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Short-term Electricity Conservation in Juneau, Alaska:

Technology and Behavioral Change in Persistence

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Abstract

An avalanche destroyed part of the main hydroelectric transmission line to Juneau, Alaska on April 16, 2008. Backup generators were able to replace the lost capacity but the use of diesel fuel for generation caused electricity prices to increase 500 percent for a 45-day period. Response to this electricity “crisis” included electricity conservation that began within 2 days of the event and reduced electricity use by 25% over the period of supply disruption relative to the same period in 2007. Conservation of about 8% relative to 2007 persisted after the transmission line was repaired and electricity rates returned to normal. A second avalanche on January 9, 2009 damaged the same section of transmission line and caused a second supply disruption, albeit lesser in duration (19 days) and magnitude of price increase (200 percent). This time observed conservation during the disruption was less (12% relative to 2007) while persistent conservation after the event increased by two percentage points to 10% relative to 2007.

We conducted a survey of residential consumers after the second avalanche to investigate the actions taken in response to these supply disruptions. Results showed an average of 10 conservation actions taken in each household, with major changes in lighting, space heating, fuel switching, and water and appliance use accounting for the observed aggregate conservation. Conservation began in *anticipation* of a complex price signal, and persisted after the disruption through both installed technology and new habits. Although past experience with short-term electricity supply shortfalls had suggested demand reduction of 3% within a few days and 20% in a few months was possible, it now appears feasible to cut electricity demand by 25% *or more* in only a few days without adverse economic consequences in some circumstances. A process of disruption inducing trial that leads to formation of new habits is apparent in persistent behavior change that complements technological change in explaining persistent conservation.

The prime motivator of a price signal may be relative, with doubling of price in the second supply disruption motivating relatively little conservation because it followed closely after the 500% price increase during the first disruption. But repeated supply disruptions may induce larger investments in technology retrofit since consumers believe preparation for the next event will pay off, which delivers increased persistent conservation. Since the impact of specific actions on overall electricity savings is a function of the effectiveness of the action and the number of people who choose to take the action each day, both factors should be considered when selecting which activities to suggest in public outreach campaigns. A method for prioritizing conservation actions for promotion according to the *impact* in electricity savings as a function of popularity, persistence and effectiveness is proposed.

A complete framework for the dynamics of electricity use before, during and after a supply disruption is proposed, with factors that pertain to the *rate* of change in electricity conservation at the start and end of the disruption proposed as complements to the conventional use of short-term price elasticity of demand to explain the *magnitude* of conservation.

1. Introduction

This paper evaluates the residential consumer response to a short-term electricity supply disruption that occurred in Juneau, Alaska in 2008. Short-term electricity shortfalls vary in magnitude, duration and response (IEA, 2005). Juneau experienced the largest recorded price increase and largest recorded electricity demand decrease (Figure 1). Furthermore, the "natural laboratory" in this case is well controlled, within an isolated community not subject to confounding factors from external road or electricity grid connections. As such, the case study affords an opportunity to study the outer limits of electricity conservation through behavioral changes that occurred under extreme conditions that included a strong but complex price signal.

A multi-disciplinary research approach is taken, drawing on economics, social science, survey research methods and statistics, with implications for energy systems planning, public policy, and climate change mitigation. Through analysis of survey data, we gain better understanding of the specific activities that produced the observed aggregate electricity conservation in Juneau. We address the interconnected questions shown in Table 1 in this paper.

Questions	Disciplines	Data
What *magnitude* of demand-side conservation can occur under the extreme conditions of a short-term electricity supply shortfall; at what *rate* can the underlying efficiency improvements and conservation activities be implemented; and will savings *persist* after the shortfall has been rectified?	Data Analysis, Statistics	Electricity Use (AEL&P), Temperature, Heating Deg. Days
What specific actions account for the immediate and persistent electricity conservation observed? How many of these involve technological versus behavioral change?	Survey Methods, Consumer Behavior	Survey Results
Which conservation actions are most effective in reducing electricity demand and which are most impactful in producing short-term and long-term electricity savings?	Survey Methods, Energy System Modeling	Survey Results, Literature
What motivates conservation behavior in the context of short-term supply shortfall events? What aspects of the response observed in Juneau, Alaska are unique to this context and what aspects may be applicable to other situations?	Survey Methods, Economics, Consumer Behavior, Public Policy	Survey Results, Literature

Table 1: Research questions and the academic disciplines and data sources used to address them.

Since short-term electricity shortfall events can and do happen, understanding effective response is important to mitigating the potential for blackouts, brownouts, and/or dramatic price increase that can cause economic hardship. Improving demand-side management and efficiency programs through better understanding of conservation behavior is also important for a variety of energy use and climate change policy goals. Furthermore, the *rate* at which energy use patterns can change is becoming salient as the time frame for achieving these goals shortens. Temporary shortfalls in electricity supply, whether from the breakdown of generation or transmission infrastructure or events in the natural world like droughts or heat waves, provide impetus for extreme demand-side conservation (IEA, 2005). As such, these events provide opportunities for study of how much demand-side efficiency improvement and conservation can happen, how fast these changes can occur, and to what extent they persist after the supply side has been repaired.

In studying the experience in Juneau, Alaska, we focus specifically on improving understanding of conservation actions taken within households. Better understanding of these behaviors can help in developing informed policies, program designs, and demand forecasts (Lutzenhiser et al, 2003). Our findings contain implications for designing effective energy efficiency programs, reveal the importance of consumer *perception* of prices in the short-run price elasticity of demand, and enable prioritizing actions based on impact. We use the understanding of events in Juneau to propose a process of disruption inducing trial and development of new habits to explain some persistent electricity conservation and to propose several predictive factors for the *rate* of conservation adjustment in a period of supply disruption. Finally, extensions to the transportation sector are discussed.

1.1 Background Literature

Examination of the electricity conservation that occurred in Juneau builds upon a large volume of previous work in the areas of household energy use and conservation behavior. Our analysis of survey data to understand what actions were taken in Juneau homes adds new and useful information to this body of knowledge by improving understanding of how the actor/device system of consumer choice and utilization of efficient technologies is affected by prices, programs, and emergent problems.

Our research necessarily spans the disciplines of economics, social science, survey research methods and statistical analysis. Our emphasis on household conservation activity required careful understanding of consumer behavior in order to design an efficient and unbiased survey tool for data collection, and we employed several statistical methods for interpretation of these data. Consideration of the mechanics of price signals and response in the economics of short-run price elasticity of demand was also important given the 500% increase in electricity price that occurred in Juneau. Finally, a growing body of research considers the potential role for demand-side management, through activities like those observed in Juneau, in greenhouse gas emission reduction for climate change mitigation.

1.1.1 Economics Literature

The primary economic questions about the observed electricity conservation in Juneau pertain to the relationship between electricity price and quantity of use. In other words, we are interested in the shape of the electricity demand curve, often summarized by the price elasticity of demand. However, in times of crisis the rate of adjustment along this demand curve and potential for change in the curve itself become salient. In other words, we face a question of dynamics in the economics of electricity use.

As a measure of the sensitivity of quantity demanded to changes in price, the price elasticity of demand is defined by the percentage change in quantity demanded for a one percent change in price. The observed conservation response to changes in electricity price in Juneau raises four questions about the electricity demand curve. First, except for special cases the price elasticity of demand will vary with position on the demand curve (i.e., the price elasticity will differ between price levels). The relatively large magnitude of electricity price change in Juneau may afford insight into the change in quantity of use when price jumps between distant locations on the demand curve. Second, the rapid change in price and relatively short duration of elevated price combined with the observed immediate *and* persistent reduction in quantity of electricity use raises questions about the short-run versus long-run price elasticity of demand. Third, the potential for fuel-switching in some areas of electricity use (e.g., heating, cooking) raises the question of cross-price elasticity of electricity demand with respect to other fuels like natural gas, oil, or wood. Finally, our focus on the timing and type of specific conservation activities in response to the electricity price increase may afford insight at the foundational level of neoclassical economics, where the mechanics of price signals and response play out in terms of discrete decisions by individuals acting in rational self-interest.

Observed price and quantity data from cross-sections that differ in price or time-series over a period where price changes have occurred can be used to estimate the demand for electricity and thereby *forecast* reactions to future price changes. But such forecasting requires strong assumptions about the “uniformity of response across both space and time” (Woods, 2008). As with any demand curve, there is difficulty in generalizing from reactions to price changes of similar size but at different price levels (i.e., continuously variable elasticity) or to price changes at similar price levels but of different size.

1.1.1.4 Conservation Activities by Individual Rational Actors

Analysis of the relationship between electricity price and consumption fits nicely into the neoclassical framework of economics wherein observed data are the aggregate result of choices made by individual rational actors. Thus, *behavioral* understanding of *how* people use electricity and with what *equipment* is the inherent foundation for economic estimation of electricity demand curves. This foundation has several implications for the estimation of demand from economic data.

Using cross-sectional data covering spatial variation in electricity prices to estimate the demand for electricity is confounded by instability in demand estimates during periods of price change (Yang, 1978). Since change in the quantity of demand is the result of changes in the equipment and behavioral patterns of electricity use, it is reasonable to suppose that a price change may induce movement of the demand curve itself as well as movement along it. There is also the problem of supposing that territories with different prices are similar enough to be used as a guide in forecasting response to price changes. But if the underlying equipment and behavioral patterns of electricity use differ, the territories may face unique demand curves. Aigner and Leamer (1984) showed that reactions may differ between locations even when controlling for location-specific variables (e.g., weather).

The reaction to a price *decrease* may also differ from the effect of a price *increase* and vice-versa (i.e., asymmetric response). Such effects in residential electricity markets were noted by

Young et al., (1983) and were later explained as “prospect theory” with reference to price effects and transaction utility by Tversky and Kahnneman (1991). Thus, past data on the effects of price decreases should be used to forecast the effects of price increases only with caution.

Using time-series data covering variation in electricity prices is confounded by the recognition that the equipment involved in energy use changes over time in response to “prices, taste, and technology” (Woods, 2008). This led to the development of a variant of error-correction model called “flow-adjusted” models that compensate for such changes (Houthakker et al., 1974; Archibald et al., 1982; Garcia-Cerrutti, 2000; Halvorsen and Larsen, 2001). In other words, it is important to consider whether the conservation measures available for households to react to price changes have changed since the data used for forecasting was generated.

In summary, the neoclassical framework for economists’ inquiry into electricity demand demonstrates the potential for *change* in the demand curve for electricity. In this context, Woods (2008) found inspiration for a behavioral study to “go beyond simple price and use data, to the physical data generating process, what people do, to provide evidence that households still have ways to easily decrease electricity use in response to higher prices and not assume they can act.” Woods further stated his research purpose as follows: “It is essential to look into the behavioral determinants of electricity demand… to ensure that there are enough common conservation behaviors to allow households to react to price increases in ways similar to what they have in the past.” In other words, a survey about behaviors can inform econometric analysis.

1.1.2 Social Science Literature

The social science literature on energy conservation is broad and deep. For the purpose of this research, we focused on the areas pertaining to short-term events, consumer attitudes and how people think about conserving energy, and research based on survey approaches similar to ours. The literature on short-term supply disruption events is summarized in section 1.1.3. The other two areas of focus are presented below.

The classic paper by Kempton and Montgomery on “Folk Quantification of Energy” provides insight into how people *think* about conserving energy, especially in the context of limited information or understanding of where and how energy is used in their surroundings and activities (Kempton and Montgomery, 1982).

Social science research on energy conservation has frequently used surveys with closed-ended questions to investigate behavior. Several such studies were conducted during the energy price increases of the 1970s (e.g., Kilkeary, 1975; Walker and Draper, 1975; Bultena, 1976; Cunningham and Lopreato, 1977; Perlman and Warren, 1977). Some studies focused on *knowledge* of conservation behaviors (e.g., Scheffler et al., 1979) and on *difficulty* in adopting conservation behaviors (e.g., Gladhart et al., 1980), and collected data on the *determinants* of demand elasticity. These determinants can be used by economists to differentiate heterogeneous populations.

Research by Wilhite et al. (2001), Blumstein et al. (2000, 2001) and Lutzenhiser (2002) emphasized a need to understand energy use, technology choice and economic behavior as a system. This emerging emphasis in the literature on person-technology-institutional systems, or "socio-technical systems" (Hughes 1989), parallels the evolution of thinking in environmental policy from command-and-control regulation in the 1970s-1980s to market-based approaches in the 1980s-1990s to sustainable development, system dynamics and community involvement in the 2000s (Lutzenhiser, 2003).

Other resources on the social science literature for household energy use and conservation include the following.

- Stern, P. and Aronson, E. 1984. *Energy Use: The Human Dimension.* New York: W.H. Freeman.
- Shove, E., L. Lutzenhiser, S. Guy, B. Hackett, and H. Wilhite. 1998. "Energy and Social Systems" pp. 201-234 in Steve Rayner and Elizabeth Malon, eds. *Human Choice and Climate Change* Columbus, OH: Battelle Press.
- Katzev, R. and T. Johnson. 1987. *Promoting Energy Conservation: An Analysis of Behavioral Research.* Boulder, CO: Westview Press.Lutzenhiser, 1983
- Lutzenhiser, L., C. Harris, and M. Olsen. 2001. "Energy, Society and Environment" pp. 222-271 in Riley Dunlap and William Michaelson, eds. *Handbook of Environmental Sociology* Westport, CT: Greenwood Press.

1.1.3 Short-term Energy Crisis Literature

Our study adds to a growing accumulation of experience with short-term electricity shortfalls, the impacts of these events, and responses to them. Each new study is generally additive to previous work since each event is different in origin, context and circumstances, magnitude, and response and results. Furthermore, the "emergency" nature of these events tends to afford little time for careful study amidst the myriad other priorities for action. As a result, detailed information on the specific actions taken in order to achieve the observed electricity conservation is generally missing in the research and documentation of prior events. Hence, our emphasis on understanding specific actions taken to conserve electricity in Juneau.

1.1.3.1 Saving Electricity in a Hurry

The book titled "Saving Electricity in a Hurry: Dealing with Temporary Shortfalls in Electricity Supplies" provides an excellent summary of existing literature on responses to a variety of short-term electricity shortfalls (IEA, 2005). Through description of the causes for several temporary shortages in electricity supply – forest fires, droughts, equipment failures and heat/cold waves – the fact that these events can and do happen is emphasized. Understanding how to effect rapid electricity conservation is paramount to avoid potential harm ranging from blackouts and brownouts to economic hardship when adjustments to the supply side are insufficient. Rapid short-term reductions in electricity demand provide a useful tool to a utility struggling to cope with a disruption on the supply side. Although these events are infrequent, the potential economic consequences are large enough to warrant advance planning.

The magnitude and duration of short-term electricity crises varies (Table 2). Brazil sustained 20% electricity conservation for several months. In Arizona, 6% conservation was sustained for six weeks in order to avoid blackouts, and Sweden cut demand by 4% for one day in anticipation of a cold wave. Given past experience that, "clever use of mass media and other strategies can cut demand 3% in only a few days to 20% in a few months and sustain those levels until the crisis has passed" (IEA, 2005), the experience in Juneau of 25% conservation achieved in only a few days appears to be an extreme example of conservation that warrants examination to understand what occurred in terms of conditions and actions (Figure 1).

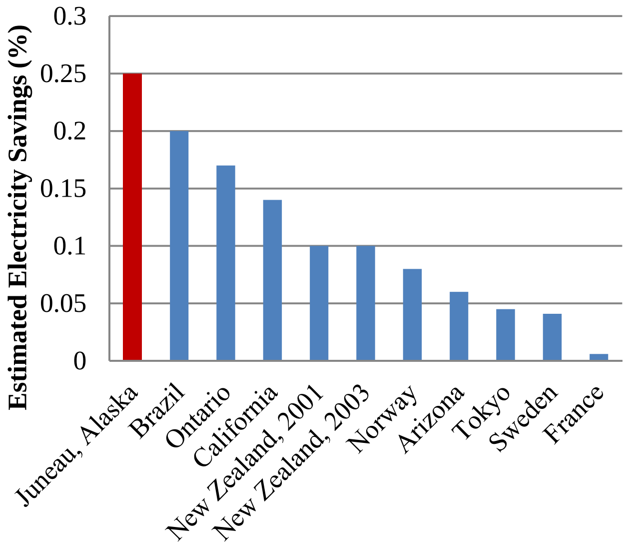

Figure 1: Summary of estimated electricity savings achieved in Juneau and other regions through programs designed to "save electricity in a hurry" (IEA, 2005).

The basic circumstances conducive for conservation playing a role in resolution of short-term electricity supply shortfalls are the following: 1) electricity supply infrastructure is intact such that consumers can get electricity, but not in the quantity (or at the price) they desire; 2) a well defined end to the shortfall is anticipated, since short-term conservation will eventually wane; and 3) the shortfall is larger or longer than what standard demand response programs like adjusting dispatchable customers can accommodate (IEA, 2005). The three major strategies to save electricity quickly are to raise prices, encourage behavioral changes, or introduce more energy efficient technologies, with the ideal mix depending on the time available to prepare, anticipated duration of the shortfall, and structure of the electricity markets (ibid). In Juneau, the surprise shortfall with relatively short anticipated duration of approximately 1.5 months and isolated electricity grid produced a heavy emphasis on price increase and behavioral change.

Although the study of crisis events is naturally focused on short-term measures, there are important interconnections with long-term energy efficiency programs. In particular, programs to "save electricity slowly" provide the infrastructure to launch a crash program to save electricity in a hurry when necessary (IEA, 2005). In contrast to saving energy "slowly" through efficiency programs like appliance efficiency standards, building codes and tax incentives, saving energy in a hurry can involve sacrifice and inconvenience because the savings need only be temporary and usage patterns can return to normal once the crisis has passed (ibid).

Public information explaining what conservation actions are effective is important to ensure consumers know how to conserve. Crafting messages to emphasize the difference that individual actions will make is important. Such media campaigns typically include calls for behavioral change (e.g., re-setting thermostats and switching off non-essential lighting) and technological change if the shortfall is expected to persist (e.g., installation of energy-efficient lighting and replacement of old equipment) (IEA, 2005).

While electricity shortfalls can create conflict in the political environment and utility sector, they often influence future electricity policies and effective resolution “may encourage implementation of more stable long-term solutions to the needs of the electricity market” (IEA, 2005). Hence, thorough understanding and execution of effective response to temporary electricity shortfalls can help turn these crises into long-term opportunities.

Location (Year)	Immediate Cause (related aspect)	Measures Taken	Warning/ Duration/ Conservation
Arizona, USA (2004)	Fire destroyed distribution station (forest fires threatened other facilities)	• Frequent press releases and requests for conservation, extensive TV coverage of problems and need to conserve, specific instructions on measures to take and most important times • Email messages to large customers and those already participating in conservation programs	2 days 6 weeks 6%
Norway (2003)	Drought, early and unusually cold winter (high dependence on electricity for heating)	• Extensive media campaigns urging conservation, daily reports of reservoir levels • Fuel switching; Creation of subsidy scheme for household electricity conservation measures • Electricity-intensive factories shut down operations and re-sold electricity on spot market	2 months 4 months 8%
Tokyo, Japan (2003)	Nuclear plants shut down (utility admits to preparing inaccurate safety reports)	• Frequent paid appeals and voluntary discussions on TV, print media reminders and requests • Utility staff visited thousands of customers to request conservation • Re-negotiation of interruptible contracts w/ large customers • Website showing current demand • Leadership by example in government buildings • Shifting & rescheduling of factory production	8 months 3 months 4.5%
Michigan, USA (2003)	Flood damages cooling system of power plant (remote location prohibits substitution via transmission)	• Major industries closed for duration of the shortage • Localized blackouts for short periods after flood, then frequent warnings of potential blackouts • Press releases appealing for conservation, including preferred times • Heavy coverage by local media, including requests for conservation	1 day 10 weeks not available
New Zealand (2003)	Drought (low coal stockpile for main thermal station)	• Intensive media campaign with suggested measures, establishing individual goals for all consumers, consumer hotline, website with real-time reservoir information • Rebates to some customers for successful conservation	1 month 6 weeks 10%
Ontario, Canada (2003)	Power failure originating in Ohio, affecting most of the NE USA and Ontario (slow re-start of nuclear power plants)	• Appeals for conservation by government and utilities on radio, TV and newspapers • Shutdown of government offices, closure of electricity-intensive industries • Electricity curtailments	None 2 weeks 17%
Europe (2003)	Heat wave and drought lead to demand up and output down	• Maximum use of interruptible contracts • Public requests to conserve through mass media	1 day, 3 weeks 0.5%
Brazil (2001)	Drought and economic upturn causing increased demand (partial market liberalization failed to increase supply)	• Extensive media coverage of shortage, daily reports on reservoir status • Electricity rationing, penalties for failure to cut consumption • Distribution of conservation devices to the poor • Higher savings goal for public sector • Strong national commitment to conservation • Fuel switching	5 months 10 months 20%
Calif., USA (2001)	Many plants out of service, reduced imports (incomplete market liberalization, natural gas shortage, drought, market manipulation by generators)	• Over 200 different programs involving all sectors • Rebates to customer who used less electricity than in previous year • Public Awareness Campaign • Extensive daily front-page media coverage • Rebates for purchase of efficient appliances and equipment • Business partnerships • Updated efficiency standards • Higher electricity prices to some consumers	12 months 9 months 7% to 14%
New Zealand (2001)	Drought (55% of New Zealand's electricity generation is hydroelectric)	• Intensive media campaign with suggested measures • Establishing individual goals for all consumers • Website with real-time reservoir information • Rebates to some customers for successful conservation • Consumer hotline	1 month 3 months 10%
Sweden (2001)	Cold wave and reduced hydro (anticipated Monday peak)	• Requests for conservation broadcast on radio and TV • Newspapers carried expanded explanations of the problem	3 days, 1 day 4%
NZ (2008)	Drought in June-July, 2008	•	3.6% to 9.7%

Table 2: Summary of short-term electricity supply shortages (IEA, 2005; Blackwell et al., 2008).

1.1.3.2 Conservation Behavior by Residential Consumers During and After the 2000-2001 California Energy Crisis

The conservation behavior that occurred in California during and after the 2000-2001 energy crisis is relevant for our research for two reasons. First, it is an example of a temporary electricity supply shortfall. Second, studies of the event through surveys with emphasis on household conservation activities provide a basis for the design of our survey tool.

One of the most thorough investigations of the conservation actions that produced electricity savings during a supply shortfall was conducted during the 2000-2001 California energy crisis by Lutzenhiser et al. (2003). In 2001 a “perfect storm” of coincident drought, shortage of natural gas, bankruptcies of major utilities, imperfect transition to liberalized electricity market, policy deadlocks between regional and federal authorities, and chance occurrences like seaweed-clogged cooling intake pipes at a nuclear power plant created a crisis of increasing prices and isolated blackouts (Bushnell, 2003).

A variety of actions were taken to increase supply and encourage rapid conservation. Residential customers saw some financial incentives, some price increases, threats of rolling blackouts, and widespread media coverage, political turmoil and uncertainty. As the looming energy crisis became clear, a novel “Flex Your Power” campaign was launched in California to appeal directly to consumers. Media messages, appeals from public officials, executive orders to state agencies, news stories, and direct contacts with large energy users all asked for voluntary conservation through *behavior* like using less lighting, turning off unused equipment, reducing air conditioning, and shifting loads to off-peak hours (Bender et al., 2002). As summer temperatures rose, people turned *off* their air conditioners *before* prices had started to rise out of a sense of shared responsibility to help their home state and others deal with the crisis. This behavior ran counter to the conventional belief that consumers would be unwilling to do without modern conveniences like air conditioning. The result in 2001 was nearly 7% reduction in electricity use, with peak summer demand reduced by 8 to 14% compared to 2000 after correcting for changes in weather and the economy.

Recognizing an opportunity to better understand conservation behavior, including “customers’ motivations, decision-making, behavioral responses, efficiency investments, actual energy savings, and persistence of saving,” the California Energy Commission initiated a study that produced data from 1,666 in-depth telephone interviews with residential households (conducted immediately following the crisis in Sept. and Oct., 2001) and 815 follow-up surveys (completed one year later, from Oct., 2002 to Jan., 2003) (Lutsenhiser, 2003). Many survey questions were open-ended, with subsequent categorization and coding for analysis, to avoid the priming effect and consequent over-reporting of behaviors that can occur when selecting from a presented list. Data were also collected on household energy use before, during and after the crisis at the utility territory level.

Lutzenhiser et al. found that conservation actions were widespread, with 75% of households reporting having taken an action (mean of 2.4 actions). Conservation behaviors were coded into the 11 general categories listed in Table 3. This categorization informed the design of our survey instrument and was used by Woods (2008) in probabilistic modeling of conservation behavior that provides a basis of comparison for our results (Table 13). We discuss consistency and differences between our research findings for Juneau and observations pertaining to the California experience made by Lutzenhiser et al. and others in section 5.10.

Action Category	Description	% of HH Reporting Action in 2001	% of *Conserving* HH Reporting (2001/2002)	Sample Adjusted Reports (2001/2002)	Population Prediction (2001/2002)
Shell Improvement	Hardware related one-time improvements to the house (e.g., windows, insulation, new fixed equipment such as water heater, AC, furnace)	7.9%	10% 11.8%	8.2% 13.2%	15.3% 17.8%
Light Bulbs	Hardware related purchase/use of compact fluorescent bulbs or other energy saving bulbs	22.2%	19.7% 14.3%	16.1% 15.4%	20.5% 14.1%
Appliances	Hardware related purchase/use of new non-fixed appliances (e.g., refrigerator, washer/dryer, window AC, fans)	10.4%	8.5% 7.5%	6.9% 9.0%	16.6% 18.0%
Lights Behaviors	Behaviors related to turning off lights or using fewer lights	65.5%	64.7% 42%	52.5% 42.5%	86.0% 89.7%
Small Equipment Behaviors	Behaviors related to household appliances (e.g., turn off, use less, unplug)	32.2%	33.5% 19.6%	27.1% 22.2%	35.9% 25.2%
Large Equipment Behaviors	Behaviors related to pools, spas, irrigation motors (e.g., turn off, use less often)	6.0%	8.5% 3.5%	6.9% 4.3%	15.6% 15.9%
Not using AC Behavior	Behavior related to not using the AC at all	9.6%	13.7% 6.1%	11.0% 15.1%	15.2% 18.8%
Other Heat/Cool Behaviors	Behaviors related to heating and cooling other than not using the AC at all (e.g., use AC less, use ceiling fans, draw curtains, night venting, thermostat up/down)	38.0%	37.4% 42.4%	30.2% 40.9%	60.2% 73.9%
H2O Behaviors	Behaviors related to using less water or using less hot water (e.g., shorter showers, wash in cold/warm water, turn water heater down)	12.2%	16.6% 10.1%	13.6% 9.8%	18.6% 9.0%
Peak Behaviors	Behaviors related to using energy during off-peak hours (e.g., washing, cooking, cleaning)	20.5%	17% 11.8%	13.6% 10.5%	21.3% 10.9%
Vague Behaviors	Behaviors that were stated in general terms (e.g., “be an over-all conserved,” “be less comfortable,” “use little energy”)	7.6%	8.7% 11.8%	7.1% 11.2%	60.0% 85.9%

Table 3: Categories of conservation behavior reported by Californians during the 2000-2001 energy crisis and the percentage of households surveyed who reported engaging in each behavior (Lutzenhiser et al., 2003). The percentage of households reporting an action in 2001 is the simple share of responses received in response to open-ended questions in the first survey by Lutzenhiser et al. The percentage of *conserving* households is the share of households that reported taking at least one action who reported taking an action in each one of the 11 categories defined. The sample-adjusted reports adjusts for the tendency to under-report activity in response to open-ended questions by including in the count respondents who reported *continuing* an action in the second survey that they had not reported taking in the first survey. The population prediction is a “lower bound on our belief about what fraction of the California population may actually be performing the action” (Lutzenhiser et al., 2003).

2. The Avalanche-Induced Electricity Supply Disruptions of 2008-2009 in Juneau, Alaska

The capital city of Alaska, Juneau sits among mountains, glaciers and fiords in southeast Alaska. The population of approximately 30,000 works primarily in government, tourism, mining and seafood industries, with average wages of approximately $41,600 (JEDC, 2009). Located within the Pacific Northwest temperate rainforest biome, Juneau receives 140-228 cm of annual rainfall and 236 cm of annual snowfall with average high temperature in July of 18.3 degrees Celsius and average low temperature in January of -6.7 degrees Celsius. Buildings do not have air conditioning and approximately 40% of Juneau households use electricity for space heating. No road or electric grid connections exist between Juneau and other communities and electricity is 100% hydroelectric, generated from several small sources in the city and from two alpine lakes 71 km south of Juneau at the Snettisham hydroelectric facility.[1]

On April 16, 2008, an avalanche severed the single 138-kV electric transmission line connecting Juneau to Snettisham. Diesel generators instantly replaced the lost power but with diesel prices over four dollars per gallon, the price of electricity jumped 500% to $0.52 per kWh (KTOO, 2009).[2]

The three-kilometer-wide, category five avalanche came down some of the steepest and most treacherous terrain on the Snettisham line and destroyed several towers and 1.5 miles of transmission cable (Figure 2). The first slide destroyed one tower and damaged the arms of two adjacent towers. A second slide destroyed a fourth tower and pulled down a fifth tower with it (Eriksen et al., 2009). Avalanche danger remained high for several days, delaying assessment of the damage.

Figure 2: Tower on the Snettisham transmission line destroyed by an avalanche (Michael Penn, Juneau Empire).

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[1] Snettisham is a 78 MW hydroelectric project that provides approximately 80% of the Juneau-Douglas area electric supply (Eriksen et al., 2009). The 138-kV transmission line runs 44 miles along rugged terrain with no road access.

