affairs and Communication. http://www.stat.go.jp/data/nihon/pdf/n0200000.pdf.

CRECER corporate website. http://www.crecer.jp/Q-A/HTML/A-11.html.

"Davis (city) QuickFacts". United States Census Bureau. http://quickfacts.census.gov/qfd/states/06/0618100.html.

Google Maps. http://maps.google.com

"Growth in Urban Population Outpaces Rest of Nation", Census Bureau Reports. https://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html

2014 Household Energy Handbook. (2013) Jyukankyo Research Institute Inc. Tokyo, Japan.

Household Energy-Saving Handbook. Tokyo Metropolitan Governments. http://www.tokyo-co2down.jp/ecology/home/.

Hoyt, T., Schiavon, S., Piccioli, A., Moon, D., and K. Steinfeld. (2013), CBE Thermal Comfort Tool. Center for the Built Environment, University of California Berkeley, http://cbe.berkeley.edu/comforttool/.

Ideas42 website. http://www.ideas42.org/

"Japan Statistical Yearbook 2010". Statistics Bureau. p. 17. http://www.stat.go.jp/data/nenkan/pdf/yhyou01.pdf.

Karjalainen, S. (2009). Thermal comfort and use of thermostats in Finnish homes and offices. *Building and Environment*, 44(6), 1237-1245.

Lehrer, D., J. Vasudev and S. Kaam, 2014. A Usability Study of a Social Media Prototype for Building Energy feedback and Operations. Proceedings ACEEE Summer Study on Energy Efficiency in Buildings. Pacific Grove, CA, August.

Meier, A., Aragon, C., Peffer, T., Perry, D., & Pritoni, M. (2011). Usability of residential thermostats: Preliminary investigations. *Building and Environment*, 46(10), 1891-1898.

Mishra, A. K., & Ramgopal, M. (2013). Field studies on human thermal comfort—An overview. *Building and Environment*, 64, 94-106.

"Monthly and Annual Consumer Behavior Survey", pg.16. Economic and Social Research Institute, Cabinet Office. http://www.esri.cao.go.jp/jp/stat/shouhi/2012/1203honbun.pdf#page=15.

OANDA Currency Converter. www.oanda.com

Peffer, T., Pritoni, M., Meier, A., Aragon, C., & Perry, D. (2011). How people use thermostats in homes: A review. *Building and Environment*, 46(12), 2529-2541.

"PG&E ZNE Study of West Village". Presentation. NORESCO, 2014

Population News of Major Cities. Statistical Information Division, Policy Bureau. http://www.city.yokohama.lg.jp/ex/stat/jinko/city/new-e.html.

"Residential Energy Consumption Survey". (Years 1993-2009). Energy Information Administration. http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#fuel-consumption. Retrieved June 30, 2014.

"Residential Sector Energy Consumption". U.S. Energy Information Administration. http://www.eia.gov/totalenergy/data/monthly/pdf/sec2_5.pdf.

"Retrieve daily data for DAVIS.A (CIMIS #6, Davis)", UCIPM online. http://www.ipm.ucdavis.edu/calludt.cgi/WXSTATIONDATA?MAP=yolo.html&STN=DAVIS.A&BACKUP=NONE&GETALL=0.

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science*, *18*(5), 429-434.

"State & County Quick Facts, Davis (city), California". US Census Bureau. http://quickfacts.census.gov/qfd/states/06/0618100.html.

"Summary of Monthly Normals 1981 - 2010".U.S. Davis 2 WSW Experimental Farm, CA, US; National Environmental Satellite, Data, and Information Service, National Oceanic & Atmospheric Administration, U.S. Department of Commerce. http://www.ncdc.noaa.gov/cdo-web/datatools/normals.

Tanabe, S., & Kimura, K. (1989). Thermal comfort requirements under hot and humid conditions. In *Proceedings of the First ASHRAE Far East Conference on Air Conditioning in Hot Climates, Singapore, ASHRAE* (pp. 3-21).

Thaler, R. H. & S. Benartzi (2004). "Save More Tomorrow: Using Behavioral Economics to Increase Employee Saving." *Journal of Political Economy* 112(1): 164-187.

"U.S. and World Population Clock". United States Census Bureau. http://www.census.gov/popclock/.

United States: 2010 Summary Population and Housing Characteristics, United States Census Bureau. https://www.census.gov/prod/cen2010/cph-1-1.pdf.

“United States Summary: 2010, Population and Housing Unit Counts”, 2010 Census of Population and Housing (PDF). United States Census Bureau. September 2012. http://www.census.gov/prod/cen2010/cph-2-1.pdf.

The World Factbook 2013-14. Washington, DC: Central Intelligence Agency, 2013. https://www.cia.gov/library/publications/the-world-factbook/.

"Yokohama City; Monthly Values of Year 2013; Major Factors". Japan Meteorological Agency. http://www.data.jma.go.jp/obd/stats/etrn/view/monthly_s1.php?prec_no=46&block_no=47670&year=2013&month=&day=&view=.

Zhang, H. “Human thermal sensation and comfort in transient and non-uniform thermal environments”, PhD thesis, University of California, Berkeley, 2003.