[2] The normal AEL&P rate during the summer, when demand is low and plentiful rainfall yields surplus water in the reservoir, was 7.9 cents per kWh. The rate normally increased to 9.5 cents per kWh in the winter, when demand peaks for home heating and the reservoir level is low since precipitation is frozen as snow. Around November 1st of 2008, AEL&P had raised the rate to 11 cents per kWh because low water level coupled with exceptionally high demand as customers switched from expensive diesel and oil to electricity heat forced generation with 90% hydro and 10% diesel.

Repair time was estimated to be three months, with an estimated 100,000 gallons of diesel costing $400,000 required per day to replace the lost hydroelectric supply (Eriksen et al., 2009). But within days Juneau had reduced its energy use nearly 25%, after adjusting for season and heating degree days (Figure 3).[3] An organized conservation campaign included a logo, information with frequent updates, and aid to the elderly and poor.[4] The average total electricity conservation during the supply disruption was approximately 205-220 MWh/day.

Local stores reported selling out of compact fluorescent (CFL) lightbulbs, the utility (AEL&P) sold out of water heater control switches, and laundry could be seen line-drying around the town. Although this period became known as the "electricity crisis" in Juneau, we use the term "supply disruption" throughout this paper in order to avoid any implied judgment regarding the conditions in Juneau.

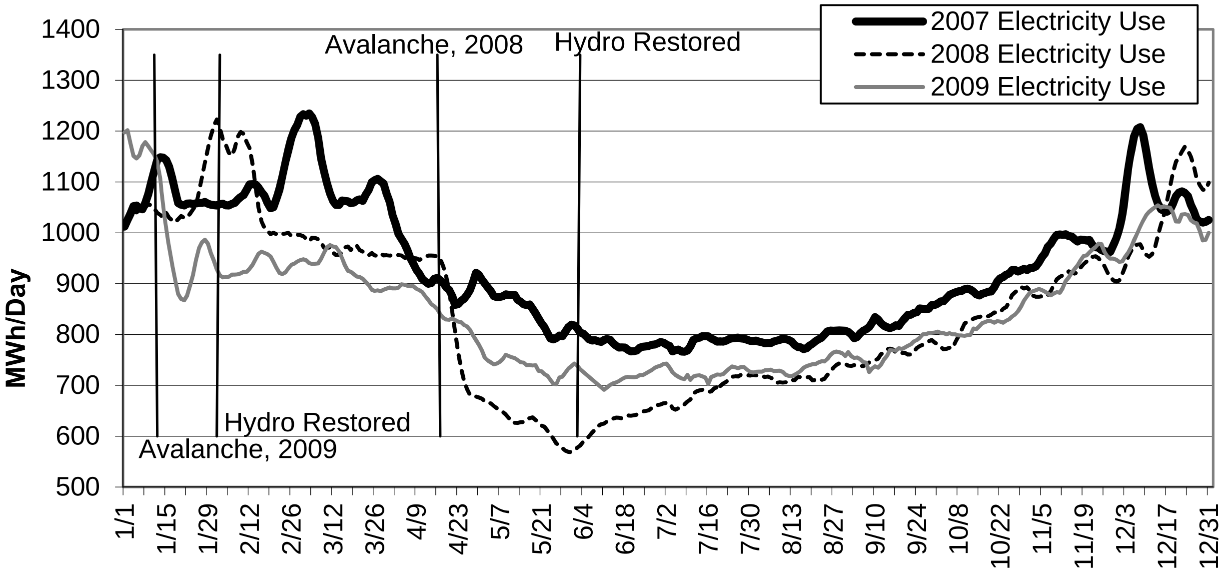

Figure 3: Rolling one-week average of Juneau daily "firm" electricity use (i.e., net of interruptible dual-fuel customers, cruise ships, and the Greens Creek Mine) in 2007 - 2009, showing 25% conservation from the year previous during the 2008 supply disruption and 12% conservation relative to 2007 during the 2009 supply disruption (Scott Willis, AEL&P). Persistent conservation after hydroelectric supply was restored was 8% in 2008 and 10% in 2009 vis-à-vis 2007. The percentage electricity savings is estimated adjusting for weather by comparing seven-day periods with the same number of heating degree days. Large spikes in electricity use during winter months due to periods of especially cold weather complicate estimation of conservation during the 2009 supply disruption.

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[3] Lengthening daylight hours and warmer weather as the Alaska winter gave way to summer may have provided a psychological boost to conservation efforts for which we do not adjust.

[4] Even with conservation, there was concern that many in Juneau would not be able to pay the higher electricity rates. Applications for disaster relief were turned down by state and federal agencies. A partnership between the city, United Way, Catholic Community Services, and the utility (AEL&P) called Juneau Unplugged included a pledge from the Juneau Assembly for $1.5 million to help low income residents, small businesses, non-profits, and day-care facilities that would have trouble paying their bills. A total of 2,200 households applied for rate relief under Juneau Unplugged and the city spent $522,000 helping them (KTOO, 2009).

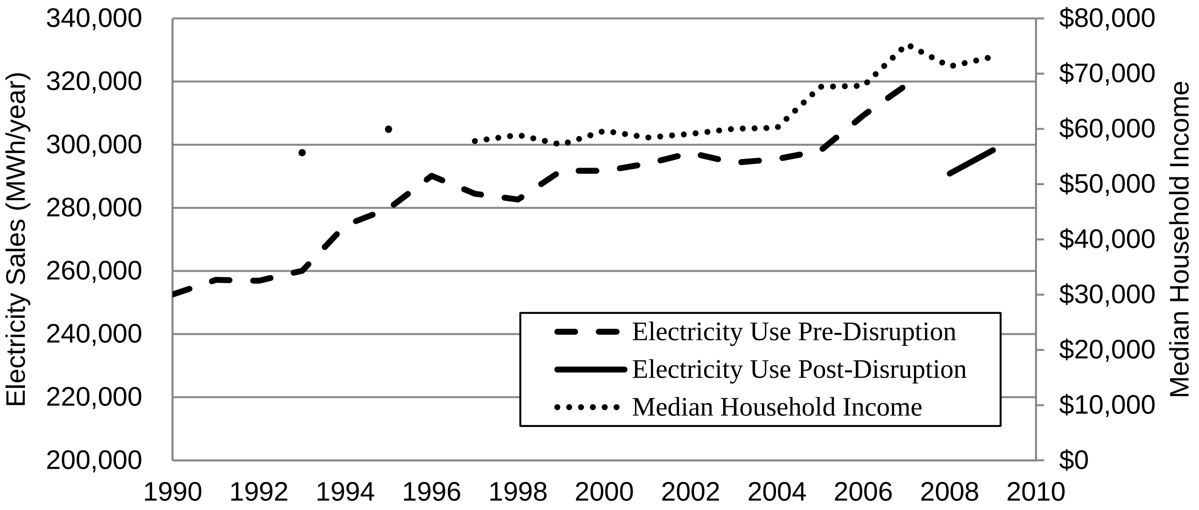

Figure 4: Historical annual firm electricity sales in Juneau, Alaska from 1990 through 2009 showing a historical annual growth rate of 1.4%. Conservation of 25% relative to 2007 during the 2008 supply disruption is equivalent to conservation of 26.4% relative to the historical growth trend. Conservation of 12% relative to 2007 during the 2009 supply disruption is equivalent to conservation of 14.8% relative to the historical growth trend. Historical growth in median household income is shown for reference. Only time will tell whether electricity use will increase back up to the historical trend or remain offset somewhat below it.

At the site of the transmission line damage, avalanche experts, electrical engineers, and work crews took advantage of a stretch of good spring weather to reconnect the city to Snettisham in just six weeks, half the time expected. The high-cost diesel-generated electricity was used for a total of 45 days but the price signal for this period was obscured by the rolling billing cycle used by the utility under which 4.5% of customers received their electric bill – and rolled onto or off of the higher billing rate - on each day of the month. As customers rolled back onto the standard summer rate of $0.079 per kWh rate after the hydroelectric connection was restored, electricity use crept back up but remained approximately 5-8% below pre-disruption levels.

Seven months later on January 12, 2009, a smaller avalanche in the same area as the 2008 event damaged the same section of Snettisham transmission line, causing a second electricity supply disruption in Juneau that lasted for 21 days. This time, however, residents were still using approximately 8% less electricity than before the first supply disruption and electricity rates increased only 200% due to decreased in diesel price since the first supply disruption ($2.25 per gallon vs. $4.00). Observed conservation during the second disruption was less than during the first (12% relative to 2007 rather than 25%) while persistent conservation after the second disruption ended increased from what it had been after the first supply disruption (10% relative to 2007 rather than 8%) (Figure 3). Variation in weather conditions between the three years does not account for changes in electricity use (Figure 5, Figure 6). A complete timeline of events is shown in Figure 7.

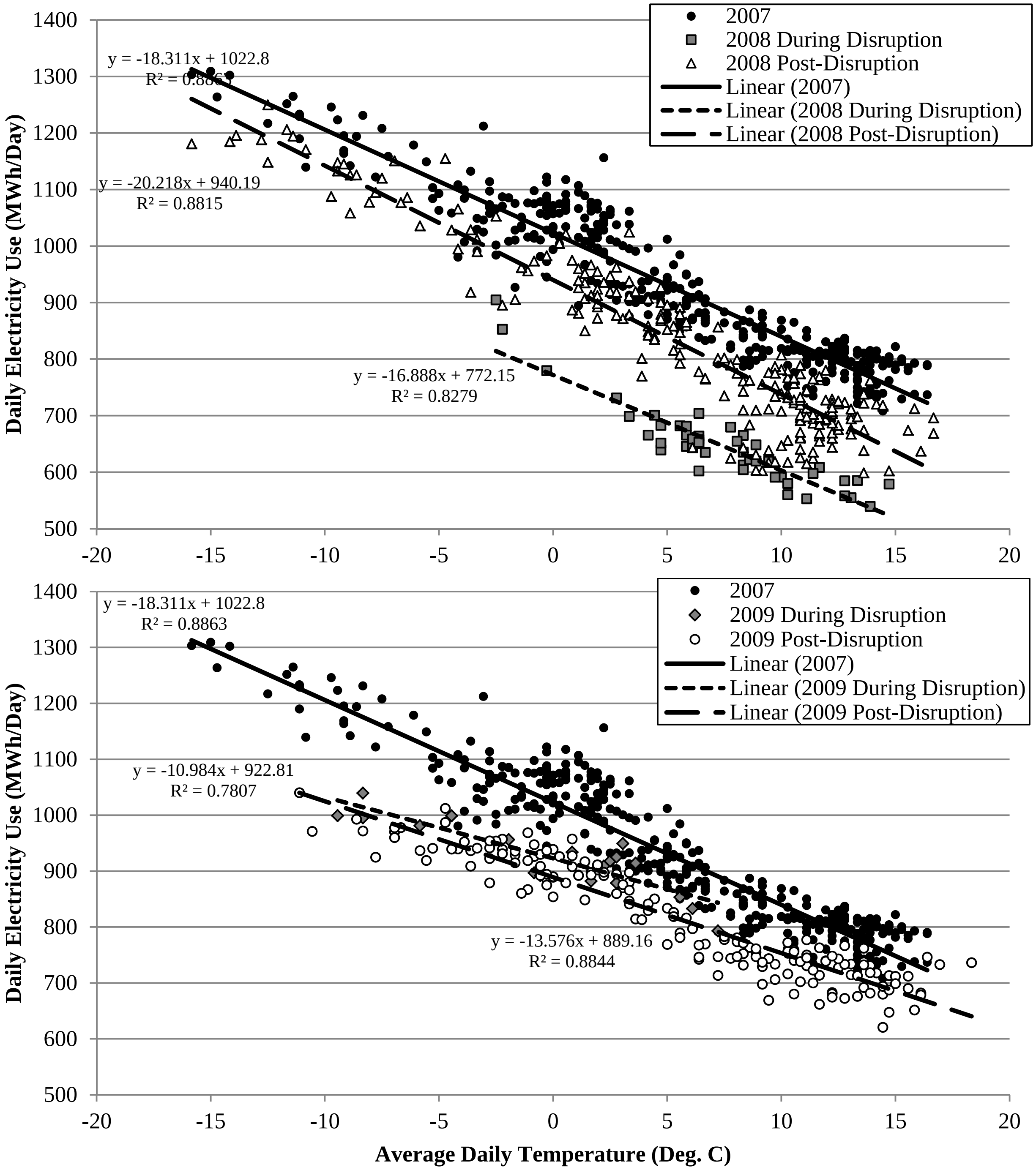

Figure 5: Comparison of the relationship between average temperature and daily electricity use across five periods: 2007 (baseline), during and after the 2008 disruption (top panel), during and after the 2009 disruption (bottom panel). Inverse correlation shows electricity use varies with temperature, in part due to high penetration of electric baseboard heating in Juneau (38%). Parallel shifts from 2007 to 2008 during and after the supply disruption show conservation not explained by differences in weather or changes in the relationship between temperature and electricity use (top panel). Changes in slope between 2007 and 2009 during and after the supply disruption suggest a change in the relationship between temperature and electricity use, perhaps due to lower thermostat settings (bottom panel).

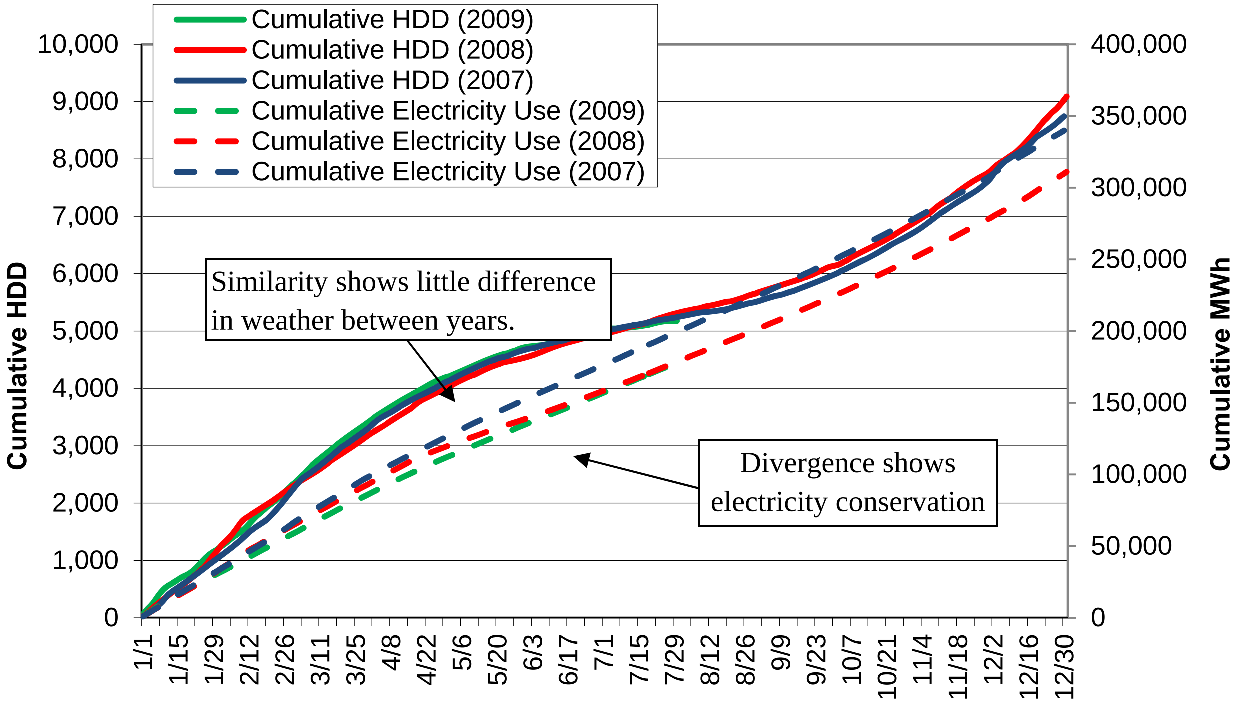

Figure 6: Year-to-year comparison of cumulative values for electricity use and heating-degree-days in Juneau from 2007 – 2009 shows large electricity conservation in 2008 and 2009 relative to 2007 despite very little difference in weather.

2.1 Timeline of Events and Electricity Conservation

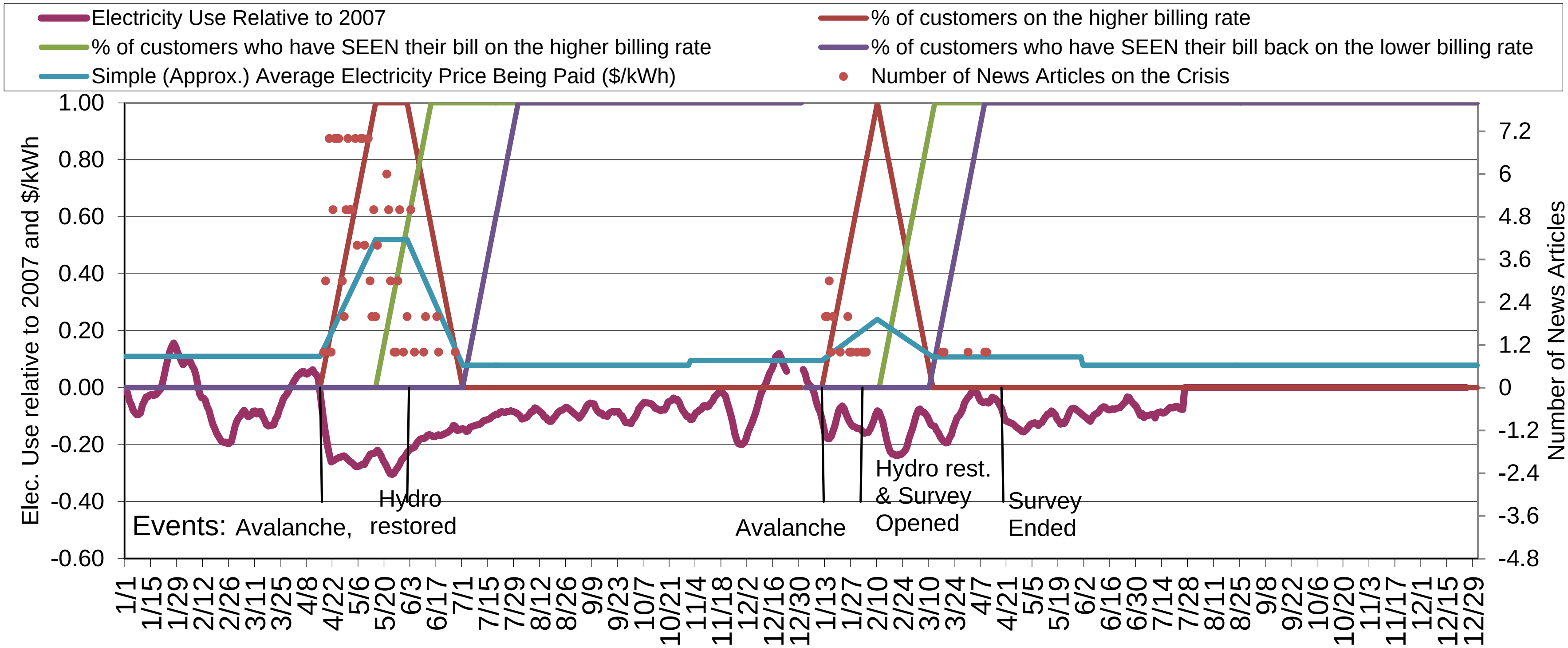

Figure 7: A timeline of events and percentage electricity conservation relative to 2007 spanning the calendar years of 2008 and 2009. The price signal of 500% increase in billing rate obscured by a rolling billing cycle under which the percentage of AEL&P customers paying the higher electricity rate increases from 0% to 100% over the first 30 days of each supply disruption. Thus, a customer may experience up to 30 days of electricity use during the disruption at normal billing rates before rolling onto the higher billing rate, and would then continue paying the higher billing rate for electricity used up to 30 days after the hydroelectric supply had been restored. There is also a one month delay in receipt of the bill reflecting this billing usage. Thus, a customer's awareness of the price signal associated with each electricity supply disruption could have been delayed by up to two months. Yet conservation occurred well before most customers were billed at the higher rate. A surge of articles in local news outlets during each crisis served to increase awareness of the higher billing rate, although some confusion over the effects of the billing cycle on exactly when each customer would be charged the higher billing rate remained. We estimated the mean price of electricity being paid as a simple weighted average of pre- and in-disruption rates, weighted by the proportion of the community on each billing rate. Fewer news articles during the second supply disruption may indicate a general perception of lesser magnitude of the event, having just been through a similar event of greater duration and electricity price increase.

3. Methods

We investigated the actions taken during and after the April, 2008 electricity supply disruption with a convenience sampled survey administered online and publicized through local Juneau media including newspaper, radio, legislative e-news, viral email, and AEL&P bill stuffers. The survey was launched on February 1st, 2009, 9.5 months after the first electricity supply disruption occurred, and closed three days after the anniversary of the powerline-downing avalanche (April 19, 2009). A total of 539 responses were received of which 424 were complete and 115 were partially complete. The survey tool is shown in Appendix A.

The survey was designed the survey to elicit information about what happened inside homes to produce the rapid 25% electricity conservation observed during the supply disruption and the persistent 8% conservation after the hydroelectric connection had been restored. Some surveys have focused on social attitudes and the behavioral aspect of energy conservation (e.g., Blackwell et al., 2008) while others emphasize equipment like heaters and appliances (e.g., the Residential Energy Consumption Survey (EIA, 2001)). We designed our survey to collect information on both equipment and use as well as conservation behavior in order to decompose the observed electricity conservation into technological and behavioral components.

We specifically asked for the person with the most knowledge about household energy use to complete the survey. Survey questions asked for detailed information about what behaviors and/or technologies accounted for conservation, what motivations produced these actions, and how the respondent perceived the situation.

The survey was also designed to minimize bias and cognitive burden in order to obtain the most reliable information possible from a rather lengthy questionnaire. As Woods (2008) notes, "open-ended questions are a rare but ideal precursor to closed-ended questions."[5] While an often-stated weakness of open response surveys is the tendency to understate action, closed-ended questions may suffer from interpretation and bias effects in over-reporting action (Schuman and Presser, 1979).[6] We used results from open-ended surveys by Lutzenhiser et al. (2003) on electricity conservation behavior during the 2001 California energy crisis and analysis of these data by Woods (2008) to inform the design of the mostly closed-ended questions in our survey.[7] We used these prior results as field testing to inform the design of closed-ended questions that adequately captured the range of likely behaviors with phrasing that facilitated interpretation and

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[5] A basic tradeoff between using open-ended and closed-ended questions is to have the respondent interpret the question (closed-ended) or have the analyst interpret the answer (open-ended) (Woods, 2008). Since we could benefit from the insights from recent open-ended questions on energy conservation and sought to collect a large amount of information efficiently, we opted to use primarily closed-ended questions in our survey tool.

[6] Without prompting for recall, respondents are likely to forget to mention some actions or may think others are too obvious to mention.

[7] We also benefitted from review of a survey tool designed by Sally Blackwell for study of a similar situation in New Zealand (Blackwell, 2009 and Blackwell et al., 2008).

minimized potential bias.[8] Thus we were able to skip the open-ended pre-test for survey design suggested by Lazerfeld (1944), although we did include several open-ended questions to gain additional insight.

Since there was a clear potential for electricity conservation to be perceived as “good” or “correct” in answering the survey, we sought to avoid the common bias from questions structured with affirmative responses indicating “good” or rational behavior. With several questions asking about long lists of conservation behaviors, we sought to reduce the potential for autocorrelation in responses through variation in question format and presented the questions in an order that would be logical to reduce respondent burden while also minimizing bias and over-reporting of conservation activities. We used the term “crisis” in the survey despite the potential bias from its connotations in order to reduce question complexity since this terminology had become common parlance in Juneau.

Finally, there was the question of timing for our survey. Some surveys have been conducted *during* a period of energy crisis while others are *post*-crisis (Lutzenhiser, 2001). We intentionally delayed our survey until eight months after the electricity supply disruption in Juneau had ended in order to allow behaviors to revert so we could collect information both on conservation activity during the 45-day electricity supply disruption as well as activity afterward. By doing so, we were able to ask respondents about what they did during the supply disruption to reduce electricity use, what they were continuing 8 months afterward, what they discontinued, and what they initiated as new behavior. These four categories are consistent with the analysis by Woods (2008). Although allowing eight months to elapse likely obscures respondents’ memory of events during the electricity supply disruption, the unexpected second avalanche refreshed those memories just prior to our survey. We emphasized in the survey wording that our questions pertained to actions taken during and after the first supply disruption of 2008 only.

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[8] In fact, Woods (2008) asserted one research purpose for open-ended survey formats is to “inform future surveys’ closed-ended questions.”

4. Results

4.1 Sample Demographics: Representative with Bias Toward the Sub-Population of Interest

Of the 539 responses were received, 424 were complete while 115 respondents skipped at least one optional question.[9] A total of 529 respondents indicated their type of energy user (e.g., household, business, government). Of these, 96% (508) were household, 2.6% (14) were small business (fewer than 15 employees), and the rest were large business or government. Since the 21 business and government responses provide an inadequate sample size for meaningful statistical analysis, we dropped these responses and analyzed the 508 responses for households only.[10]

	Survey Sample	Juneau Population
Female (n=422)	59.7%	49.8%
Over-25 with Bachelor's degree or higher (n=414)	69%	36%
Household Income (median)	$87,500	$60,195
Household Size	2.5	2.6
Home Ownership	85%	63.7%

Table 4: Comparison of survey sample socio-demographics with Juneau population (US Census).

As with any survey, there is likely self-selection bias in those who chose to participate in the survey towards people who were aware of the electricity supply disruption, engaged in the community, and chose to take action to conserve electricity. Respondents to our survey were uniformly aware of the supply disruption (section 4.3.1) and nearly all took some action to conserve electricity during the disruption (section 4.4). But since the primary intent for this research was to better understand *how* 25% electricity conservation was achieved during the period of supply disruption and *how* 8% conservation persisted afterward, the people who chose to take action are in fact the population of interest. Thus, while the sample is likely not representative of the Juneau population as a whole, it is more representative of the sub-population of electricity-conserving people in whom we are interested for understanding behavior.

Our sample is generally representative of the Juneau population, with notable bias toward women with higher than average education and income and toward home ownership rather than rental (Table 4). For the role in the household, 43% of respondents indicated head of household status, 37% indicated "wife" and 23% indicated "husband" (n=519). The percentage of unmarried respondents implied by these results (40%) is approximately consistent with the

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[9] The prevalence of incomplete responses (21%) may indicate fatigue due to survey length, which took approximately 30-45 minutes for most respondents, and may imply declining response quality in later questions. Anecdotal evidence from open-ended responses supports this supposition (e.g., "this survey is too long"). We report the number of responses received for each question in our results.

[10] Comparison between our results for household electricity conservation and information about business electricity conservation activity collected in a separate survey conducted by the Juneau Economic Development Council (JEDC) is provided in appendix D.

percentage who reported not being married in a separate question (32%). The age distribution of survey respondents is approximately representative of the Juneau population, with the under-18 cohorts missing (Table 5, Figure 9).

	Survey	US Census	Over-18 Census
Persons < 5 years old	0.0%	6.1%	
Persons < 18 years old	0.2%	24.0%	
Persons age 18 to 65	90.3%	68.5%	90%
Persons ≥ 65 years old	9.7%	7.5%	10%

Table 5: Age demographics of survey respondents and Juneau population (from 2000 US Census; n=402).

The bias in our sample towards higher education and income is consistent with self-selection bias toward those who may have been better prepared for learning quickly how to adopt electricity conservation measures (education) and those who took more electricity conservation actions due to greater ability to make investments in energy efficiency when prompted to do so (income).[11] Thus, it may be reasonable that education, income, and home ownership contribute to energy conservation behavior through the general ability to do so. However, as Lutzenhiser et al. (2003) documented, *behavioral* change for energy conservation is an equal-opportunity option for which at least income and home ownership confer no particular advantage in ability.

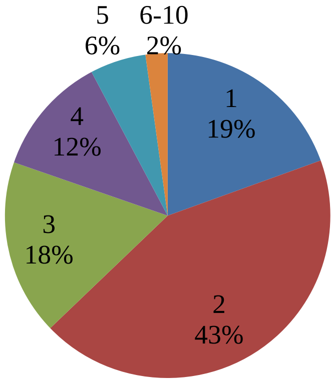

Figure 8: Household Sizes in the Survey Sample (n=504)

The average household size for our sample (2.5) is approximately equal to the average reported for Juneau in the 2000 US Census (2.6), with 92% of the sample households with 4 or fewer people and 19% single-person households (Figure 8; US Census, 2000). The average home size for survey respondents is 1,680 square feet, with an approximately normal distribution except a spike at 2,000 to 2,200 square feet (Figure 11).[12] These results along with the bias toward home ownership are consistent with self-selection bias toward those who took more electricity conservation actions than others since conventional wisdom holds that it is easier for home owners to make investments in energy efficiency due to authorization and alignment in principal-agent relationships for reaping the benefits of those investments.

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[11] Only 11.4% of respondents received financial assistance associated with the electricity crisis (n=416).

[12] The average home size in the United States was approximately 2,330 square feet in 2004, up from 1,400 square feet in 1970 (NAHB, 2006).

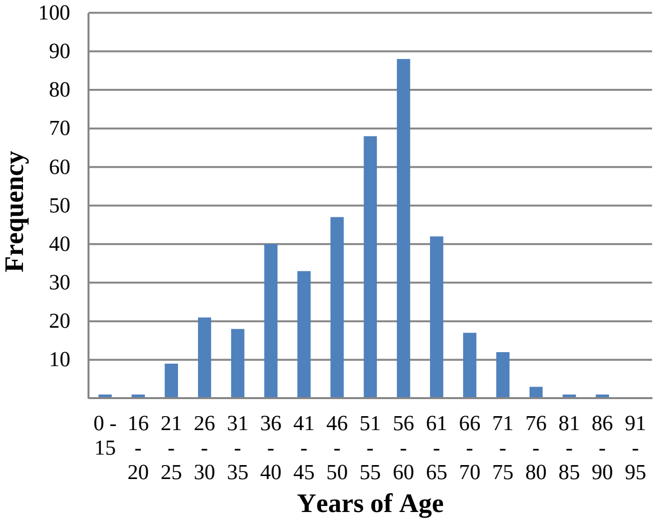


Figure 9: Age of Survey Respondents (n=402).

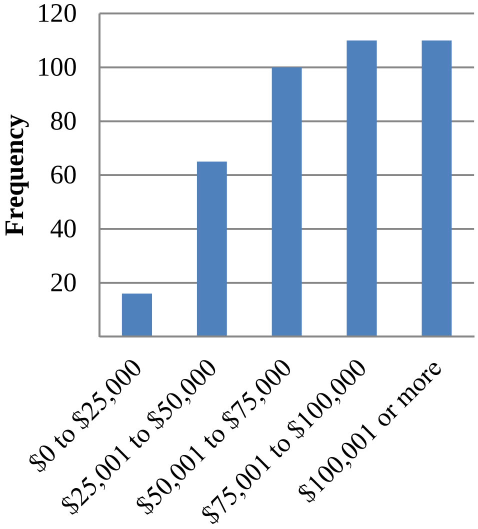


Figure 10: Household Income for the survey sample (n=401).

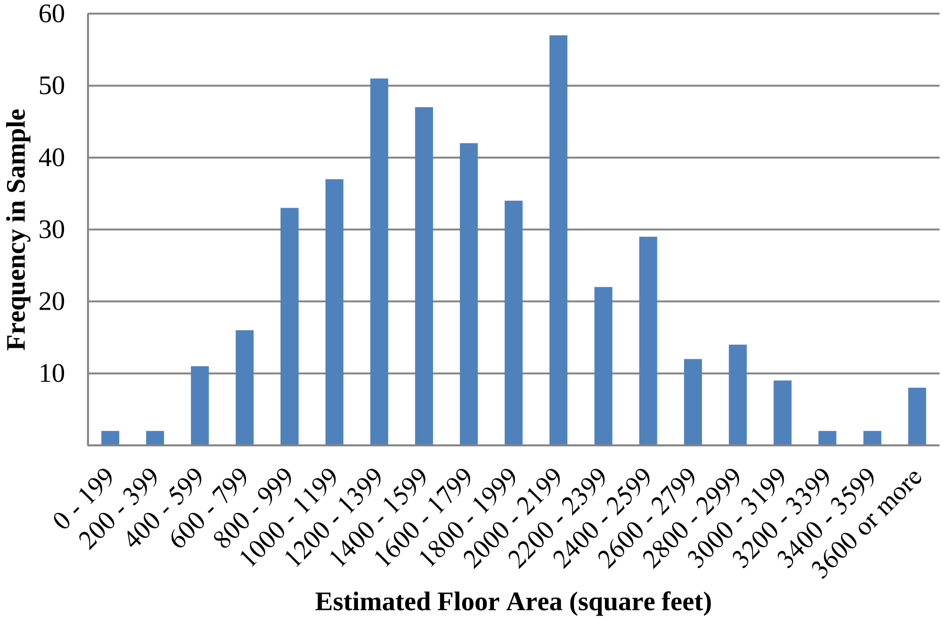


Figure 11: House Size for Survey Sample (n=411)

The geographic distribution of survey responses is fairly representative of the Juneau population, with notable bias towards the downtown and West Juneau area and away from the Mendenhall Valley area (Figure 12). A map showing these neighborhood boundaries and the location of survey respondent households is provided in Figure 13.

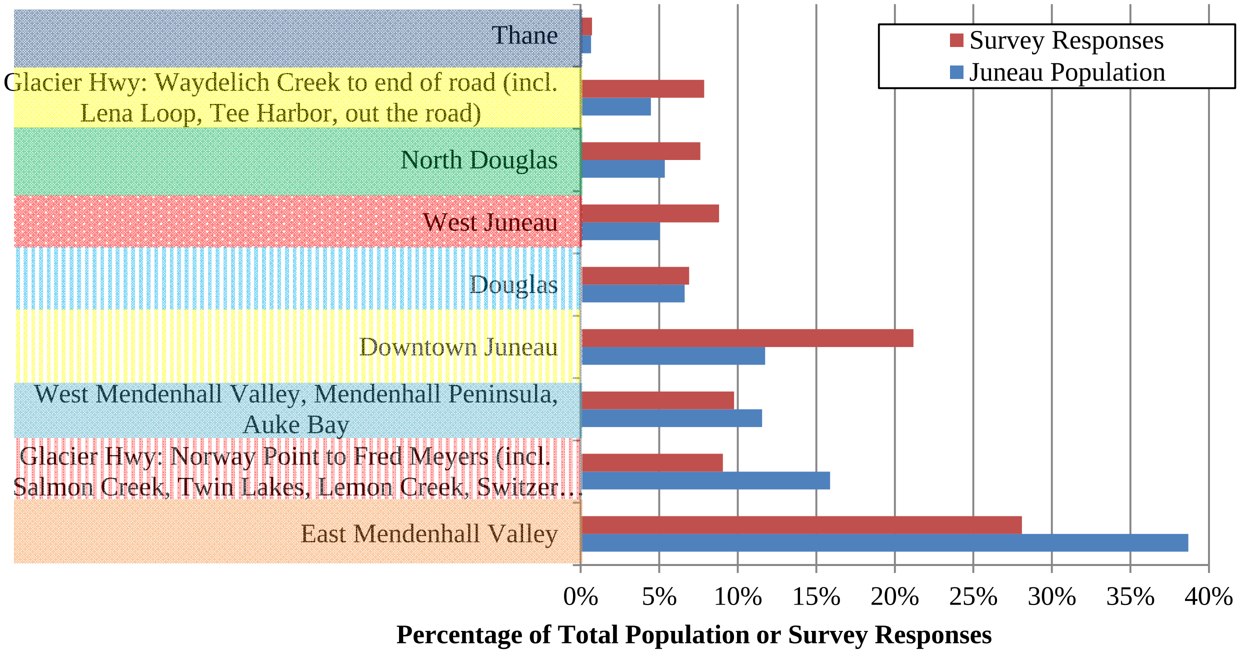
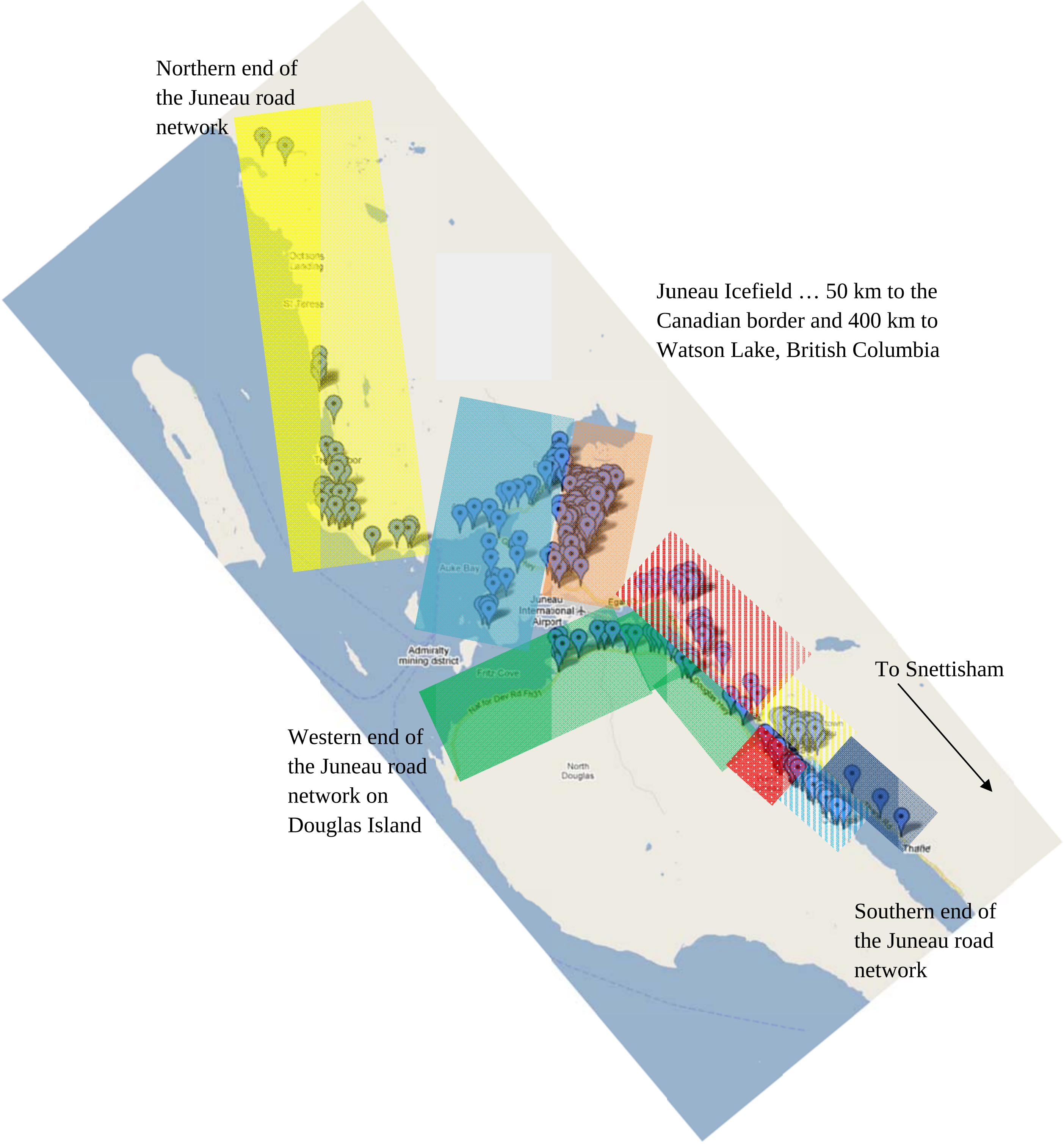


Figure 12: Geographic distribution of Juneau population and of survey responses.



Northern end of the Juneau road network

Juneau Icefield … 50 km to the Canadian border and 400 km to Watson Lake, British Columbia

To Snettisham

Western end of the Juneau road network on Douglas Island

Southern end of the Juneau road network

Figure 13: Map of Juneau showing the location of survey responses, neighborhood boundaries, power line from Snettisham, and no road or power line connections outside the community.

4.2 Existing Household Appliances

Redundancy in existing household appliances afforded an opportunity for electricity conservation through fuel switching. This is especially true for home heating sources and cooking alternatives (including stoves, ovens, microwaves, and grills). More than one source for space heating exists in as many as 2/3 (66%) of respondent homes (Figure 14), which implies an ability to vary the fuel mix used for space heating.[13] Only one quarter of respondents said electricity was their primary source of space heating while 13% said electricity *and* other sources were the primary sources of space heating.[14]

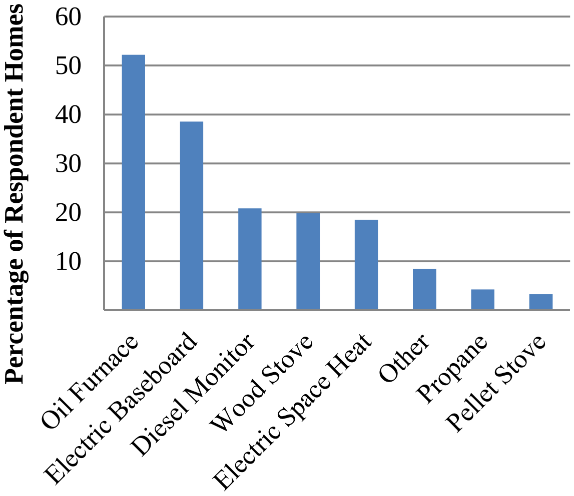


Figure 14: Space Heat Source(s) Available in Survey Respondent Homes (n=519). A “monitor heater” is an oil-fueled, forced-air heating system resembling a large free-standing space heater; “monitor” is a registered trademark of Monitor Products, Inc. which has gained brand recognition in Juneau synonymous with this type of heater, like Kleenex for facial tissue.

The electric utility in Juneau had noticed increasing load prior to the avalanche from customers switching to electric heat due to high cost of home heating oil and other alternatives. When electricity price spiked during the 2008 supply disruption, it may have been easy for these customers to switch back to their original heating sources.

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[13] However, we lack information on how actively the mix is managed or over what range it could be varied (i.e., whether the units are sized to be fully redundant at one extreme or fully complementary at the other).

[14] Note, only one respondent said he or she didn't know what primary source of space heating was used, which indicates good understanding of energy use for space heating in the home among survey respondents.

The majority of respondents (62.5%) use electricity as the primary source of water heat (n=485). Similar to space heat, only 2 respondents said they didn't know their source for water heat, indicating good understanding of energy use for water heat.[15] In contrast to space heat, however, 94% of respondents had only one source for water heating. Without redundancy in water heating sources available, the capability for electricity conservation through fuel switching in water heating with existing equipment did not exist. Only 6 respondents said they replaced their water heater during the supply disruption and only 9 said they used power-saving setting on their water heater.

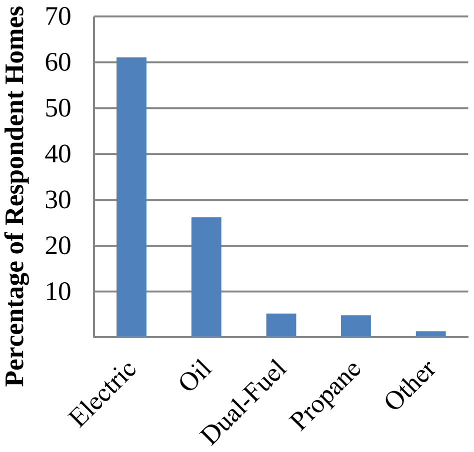

Figure 15: Water heat sources available (n=519)

4.3 Awareness, Sources of Information, Opinions & Motivations, and Perceptions of Electricity Conservation

4.3.1 Awareness

Survey respondents were uniformly aware of the supply disruption, with 99% aware of the transmission line damage (n=485) and 98% aware that diesel generators were providing backup power (n=485).

However, only 68% of respondents answered correctly that Juneau was *not* in danger of running out of electricity, since backup generation capacity was more than adequate for meeting demand; 17% said Juneau was in danger of running out and 14% said they didn't know (n=483). Furthermore, 76% were motivated to conserve through concern for others and 54% conserved to help others, and 51% said they benefited from others' electricity conservation despite the fact that conservation would have negligible impact on electricity price since nearly 100% diesel generation would be used regardless of the level of demand (n=423).[16] Thus, altruism appeared to be a motivation for conservation, in part due to incorrect perceptions of shortage and ability to influence price.

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[15] Note, the 6% of respondents who said they have electricity *and* other sources for the primary water heat is consistent with the 5% of respondents who said they have dual-fuel water heating systems.

[16] It is also important to note that 34% of respondents said they didn't know whether they benefitted from others' conservation, perhaps suggesting confusion either during the crisis or with the survey question.

4.3.2 Sources of Information & Leadership

Respondents used an average of four different sources of information on electricity conservation and supply (Figure 16). The most common sources were radio, newspaper, and word of mouth. The frequency of word-of-mouth suggests active dialog as the electricity crisis became the talk of the town. The electric utility (29%), friends and neighbors (16%), the mayor (9%) and local government (8%) were most frequently cited as having provided leadership (Figure 17). This contrasts with many previous short-term supply disruptions in which the utility and government were subjected to blame (IEA, 2005).

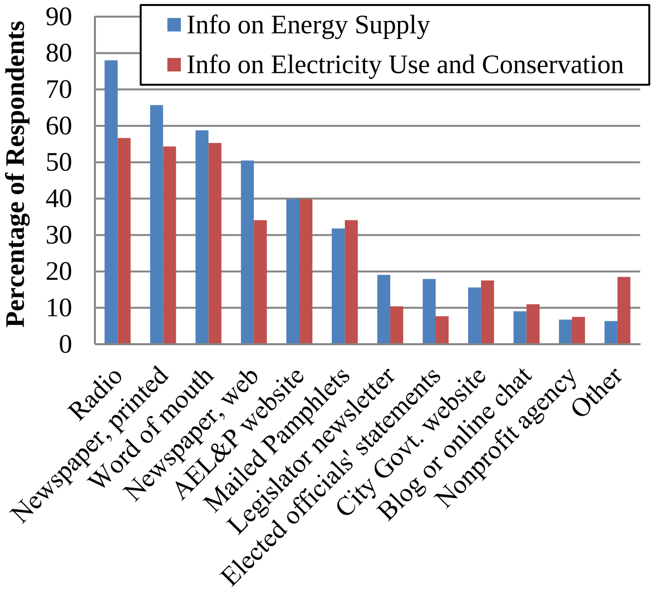

Figure 16: Sources of information for electricity supply and electricity use and conservation (n=519)

4.3.3 Opinions & Motivations

There was general consensus among respondents that the loss of hydro-electricity and the associated increase in the price of electricity had an important impact on the respondent and his/her household as well as the people, businesses, and economy of Juneau (Figure 18).

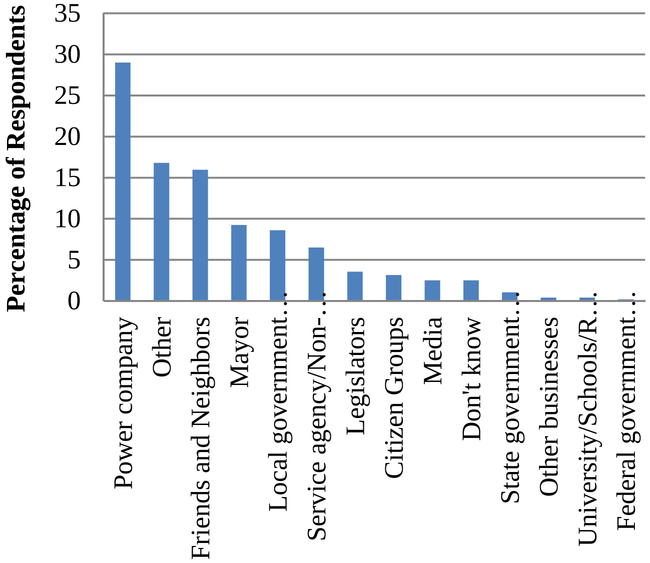

Figure 17: Who provided leadership during the supply disruption (n=476)

The majority (77%) of respondents did not single out any particular group as one which should have done the most to conserve electricity during the supply disruption, opting instead to say everyone should have conserved equally (Figure 16). This egalitarian answer may be an indication of the coming together in the community against a common challenge that we observed elsewhere in the survey results. For those who did single out a group, government was the most frequently mentioned (11%). When asked if anyone did not do enough to conserve electricity during the supply disruption, 41% of respondents said they did not know and 12% said everyone did enough (Figure 17). The entities fingered the most for slacking in conservation were Government (18%), Business (10%), Apartment Renters (7%) and Homeowners (3%).

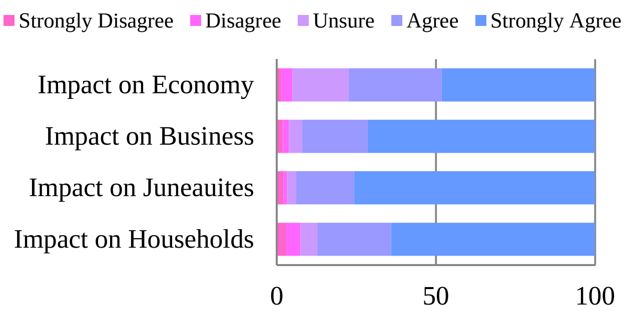

Figure 18: Responses to whether the loss of hydroelectricity and associated price increase had an important impact on the economy, businesses, households, and citizens of Juneau (n=470).

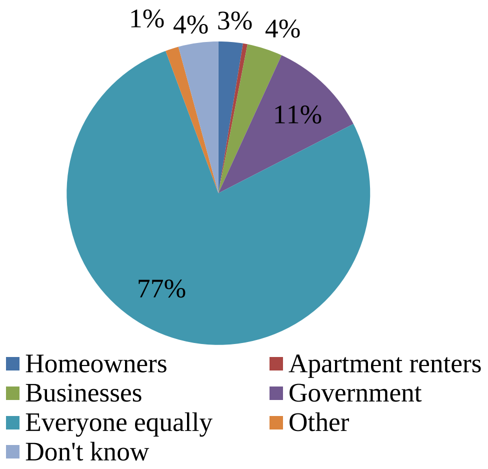

Figure 19: Who should have done the most to conserve electricity during the crisis?

While motivation for engaging in electricity conservation came both from concern for self and from concern for others, respondents were somewhat more motivated by personal concern about electricity shortage (85% agreed) than by potential consequences for others (77% agreed) (Figure 21). Despite the fact that conservation by one person would have little impact on electricity price for others, many respondents appear to have felt that their failure to conserve would adversely impact others.

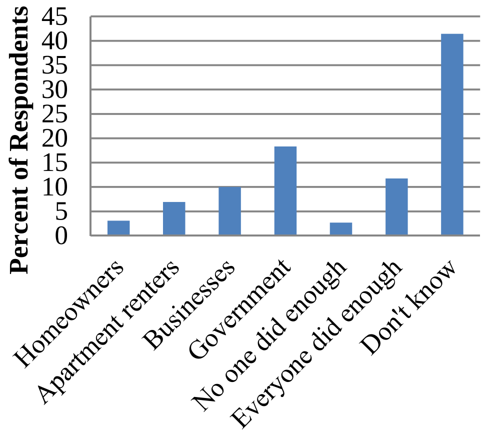

Figure 20: Groups identified as not having done enough to conserve during the crisis.

A general perception of little difficulty in conservation complemented these motivations in generating conservation action, with 65% of respondents agreeing that it was not difficult to conserve (Figure 21). This finding suggests that the dramatic conservation steps taken during the supply disruption, including behavioral changes to forgo or reduce some services, were *not* perceived as a sacrifice that was difficult to make for 65% of respondents. Another 26% of respondents, however, did perceive difficulty and sacrifice in their efforts to conserve.

Respondents generally agreed that they were not using as little electricity as possible before the supply disruption (65% disagreed or were unsure about whether they were already using as little electricity as possible; Figure 22). This suggests recognition among respondents, albeit after the disruption, of their ability to reduce electricity use. For the 36% of respondents who believed they were already using as little electricity as possible before the supply disruption, nearly all found a way to use even less during the disruption. New information or attention may have revealed previously unknown ways to conserve, or the definition of what was "possible" may have changed during the disruption (i.e., these people were willing to make sacrifices in services that were previously seen as impossible).

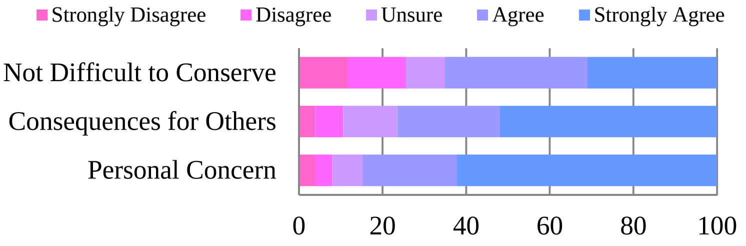

Figure 21: Motivations for willingness to conserve electricity during the supply disruption (n=466).

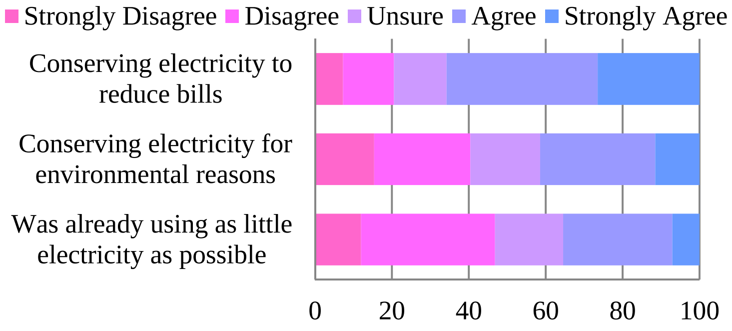

Figure 22: Motivations for conservation behavior *before* the electricity supply disruption.

The share of respondents who were motivated to conserve electricity for environmental reasons stayed nearly constant before (42%), during (43%) and after (42%) the supply disruption (Figure 23). This may be surprising given the stark differences in environmental impact between diesel and alpine lake hydroelectric generation. In contrast, the share of respondents who were motivated to conserve to reduce utility bills increased from 66% before to 86% during the supply disruption, but then remained at 73% afterward (Figure 22). The price signal appears to have been a strong motivator and the supply disruption may have had a lasting effect on increasing electricity price awareness and sensitivity.

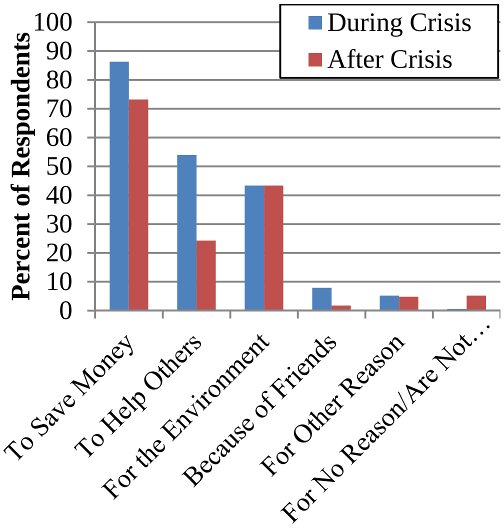

Figure 23: Reasons given for electricity conservation during and after the supply disruption (n=519).

On average, respondents identified two reasons for acting to conserve electricity during the supply disruption and only 1.5 reasons for continuing to conserve afterward. This may indicate a general decrease in the number of reasons respondents could identify for conservation once a "crisis" was not at hand. Yet even in “normal” circumstances, respondents continued to identify an average of 1.5 reasons for conservation activities. Since we do not have information on the number of reasons respondents would have identified for conservation prior to the disruption, we cannot comment on whether the 1.5 average number of reasons was the pre-disruption baseline, whether conditions during the disruption increased this number by only 0.5 on average, or whether the experience heightened awareness and thereby left a residual increase in identification of reasons to conserve.

4.3.4 General Perceptions of Electricity Conservation

The impression of electricity savings achieved as a result of the actions respondents took appears approximately normal, centered around 30% with an optimistic group reporting more than 40% savings (Figure 24). Half of the respondents (51%) thought their energy use had decreased 20-30% during the supply disruption while 32% believed it had decreased 40% or more (only 12% said use decreased by 10% or less). Assuming some self-selection bias in our survey participation toward those who were more engaged in conservation, the self-reported electricity conservation is consistent with the observed 25% electricity conservation community-wide. Thus, it appears respondents had an accurate perception, several months after the fact, of how much their electricity use during the disruption was as compared to pre-disruption levels.

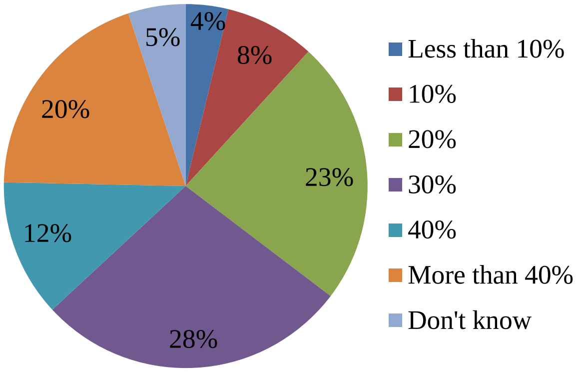

Figure 24: Respondent perception of decrease in electricity use during the crisis.

However, respondents thought their electricity use *after* the disruption was an average of 9% more than during the disruption but 5% less than before the disruption, implying a perception of 15% electricity conservation during the disruption (Figure 25, Figure 26). Thus, the perception of electricity use appears inconsistent, depending on what question is used to elicit the information. On the one hand, asking directly about the decrease in electricity use during the supply disruption seems to produce a slight over-estimate of conservation while asking about electricity conservation obliquely with questions about use before and after the supply disruption seems to produce an underestimate of the degree of electricity savings respondents were able to achieve. It is possible, however, that greater electricity conservation in commercial and government sectors offset less conservation among households or vice-versa, meaning average household conservation during the supply disruption could differ from the observed aggregate 25%. It is also possible that the oblique approach may simply be too complicated, with too much cognitive burden in the face of an already difficult estimation request, to get an accurate answer.

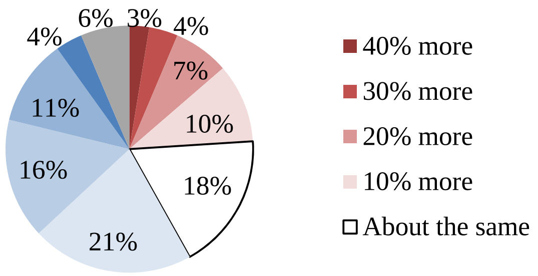

Figure 25: Perceived difference in energy use after the supply disruption as compared to before the disruption.

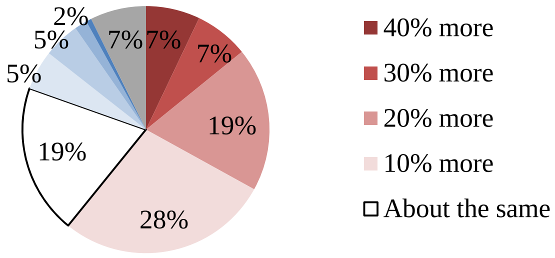

Figure 26: Perceived difference in energy use after the supply disruption as compared to during the disruption.

More than 3/4 of respondents (77%) agreed that they were using less electricity at the time of our survey (i.e., 8 months after hydroelectric supply was restored) than they had been using before the supply disruption (Figure 27).[17]

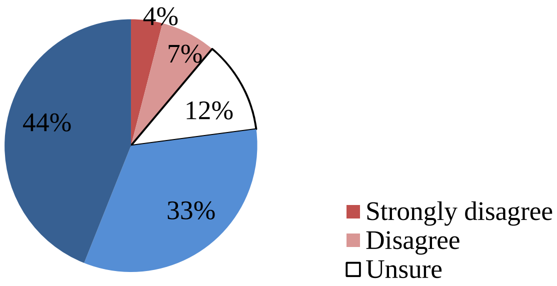

Figure 27: Agreement with the statement: "I now use less electricity than before the crisis."

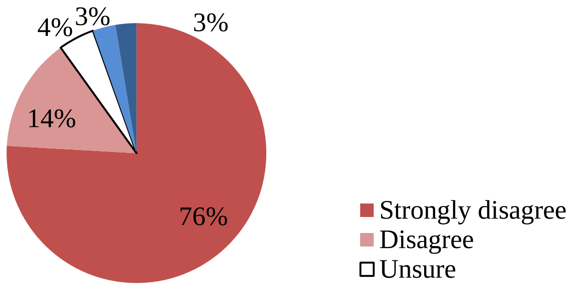

Figure 28: Agreement with the statement: "I now use more electricity than before the crisis."

Furthermore, 80% of respondents disagreed that the supply disruption had not changed their use of electricity (i.e., agreed that the disruption had changed their use of electricity) and 68% agreed that their attitude toward using electricity had changed since the disruption (Figure 29, Figure 30).

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[17] This finding is confirmed by a calibration question that asked the reverse (Figure 28): 90% of respondents disagreed that they now use more electricity than they had been using before the crisis, which is approximately equal to the 77% who agreed they now use less electricity plus the 12% who were unsure.

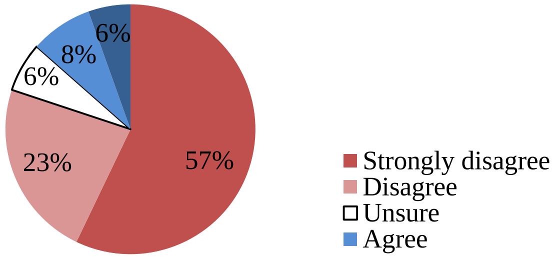

Figure 29: Agreement with the statement: "the crisis did not change my use of electricity."

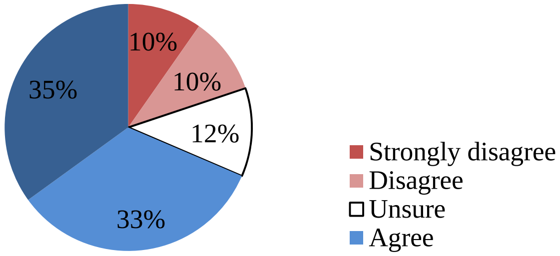

Figure 30: Agreement with the statement: "my attitude to using electricity changed since the crisis."

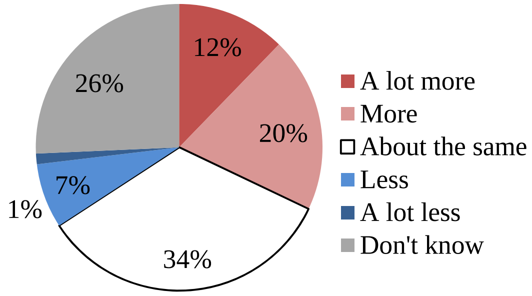

Figure 31: Perception of whether the respondent reduced their electricity use during the supply disruption by more than their neighbors did.

When asked whether they had reduced electricity use more than their neighbors had during the supply disruption, 60% of respondents were unsure or thought they had reduced use about the same (Figure 31). But 32% of respondents felt they had conserved more than their neighbors, which is a sentiment of inequity that could have undermined cooperation had the supply disruption been protracted. Only 8% of respondents thought they had conserved less than their neighbors, which may be true for our sample if self-selection bias in fact produced a sample with 92% of respondents with above-average electricity conservation during the supply disruption.

The distribution of perception about relative conservation appears centered around "about the same," implying there was a generally feeling of equity in everyone doing the same for conservation. This is corroborated by 77% of respondents saying everyone should have conserved equally and relatively small percentages naming any particular entity as not having done enough.

4.4 Actions Taken During & After the Electricity Supply Disruption

On average, respondents took close to 10 actions (mean 9.75) in order to conserve electricity during the supply disruption (Figure 32). In contrast, respondents reported stopping or reverting an average of only 3 actions after the hydroelectric connection had been restored. Although there may be bias in these results due to respondents seeking to please the researcher, this difference suggests persistent energy conservation from actions taken during the supply disruption that had not been reverted 8 months later at the time of our survey.

Closer examination of the difference between the number of respondents who reported taking an action and the number who reported stopping/reverting can give an indication of the most persistent and least persistent changes. The magnitude of difference indicates a combination of persistence and popularity while the percentage of those who acted who did not revert the action is purely an indication of persistence. The most popular and persistent actions (largest difference) were the following: 1) light bulbs replaced with CFL, 2) the habit of turning off lights, 3) the habit of turning off appliances when not in use, 4) having fewer lights on, 5) using electrical devices less often, 6) washing full loads of laundry and/or with cold water, 7) unplugging appliances when not in use, 8) keeping the thermostat at a lower temperature, 9) only heating rooms in use, and 10) using power-saving settings on appliances. The most persistent actions (i.e., lowest percent reversion) were the following: 1) Sealing/weatherization, 2) bulbs replaced with CFL, 3) use of reduced light output bulbs, 4) insulation in attic, walls, or floor, 5) only heating rooms in use, 6) using power-saving settings on appliances, 7) washing full loads of laundry and/or in cold water, 8) reduced number of bulbs in light fixtures, 9) the habit of turning lights off, and 10) Other.

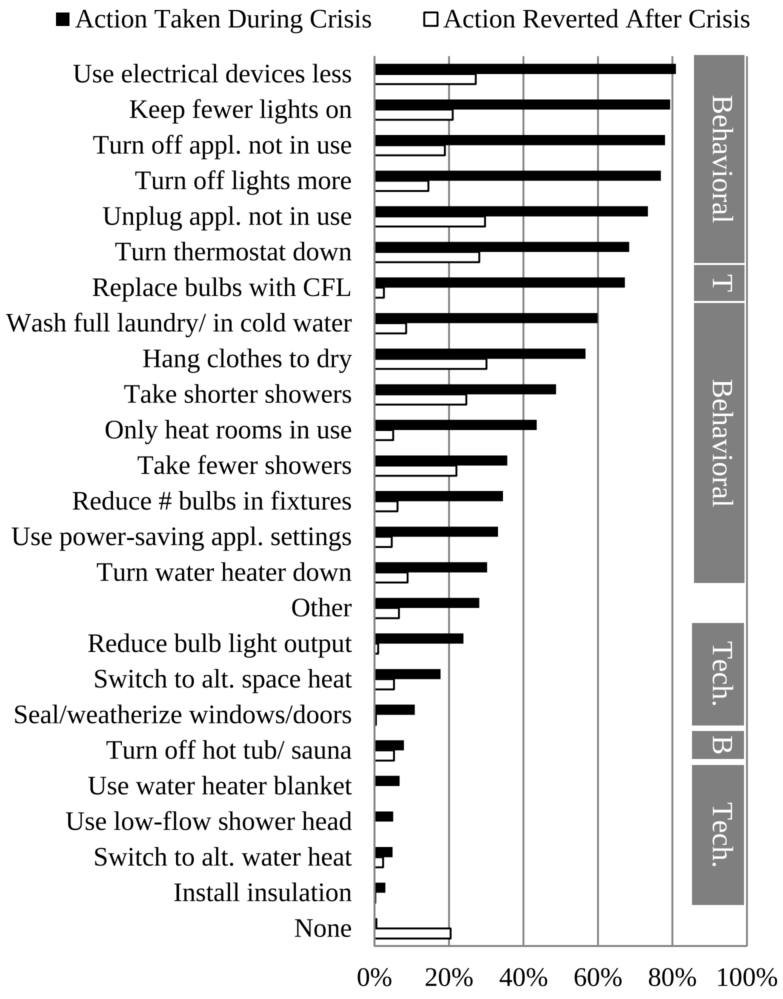

Figure 32: Conservation actions taken during, and reverted after, the 2008 Juneau electricity supply disruption, grouped according to a behavioral versus technological dichotomy.

4.4.1 Behavioral vs. Technological Actions

A dichotomy between behavioral and technological actions can be useful for analyzing conservation activities.[18] Respondents engaged in a lot of different conservation activities, but these activities were dominated by behavioral change: using electrical devices less often (81%), having fewer lights on (79%), turning off appliances when not in use (78%), turning off lights more frequently (77%), unplugging appliances when not in use (73%), turning down the thermostat (68%), washing full loads of laundry and/or in cold water (60%), hanging clothes to dry (57%), taking shorter showers (49%), only heating rooms in use (44%), taking fewer showers (36%), reducing the number of bulbs in fixtures (34%), and turning down the water heater (30%) (Figure 32).

For technological changes, installing compact fluorescent lightbulbs dominated (67%), but there were others as well: reducing bulb brightness (24%), switching to alternative heat source (18% for space, 5% for water), and several others.

Reversion to normal activities after the supply disruption also occurred mostly on the behavioral side, but to a much lesser extent than the actions that were claimed during the disruption. This implies persistent conservation due to persistent behavior change. See section 4.4 for analysis of actions reverted after the hydroelectric connection was restored.

Anecdotal evidence from the open-ended survey questions suggests persistent behavior change among some respondents. For example, one respondent said, “It was fun to hang laundry outside to dry. I will do that again this summer, regardless of power cost.” However, other anecdotes suggest that conservation behavior persisted over the summer months when weather was less harsh but then began to revert when fall weather set in. For example, several respondents said they left their thermostat set to low “crisis” levels during the summer but turned the heat back up in September and October. These comments are consistent with the more general response that weather was one of the limiting factors preventing further energy conservation action (Figure 53).

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[18] A view that consumer demand for energy is inflexible leads to emphasis on hardware programs to improve efficiency without behavioral change (Lutzenhiser et al., 2003). To achieve least-cost utility planning through energy non-use and to reduce environmental impacts from increasing energy use, the emphasis of policy in California in the 1980s and 1990s was on achieving predictable conservation through technology (ibid). Voluntary conservation was seen as too “undpredictable and intractable” and the consumer was largely ignored as policy focused on a resource acquisition approach: efficiency as a source of supply (ibid). Btu with deregulation of energy markets in the 1990s, interest in behavior emerged as emphasis shifted to establishing a “correct” price signal and set of available energy efficient technologies so that rational consumers would adopt conservation at an optimal level. Thus, how much conservation can come from technological efficiency versus behavioral change (and sacrifice) have become important questions. Two dichotomies are central to understanding demand-side response to short-term supply shortfalls: temporary conservation vs. persistent conservation and behavioral activity vs. technological change.

4.4.2 First Actions Responding to the Start and End of the Electricity Supply Disruption

The response to announcement of the avalanche was rapid, with 77% of respondents taking their first action in response to the electricity supply disruption within one day after the avalanche occurred (Figure 33). In contrast, the response to repair of the transmission line was more gradual. The average response time at the beginning of the supply disruption was one day while the average response time to restoration of the hydroelectric connection was 14 days.[19] While only 4% of respondents took their first action in response to the *start* of the supply disruption more than 4 days after the avalanche, 37% of respondents took their first action in response to the *end* of the disruption more than 4 days after the restoration of the hydroelectric connection.

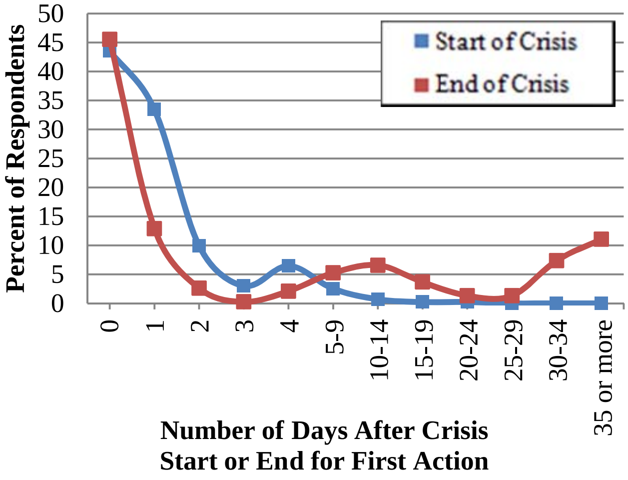

Figure 33: Delay for first action in response to the beginning and end of the electricity supply disruption in Juneau.

A majority (86%) of the first actions taken in response to the supply disruption were behavioral rather than technological, with turning off lights (19%), unplugging and turning off breakers (18%), and turning down thermostats for space heating (16%) the most predominant activities (Figure 34). The predominance of behavior in the initial response actions is generally expected since implementing technological changes like installing different light bulbs or appliances requires more time in decision-making, procurement, and implementation. It is therefore interesting to note which technological changes constitute the 14% of first conservation actions that were not behavioral: installing CFL bulbs (9%) and fuel switching with existing equipment (5%). Using existing household equipment for fuel switching (e.g., cooking on a grill rather than electric stove or heating with wood fire rather than baseboard resistance heaters) skirts the primary hurdles of purchase and installation for technological change. For CFL, households may have already owned some CFL bulbs in inventory (especially if their practice was to wait to replace a bulb until the old bulb burned out, as reported by 85% of respondents) or were aware of the energy efficiency improvement of CFL over incandescent bulbs prior to the supply disruption and found it a relatively easy purchase to make and implement. In any case, installation of CFL appears to be a relatively easily technological change that will deliver persistent energy savings.

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[19] Variability in respondents' stated date of first actions may suggest difference in what was perceived to constitute an action as well as difference in the timing of taking action. The variance in delay for first action in response to the start of the crisis was 4.7 days and the variance in delay in response to the end of the crisis was 736 days.

Easily implemented is also easily reverted. Ninety-five percent of the first actions survey respondents took immediately after the supply disruption *ended* were behavioral (Figure 35). This finding is consistent with the notion that technological changes made in response to the electricity supply disruption are more persistent than behavioral changes. Of the 5% of first actions taken when the disruption ended that were technological in nature, all involved switching the energy source for a service (e.g., heating, refrigeration) back to electricity.

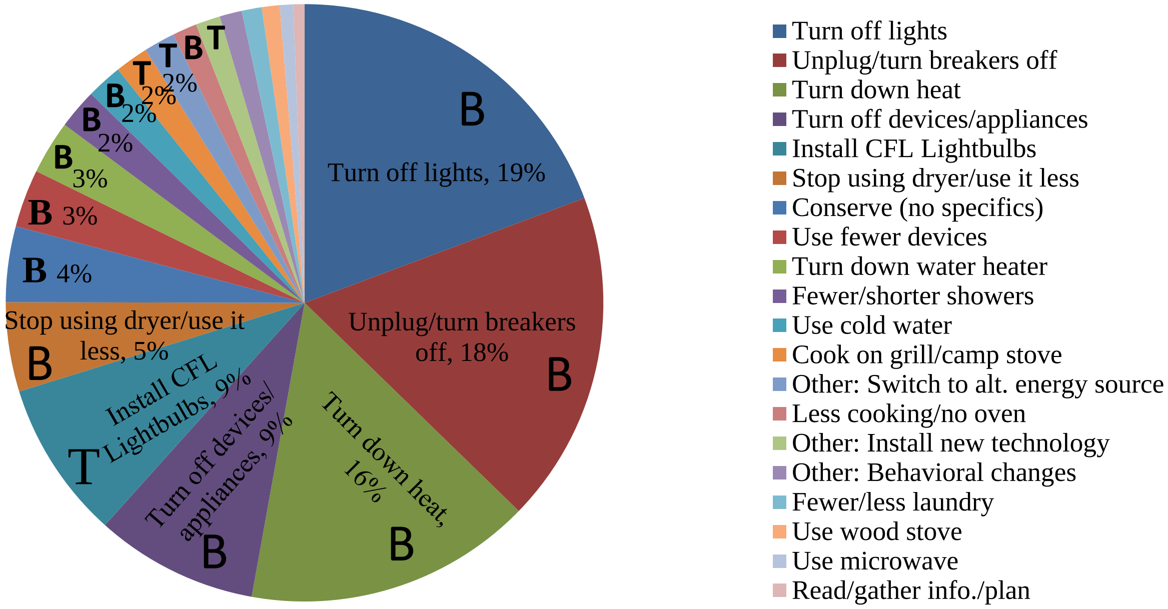

Figure 34: Initial action(s) taken *immediately* in response to the 2008 electricity supply disruption. Eighty-six percent of these actions were behavioral rather than technological. Of the remaining 14 percent of actions that were technological, most involved using more efficient existing household appliances (e.g., microwave for cooking, CFL for lighting) or switching to alternative energy sources (e.g., using wood stove for space heating). A capital "B" denotes behavioral actions while a capital "T" denotes technological actions.

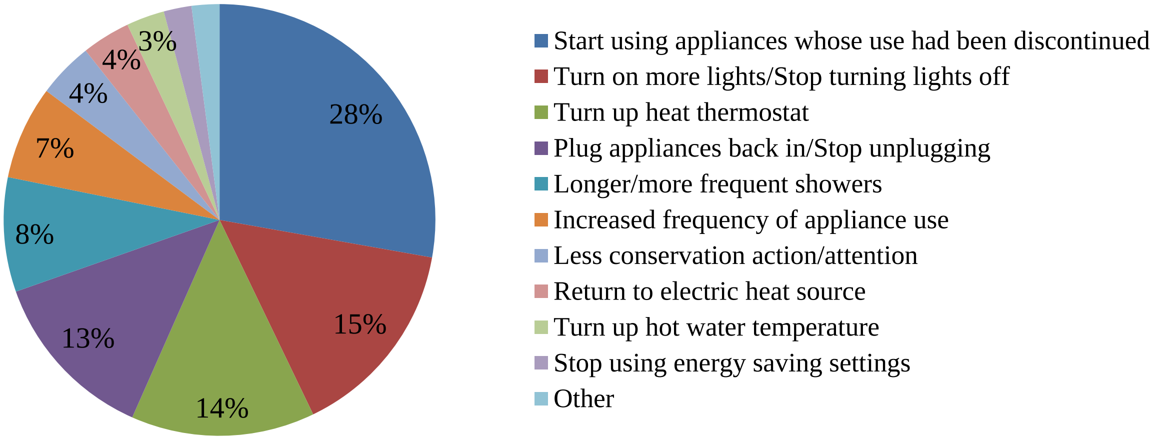

Figure 35: The first action(s) taken immediately *after* the 2008 electricity supply disruption *ended*. Ninety-five percent of these actions were behavioral rather than technological, which is

consistent with greater persistence of technological changes made during the disruption than behavioral changes. Of the remaining 5 percent of actions that were technological, most involved switching back to less efficient appliance use (e.g., stop using energy saving settings) or back to electric household appliances from those using alternative energy sources (e.g., return to electric space heating).

The following sections (4.4.3 through 4.4.7) describe results from follow-up questions that pertain to sub-groups of our survey sample. For example, respondents who listed shorter showers among the actions they took during the supply disruption saw several questions about what their shower duration had been before, during, and after the disruption. Respondents who did not list shorter showers among their actions did not see these questions when taking the survey. Consequently, it is important when interpreting the results in these sections to remember that they pertain to a sub-set of the entire survey sample. It is also important to acknowledge that these questions appeared relatively late in the survey and may therefore suffer from several sources of bias: small sample statistics, self-selection bias for participating in the survey, self-selection bias in choosing to answer the question, and respondent fatigue in coming late in the survey. However, the response rates within each sub-group (85-95%) were quite good across all questions.

4.4.3 Lighting

Respondents reduced electricity use in lighting through technology and behavior change. The 67% of respondents who installed CFL replaced an average of 12 incandescent bulbs and were using CFL in 73% of their light fixtures 8 months after the supply disruption had ended (Figure 36).[20,21] Note, however, that the 100,000 total CFL sales implied by this reported behavior if repeated equally across the Juneau population (i.e., 12,500 households x 67% x 12 bulbs/household) exceeds the total quantity supplied in Juneau.

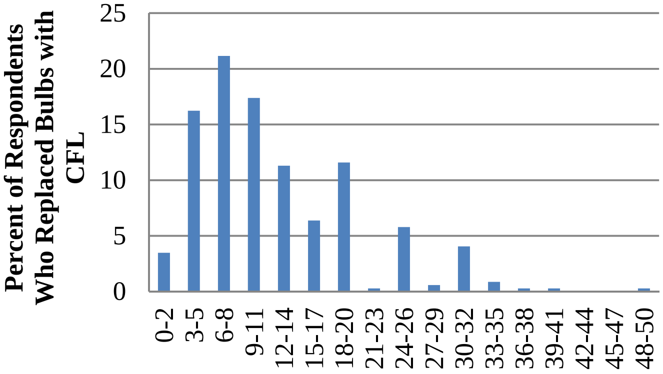

Figure 36: Number of light bulbs replaced with CFL per household during the supply disruption by 66% of respondents (n=345 of the 349 who said they installed CFL, 99% response rate).

Assuming replacement of 100 W incandescent bulbs (approx. 1,600 lumen) with similar light output CFL (approx. 25 W), four hours daily use, and average CFL replacement behavior in all

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[20] Eight respondents specifically noted use of light-emitting diode (LED) bulbs, which are currently more efficient than CFL, while others believed specialized fixtures (e.g., dimmers, odd socket sizes) would not accommodate CFL.

[21] CFL household saturation is much lower throughout the United States, with approximately 11 percent CFL saturation in CFL-appropriate sockets in the residential sector (US DOE, 2009).

12,500 households in Juneau, the total energy savings for bulb replacement with CFL in Juneau would have been 45 MWh/day (approximately 20% of the 205-220 MWh/day average total electricity conservation during the supply disruption.

The 79% of respondents who had fewer lights on during the supply disruption reduced the number by an average of 4.4, with average persistent reduction of 26% among the 58% of respondents who maintained fewer lights on after the disruption had ended (21% of respondents reverted to the pre-disruption number of lights).

Only 15% of respondents said they were replacing incandescent lighbulbs with CFL before the incandescent bulb burned out at the time of our survey. On average, respondents were changing 0.8 bulbs per month 8 months after the supply disruption had ended.

Thus, install base for CFL and keeping fewer lights on appear to be sources of persistent electricity savings induced by the supply disruption.

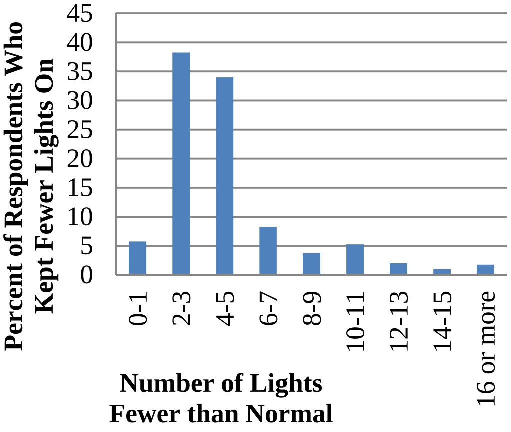

Figure 37: Number fewer lights kept on than normal during the electricity supply disruption by 77% of respondents (n=400 of the 412 who said they kept fewer lights on, 97% response rate).

4.4.4 Space Heating

On average, respondents reduced their thermostat setting by 3.5 degrees Celsius during the electricity supply disruption, from 19.6 deg. C to 16.1 deg. C. The distribution has a long tail with a few respondents (9) reducing their thermostat setting by more than 8.3 deg. C (Figure 38). These outliers may include people who supplemented electric heat with an alternative source (e.g., wood stove).

Although this distribution of thermostat settings shifted back toward higher temperatures after the disruption ended, persistent electricity conservation through persistent change to lower thermostat settings is evident (Figure 39). The average increase from thermostat settings during the disruption was only 1.2 deg. C and survey respondents' average thermostat setting after the supply disruption ended was 2.0 deg. C lower than it had been before the disruption began (17.6 C after vs. 19.6 C before).

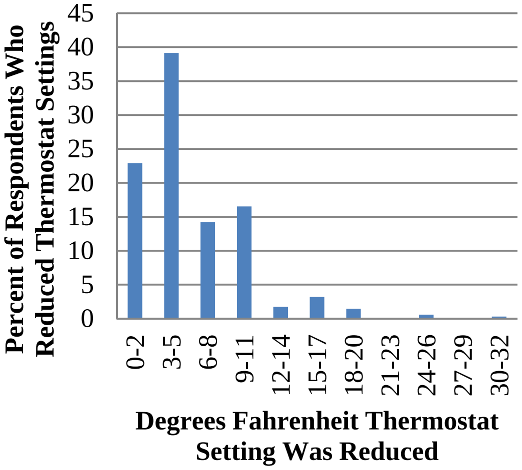

Figure 38: Reduction in thermostat setting during the electricity supply disruption by 66% of respondents (n=345 of the 355 who said they reduced thermostat settings, 97% response rate).

For those who switched to an alternative source of space heating during the supply disruption, 63% switched to wood and 17% switched to oil (6% also switched to Monitor Heaters (diesel) and 5% switched to Pellet Stoves (wood)).

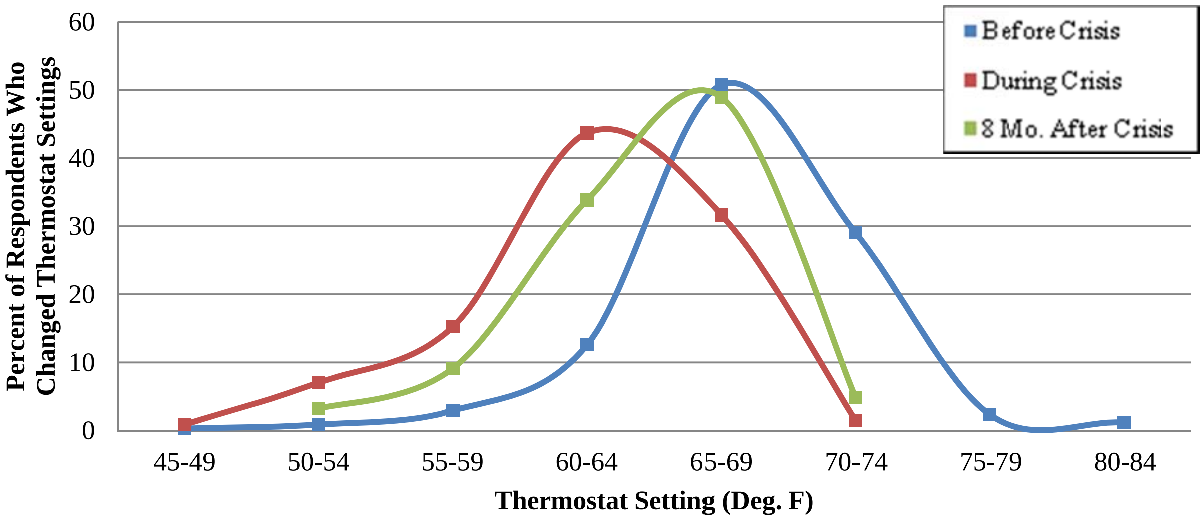

Figure 39: Thermostat settings before, during, and 8 months after the electricity supply disruption by 66% of respondents (n=341 of the 355 who said they reduced thermostat settings, 96% response rate).

4.4.5 Appliances

The 30% of respondents who used power-saving settings on appliances during the supply disruption did so with only one or two appliances (average 1.4; Figure 40). But unlike some other behaviors, use of power-saving settings continued unabated after the disruption, with the share of respondents using these settings holding at 29% eight months after the disruption and the average number of appliance types for which a power-saving setting was in use increasing slightly to 1.5. The most common appliance type for use of power-saving settings was the dishwasher (55-59%), followed by the clothes washer (17-20%), clothes dryer (7-8%), and computer (5%) (Figure 41, Figure 42).[22]

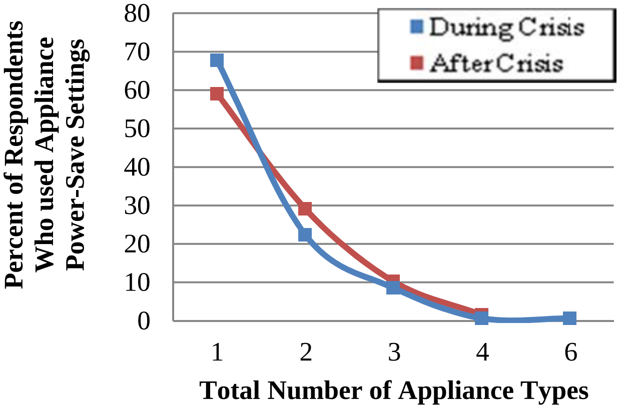

Figure 40: Total number of appliance types used on power-saving settings during and after the electricity supply disruption. The metric “appliance type” is used to approximate the number of appliances because the survey data do not reveal whether a person who used the power-saving setting on a dishwasher (for example), used it on one or multiple dishwashers.

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[22] From the compilation of open-ended responses received, we defined "types" of appliances as the following: Dishwasher, Coffee Maker, Refrigerator, Microwave, Clothes Washer, Water Heater, Clothes Dryer, Computer,

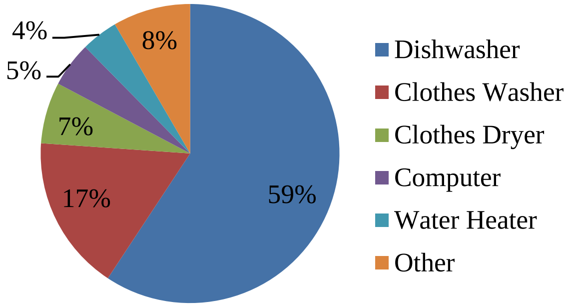

Figure 41: Appliances used on power-saving settings during the electricity supply disruption by 30% of respondents.

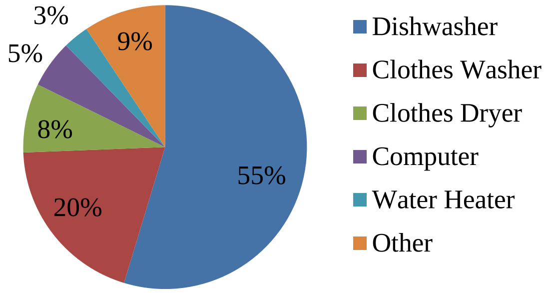

Figure 42: Appliances used on power-saving settings 8 months after the hydroelectric connection was restored by 29% of respondents.

However, 59% of respondents who used power-saving settings had been doing so prior to the disruption, which implies a 59% discount on electricity savings attributed to this behavior.

Only 10% of respondents replaced appliances with more efficient ones after the supply disruption (mean of 1.8 appliances replaced for those who did), and 70% of these people said they would have replaced the appliances even if the disruption had not occurred. Thus, there is no clear indication of whether the electricity supply disruption motivated purchase of more efficient appliances.

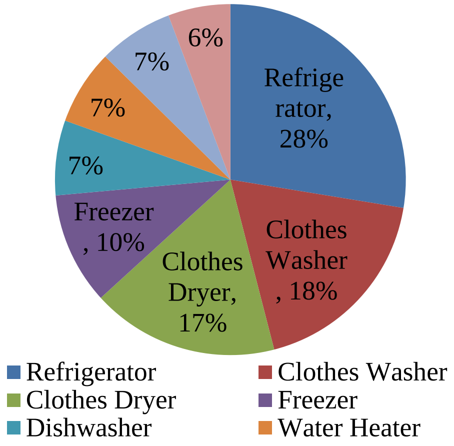

Figure 43: Appliances replaced after the electricity supply disruption by 10% of respondents.

4.4.6 Standby Power

The phenomenon of standby power loss, or the energy used by appliances while not performing their intended service, was widely recognized by respondents with 67% taking action to reduce the loss by unplugging at least one appliance during the electricity supply disruption (mean of 4.2 appliance types unplugged).[23,24,25] Many respondents mentioned that they looked for LED or

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Printer, and Dehumidifyer. This list is an indication of the consumer perception of what appliances have power-saving setting options that are acceptable to use.

[23] Examples include the digital clocks on microwaves and other appliances and the resistive heat loss of power supplies left plugged in. In addition, some appliances draw power continuously in order to provide a service despite infrequent use of that service. Examples include clocks that are rarely glanced at for the time and telephones that are rarely used to answer a call.

[24] The term "unplugging" includes hard-off via a power strip as well.

[25] From the compilation of open-ended responses received, we defined "types" of appliances as the following: Refrigerator/Freezer, Chargers, Clocks, Microwave, Printer, Modem/Router, Shredder, Dishwasher, Stove/Oven, Blender/Mixer, Telephone, Toaster, Space Heater, Lights/Lamps, Water Heater, Lights/Lamps, Water Heater, Washer/Dryer, Iron, Hair Dryer, Door Bell, DVR, Television, Battery Backup/Surge Protector, Computer, CoffeeMaker, CoffeeMaker, Stereo/Radio, Cable Box. Note, respondents may have unplugged multiple appliances within each category.

other glowing lights when an appliances was turned off as a signal for what to unplug in order to reduce standby power loss. Some of this behavior persisted after the disruption ended, with 38% of respondents still unplugging at least one appliance when not in use eight months after the hydroelectric connection was restored (mean of 3.2 appliances for those doing so).[26] Anecdotally, many "forgotten" or "spare" devices like clocks and televisions in guest rooms and spare refrigerators or freezers remained unplugged.

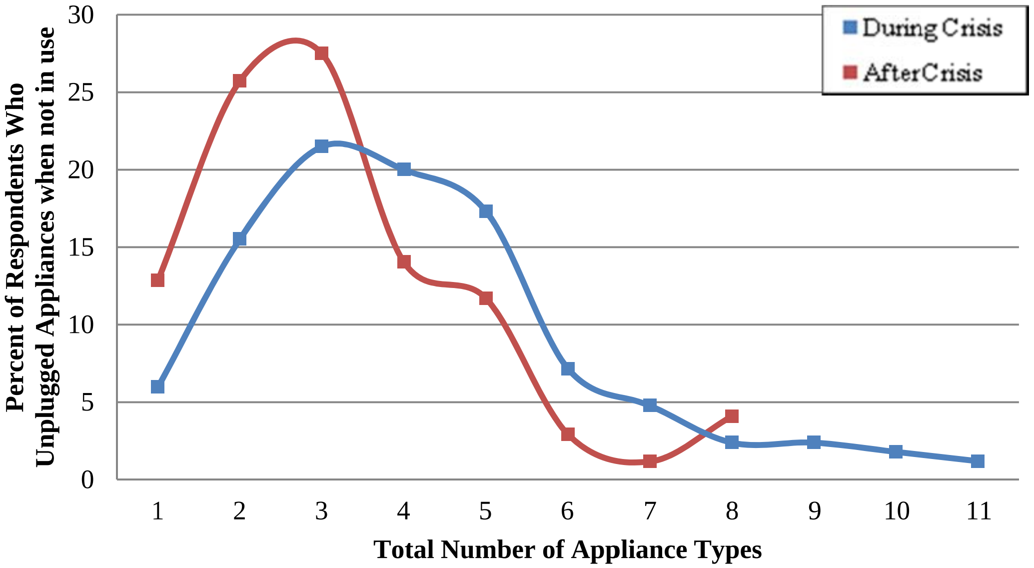

Figure 44: Total number of appliance types unplugged when not in use during and after the electricity supply disruption by 65% of respondents (n=335 of the 381 who said they unplugged appliances during the disruption, 88% response rate). The metric "appliance type" is used to approximate the number of appliances because the survey data do not reveal whether a person who unplugged a clock (for example) did so for one or several clocks.[27]

We do not have information from the survey with which to evaluate the frequency with which respondents were unplugging devices. The frequency may have decreased after the electricity supply disruption ended as motivation for diligence waned and usage patterns returned to normal. Since electricity savings through reduced standby loss is a function of the number and type of devices unplugged as well as the frequency and duration of being unplugged, we lack sufficient information for estimating the magnitude of electricity savings from these actions.

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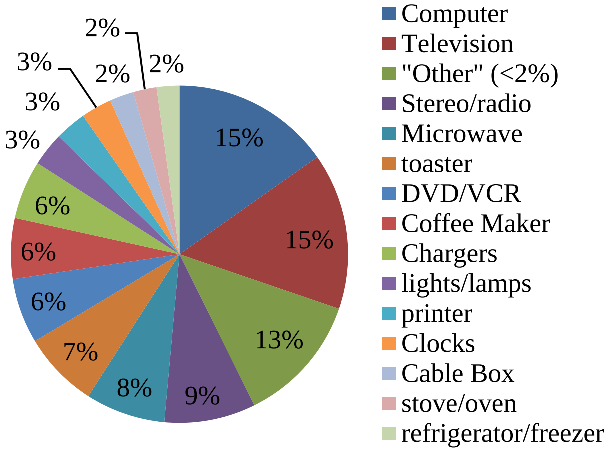
[26] Answers to questions about after the crisis are potentially aided by recall (actions were more recent) and may be subject to bias from prompting because these questions came later in our survey after participants had answered similar questions about activity during the crisis. These answers may also suffer from fatigue as respondents worked to complete the relatively long survey. The net effect of these factors is hard to gauge. Where respondents wrote "same as previous question" (or variation), the list of appliances provided in the previous question was copied.

[27] For example, once respondent provided the following list: "3 TVs, 2 DVD players, 3 VCRs, 4 video game systems, microwave, toaster, floor lights, computer, printer, stereo, 2 portable stereos, electric toothbrush, clock radio, 2 battery and 2 video game chargers, guitar amp, 2 curling iron/hair straighteners."



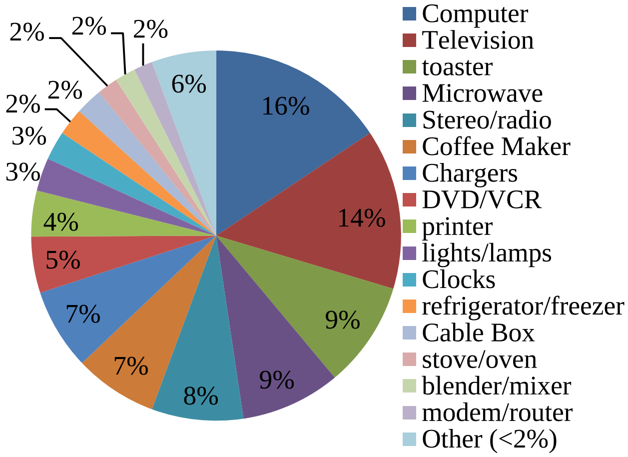


Figure 45: Appliances unplugged during the 2008 electricity supply disruption when not in use by 67% of respondents.

Figure 46: Appliances still being unplugged when not in use 10 months after the 2008 electricity supply disruption by 38% of respondents.

4.4.7 Water Heating and Use

As discussed earlier, Juneauites generally did not have the option of electricity conservation in water heating by fuel switching during the supply disruption. This left the following primary options for electricity conservation in water heating: 60% of respondents washed full loads of laundry and/or washed in cold water, 49% took shorter showers, 36% took fewer showers, 30% turned down the temperature on their water heater, 8% turned off their hot tub or sauna, 7% installed water heater blanket(s), 5% installed low-flow shower heads, and 2% installed a water heater timer or turned off the heater at the breaker (the equivalent of unplugging when not in use).

The 49% of respondents who shortened their showers during the supply disruption did so by an average of 4.9 minutes (Figure 47) and 49% of these people kept their shower duration after the disruption had ended shorter than before the disruption by an average of 3.6 minutes. The reversion in shower time after the disruption came most through people shifting from a 4-5 minute reduction back to normal (i.e., 0 minute reduction). But for about 21% of respondents, the reduction in shower time was persistent (Figure 49). Thus, for 21% of respondents, shortening the length of showers appears to be a persistent behavior change that accounts for some of the persistent electricity conservation.

For those people who shortened their showers during the supply disruption and continued to keep them shorter after the disruption had ended, the average shower duration after the disruption was 6.6 minutes. This implies that for this sub-group (21% of respondents), the average duration before the disruption was 10.2 minutes (6.6 + 3.6) and the average duration during the disruption was approximately 5.3 minutes (10.2 - 4.9).[28]

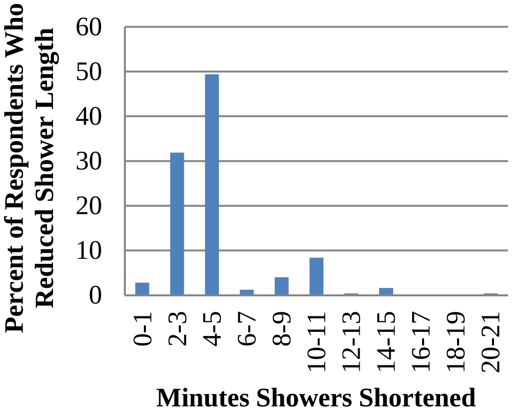


Figure 47: Amount showers shortened during the electricity supply disruption by 48% of respondents (n=251 of the 253 who said they took shorter showers, 99% response rate).

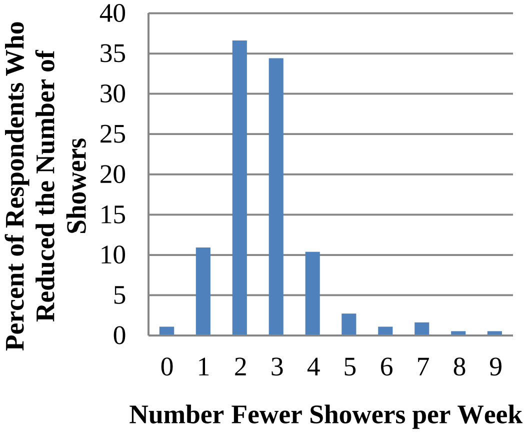


Figure 48: Number fewer showers per week during the electricity supply disruption by 36% of respondents (n=183 of the 185 who said they took fewer showers, 99% response rate).

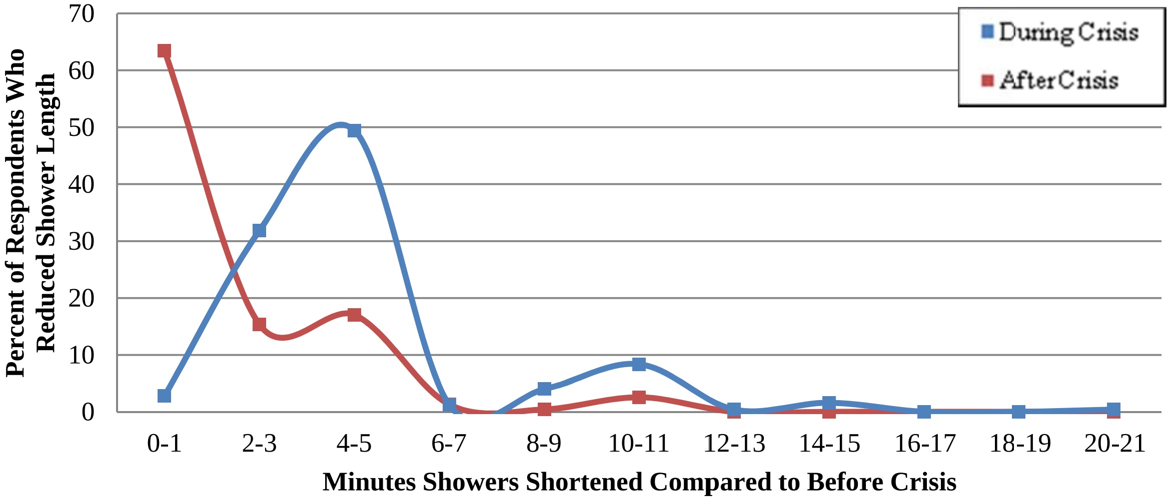


Figure 49: Amount showers were shortened during and after the electricity supply disruption as compared to before the disruption by 48% of respondents (n=251 of the 253 who said they took shorter showers, 99% response rate).

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[28] The 4.9 minute reduction during the crisis in this calculation is an approximation taken from the larger sub-group that includes the people who stopped shortening their showers when the crisis was over.

The 36% of respondents who took fewer showers during the disruption cut down by an average of 2.6 showers per week and 38% of these people kept the number of showers per week fewer after the disruption had ended than before it started by an average of 2.1 per week (Figure 48, Figure 51). Thus, for 12% of respondents, reducing the number of showers appears to be a persistent behavior change that accounts for some of the persistent electricity conservation.

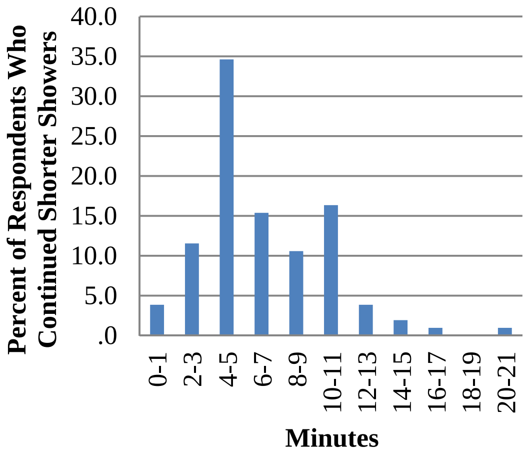

Figure 50: Average shower duration 8 months after the electricity supply disruption for the 21% of respondents who continued to reduce shower duration (n=104 of the 125 who said they continued to take shorter showers, 83% response rate).

For those people who reduced their number of showers during the electricity supply disruption and continued to take fewer showers after the disruption had ended, the average number of showers per week after the disruption was 3.7 (Figure 52). This implies that for this sub-group (12% of respondents), the average number of showers before the disruption was 5.8 (3.7 + 2.1, i.e. less than one per day) and the average number of showers per week during the disruption was approximately 3.2 (5.8 - 2.6).[29]

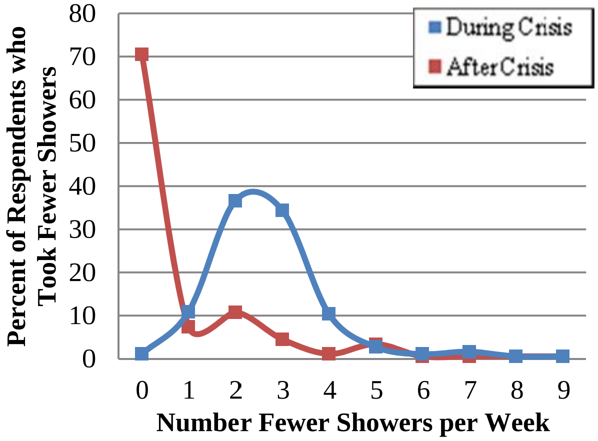

Figure 51: Number fewer showers taken during and after the electricity supply disruption as compared to before the disruption by 36% of respondents (n=185).

Based on these estimates of shower frequency and the estimates of shower duration given previously, we can compare the relative magnitude of water savings from these two types of action. Assuming pre-disruption shower duration of 10.2 minutes and average flow rate of 2.64 gallons per minute, reduction in shower frequency from 5.8 per week to 3.2 per week saved 70 gallons per week during the disruption and the difference between 5.8 showers per week before the disruption and 3.7 showers per week after the disruption implies continued savings of 57 gallons per week. Assuming average shower frequency of 5.8 per week and average flow rate of 2.64 gallons per minute, reduction in shower duration from 10.2 minutes before the disruption to 5.3 minutes during the disruption saved 75 gallons per week and the difference between 10.2 minutes shower

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[29] The 2.6 number of reduction during the crisis in this calculation is an approximation taken from the larger sub-group that includes the people who stopped taking fewer showers when the crisis was over.

length before the disruption and 6.6 minutes shower length afterwards implies continued savings of 55 gallons per week. Thus, the actions of reducing shower frequency and shower duration appear approximately equal in magnitude of water (and energy) use conservation.

Water conservation delivers cascading electricity savings through reduced pumping in addition to reduced heating. Furthermore, these cascading savings would have helped all Juneau residents through reduced municipal water service cost that may have translated into reduced taxes.

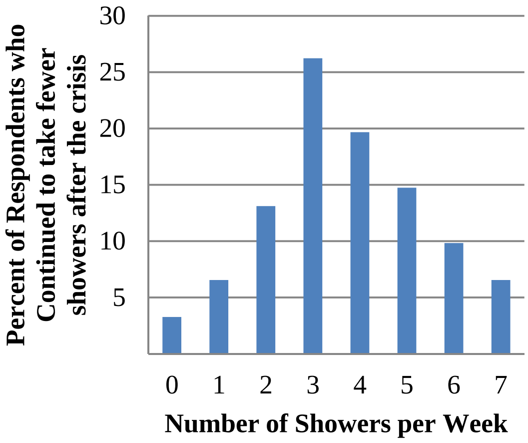

Figure 52: Average number of showers per week 8 months after the electricity supply disruption had ended for the 12% of respondents who continued to take fewer showers (n=61).

4.4.8 New Actions Taken After the 2008 Electricity Supply Disruption

The electricity supply disruption prompted continued actions to conserve electricity even after the hydroelectric connection was restored. Fifty-five percent of respondents took a *new* action after the supply disruption had ended, with installing additional insulation (18%), replacing appliances (10%), replacing windows (5%) and switching to an alternative source for space heating (5%) the most common.[30] Saving money continued to be the dominant motivation for continued conservation after the supply disruption (for 73% of respondents). The short-term price spike during the disruption may have raised awareness of utility costs in such a way that persistent conservation was induced. Anecdotal evidence from survey comments suggests these actions were taken because of new awareness about the payback of investments in energy efficiency and/or for preparedness in anticipation of future supply disruption events.

4.5 Estimated Electricity Savings and Impact for each Conservation Action

The most "impactful" actions for long-term electricity savings will be those that are popular (i.e., many people took the action during the supply disruption), persistent (i.e., few people reverted after the disruption) and effective in reducing energy use. In other words:

Long-term electricity savings = f(popularity, persistence, effectiveness)

We can identify the most popular and persistent actions in the intersection of the two top-10 lists presented above: 1) bulbs replaced with CFL, 2) the habit of turning lights off, 3) the habit of turning appliances off when not in use, 4) having fewer lights on than normal, 5) washing full loads of laundry and/or in cold water, 6) only heating rooms in use, and 7) using power-saving

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[30] The frequency of "other" (15%) suggests the list we provided in the survey was not adequately inclusive.

settings on appliances. From this list, we can identify the most impactful actions for long-term electricity conservation as those that produce relatively large changes in electricity use.

4.6 Could Even More Electricity Conservation Occur?

Although the 25% reduction in electricity use observed during the Juneau electricity supply disruption was large relative to other examples of short-term electricity conservation (Table 2, Figure 1), 48% of respondents said nothing prevented them from taking other energy-saving actions during the supply disruption (Figure 53). This result suggests even greater electricity conservation may have been possible through increased conservation activities for half of respondents and through technology (if affordable and with equal or greater service) for the other half.

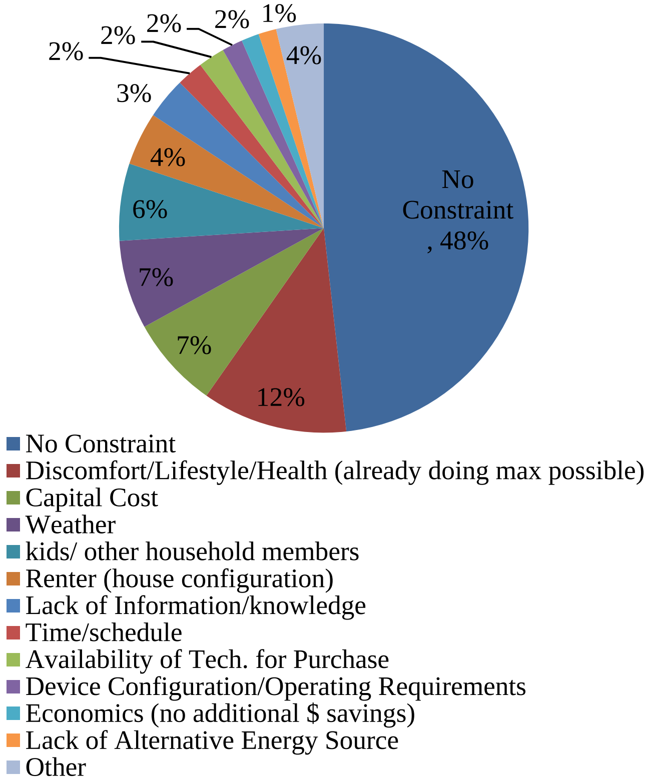

Figure 53: Constraints cited as preventing further energy-saving action during the 2008 electricity supply disruption.

When asked what they would do differently if a similar event were to happened again, most respondents said they would do nothing different (Figure 54). In fact, respondents *had* experienced a second similar event just several weeks before their participation in our survey, and energy conservation during the second supply disruption was less dramatic than in the first. This suggests that Juneauites did ease back from their dramatic first-disruption conservation efforts during the second supply disruption. We cannot tell, however, how much of this change to attribute to a change in behavior or motivation (e.g., the second disruption was less scary having "been there, done that" as one respondent said) versus lesser severity in terms of duration (26 days shorter) and electricity rate increase (doubling rather than five-times increase).

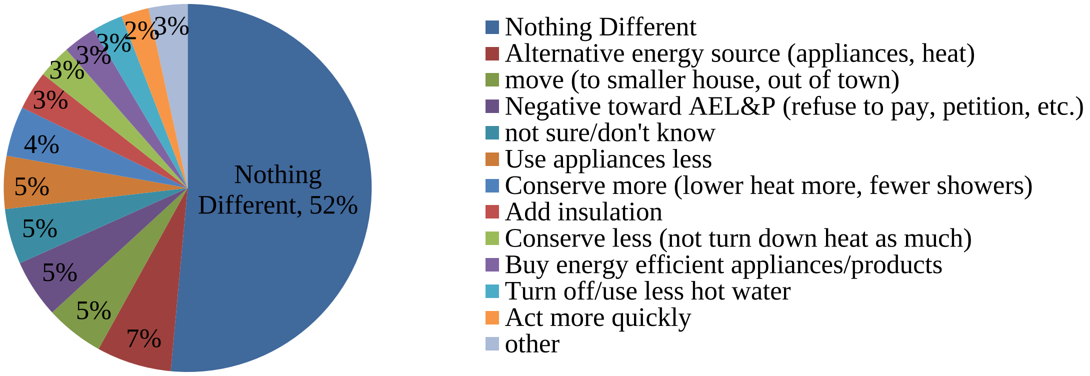

Figure 54: Response to the question, "What would you have done differently if the crisis were to happen again?"

When asked what next action they would take if the electricity supply disruption had been "bigger" in some way, only 17% of respondents said they would not take any further action and only 7% did not know what the next action would have been (Figure 55). These results suggest that conservation could have been even greater than the 25% observed if the disruption had been "bigger" (e.g., risk of blackouts) and that access to information would not inhibit these actions. The most frequent categories of next actions mentioned were to use appliances less (16%), switch to an alternative energy source for appliances or heat (13%), increase conservation behavior like turning down the heat (12%), add insulation (9%), and move to a smaller house or out of Juneau entirely (8%).

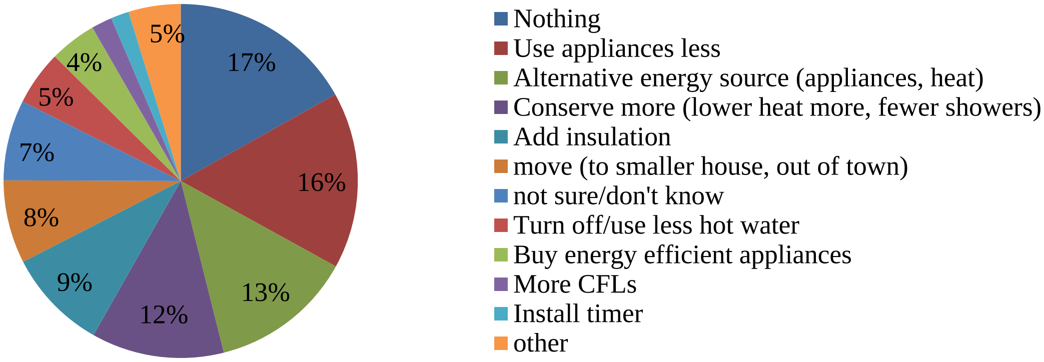

Figure 55: The next action beyond actions taken during the 2008 electricity supply disruption that respondents would have taken if the disruption had been "bigger" in some way.

4.7 Differences Between Sub-Groups

4.7.1 Cluster Analysis for Segmentation

As with any population, it is likely that segments within Juneau share similar attitudes and opinions within the segment that are different from other segments. Such differences provide the basis for segmentation through cluster analysis. With segmentation complete, the researcher can then look for identifying characteristics of each homogeneous segment (e.g., age, gender, income, primary sources of information) and look for significant differences between segments in electricity conservation activity during the supply disruption. This segmentation can enable targeted media campaigns and outreach support.

We used attitudinal Likert-scale questions on motivations for conservation behavior before the supply disruption to define the six segments shown in Table 6 with the between-groups linkage method of hierarchical clustering based on squared Euclidean distance offered in the SPSS software package.[31]

Pre-Disruption Behavior	Already using as little Electricity as possible	Conserving due to concern about the Environment	Conserving due to concern about electricity bills	Cluster Name
Cluster 1 (15%)	Agree (4.09)	Disagree^{+} (2.23)	Strongly Agree (4.78)	Penny Pinchers
Cluster 2 (30%)	Disagree^{+} (2.25)	Disagree^{+} (2.15)	Agree^{-} (3.74)	Economizers
Cluster 3 (34%)	Unsure^{+} (3.18)	Agree^{+} (4.28)	Agree^{+} (4.28)	Eco-Economizers
Cluster 4 (14%)	Disagree^{-} (1.80)	Disagree^{-} (1.68)	Disagree^{-} (1.66)	Non-conservers
Cluster 5 (5%)	Agree (3.95)	Agree^{+} (4.19)	Disagree^{-} (1.86)	Eco-Extremes
Cluster 6 (3%)	Disagree^{-} (1.64)	Agree^{+} (4.14)	Disagree^{-} (1.71)	Eco-Moderates

Table 6: Description of six respondent segments based on survey question 2.10 (n=466). The relative size of each segment in our sample is given in parentheses.

The six distinct clusters are named for easy reference according to the unique combination of answers respondents in the cluster gave to question 2.10. The *Penny Pinchers* are more extreme in their electricity conservation to save money than *Economizers*, and *Eco-Extremes* are more extreme in their electricity conservation for environmental protection than *Eco-Moderates*. *Eco-Economizers* are motivated to conserve electricity from concern for the environment and their utility bills while *Non-conservers* are not motivated to conserve by bills or the environment.

Relatively little distinction in identifying characteristics exists for these segments. *Eco-Economizers* and *Non-conservers* have fewer than average men among them and *Economizers* and *Non-conservers* have more home-owners among them than average (Table 7). But the differences in gender, home ownership, average household income, and age between the segments are not statistically significant at the 5% level. *Non-conservers* and *Economizers* are relatively evenly spread across education level while *Eco-economizers*, *Eco-moderates*, and *Eco-extremes* are more concentrated around a Bachelor's degree level of education (Table 8). Finally, there is little difference between segments in their primary sources of information for energy supply during the disruption (Table 10) and for how to conserve (Table 9).

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[31] We designed questions 2.8 through 2.10 and 5.5 in the survey for this purpose. All four questions asked respondents to indicate their agreement with several statements on the same 5-point Likert scale from 1=strongly disagree, 3=unsure, to 5=strongly agree. A high degree of agreement among respondents on question 2.8 (Figure 18), 2.9 (Figure 21) and 5.5 (Figure 27, Figure 28, Figure 29, Figure 30) generated relatively little information with which to segment survey respondents. Consequently, we used the variability in 466 valid responses to question 10 (Figure 22) to identify the six clusters described in Table 6.

Identifiable Characteristics	Percent Men	Percent Who Own Their Home	Avg. Household Income	Average Age
Penny Pinchers	48%	78%	$71,700	50.6
Economizers	45%	89%	$87,000	50.3
Eco-Economizers	34%	83%	$77,300	52.3
Non-conservers	32%	91%	$84,700	50.3
Eco-Extremes	42%	74%	$73,500	49.6
Eco-Moderates	50%	85%	$88,500	51.5

Table 7: Summary of identifying characteristics for six distinct segments identified.

	HS Diploma	1 Yr. College	Associates	Bachelors	Masters	Prof. Deg.	Doctorate
Penny Pinchers	13%	17%	16%	38%	11%	3%	2%
Economizers	7%	12%	14%	36%	18%	10%	4%
Eco-Economizers	0%	8%	12%	40%	28%	5%	7%
Non-conservers	14%	22%	9%	29%	16%	3%	7%
Eco-Extremes	5%	5%	0%	58%	16%	11%	5%
Eco-Moderates	0%	0%	0%	71%	7%	7%	14%

Table 8: Distribution of respondent segments by education.

	Radio	News-paper	News-paper Web	AELP Web	City Gvt. Web	Word of Mouth	Leg. News	Elected Official	Pam-phlet	Blog/ Chat	Non-profit	Other
Penny Pinchers	65%	45%	35%	43%	10%	49%	7%	10%	28%	17%	6%	26%
Economizers	59%	59%	39%	41%	17%	61%	14%	12%	42%	12%	9%	23%
Eco-Economizers	64%	63%	34%	46%	25%	71%	11%	7%	37%	8%	9%	15%
Non-conservers	52%	58%	45%	54%	25%	62%	8%	6%	45%	12%	6%	22%
Eco-Extremes	71%	62%	24%	19%	10%	62%	10%	0%	33%	19%	10%	24%
Eco-Moderates	64%	71%	36%	29%	14%	71%	36%	7%	29%	29%	7%	7%

Table 9: Sources of information for how to conserve electricity used by each segment.

	Radio	News-paper	News-paper Web	AELP Web	City Gvt. Web	Word of Mouth	Leg. News	Elected Official	Pam-phlet	Blog/ Chat	Non-profit	Other
Penny Pinchers	83%	61%	51%	41%	13%	55%	13%	13%	23%	12%	3%	9%
Economizers	86%	71%	60%	42%	17%	63%	26%	19%	32%	12%	8%	6%
Eco-Economizers	87%	75%	52%	46%	19%	65%	20%	20%	38%	6%	9%	6%
Non-conservers	83%	71%	57%	55%	22%	69%	15%	20%	42%	9%	9%	9%
Eco-Extremes	86%	71%	52%	24%	14%	71%	24%	38%	52%	14%	0%	10%
Eco-Moderates	86%	93%	50%	36%	7%	79%	57%	29%	50%	21%	7%	7%

Table 10: Sources of information about energy supply used by each segment.

There are several noteworthy examples among the statistically significant differences between segments in electricity conservation activity during the supply disruption (Table 11). In general, *Penny Pinchers* and *Eco-Extremes* earn less than other segments while *Economizers*, *Non-conservers* and *Eco-Extremes* have larger households. More *Non-conservers*, *Eco-Extremes* and

Eco-Moderates use oil furnace for space heat while *Penny Pinchers* tend to favor electric heat (perhaps due to lower up-front cost).

More *Penny Pinchers* and *Eco-Extremes* were using power-saving settings on appliances before the electricity supply disruption than were other segments and *Penny Pinchers*, *Economizers* and *Eco-Economizers* were more willing to take fewer showers during the supply disruption than were other segments. *Eco-Moderates* installed fewer CFL than did other segments, but unplugged more appliances when not in use.

Eco-Extremes and *Eco-Moderates* turned off lights and appliances *less* during the disruption than the other segments, *Penny Pinchers* purchased *more* CFL during the disruption than any other segment, and *Eco-Extremes* used electrical devices less often, had fewer lights on than normal, reduced the number of bulbs in light fixtures and used lower output bulbs *less* during the disruption than other segments. These counter-intuitive patterns may have been due to engaging in more of these conservation activities than other segments before the supply disruption occurred (hence less action taken during the disruption).

Eco-Extremes and Eco-Moderates took their first action to revert behavior after the disruption had ended *faster* than did any other segment[32] while more Economizers and Non-Conservers returned to normal frequency of electrical device use and number of lights on after the disruption had ended than did other segments. But more Penny Pinchers and Eco-Economizers stuck with unplugging appliances when not in use after the disruption ended than did other segments and Eco-Economizers, Eco-Extremes and Eco-Moderates were more motivated to continue electricity conservation in order to help others than were other segments. Non-conservers and Eco-moderates reduced the number of lights kept on after the disruption ended vis-à-vis before the disruption by a higher *percentage* than did any other segment.

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[32] This behavior may have been the result of greater perceived sacrifice in more extreme conservation than other segments or may have been due to less effort devoted to understanding the rolling billing cycle and timing of coming off the higher rates than taken by the more economically-motivated segments.

	PP	Econ	EEcon	NC	EE	EM	Sig.[1]
Average Number of People in the Household	2.43	2.62	2.26	2.74	2.62	2.29	*
Estimated average household income[2]	$74,385	$90,733	$80,597	$88,793	$75,735	$93,269	
Percent who have oil furnace for space heat	43%	59%	51%	66%	67%	71%	**
Percent who do not use electricity as primary heat	51%	58%	64%	74%	71%	50%	*
Percent who use electricity for water heating	65%	60%	73%	60%	48%	64%	*
Percent who use oil for water heating	28%	32%	21%	42%	29%	29%	*
Info. on electricity supply from Legislator newsletters	13%	26%	20%	15%	24%	57%	**
Info. on electricity supply from mailed pamphlets	23%	32%	38%	42%	52%	50%	*
Info. on electricity conservation from AEL&P website	43%	41%	46%	54%	19%	29%	*
Info. on electricity conservation from City Gov't website	10%	17%	25%	25%	10%	14%	*
Info. on electricity conservation from Leg. Newsletters	7%	14%	11%	8%	10%	36%	*
Info. on electricity conservation from blog/chat	17%	12%	8%	12%	19%	29%	*
Action during: used electrical devices less often	87%	92%	94%	87%	75%	93%	*
Action during: took fewer showers	41%	40%	47%	29%	20%	29%	*
Action during: had fewer lights on than normal	85%	95%	87%	92%	70%	86%	**
Action during: reduced number of bulbs in fixtures	32%	49%	36%	37%	20%	36%	*
Action during: used lower light output bulbs	32%	33%	20%	29%	10%	36%	**
Action during: turned lights off more frequently	78%	91%	87%	92%	70%	64%	**
Action during: turned appliances off when not in use	81%	95%	86%	92%	65%	71%	**
Action during: used power-saving settings on appl.	35%	43%	32%	48%	30%	14%	*
Acted to save money	99%	99%	96%	98%	85%	93%	**
Acted for the environment	16%	38%	73%	31%	85%	71%	**
Acted to help others	40%	58%	64%	68%	80%	79%	**
Average Number of CFL purchased and installed	14.0	13.4	10.3	12.9	10.3	7.4	**
Average Number of Appliances Unplugged[3]	4.0	4.3	4.0	4.1	3.7	6.3	**
Avg. Number of Appl. used in power-saving mode[3]	1.3	1.4	1.7	1.3	1.2	3.0	**
Percent who used power-saving settings pre-disruption	81%	56%	65%	34%	83%	50%	**
Action Stopped After: None	32%	16%	31%	18%	26%	7%	**
Action Stopped After: using electrical devices less often	29%	46%	20%	41%	21%	29%	**
Action Stopped After: fewer lights on than normal	18%	33%	14%	43%	21%	29%	**
Action Stopped After: reduced # of bulbs in fixtures	3%	12%	3%	11%	5%	7%	**
Action Stopped After: turning lights off more frequently	12%	26%	10%	25%	16%	7%	**
Action Stopped After: appliances off when not in use	18%	26%	18%	38%	11%	7%	**
Action Stopped After: unplug appliances not in use	27%	40%	27%	49%	42%	50%	**
Action Stopped After: using power-saving appl. settings	2%	9%	3%	10%	0%	0%	*
Continuing to conserve to save money	95%	90%	89%	82%	63%	71%	**
Continuing to conserve because friends are too	2%	3%	1%	0%	11%	0%	*
Continuing to conserve for the environment	20%	36%	82%	40%	74%	64%	**
Continuing to conserve to help others	11%	26%	40%	25%	37%	36%	**
Average number of light bulbs are replacing per month	0.7	1.0	0.6	0.7	1.2	0.3	*
Average number of showers/week after the disruption	3.4	3.5	3.4	6.2	N/A	N/A	**
Percent fewer lights kept on now than pre-disruption	19%	25%	26%	39%	19%	42%	**
Avg. number days after disruption ENDED for 1st action	17.6	15.2	11.8	18.9	1.8	1.7	*
Agreement: now use less electricity than pre-disruption	3.8	4.2	4.1	3.9	4.0	4.4	*
Agreement: attitude toward using electricity changed	3.3	3.9	3.8	3.9	3.2	3.9	**
Percent who thought business did not conserve enough	1%	11%	15%	8%	24%	21%	**
Percent who thought no one conserved enough	7%	1%	4%	0%	5%	0%	*
Percent who though everyone conserved enough	17%	9%	11%	20%	10%	29%	*

Table 11: Statistically significant differences between the six respondent segments identified based on pre-disruption behavior. Segments are abbreviated as Penny Pinchers (PP), Economizers (Econ), Eco-Economizers (EEcon), Non-Conservers (NC), Eco-Extremes (EE), and Eco-Moderates (EM). [1]Statistical significance level is indicated by one star (*) for the 10% level and two stars (**) for the 5% level. [2]Household income is estimated as the average of the range selected by survey respondents. [3]Actually the average number of *types* of appliances unplugged since we cannot tell how *many* "radio" or "TV" a person unplugged.

Statistically significant observations pertaining to specific segments include the following:

- *Penny Pinchers* tend not to use oil furnace for space heating, favoring electric heat instead.[33] The *Penny Pinchers* purchased more CFL than any other segment and they were generally not motivated to conserve from environmental concern as much as the other segments, either during or after the supply disruption.
- *Economizers* were more willing than other segments to reduce the number of bulbs in light fixtures during the disruption.
- *Non-Conservers* use oil for water heating more than do the other segments and were taking more showers per week after the disruption ended than the other segments.
- *Eco-Extremes* use alternatives to electricity for water heating more than do the other segments, used the AEL&P website for information about electricity conservation less than the other segments, and took the actions of using electrical devices less often, having fewer lights on than normal, reducing the number of bulbs in light fixtures, and using lower output bulbs during the supply disruption than did other segments. This may have been due to engaging in more of these conservation activities before the disruption occurred. Fewer Eco-extremes continued to conserve electricity after the disruption ended in order to save money (other motivations were more important).
- *Eco-Moderates* tended to get information from legislator newsletters and blogs or internet chats more than other segments. Fewer Eco-Moderates engaged in the activity of using power-saving settings on appliances than did other segments, but those who did use power-saving settings did so on more appliances than did other segments. Eco-Moderates also installed fewer CFL than did other segments, but unplugged more appliances when not in use.

4.7.2 Home Owners and Home Renters

We used survey respondents' self identification as a home owner or renter to segment our sample into two groups and then looked for statistically significant differences between these groups in responses to the other survey questions. The following observations are evident in the results shown in Table 12. Those who own homes tend to be older, with larger living area, household size and higher average household income than those who rent. More home owners have alternative sources of space heating (wood stoves and diesel monitor heaters) than do renters and fewer home owners use electricity as their primary source of space heating.[34] Home owners get information from the printed newspaper more than from the newspaper website while renters get information from the newspaper website more than from the printed version.

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[33] This may be due to lower up-front capital cost in the original heating system installation decision made by the home builder or landlord (if the respondent is renting). Although not a statistically significant difference from other segments, 20% of Penny Pinchers rent their homes while only 8% of Non-Conservers, 10% of Economizers, 13% of Eco-Economizers, and 15% of Eco-Moderates rent their homes.

[34] These patterns may be due to lower up-front capital cost incurred for the landlord to install electric baseboard heat.

	Own	Rent	Sig.[1]
Average age of respondent (yr.)	52	43	**
Household Building Area (sq. ft.)	1,766	1,043	**
Estimated average household income[2]	$ 87,574	$ 60,142	**
Average number of people in the household	2.5	2.0	**
Percent who have a wood stove	24%	9%	**
Percent who have a diesel monitor heater	24%	11%	**
Percent for whom electricity is the primary heat source	22%	42%	**
Percent who don't know their primary water heat source	0%	2%	**
Percent who correctly identified alternative electricity generation source	99%	95%	*
Percent who believed Juneau was not in danger of running out of electricity	71%	53%	**
Percent who didn't know whether there was danger of running out of electricity	10%	24%	**
Percent who got Info. on electricity supply from printed newspaper	73%	64%	*
Percent who got Info. on electricity supply from newspaper website	50%	69%	**
Percent who got Info. on electricity supply from nonprofit agencies	6%	15%	*
Percent who got Info. on electricity conservation from printed newspaper	61%	42%	**
Percent who got Info. on electricity conservation from city gov't website	20%	11%	*
Percent who got Info. on electricity conservation from internet blog / chat	11%	24%	**
Percent who got Info. on electricity conservation from nonprofit agencies	7%	11%	*
Agreement: already using as little electricity as possible pre-disruption	2.8	3.1	*
Action During: shower head	6%	2%	**
Action During: shorter showers	52%	62%	*
Action During: weatherization	11%	20%	*
Action During: hot tub off	11%	2%	*
Acted During to save money	98%	93%	*
Average reduction in thermostat setting during the disruption (deg. Fahrenheit)	5.6	7.3	*
Average number of lights fewer than normal used during the disruption	5.2	3.2	*
Stopped After: taking shorter showers	26%	40%	**
Stopped After: hanging laundry to dry	36%	29%	**
New Action After: none	46%	67%	**
New Action After: adding insulation	26%	10%	*
Reasons to continue conservation: don't know	3%	7%	*
Avg. amount thermostat set lower post-disruption than pre-disruption (deg. F)	4.1	6.1	*
Duration of average shower after the disruption (minutes)	6.4	8.7	**
Average number of showers per week after the disruption	3.6	5.0	**

Table 12: Statistically significant differences between home owners and renters. [1]Statistical significance level is indicated by one star (*) for the 10% level and two stars (**) for the 5% level. [2]Household income is estimated as the average of the range selected by survey respondents.

Home owners made more investments in energy efficiency during the electricity supply disruption (e.g., installing low-flow shower heads) and after the disruption (e.g., adding insulation) than did renters.[35] A notable exception is in low-cost and temporary investments like weatherization that were engaged in more by renters than home owners. Conversely, renters made more behavioral changes for electricity conservation during the supply disruption than did home owners, including taking shorter showers and turning the thermostat down more. A notable

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[35] These findings are consistent with Lutzenhiser et al. (2003), who “found very few shell improvements in renter-occupied housing.”

exception is in the number fewer lights used during the disruption, which was greater for home owners. This may be due to a larger number of total lights in the household, commensurate with higher average floor area.

Although more renters shortened their average shower duration during the supply disruption than did home owners, more renters also reverted to pre-disruption shower duration after the disruption ended and the average number and duration of showers after the disruption ended was higher for renters than for home owners. However, renters maintained a larger reduction in average thermostat setting after the disruption ended vis-à-vis before it occurred.

5. Discussion

5.1 Survey Design

Surveys give an *indication* of behavior, not the behavior itself. Respondents may have forgotten actions they took in the past, may misunderstand the question being asked, and may intentionally or unintentionally misrepresent actions that have taken or are taking. Thus, the probability of reporting an action on the survey is the product of the probability of performing the action and probability of recalling and reporting that action. Both of these probabilities will differ for each action. As with any survey, the closed-ended questions in our survey carried the risk of *prompting* incorrect recall while the open-ended questions in our survey carried the risk of lower recall probability. For the 2001 California energy crisis, Woods (2008) developed an elegant method for estimating the "primal probability" of *reporting* a behavior that was taken in response to an open-ended survey question (Pr), the probability of performing an action during the crisis period ($P^a_{t=1}$), and conditional probabilities of performing an action in the post-crisis year given not having taken the action during the crisis ($P^a_{t=2|\sim a,t=1}$) or having taken the action during the crisis ($P^a_{t=2|a,t=1}$) for 11 categories of action (Table 13).

We lack data to perform such analysis (i.e., repeated interviews with each respondent during a "period small enough so that there is no change in behavior, but long enough so the two interviews can be treated as being independent") but rely on good structuring of closed-ended questions informed by the work of Woods and others in order to make similar analysis of *reported* behaviors to that of Wood's *estimated* behaviors derived from open-ended questions.[36]

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[36] As Woods (2008) noted, "what is striking is how much larger [the estimated probabilities] are relative to what is directly observed in the survey data. This is a direct consequence of the understatement problem [of open-ended questions]… Households perform conservation action far more frequently than they report it [in open-ended questions]. The difference is because of the low recall rate during the interviews. Therefore, when conducting surveys with open-ended questions this understatement bias should be taken seriously and treated, when possible, with repeated surveys."

Behavior (Woods, 2008)	Lutzenhiser et al., 2003	Probability of *reporting* an action that was taken (P_r)	Probability of performing action during electricity crisis year ($P^a_{t=1}$)	Probability of performing the action in post-crisis year (given)		Juneau Survey Results	
	Percent reporting action during crisis			no action in crisis year ($P^a_{t=2\|\sim a,t=1}$)	took the action in crisis year ($P^a_{t=2\|a,t=1}$)	Percent reporting action during disruption	Percent reporting action after disruption
Shell Improvement	7.9%	0.297 (0.248,0.357)	0.324 (0.252, 0.397)	0.08 (0.038, 0.129)	0.983 (0.883, 1)	20%	34%
Light bulbs	22.2%	0.713 (0.301,0.892)	0.232 (0.203, 0.387)	0.018 (0.007, 0.055)	0.39 (0.304, 0.871)	73%	71%
Appliances	10.4%	0.116 (0.065, 0.568)	0.539 (0.139, 0.878)	0.275 (0.025, 1)	0.956 (0.312, 1)	11%	10%
Lights behaviors	65.5%	0.978 (0.908, 1)	0.626 (0.592, 0.66)	0.05 (0.027, 0.079)	0.33 (0.305, 0.361)	90%	81%
Sm. equip. behaviors	32.2%	0.817 (0.701, 0.926)	0.36 (0.33, 0.397)	0.04 (0.021, 0.064)	0.305 (0.259, 0.37)	93%	87%
Lg. Equip. behaviors	6.0%	0.883 (0.731,1)	0.083 (0.064, 0.1)	0.003 (0.0, 0.007)	0.237 (0.163, 0.327)	8%	3%
Not using AC behaviors	9.6%	0.445 (0.285,0.58)	0.247 (0.208, 0.336)	0.198 (0.117, 0.365)	0.454 (0.315, 0.788)	N/A	N/A
Other heat or cool behaviors	38.0%	0.345 (0.311,0.394)	0.892 (0.777, 0.988)	0.549 (0.202, 1)	0.977 (0.909, 1)	79%	67%
H2O behaviors	12.2%	0.689 (0.1, 0.8)	0.201 (0.175, 0.904)	0.009 (0.002, 0.037)	0.242 (0.175, 0.97)	81%	71%
Peak behaviors	20.5%	0.651 (0.097, 0.79)	0.212 (0.185, 1)	0.01 (0.002, 0.146)	0.283 (0.2, 0.976)	N/A	N/A
Vague behaviors	7.6%	0.187 (0.093, 0.241)	0.49 (0.362, 0.848)	0.129 (0.05, 1)	1 (0.967, 1)	30%	35%

Table 13: Estimated probabilities for electricity conservation activities during and after the 2001 energy crisis in California (Woods, 2008) and corresponding percent of respondents in our survey who reported actions in these categories during and after the 2008 supply disruption in Juneau. Data for the probability of *reporting* an action given by Woods were collected by Lutzenhiser et al. (2003) in response to open-ended questions like, "did you make any changes in energy use?" Data from the Juneau survey were collected in response to closed-ended questions, with answer options informed by the work of Lutzenhiser et al., Woods and others. Description of the 11 categories of conservation action defined by Lutzenhiser et al. is given in Table 3.

Since the use of open-ended questions comes with the cost of downward bias in observed prevalence of conservation behaviors due to forgetfulness and because we lacked the ability to use repeated surveys for modeling the forgetfulness process, prompting recall with well crafted closed-ended questions was appropriate.

However, as with any survey, hindsight revealed several shortcomings in our survey design. For example, responses to the question "how many minutes shorter were your showers [during the crisis]" ranged from 1 to 20 minutes. But shortening the average time *per shower* by 20 minutes is hard to believe. Unfortunately, we have no good way of telling what responses are typos and, due to ambiguous question wording, which respondents gave average time reduction *per shower* versus *per week* (or some other unit of measure). In such instances, we used responses to other survey questions as a means to decipher the ambiguous response. In the case of showering behavior, lack of correlation between responses to "how many minutes shorter were your showers" and "how many fewer showers per week" suggests that respondents generally interpreted the former question as intended (i.e., reduction in shower duration per shower rather than reduction in total showering time per week).

5.2 The Conservation Climate in the Juneau Community

Radio and newspaper were the most-cited sources of information, but word of mouth was a close third. This suggests there was a lot of conversation happening in the community; the electricity "crisis" was the talk of the town. Furthermore, very few respondents pointed a finger at who should have conserved the most or who didn't conserve enough and were willing to acknowledge leadership from others during the electricity supply disruption. Survey respondents also generally perceived a large impact on their household, business, *and* the Juneau community as a whole from the electricity supply disruption. These findings suggest a predominant attitude of collaboration in the face of a shared challenge among the residents of Juneau. Thus, one might characterize the atmosphere as an open dialog with positive mutual interdependence for the shared challenge presented by the electricity supply disruption.

It is also interesting to note that the electric utility AEL&P and the local government received a lot of credit for leadership. This is unique among situations of short-term supply shortfall where government and utilities are often blamed as culprits in energy crises. Provision of real-time information, including an energy scorecard published in the newspaper and repair progress on their website, and engaging in public discourse with letters to the editor and interviews on the radio may have contributed to this superior public image.

But there were members of the Juneau community who were upset with AEL&P and the government, some of whom voiced their concerns in letters to the editor. The complaints against AEL&P centered around the occurrence of a supply disruption event (i.e., accusation of inadequate avalanche protection in Snettisham line design) and passing the cost on to ratepayers. With history in Alaska of subsidy for high fuel cost in rural communities, there was a push for disaster relief funds in Juneau and some heated discussion about who would pay for the high cost of diesel generation. This uncertainty in whether the higher rates would be born directly by customers is another complication in the price signal that renders a traditional economics approach of estimating short-term demand elasticity from aggregate data inadequate for understanding the dynamics of conservation response. The complaints against city government centered around not doing enough to conserve (e.g., why are the streetlights still on?). But the open engagement and timely sharing of information by AEL&P and city government leaders seems to have encouraged strong motivation for conservation to help others and the Juneau community.

The prevalence of helping others and environmental protection as reasons for conserving electricity during the supply disruption suggests an element of altruism and community solidarity. But the solidarity toward helping others in the community dropped noticeably for conservation after the disruption, perhaps due to a sense that the crisis and need for help had passed, while the motivation for conservation to help the environment continued unabatted. This persistence of environmental protection as a reason for conservation after the hydroelectric connection was restored is interesting since Juneau's electricity is supplied almost entirely by hydroelectric from alpine lakes without the use of dams and without impact on anadromous fish spawning grounds (i.e., by one of the environmentally "cleanest" sources of electricity).

5.3 Motivations for conservation

To plan for future short-term supply shortfalls and demand-side management, it is useful to consider *why* the residents of Juneau engaged in conservation activities during and after the electricity supply disruption. In other words, what motivates conservation behavior?

The first condition for conservation behavior is perception of a crisis (or other reason to conserve). Survey respondents shared a general sense of important impact of the Snettisham transmission line damage on their household. The very large price increase is a likely source of this perception since blackouts were never mentioned (in fact, transition to diesel backup generation was seamless in Juneau). Furthermore, respondents also shared a general sense of important impact of the supply disruption on other residents, businesses and the entire economy of Juneau. This fostered an egalitarian perception of responsibility for conservation and coming together in the community against a common challenge. Respondents were motivated to reduce electricity use by concern for both themselves and others.

The economic motivation to reduce utility bills was the strongest single motivation for conservation action both before (for 66% of respondents), during (for 86% of respondents), and after the supply disruption ended (for 73% of respondents). The lasting increase in this motivation may explain some persistent conservation. In other words, the price signal appears to have been a strong motivator and the supply disruption event may have had a lasting effect on increasing electricity price awareness and sensitivity.

Environmental reasons also remained a strong motivator for one group of survey respondents before (for 42% of respondents), during (for 43% of respondents), and after the supply disruption ended (for 42% of respondents) despite the changes between generation sources with significantly different environmental impact (i.e., alpine lake hydro to diesel generator and back). Similarly, the motivation for conservation in order to help others is left somewhat unexplained since it is not clear how much one person's conservation would help reduce the utility bill for others in this situation where the price per kWh would change very little with quantity demanded (i.e., generation was nearly 100% diesel no matter what the quantity of electricity used). In any case, the prevalence of helping others (for 54% of respondents) and environmental protection (for 43% of respondents) as reasons for conserving electricity during the disruption suggests an element of altruism and community solidarity.

5.4 Magnitude, Rate and Persistence of conservation response

The electricity supply disruptions in Juneau stimulated the largest percentage short-term household conservation that has been documented. The conservation undertaken in Juneau lessened the blow of an electricity supply disruption that many had predicted would become an economic crisis. Furthermore, it appears that a “bigger” disruption – perhaps with some combination of higher price, longer duration or threat of blackouts – could induce even more conservation. Even when conservation reaches 25% it appears there is still room for additional conservation behaviors if prompted by bigger stimulus.

The question of how fast conservation can occur is particularly relevant for crises of short-term supply shortfall. In Juneau, 25% conservation was achieved in less than a week, with initial action in the first 1-2 days. Thus, the onset of electricity conservation during the first electricity supply disruption in Juneau was indeed rapid. The prevalence of electricity use as a primary source of home heating and redundancy in home heating systems may have helped enable this rate of change through providing the opportunity for immediate conservation through fuel switching and/or thermostat reduction. Conservation can occur *quickly* with behavioral actions (86%) and some technology/fuel switching, but conditions in Juneau may have been especially conducive to both the rate and magnitude of conservation response.

The question of persistence in electricity conservation is particularly relevant when considering longer-term electricity supply planning after a crisis event. Does a short-term jolt to the system initiate some inertia that continues after the crisis? Consistent with prior research by Lutzenhiser et al. (2003), our results suggest electricity conservation can persist after the supply shortfall is resolved and can persist through behavioral change, although to a lesser degree and with less certainty than technological change. Lutzenhiser et al. found that about half of the 7-14% conservation that occurred during the 2001 California energy crisis persisted into 2002 while we observed persistent conservation after the first Juneau supply disruption of 8% (approximately 30% of conservation levels during the disruption) and persistent conservation after the second supply disruption of 10% (approximately 80% of conservation levels during the disruption).

Consistent with previous studies, we found that technological change produces persistent electricity conservation. But the explanation appears more complex than the simple fact that more efficient technologies remain in use once installed. For example, CFL purchase and installation appears to be a sticky behavior (implying persistence on the behavioral side of technological change) and some persistent conservation is related to following through with technological change. These kinds of sticky behavior and follow-through on technology retrofits may explain the increase in persistent conservation observed with repeated supply disruptions.

Conventional wisdom holds that conservation behavior is less persistent than technological change. Although we do not find evidence to the contrary, it does appear that voluntary conservation continues after a supply disruption event. Previous work by Woods (2008) concluded that "there was a large decrease in the number of households shutting off or using fewer lights [after the crisis]. Lights are the [proverbial] canary in the coal mine. They are the first measure people turn to in a crisis and the first they drop when the crisis abates." Thus, it is tempting to conclude that technology explains most of the persistent electricity conservation observed in Juneau. However, the supply disruption appears to have motivated development of some energy saving behavior that has become habit, like unplugging appliances to reduce standby power loss, using power-saving settings on appliances, and changes in water use and thermostat settings.[37] These results are consistent with Lutzenhiser et al. (2003), who found that 95% of households in California that had taken one or more conservation actions during the summer of 2001 were still engaging in at least one action when surveyed in 2002. How long these new habits will persist is an interesting question that only time will tell.

Perhaps the most impactful example of persistent electricity conservation through behavioral change is to be found in space heating, mostly through reduction in variance with households lowering extremely high thermostat settings. Some explanation for this persistent behavior change in lower thermostat settings may be found in acclimation to lower temperature. Some survey respondents mentioned feeling too warm when they initially turned thermostats back up after the supply disruption had ended and some mentioned being more aware of the weather and turning heat up only on particularly cold days. Other respondents talked about more active control of space heating, essentially using the thermostat as a manual set-back control by turning the setting down at night and back up in the morning.[38] Thermal comfort is a function of more than just temperature and when prompted it appears survey respondents were able to find thermal comfort at a lower ambient temperature. This is an important finding because, as Woods (2008) notes, "Because 89.2% of the population already adjusts their thermostat to a certain extent, the effort to convince more people to do so has hit declining returns. Effort should be diverted to inducing people to make larger changes in their thermostat settings. If households are going to react to increases in the price of electricity through these behaviors, we must look towards a greater intensity rather than greater proliferation of these behaviors." It appears that a short-term energy crisis like the supply disruption in Juneau is one way to induce trial and acceptance of such larger changes in thermostat settings.

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[37] Anecdotes indicating high cost in the hastle of unplugging appliances when not in use, especially for inconvenient plug locations, suggest an opportunity for hard-off and automatic-off power strips and household wiring to ease the behavioral burden of reducing standby power loss.

[38] Note, this behavior is consistent with prior research on heuristics in home heating control (Kempton, 1986; Kempton, 1987).

5.5 Actions for Immediate and Persistent Conservation

The *first* actions taken in response to announcement of the electricity supply disruption in Juneau that produced immediate conservation were predominantly behavioral actions (e.g., turning off lights, unplugging devices, turning down the heat). For sustained conservation during the supply disruption, the actions were both technological and behavioral (e.g., replacing light bulbs with CFL, turning off lights more frequently, turning off appliances when not in use). For persistent electricity conservation after the supply disruption ended, the actions with lowest percent reversion were predominantly technological (e.g., weatherization, bulbs replaced with CFL, use of reduced light output bulbs, insulation in the attic/walls/floor). The impact of these actions in terms of contribution to electricity savings is a function of popularity, persistence and effectiveness.

The question of how much of the immediate and persistent conservation is attributable to technological efficiency versus behavioral change is important for design of future policy and programs. As Lutzenhiser et al. (2003) noted, energy efficiency programs have traditionally emphasized technology solutions despite the predominance of behavioral actions in short-term electricity conservation because of perceived uncertainty in the magnitude, persistence and reliability of behavior change. Our survey results are consistent with past research showing that changes in behavior as opposed to technology account for most of the observed electricity conservation in short-term supply shortfall events.[39]

It appears behavioral change for electricity conservation is an equal-opportunity option for which income and home ownership confer no particular advantage in ability. Furthermore, behavioral changes to forgo or reduce some services were generally not perceived as a sacrifice that was difficult to make by ¾ of survey respondents. This result is consistent with Lutzenhiser et al. (2003), who found that nearly 60% of respondents in their study of the 2001 California energy crisis reported their conservation actions had no serious effect on quality of life and over 75% reporting they were likely to continue the behavior.

Respondents' willingness to reduce thermostat settings is analogous to the consumer willingness to turn off air conditioning documented during the California energy crisis of 2001. In both cases, these behavioral actions likely produced a large portion of observed electricity conservation. When prompted, people appeared able to find thermal comfort in Juneau at lower ambient temperature with less home heating, although some anecdotes mentioned increased discomfort. In California, people appeared able to find thermal comfort at higher ambient temperature with less home cooling. This finding is significant because residential heating and

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[39] For the California energy crisis of 2001, Lutzenhiser et al. found that "eighty-four percent of all actions reported were behavioral in nature, which is not surprising since these can be made on short notice… the most common technological action was installation of CFL bulbs, which is likely to be the easiest technology action to take" (Lutzenhiser et al., 2003).

cooling are rarely targets of energy efficiency programs since climate control in the house is generally thought to be a "lifestyle" choice that is strongly preferred by consumers.

Finally, adopting conservation activities are sometimes subject to constraints in ability. For example, home owners were more likely to make conservation investments in the house (e.g., insulation and low-flow shower heads) while apartment renters were more likely to change behavior (e.g., shorter showers and turning the thermostat down more). Thus, we find some evidence that *behaviors*, where everyone has equal opportunity to act, are differentially adopted more by those who are constrained in the opportunity to engage in other conservation activities like long-term technological investments. This result differs from prior research by Lutzenhiser et al. (2003), who found that behavioral changes are more evenly distributed across socio-demographic segments.

5.6 Comparison of First and Second Electricity Supply Disruptions

We did not include questions about activity during or after the second electricity supply disruption of 2009 in our survey. Consequently, interpretation of the observed conservation magnitude during the second disruption is based on anecdotal evidence and publicly available information.

It appears the residents of Juneau responded more gradually and with lesser degree when the second avalanche occurred, with the confidence of a "been there, done that" attitude. Anecdotes suggest this response was from conservation fatigue (e.g., people tired of unplugging appliances) and from confidence they would get through the supply disruption okay having been through the first one.[40] The prime motivator of a price signal may be somewhat relative. Although electricity rates doubled in the second supply disruption, this was less than the recent experience of a 500% increase and therefore may have worked to dampen response.[41] The timing of the electricity supply disruption in January rather than April may have limited conservation activity as well.[42]

But repeated events may induce larger investments in technology and retrofit that deliver an increase in persistent conservation. Several respondents mentioned new investments made during the second supply disruption in the open-ended survey questions.[43] It also appears that more

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[40] One respondent said, "I'm talking to a lot of people that aren't doing as much this time, particularly with the less convenient things. At my own house, we are back to not using the oven, but I am not crawling behind the TV each night to unplug all the boxes like I did last year. There doesn't seem to be as much interest and enthusiasm for conservation this time around."

[41] One respondent said, "our 200% increase doesn't sound too bad when compared to last year's nearly 500% one, so people aren't nearly as frightened."

[42] One respondent said, "it is colder and darker than last time. We have to have some lights on, and it is not possible to completely turn off the heat like many people did last time. Some of what folks did is just not possible right now." Another said, "The unfortunate aspect of this avalanche is that it happened in January… I hadn't realized how nice it was last time to have things happen in the summer."

[43] One respondent said, "we participated in the AHFC energy upgrade rebate program during which we added insulation, replaced an old door, replaced the oil furnace, installed setback thermostats and did a lot of caulking. Our

Juneauites were aware of the relationship between the AEL&P billing cycle and when they would be paying the higher electricity rate by the time of the second supply disruption. AEL&P continued a public information campaign to notify customers that they would start and stop paying the high rates according to their position in the billing cycle. A letter to the editor of the local newspaper describing the situation for one customer who would not start paying the higher rate until February 11 and would continue to pay it until March 13 also heightened awareness (appendix E). AEL&P received "a few" calls from "well-informed" customers early on in the second supply disruption wanting to know what billing cycle they were on and when they should start conserving (personal communication, Scott Willis, AEL&P). This awareness served to dampen response to the supply disruption on either end, with conservation ramping up more gradually as the higher rates rolled out and conservation reverting more gradually as the higher rates rolled back.

5.7 Home Owners and Home Renters

The sub-groups defined by those who own and those who rent their homes are interesting to compare because of the principal-agent problem that often exists in energy use and efficiency investment. In general, tenants who pay utility bills are the primary beneficiaries of energy efficiency improvements while landlords who make capital investment decisions are the primary source of such improvements. Without deriving benefit from these investments through reduced utility bills, the landlord lacks incentive to make such investments. Jaffe and Stavins (1994) describe this landlord-tenant variant of the principal-agent problem in energy efficiency as follows: "[I]f the potential adopter is not the party that pays the energy bill, then good information in the hands of the potential adopter may not be sufficient for optimal diffusion; adoption will only occur if the adopter can recover the investment from the party that enjoys the energy savings. Thus, if it is difficult for the possessor of information to convey it credibly to the party that benefits from reduced energy use, a principal/agent problem arises."[44]

Renters may also be disallowed from making some investments in energy efficiency themselves (e.g., modifications to the building envelope) and will also be reluctant to make investments in energy efficiency themselves if the payback period is longer than their expected tenure and the investment cannot be taken with them.

Thus, the principal agent problem in energy efficiency does not require information asymmetry since both the landlord and tenant may be aware of the overall costs and benefits of energy-efficient investments but will still not make the investment so long as the landlord pays for the

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electric usage is down over 50%, much of which is due to the new water heater and refrigerator we bought during the crisis."

[44] As Murtishaw and Sathaye (2006) observe, "in the residential sector, the conceptual definition of principal and agent must be stretched beyond a strictly literal definition" because it is often difficult to describe who is the principal and who is the agent. In the landlord-tenant case, the principal is the tenant who has "hired" the landlord through the payment of rent.

equipment and the tenant pays the energy bills. But since energy consumption is a function of both technology and behavior, an opposite principal-agent problem arises when the utility bills are paid by the landlord, leaving the tenant with no incentive to moderate her energy use. We see evidence of all of these permutations of principal-agent problems in our survey data.

5.8 A Complex Price Signal

The economic motivation to reduce utility bills was the strongest single motivation for conservation action before, during and after the supply disruption ended. However, some perplexing elements of the economic motivation exist. Conservation action occurred in *anticipation* of the actual price signal, with the full 25% reduction in demand realized weeks before everyone in Juneau was on the higher electricity rate and more than a month before anyone had seen a bill calculated at the higher rate.[45] This finding is significant since conventional wisdom holds that conservation action will occur only *after* price increases. Conversely, it appears the economic motivation did not translate into execution of many investments that deliver rapid payback (e.g., only 7% of respondents invested in water heater blankets). Lack of information regarding the financial performance of these investments and/or of available capital to make them may have been limiting factors, but more nuanced cognitive and behavioral dynamics may be involved as well.

One explanation for the differential response rate at the beginning and end of the first supply disruption in Juneau may be the timing of AEL&P billing cycles and growing awareness among customers of when they would pay the higher electricity rates. The initial announcement by AEL&P of the avalanche damage and estimated rate increase included the intent to assess the rate increase immediately (personal communication, Scott Willis and Gayle Wood, AEL&P). Hence, the rapid conservation response may have been economically motivated, with the sense of common cause within the community (and other motivations) observed in our survey results developing more slowly.

Somewhat later, however, AEL&P realized the rate increase could not legally be assessed under emergency provisions of their governing regulations until 14 days had passed (personal communication, Scott Willis). Furthermore, AEL&P decided it would be more fair to assess the rate increase according to the company's rolling billing cycle (1/22nd of customers receive a bill each weekday) since immediate assessment of the rate increase would charge some customers a higher rate on electricity used prior to knowledge of the avalanche.[46] By assessing the rate increase according to the rolling billing cycle, no customers would suffer the higher rate on electricity they had used before the supply disruption. But the start of higher rates for individual customers could lag the avalanche date by up to 30 days, with the end of the higher rates also

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[45] This result is consistent with behavior during the California energy crisis of 2001 where action was taken despite sporadic and uneven price increases that often came *after* the conservation action was initiated (Lutzenhiser et al., 2004).

[46] AEL&P simply lacked the staffing to read all electric meters on the day the supply disruption began.

lagging the end of the supply disruption by the same number of days. Development of this plan (and understanding among AEL&P customers) occurred too late for those customers who would not pay a rate increase until several days into the supply disruption to modify their conservation behavior (i.e., did not dampen the rapid onset of conservation). But awareness had increased by the end of the disruption, and AEL&P was receiving calls from customers asking when their individual rate would revert to normal. Customers who continued to pay the higher rate for several days after the disruption ended due to their position in the billing cycle were more likely to continue conservation activity after hydroelectric power was restored.

This dynamic helps explain why the initial electricity conservation at the start of the supply disruption was very rapid while increasing electricity use after transmission line repairs were complete was more gradual. In other words, some of the persistent electricity savings in the first month after the disruption had ended may have been due to uncertainty in some households about whether the associated higher electricity rates had really ended for them.

5.9 The Economics of Short-Term Conservation

Three observations relate to the economic motivation for electricity conservation and price signal that occurred in Juneau. First, the economic motivation for conservation behavior appeared dominant among most survey respondents despite a messy price signal (due to the AEL&P rolling billing cycle) and inelastic demand of approximately -0.05 (i.e., 25% decrease in demand with 500% increase in price). In fact, the demand inelasticity may be due to the relatively invisible price signal, that is both separate and delayed from decisions/actions that use electricity. The greater magnitude of observed electricity conservation in Juneau vis-à-vis other short-term supply shortfalls may be due predominantly to the greater magnitude in price change.

Second, the more rapid onset of electricity conservation observed during the first supply disruption and the more gradual reversion in conservation observed after the second disruption may both be a product of increasing understanding of the rolling billing cycle. By the second disruption, the implications of the rolling billing cycle had been fully observed and more Juneau residents had came to understand that they might not start paying the higher rate for up to 30 days after the supply disruption had begun and might continue to pay the higher rate for up to 30 days after it had ended. Consequently, it would be logical observe more gradual onset of conservation at the start of the second supply disruption as well as more persistent conservation for several weeks at the end of the second period of disruption in the aggregate as individual households timed conservation behavior with their individual period of higher billing rate.

Third, one aspect of the rapid onset of electricity conservation behavior left unexplained by our research is why nearly everyone had reached their peak conservation within the first week of the supply disruption when very few people were actually paying the higher rate for the electricity being used and no one had *seen* that they were paying the higher rate in an electricity bill. In other words, conservation action occurred in *anticipation* of the price signal.

5.10 Comparison with Other Short-Term Supply Shortfall Events

Past experience with short-term electricity supply shortfalls has shown that demand reduction of 3% in only a few days and 20% in a few months is possible (IEA, 2005). It now appears that in circumstances like those present in Juneau, it is feasible to cut electricity demand by 25% or *more* in only a few *days* without adverse economic consequences (Figure 1).

The potential for conservation to impact electricity price is an important difference between short-term supply disruptions. In Juneau, altruism appeared to be a strong motivation for conservation despite negligible impact of conservation on electricity price. With the connection to inexpensive hydroelectric power broken, high-cost diesel generation was the source of each kWh no matter the level of demand.[47] In contrast, during the 2001 drought in Brazil conservation kept demand within the generation capacity of low-cost hydro, thereby obviating the need for diesel generation and keeping electricity prices low for everyone (Parente, 2002). Thus, although the situation in Juneau vis-à-vis other short-term energy crises appeared to be a pure price signal with no danger of "running out", there was a strong perception within the community of altruistic action for community benefit.

5.10.1 California Energy Crisis of 2001

Our findings for Juneau's experience with conservation behavior are generally consistent with observations made for the California energy crisis of 2001 by Lutzenhiser et al (2003). Changes in behavior as opposed to hardware efficiency improvements (what we call technology) accounted for most of the observed electricity conservation in both cases.[48] The most common technological action in both California and Juneau was installation of CFL bulbs, which is likely to be the easiest technology action to take.

Consumer willingness to conserve through changes in their household temperature – by turning off air conditioning in California and turning down thermostats in Juneau – produced large electricity savings due to the frequency of action and magnitude of electricity savings produced by it.[49] This finding is important because residential heating and cooling are rarely targets of energy efficiency programs since climate control is generally thought to be a "lifestyle" choice that is strongly preferred by consumers.

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[47] This simplistic description is not entirely correct since several small hydroelectric generating facilities within the community of Juneau (primarily Salmon Creek) continued to produce approximately 10% of total electricity. As conservation reduced demand the share of electricity generated from these facilities increased. However, the contribution remained too small to have a material effect on the cost of electricity (personal communication, Scott Willis, AEL&P).

[48] Eighty-four percent of all actions reported in California were behavioral in nature, which is not surprising since these can be made on short notice. An estimate made by Goldman et al. (2002) of 1,100 MW of customer load reduction produced by energy efficiency and onsite generation projects initiated in 2001 suggests that the other 70-75 percent of observed load reductions was due to conservation behavior.

[49] In California, cooling accounted for 35.5 percent of peak power and 7.4 percent of annual electric energy consumption (CEC, 2003b), and 29-36 percent of households with air conditioning reported using less or no AC during the 2001 crisis (Lutzenhiser, 2003).

Conservation action was also taken in both cases in anticipation of price increases that came after the conservation action was initiated.[50] This finding is important since conventional wisdom holds that conservation action will follow price increases.

The specific conservation actions chosen appear to be influenced by constraints on the ability to take each action. For example, behaviors where everyone had equal opportunity to act (e.g., turning off unused lights and equipment) were taken equally while home owners were more likely to make investments in the house (e.g., insulation, energy efficient appliances), apartment renters were more likely to make investments in energy efficient small appliances and lights, and lower income groups were less likely to make building and appliance changes (due to having fewer resources and less home ownership). Thus, behavioral changes are more of an equal-opportunity action than investments in technological change and are therefore distributed more evenly across socio-demographic segments.

Electricity conservation persisted in both cases after the supply shortfall was resolved through a combination of changed habits and installed technology, with continuing action for new conservation measures mostly in the area of longer-term technology investments. About half of the 2001 crisis conservation persisted into 2002 after controlling for differences in weather and changes in the economy (i.e., electricity use was 3.7% higher than in 2001 but still 3.2% lower than in 2000) (Figure 56; CEC, 2003a).[51]

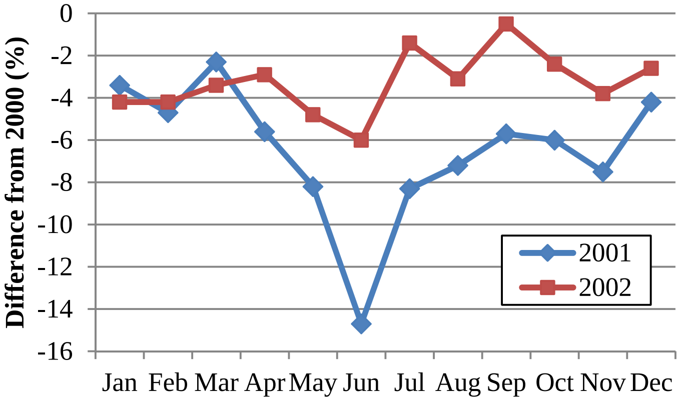

Figure 56: Monthly electricity use in the California ISO area in 2001 and 2002 relative to 2000.

Conservation can persist through behavioral change, although to a lesser degree and with less certainty than technological change. However, our results suggest several nuances in this conventional wisdom. First, CFL purchase and installation appears to be a sticky behavior, with 96% of households who purchased CFLs during the disruption continuing to do so afterward. This implies some persistence on the behavioral side of technological change as well. Second, there also appears to be a component of persistent conservation related to following through with technological changes since the new conservation actions taken after the supply disruption were primarily longer-term and bigger investments that couldn't be completed during the disruption

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[50] The price signal in both cases was also complicated by uncertainty in magnitude and timing. However, the magnitude of price increase experienced in Juneau was many times greater than during the California crisis.

[51] Voluntary conservation continued in California, with nearly 60% of respondents in the study by Lutzenhiser et al. reporting their conservation actions had no serious effect on their quality of life and over 75% reporting they were likely to continue the behavior. Ninety-percent of households that had taken one or more conservation actions during the summer of 2001 were still engaging in at least one action when surveyed in 2002 (Table 3).

and hadn't been completed prior to it. Thus, the supply disruption may have prompted new long-term actions and/or motivated follow-through on things like adding insulation and replacing windows. Repeated supply disruptions may also induce larger investments in technology retrofit that deliver increase in persistent conservation as consumers increasingly believe preparation for the next event will pay off.

Finally, reductions in energy use were somewhat concentrated in both cases, with a subset of the population making larger changes that the population average (i.e., a long tail and negative skew in histograms due to "super-savers").

5.11 A Method for Prioritizing Conservation Actions for Promotion

Media campaigns to alert the public of the need to conserve and to educate the public on how to conserve are important for successful response to a short-term supply disruption (IEA, 2005). But which conservation actions should be touted in the limited number of touch points with the public? One way to make this decision is to prioritize based on which actions will have the most impact on electricity savings.

The most "impactful" actions for electricity savings will be those that are effective in reducing energy use *and* are popular (i.e., many people will take the action during the supply disruption) and persistent (i.e., few people reverted during or after the disruption). Since impact for electricity is a function of popularity, effectiveness and persistence, all three factors should be considered when selecting which conservation activities to suggest in public outreach campaigns.

Our research shows that the most popular and persistent actions were replacing bulbs with CFL, the habit of turning lights off, the habit of turning appliances off, having fewer lights on than normal, washing full loads of laundry and/or in cold water, only heating rooms in use, and using power-saving settings on appliances. Combined with assessment of efficacy in reducing energy use, this information on popularity and persistence can be used to create a prioritized list of the most impactful conservation actions.

5.12 A Process of Disruption Inducing Trial leading to Formation of New Habits

Conventional wisdom holds that conservation behavior is less persistent than technological change. Although we do not find evidence to the contrary, it does appear that voluntary conservation continues after a supply disruption event (Table 14). For example, 38% of survey respondents were still unplugging an average of 3.2 appliances to reduce standby power loss 9 months after the hydroelectric connection was restored. Similarly, nearly *all* of the 30% of respondents who used power-saving settings on appliances during the disruption continued to do so after it ended. We also found some persistence in showering behavior for 12% to 20% of respondents. Persistent electricity conservation through behavioral change in space heating occurred mostly through reduction in variance with households lowering extremely high thermostat settings. Since thermal comfort is a function of more than just temperature, it appears survey respondents were able to find thermal comfort at a lower ambient temperature when prompted. Thus, it appears that a short-term energy crisis like the supply disruption in Juneau is one way to induce trial and acceptance of large changes in thermostat settings. In general, supply disruptions induce *trial* with larger changes in behavior (like thermostat settings) than would otherwise occur and this trial causes a recalibration of what is preferred (for thermal comfort) for some people. The result is persistent electricity savings through formation of new habits.

Activity (% of Respondents)	Before Disruption	During Disruption	After Disruption
Avg. Thermostat Setting	19.6 deg. C (100%)	16.1 deg. C (66%)	17.6 deg. C (66%)
CFL bulb use	Baseline N/A	12 new bulbs (67%)	CFL in 73% of fixtures (67%)
Fewer Lights On	Baseline (0 Fewer) (100%)	4.4 Fewer (79%)	26% Fewer (58%)
Average Number of Unplugged Appliances	Baseline N/A	4.2 Appliances (67%)	3.2 Appliances (38%)
Avg. Number of Appliances Used on Power-Saving Setting	Avg. Number N/A (18%)	1.4 Appliances (30%)	1.5 Appliances (29%)
Showering	Baseline	4.9 Minutes Shorter (49%) 2.6 Fewer per Week (36%)	3.6 Minutes shorter (21%) 2.1 Fewer per week (12%)

Table 14: Summary of some persistent behavior change showing a process of disruption inducing trial with large changes that persist in recalibration to new preferences (i.e., habits).

5.13 A Framework for Dynamics in Electricity Use Before, During and After Supply Disruption

Saving money was a common motivation for conservation activity in Juneau and the implied short-term price elasticity of demand is approximately equal across the two supply disruptions: -0.05 for the first supply disruption (i.e., 25% decrease in demand with 500% increase in price) and -0.6 for the second (i.e., 12% decrease in demand with 200% increase in price). The inelastic demand may be due in part to a relatively “invisible” price signal for electricity that is both separate and delayed from decisions about electricity use. Thus, it appears short-run price elasticity of demand provides a reasonable approximation for the *magnitude* of conservation during a short-term supply disruption.

But the *rate of change* in electricity use at the beginning and end of a supply disruption is not adequately explained by economics. The more rapid onset of electricity conservation observed during the first supply disruption in Juneau and the more persistent conservation observed after the second disruption may both be a product of increasing understanding of the rolling billing cycle. But one aspect of the rapid onset of electricity conservation behavior left unexplained by our research is why nearly everyone had reached their peak conservation within the first week of the supply disruption when very few people were actually paying the higher rate for the electricity being used and no one had *seen* that they were paying the higher rate in an electricity bill.[52] It appears that conservation behavior occurred *before* the price signal, in *anticipation* of it, implying economic estimates of short-term price elasticity of demand are largely irrelevant for understanding the behavioral responses that determine the rate of conservation out the outset of short-term supply disruptions and persistence of conservation afterward.

Comparison across supply disruption events may provide a basis for developing a complete framework for the dynamics of electricity use before, during and after a supply disruption. Each event can be broken into three periods: 1) an adjustment period that begins at the outset of the supply disruption during which electricity use is decreasing; 2) a maintenance period during the supply disruption during which electricity use stays relatively constant at some level below normal; and 3) a reversion period that begins at the end of the supply disruption during which electricity use increases back toward normal. Based on the comparison of these three periods across the varying conditions of many short-term supply disruptions shown in Figure 57, the factors shown in Table 15 appear salient for the rate of change in electricity use during the adjustment and reversion periods. Estimation of relationships based on these factors will enable forecasting of both the magnitude and rate of electricity conservation that may occur in response to future supply disruptions, and the longevity of persistent savings that may linger afterward.

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[52] Although respondents had likely *heard* about the rate increases, since the utility was working to spread awareness through all forms of local media, it may have been difficult to understand the magnitude of monthly bill increase until seeing an actual bill. Awareness of the utility billing cycles also increased during the first and second crises, as residents were first told the rate increase would be retroactive to 15 days before the first avalanche, then would be effective as of the date of the avalanche, and finally would be effective on the first billing cycle after the avalanche (and extend to the first billing cycle after repairs were complete). By the second avalanche, the utility was receiving calls from savvy customers asking when their meter would be read (i.e., their billing cycle) so they would know when they had to start conserving and could stop doing so.

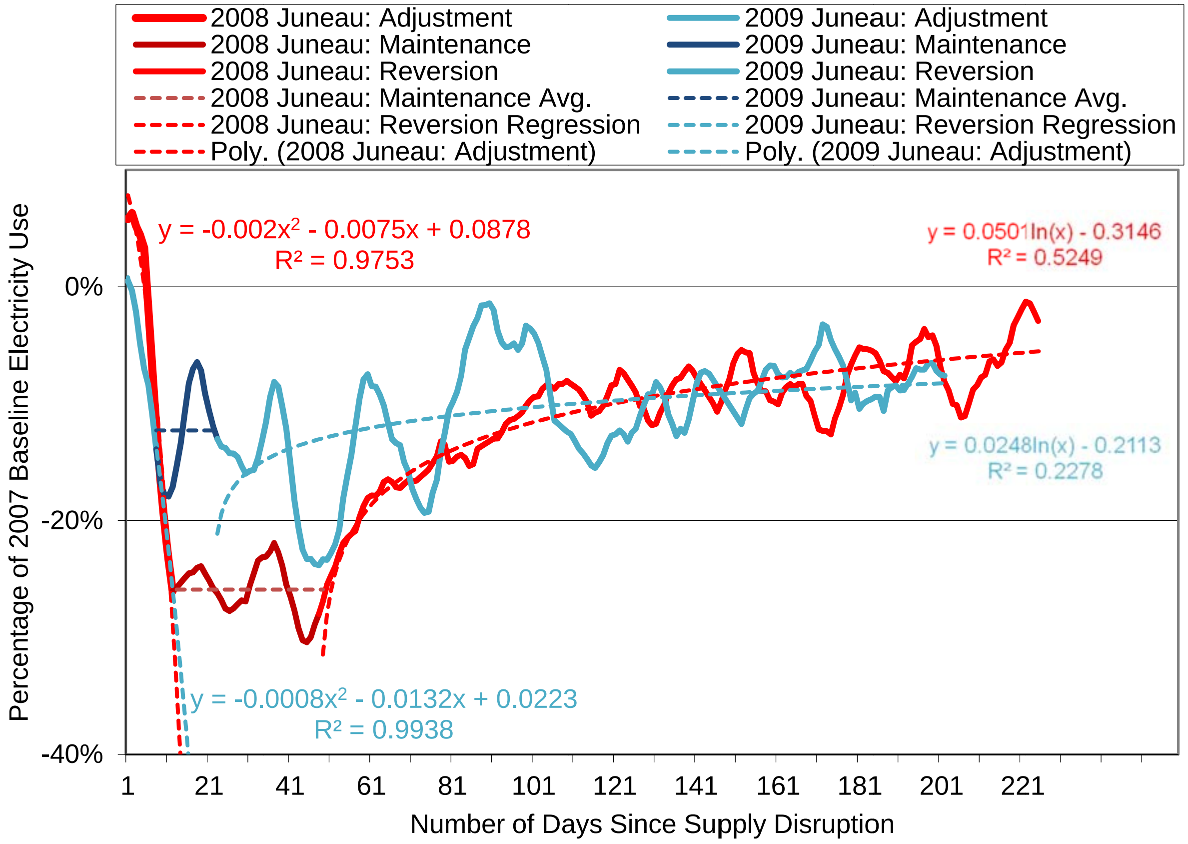

Figure 57: Estimated regressions for the adjustment, maintenance and reversion periods of the two supply disruptions in Juneau.

Factor	Adjustment	Maintenance	Reversion
Short-run Price Elasticity of Demand		X	
Rate of Change in Electricity Price, before and after	X		X
Percentage of Total Energy that is Electricity	X	X	X
Percentage of Homes Heated/Cooled with Electricity	X	X	X
Availability of Equipment for Fuel Switching	X	X	X
Length of Advance Warning	X		
Percentage of Conservation from Technology			X

Table 15: Factors that may be salient for the *rate* of electricity conservation during adjustment to a supply disruption, the *magnitude* of sustained conservation during the disruption, and the *persistence* of conservation after the supply shortfall has been remedied.

5.14 External Validity of the Juneau Experience

Relatively few places in the world share the unique context found in Juneau: 100% hydro electricity, geographic isolation from road and grid networks, temperate maritime climate where heat is used nearly year-round. These conditions may accentuate the ability for more dramatic short-term electricity conservation for at least two reasons. First, a relatively large share of total energy use is in the form of electricity, creating more opportunities for conservation. Second, a relatively high percentage of homes use electricity as the primary heat source, enabling conservation through thermostat reduction. Furthermore, many homes have a secondary heating alternative that enables fuel switching as well. The astounding rate of conservation response in Juneau, with 25% conservation achieved in less than a week, may have been due in part to the prevalence of electricity use as a primary source of home heating and redundancy in home heating systems that enables large impact from fuel switching and thermostat reduction. Thus, the 25% demand reduction achieved in Juneau may not be feasible in other situations.

It may also be true that less investment in energy efficiency had occurred in Juneau prior to the supply disruption than has occurred in other locations for several reasons. In homes heated with electricity, waste heat from an inefficient light bulb or appliance offsets electric resistance heating. In places like Juneau where air conditioning is not used, waste heat produced inside the building envelope does not compound air conditioning load. When electricity price is relatively low, the economics of investment in energy efficiency are not as strong.

5.15 Best Practices for Response to a Short-term Supply Shortfall

Prior research has established a comprehensive list of best practices for response to short-term electricity supply shortfalls (IEA, 2005). Our research on Juneau’s experience tends to confirm these recommendations. The alignment of Juneau’s response with these best practices is summarized in Table 16 - Table 20.

A mass media campaign can be surprisingly effective at quickly reducing electricity demand. The messages should avoid blaming consumers for the problem, should convince them that individual actions will make a difference, and should explain in simple terms what actions will save electricity (IEA, 2005). Typical campaigns ask consumers to re-set thermostrats to reduce heating or cooling, turn off non-essential lighting, adjust schedules for the use of electricity-intensive equipment, turn off office equipment or enable them to “sleep” in lower power modes. Campaigns may also include rebates for successful conservation. Regular collection and dissemination of data related to energy consumption and savings will help a campaign focus on conservation measures that will save the most electricity.

	Best Practice	Description	Implemented in Juneau?
Step 1	Identify the Kind of Electricity Shortfall	Energy or Capacity (i.e., what kind of electricity needs to be saved, peak or base load)	**Yes**, the shortfall was in capacity since ample backup generation capacity existed to cover all peaks in demand
Step 2	Estimate the Probable Duration	How long will the shortfall last	**Yes**, although initial assessment took several days to complete due to bad weather and finalizing repair plans took several more days; repairs were finished ahead of schedule.
Step 3	Breakdown Energy Consumption by End-use	Who and what is using electricity	**No**. Aside from large customers with interruptible power contracts, AEL&P did not have a good inventory of who and what use electricity in Juneau.
Step 4	Developed Ranked Lists of Measures	Which measures area available and what should be done first	**No**. Without advance preparation, response priorities and recommendations evolved as the supply disruption unfolded, with improvization and learning and a variety of communication channels.
	Question: Can Electricity Prices Rise Quickly and for Whom?		**Yes**, with uniform price increase for all customers set by the cost of backup diesel generation. But timing was complicated by 14-day delay for regulatory approval and implementation according to rolling billing cycle for fairness given meter reading constraints.

Table 16: Best practice for shortfall response process (adapted from IEA, 2005). The four steps represent an ideal that may take months or years to execute properly. The price signal is the most important means of informing consumers of an electricity shortage.

Measure	Description	Implemented in Juneau (% of respondents)
Replace incandescent lights with compact fluorescent (CFL) bulbs	Cuts power consumption by about two-thirds; availability in demand spike depends on supply chain	Yes (67%)
Insulate building envelopes	Limited by building design, available labor supply, construction schedules, etc. More economic when coordinated with other improvements.	Yes (3%)
Install building management systems and improved controls and sensors		Anecdotes of set-back thermostat and heat exchanger installation.
Insulate water heater storage tanks	Reduces large storage losses. Anti-convection valves will provide further savings but need a plumber.	Yes (7%)
Convert old roofs into "cool roofs" by applying reflective coating	Saves less if roof is already well-insulated and may save nothing during peak if AC is undersized.	N/A since no AC in Juneau.
Replace motors with more efficient units	Retrofits to motor systems can cut use 75% but require careful consideration of the application.	Anecdotes of mgmnt. and replacement in septic systems.

Table 17: Measures to reduce residential electricity use through technology retrofit (adapted from IEA, 2005).

Measure	Description	Implemented in Juneau (% of respondents)
Increased reliance on (or switching entirely to) wood fired boilers	Especially useful in winter-peaking countries such as Norway, New Zealand and Austria	Yes; Juneau has winter peaks in electricity demand.
Replacing in-line electric water heaters with natural gas	This is an appliance unique to Brazil.	No.
Replacing electric resistance water heaters with natural gas or oil-fired units	A lively fuel-switching market already exists (in both directions) for these appliances.	Option not included in survey; anecdotes suggest respondents did not take this action.
Replacing electric clothes dryers and stoves with natural gas-fired equipment	This can be easily accomplished only in homes where gas service already exists.	No; homes in Juneau generally do not have natural gas service.
Solar water heating in place of electric resistance water heating	Large savings are possible but rapid deployment is difficult.	No, inadequate solar resource in Juneau.
Photovoltaic electricity replacing mains electricity	Insignificant contribution today although may be politically necessary to gain support for other measures.	No, inadequate solar resource in Juneau.
Use line-drying of clothes to substitute for electric clothes dryer	Requires space and cultural acceptance (or re-acceptance).	Yes (56%)

Table 18: Measures to reduce residential electricity use through fuel switching (adapted from IEA, 2005).

Measure	Description	Implemented in Juneau (% respondents)
Switch off unneeded lights inside home	This measure can start immediately and "signals" a commitment to neighbors and friends. Actual savings may be small.	Yes (79%)
Switch off computers and peripherals when not logged on	Computers and their peripherals can easily draw 500 watts when all devices are switched on. A large portion of this can be eliminated even if modem and CPU must remain on.	Yes (78%)
Unplug video and audio equipment	An audio/video entertainment center may draw 25 watts even when switched off.	Yes
Take shorter showers and fewer baths	The electricity needed to sustain a moderate-flow shower averages over 10 kW and baths consume even more energy. This conservation measure applies only where water is heated electrically.	Yes (49%)
Practice more efficient dishwashing	Use less hot water while hand-washing dishes. Rely more on an automatic dishwasher which (when full) uses less energy than hand-washing.	Yes
Raise/lower indoor temperatures	Warmer indoor temperatures in the summer and cooler temperatures in the winter cut electricity use by several percent (or more). This measure applies only where cooling and heating are done electrically.	Yes (68%)
Switch off outside decorative lighting and reduce "security" lighting	Outside lighting for decoration (including Christmas lights) may have a combined power of several hundred watts operating continuously or for large parts of evenings.	Yes
Lower water heater storage tank temperature	In homes with electric resistance storage heaters, lowering the storage temperature can cut standby losses by 100 kWh per year (or more). This may result in more occasions when the tank runs out of hot water.	Yes (30%)
Unplug miscellaneous equipment with standby except when being used	Many small devices - especially those with external power supplies - draw power even when switched off. Each charger draws 0.5 to 2 watt. Chargers for mobile phones, portable tools, small radios, etc. are all candidates for unplugging. This measure requires constant vigilance.	Yes (73%)
Shorten pool filter pump cycles	Swimming pools require filter pumps (0.5 to 2 kW) operating several hours a day. Cycle time can often be shortened without sacrificing sanitary conditions.	No (no home pools in Juneau)
Unplug hot tubs	Most hot tubs and spas are electrically heated and consume 2,000 to 6,000 kWh/year.	Yes (8%)
Use alternative fuels for heating & cooking	Some homes have back-up heating systems relying on wood or oil. Others can switch from microwave ovens to conventional gas stoves.	Yes (18%)
Unplug waterbed heater	In some regions of the United States nearly 10% of homes have heated waterbeds, each consuming 500 to 1,000 kWh/year.	Option not in survey
Practice more efficient clothes washing	New detergents make it possible to wash clothes with much less hot water (or none if the water is soft).	Yes (60%)
Unplug freezer or second refrigerator	A refrigerator or freezer draws 400 to 1,000 kWh/year.	Yes
Correctly regulate hot water circulation pump for boiler	Correctly regulating the boiler so that the circulation pump is controlled by the ambient thermostat can produce annual energy saving of 227 kWh/year.	Option not in survey
Dry clothes on clothes line rather than with clothes dryer	Hanging wet laundry rather than using electric dryers can save as much as 1,000 kWh/year	Yes (56%)

Table 19: Measures to reduce residential electricity use quickly through operational (behavioral) changes (adapted from IEA, 2005).

Ultimately, implementation of conservation is the consumer's responsibility, so it is important to mobilize conservation activity. In the chain of events necessary to stimulate consumer actions (Table 20), an 80% success rate at each step will produce only about 10% of all consumers who actually achieve electricity savings. Thus, achieving success in every step is critical to overall electricity conservation.

Step	Primary Tools	Juneau Events
1.) Consumer learns that a shortfall exists	Media - explain shortfall cause, effect, expected duration - fundamentally a marketing campaign	Radio, newspaper, websites… and word of mouth
2.) Regardless of cause, the consumer recognizes that measures to reduce electricity must be taken	Media - explain shortfall cause, effect, expected duration - fundamentally a marketing campaign	Radio, newspaper, websites, pamphlets… including real-time information about system status
3.) Consumer recognises that his/her contribution will help mitigate the shortfall	Explain Electricity shortfall, link consumer actions to solving the shortfall, convince that individual actions can make a difference	Radio, newspaper, websites, pamphlets… including community electricity use scorecard
4.) Consumer decides to reduce electricity use	Motivation - higher prices, community solidarity, etc.	Radio, newspaper, websites, pamphlets… including community electricity use scorecard
5.) Consumer selects feasible measure from universe of alternatives	Programs to channel consumers to productive, energy-conserving investments and behavior	
6.) Consumer selects measure(s) to implement	Programs to ensure implementing selected measures is within the consumer's abilities	Financial assistance available from city government
7.) Consumer arranges for implementation of measure (buys, hires, studies, etc.)		Shortage for CFL constrained implementation as demand outstripped supply
8.) Consumer implements measure		
9.) Electricity use declines (assuming measure works as intended)		
10.) The measure is repeated (if sustained consumer action is required)		

Table 20: Chain of events required to mobilize conservation (adapted from IEA, 2005).

The dramatic speed *and* magnitude of electricity conservation that occurred in Juneau, Alaska in the spring of 2008 was partly due to a dramatic price signal. But empirical studies of energy efficiency (Stern et al., 1986a; Abrahamse et al., 2005), environmental (NRC, 2002; Gardner and Stern, 2002), and health-promoting (Abroms and Maibach, 2008; Snyder and Hamilton, 2002; Snyder et al., 2004) interventions at the individual and household level suggest that the price elasticity of demand (i.e., economic stimulus) is just one factor whose effect can vary by a factor of 10 depending on other non-financial aspects of the intervention (Dietz et al., 2009). In fact, Dietz et al. (2009) contend that the most effective interventions typically include the following elements:

1. Combine several policy tools (e.g., information, persuasive appeals, and incentives) to address multiple barriers to behavior change;
2. Use strong social marketing, often featuring a combination of mass media appeals and participatory, community-based approaches that rely on social networks and can alter community social norms;
3. Address multiple targets (e.g., individuals, communities, and businesses).

Thus, the success of the intervention that occurred in Juneau in the days after the 2008 avalanches was likely due to a combination of financial incentives, appeals, information, informal social influences, and efforts to reduce transaction costs involved in reducing electricity use. For example,

- The impact of the very large financial incentive of $0.52 per kWh was likely blunted by the fact that most AEL&P customers would not *see* the rate increase until weeks into the supply disruption due to the rolling billing cycle.
- A My Turn article by Juneau Mayor Bruce Botelho printed in the Juneau Empire on April 23, seven days after the connection to Snettisham was cut, was titled “We’re all in this together” and appealed to families, businesses and government agencies (the largest employers in Juneau) to “protect those who are most vulnerable” and “conserve energy with a vengeance” rather than lash out in anger to assign blame for the supply disruption (Botelho, 2008). The letter also highlighted sources of information for energy conservation tips.
- A second My Turn by Mayor Botelho on May 18 focused on information about the link between conserving water and reducing electricity use (water use and the associated pumping and treatment is the single largest municipal electric use in Juneau).
- Businesses who turned off 50% of their lights were accepted and even rewarded for it while those who left all lights on were ostracized. This is an example of establishing a new social norm in the community.
- The Juneau Assembly’s quick action to authorize $3 million in grants and loans made available to families and small businesses most at risk helped to defray the transaction costs associated with investing in energy efficiency.
- A Juneau “Energy Score Card” was published on the local newspaper website with daily electricity (MWh) and diesel (gallons) usage totals.

Finally, the transition back to normality after a short-term supply shortage is corrected has important impacts for preparation for the next shortfall event. The wisdom of such preparation was made obvious in Juneau when the second supply disruption occurred less than one year after the first. Important actions at the end of a supply shortfall event include evaluation of program effectiveness and conservation behavior, including research like presented in this paper, to improve response to the next crisis. “A small investment in determining which programs saved electricity and how much they cost can make the next conservation program more effective and economical" (IEA, 2005). There are many potential metrics for program impact evaluation, including quantity of energy saved, energy savings per dollar invested and expected persistence of energy savings. Collection of information during the crisis will be important for successful evaluation afterward.

6. Conclusions

In this paper, we have documented a short-term electricity disruption of exceptional magnitude in price increase and demand reduction. Through a questionnaire of closed-ended questions designed with insight from prior open-ended surveys implemented for other electricity supply shortfall events, we sought to understand *how* the conservation occurred.

Past experience with short-term electricity supply shortfalls has showed that demand reduction of 3% in only a few days and 20% in a few months is possible (IEA, 2005). It now appears that in circumstances like those present in Juneau, it is feasible to cut electricity demand by 25% or *more* in only a few *days* without adverse economic consequences. Furthermore, changes in behavior and technology induced by a transient crisis can produce persistent electricity conservation.

The magnitude of electricity conservation during the supply disruptions decreased from the first to the second disruption (25% vs. 12%) such that the implied price elasticity of demand was nearly identical. This suggests that price is a prime motivator for conservation. However, the persistent conservation after these disruptions increased (8% vs. 10%). Thus, it also appears that persistent conservation may increase as the "crisis" becomes more "routine" due to higher expectations of future price increases.

Juneau's experience reinforces some of the major findings from previous studies of short-term energy crises (IEA, 2005). There are three major strategies to save electricity quickly: raise electricity prices, encourage behavioral changes, and introduce more energy efficient technologies. Juneau was forced to do the first strategy due to high diesel prices, although the strength of this price signal was weakened by complications in implementation.[53] Demand response may have been even greater had the signal been stronger, although conservation behavior did occur in *anticipation* of higher prices. Juneau also did a lot on the second strategy with a city-wide campaign in a location where isolation stimulated awareness. But Juneau may have been constrained on the third strategy due to the "surprise" of an unexpected avalanche providing no time for preparation and delays in the supply of energy efficient technologies to Juneau (especially CFL). If the crisis appears rapidly and/or lasts only a short time, the role of

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[53] There are often administrative, political and technical obstacles to raising electricity prices quickly and AEL&P's experience with regulatory requirement to wait 14 days before raising price and difficulty in implementation due to the rolling billing cycle is not unique.

technological efficiency in conservation will likely be limited, which will reduce the persistent savings. When implemented, technical improvements often include installation of energy-efficient lighting (especially CFL) and replacement of old equipment with new and efficient units, and provide more reliable (and persistent) electricity savings.

In addition, our findings are consistent with lessons learned from the 2001 California energy crisis (Lutzenhiser et al., 2003). "Consumers are clearly willing to respond positively to credible requests for demand savings in crisis or system emergency conditions." Although electricity demand may be driven by relatively fixed needs, desires and comfort requirements, there may also be significant amounts of redundant or wasteful energy use and consumers are also willing to change their needs, desires and comfort requirements. This implies that energy policies and programs designed to reduce energy use should include influence and motivation for households to take both hardware actions and behavior changes.

The magnitude of conservation realized depends on the consumer's level of concern, capacity to act, and conditions and constraints surrounding that action (Lutzenhiser et al., 2003). In general, concern is a function of belief that the problem at hand is real and perception that it is important. Capacity is a function of whether action is possible, can be implemented and will have an effect. Conditions are a function of whether consumer participation is seen to be reasonable and equitable. How these three factors vary will affect the success of policy strategies. For example, people often have more capacity to act on behavioral changes than technological investments, although information and knowledge of what behaviors to change can be limiting (hence a role for media campaigns). Lutzenhiser et al. provide the following compelling summary of implications. "If we are coming to see consumer behavior as a potentially significant element in energy policy, and if we can understand that conservation and efficiency choices are strongly shaped on the consumer side by concern, capacity and conditions (the "three C's"), then we are opening the door on new *imagery* — new ways of thinking about, conceptualizing, imagining, seeing energy use and the energy user. When we move to a more realistic notion of how persons and their machines, and persons and their buildings interact with one another in natural and built environments, we can see a variety of features of that re-imagined world that are salient to energy policy."

However, the situation in Juneau also presented some unique and new findings. For example, electricity shortfalls often take place in a politically charged environment where many institutions have lost credibility and politicians and/or high executives have lost their jobs. But sentiment in Juneau was generally one of collaboration toward a shared challenge. Perhaps this was because the electricity supply disruption was caused by an "act of God" without culpability for one actor (although some questioned why the Snettisham line was not more protected against avalanche damage).[54] Survey respondents generally did not assign blame to anyone, and actually

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[54] When the Snettisham line was built in the early 1970s, diesel fuel was an inexpensive and reliable backup power source. Consequently, the line was built according to an accepted standard of care without avalanche diversion

ascribed credit for leadership to AEL&P and others. The biggest complaint against AEL&P was in communication of the billing cycle and fairness of charging higher rates at different times.

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structures or other preventive measures (e.g., avalanche control) that acknowledged the low probability of catastrophic avalanches. There had been only three documented outages caused by avalanches along the line prior to the 2008-2009 events. Although fast-track reconstruction of the Snettisham line after the 2008 avalanche and bypass solution after the 2009 avalanche were the fastest and least-expensive ways to restore the line to service (appendix C), the search for a long-term solution to the avalanche hazard on the Snettisham line produced several alternatives including diversion structures, breakaway conductor, reroutes to less avalanche-prone locations, a submarine cable in the waterway below, diversification of new generation sites (including hydroelectric power at Lake Dorothy), practical avalanche mitigation strategies, and more. Based on the research presented here and in previous studies of short-term conservation in the face of supply shortfalls, the proven ability for conservation should also be considered in determining the most economical solution.

References:

Abrahamse W, Steg L, Vlek C, Rothengatter T (2005) A review of intervention studies aimed at household energy conservation, *J Environ Psychol* 25:273-291.

Abroms LC, Maibach EW (2008) The effectiveness of mass communication to change public behavior, *Annu Rev Public Health* 29:219-234.

Aigner, D.J., Leamer, E.E. (1984) Estimation of time-of-use price response in the absence of experimental data: an application of the methodology of data transferability, *Journal of Econometrics* 26, 205-227.

Archibald, R.B., Finifter, D.H., Moody, C.E.J. (1982) Seasonal variation in residential electricity demand: evidence from survey data, *Applied Economics* 14, 167-181.

Blackwell, Sally (2009) Electricity Conservation in Context: A mixed methods study of residential conservation behavior during an electricity shortage in New Zealand, Behavior Energy & Climate Change Conference, Washington, D.C., November 15-18. <http://www.aceee.org/conf/09becc/09beccindex.htm>.

Blackwell, Sally, Ralph Chapman and Traciano L. Milfont (2008) Household Electricity Conservation in a Supply Shortage in New Zealand, Behavior Energy & Climate Change Conference, Sacramento, California, November 16-19, < http://piee.stanford.edu/cgi-bin/htm/Behavior/becc_conference.php>.

Bender, S., M. Moezzi, M. Gossard, and L. Lutzenhiser. 2002. "Using Mass Media to Influence Energy Consumption Behavior: California's 2001 *Flex Your Power* Campaign as a Case Study" *Proceedings, American Council for an Energy Efficient Economy*. Washington, DC: ACEEE Press 8.15-8.28.

Botelho, Bruce (2008) "My Turn: We're all in this together" in the Juneau Empire, April 23, http://www.juneauempire.com/stories/042308/opi_271345284.shtml.

Brown MA, Chandler J, Lapsa MV, Sovacool BK (2008) Carbon Lock-In: Barriers to Deploying Climate Change Mitigation Technologies, Oak Ridge National Laboratory, Oak Ride, TN, Publication No. ORNL/TM-2007/124.

Bultena, G. (1976) Public response to the energy crisis: a study of citizens' attitudes and adaptive behaviors, Technical Report, Iowa State University, Ames.

Bushnell, James (2003), "California's Electricity Crisis: A Market Apart?" Center for the Study of Energy Markets, Paper CSEMWP-119, University of California Energy Institute, Berkeley.

CEC (California Energy Commission). 2003a. *Revised Energy Conservation Impact Assessment.* Sacramento, CA: California Energy Commission.

CEC (California Energy Commission). 2003b. *California Energy Demand 2003-2013 Forecast.* February 11, 2003. Staff draft report #100-03-02SD.

Cunningham, W.H., Lopreato, S.C. (1977) Energy Use and Conservation Incentives: A Study of the Southwestern United States, Praeger Publishers, New York.

Dietz, Thomas, Gerald T. Gardner, Jonathan Gilligan, Paul C. Stern and Michael P. Vandenbergh (2009) Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions, *PNASI* 106(44), 18452-18456.

Energy Information Administration (2001) 2001 residential energy consumption survey, form eia-457a (2001) – household questionnaire, Technical Report, US Department of Energy.

Eriksen, Eric, Dan Zacharda and Jim Multerer (2009) After the Avalanche, *Transmission and Distribution World*, March 1, http://tdworld.com/overhead_distribution/avalanche-prone-transmission-lines-0903/index2.html

Fast Company (2007) Next Time, We Say We Boil a Consultant, Online accessed 5 January 2010 < http://www.fastcompany.com/magazine/01/frog.html>.

Forgey, Pat (2009) "City gets some protection for its power lines," Juneau Empire, 2 October, http://www.juneauempire.com/stories/100209/loc_500171488.shtml.

Garcia-Cerrutti, L.M. (2000) Estimating elasticities of residential energy demand from panel county data using dynamic random variables models with heterskadastic and correlated error terms, *Resource and Energy Economics* 22, 355-366.

Gardner GT, Stern PC (2002) *Environmental Problems and Human Behavior*, Pearson Custom Publishing, Boston, 2nd ed.

Gladhart, P.M., Zuiches, J.J., Morrison, B.M. (1980) Impacts of Rising Prices upon Residential Energy Consumption, Attitudes, and Conservation Policy Acceptance (Chapter 6).

Goldman, C., J. Eto and G. Barbose. 2002. *California Customer Load Reductions During the Electricity Crisis: Did They Help to Keep the Lights On?*. LBNL 49733, Berkeley, CA: Lawrence Berkeley National Laboratory.

Halvorsen, B., Larsen, B.M. (2001) The flexibility of household electricity demand over time, *Resource and Energy Economics* 23, 1-18.

Houthakker, H., Verleger, P.K.J., Sheehan, D.P. (1974) Dynamic demand analysis for gasoline and residential electricity, *American Journal of Agricultural Economics* 56(2), 412-418.

Hughes, T.P. 1989. "The Evolution of Large Technological Systems." pp. 51-82 in W. Bijker, T. P. Hughes, and T. Pinch, eds. *The Social Construction of Technological Systems.* Cambridge, MA: MIT Press.

International Energy Agency (IEA) 2005 Saving Electricity in a Hurry: Dealing with Temporary Shortfalls in Electricity Supplies, OECD/IEA, online < http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=1481>

International Energy Agency (IEA) 2007 Mind the Gap – Quantifying Principal-Agent Problems in Energy Efficiency, Tanaka, Nobuo ex. ed., OECD/IEA, online <http://www.iea.org/textbase/nppdf/free/2007/mind_the_gap.pdf>

Jaffe, Adam B and Stavins, Robert N. (1994) Energy-Efficiency Investments and Public Policy, *Energy Journal* 15(2), 43-65.

Juneau Empire (2008) Empire editorial: In time of hardship, find ways to help, May 4, http://www.juneauempire.com/stories/050408/opi_275269851.shtml.

Juneau Economic Development Council (JEDC) (2009) 2009 Juneau and Southeast Alaska Economic Indicators, viewed online on 9 Feb. 2010 <http://www.jedc.org/forms/Juneau%20and%20SE%20Indicators%202009%20FINAL.pdf>

Kempton, W. and Montgomery, L. (1982) Folk Quantification of Energy, *Energy* 7(10), 817-827.

Kempton, W. (1986) Two theories of home heat control, *Cognitive Science* 10: 75-90.

Kempton, W. (1987) Variation in Folk Models and Consequent Behavior, *American Behavioral Scientist* 31(2): 203-218.

Kilkeary, R. (1975) The energy crisis and decision-making in the family, Technical Report, National Technical Information Services, US Department of Commerce, Springfield.

KTOO Radio (2009) *Avalanche a year later*, Producer Rosemarie Alexander, April 16, http://www.ktoo.org/audiofile.cfm?clip=3819.

Lazerfeld, P.F. (1944) The controversy over detailed interviews – an offer for negotiation, *Public Opinion Quarterly* 8, 38-60.

Lutzenhiser, L. (2001) An exploratory analysis of residential electricity conservation survey and billing data: Southern California edition, Consultant Report 400-020006F, California Energy Commission.

Lutzenhiser, L. 2002a. “Greening the Economy From the Bottom-Up? Lessons in Consumption From the Energy Case” pp. 345-356 in Nicole W. Biggart, ed. *Readings in Economic Sociology* . Oxford: Blackwell.

Lutzenhiser, L. 2002b. “Marketing Household Energy Conservation: The Message and the Reality” pp. 49-66 in Paul C. Stern and Thomas Dietz, eds. *New Tools for Environmental*

Protection: Education, Information, and Voluntary Measures. Washington, DC: National Academy Press.

Lutzenhiser, Loren, Richard Kunkle, James Woods, and Susan Lutzenhiser, 2003. "Conservation Behavior by Residential Consumers During and After the 2000-2001 California Energy Crisis" pp. 146-200. *CEC Public Interest Energy Strategies Report.* Pub. # 100-03-012f.

Murtishaw, S. and J. Sathaye, 2006. *Quantifying the Effect of the Principal–Agent Problem on US Residential Use,* Report LBNL-59773

National Association of Home Builders (NAHB), 2006, Housing Facts, Figures and Trends, March, accessed online 11 Feb. 2010 <http://www.soflo.fau.edu/report/NAHBhousingfactsMarch2006.pdf>.

National Research Council, NRC (2009a) Electricity from Renewable Sources: Status, Prospects and Impediments, National Academy Press, Washington, DC.

National Research Council, NRC (2009b) Liquid Transportation Fuels from Coal and Biomass: Technological Status, Costs and Environmental Impacts, National Academy Press, Washington, DC.

National Research Council, NRC (2002) *New Tools for Environmental Protection: Information, Education, and Voluntary Measures,* National Academies Press, Washington, DC.

Pacala S., Socolow R. (2004) Stabilization wedges: Solving the climate problem for the next 50 years with current technologies, *Science* 305:968-972.

Parente, Pedro (2002) Looking Beyond the Energy Crisis: Scenarios for a Renewed Brazilian Electric Power Sector, Minister of the Presidency, Acting Minister of Mines and Energy, Head of the Energy Crisis Committee, Washington, D.C., March.

Perlman, R., Warren, R.L. (1977) Families in the Energy Crisis: Impacts and Implications for Theory and Policy, Ballinger Publishing Company, Cambridge.

Scheffler, O.S., Schwartz, S.I., Tardiff, T.J. (1979) Energy conservation attitudes and behavior in small cities: Davis and Woodland, California, Technical Report, University of California, Environmental Quality Series No. 31, Davis.

Schuman, H., Presser, S. (1979) The open and closed question, *American Sociological Review* 44, 692-712.

Snyder LB, Hamilton MS (2002) in *Public Health Communication: Evidence for Behavioral Change*, ed Hornik RC (Erlbaum, Mahwah, NJ), pp 357-384.

Snyder LB, et al. (2004) A meta-analysis of the effect of mediated health communication campaigns on behavior change in the United States, *J Health Communication* 9(Suppl 1):71-96.

Stern PC (2008) in *The Cambridge Handbook of Psychology and Economic Behaviour*, ed Lewis A, Cambridge University Press, Cambridge, UK, pp 363-382.

Stern PC, et al. (1986) The effectiveness of incentives for residential energy conservation, *Evaluation Rev* 10:147-176.

Stern PC (1986) Blind spots in policy analysis: What economics doesn't say about energy use, *J Policy Anal Manag* 5:200-220.

Tversky, A., Kahnneman, D. (1991) Loss aversion in riskless choice: a reference-dependent model, *The Quarterly Journal of Economics* 106(4), 1039-1061.

United States Census Bureau (2000) Juneau City and Borough, Alaska, Online < http://factfinder.census.gov/servlet/SAFFFacts?_event=&geo_id=16000US0236400&_geoContext=01000US%7C04000US02%7C16000US0236400&_street=&_county=juneau&_cityTown=juneau&_state=04000US02&_zip=&_lang=en&_sse=on&ActiveGeoDiv=&_useEV=&pctxt=fph&pgsl=160&_submenuId=factsheet_1&ds_name=ACS_2008_3YR_SAFF&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry=> accessed 4 Jan. 2010.

United States Department of Energy (US DOE), 2009, CFL Market Profile, March 2009, accessed online 12 Feb. 2010 < http://www.energystar.gov/ia/products/downloads/CFL_Market_Profile.pdf>.

Walker, N., Draper, E. (1975) The effect of electric price increases on residential usage by three economic groups: a case study, Technical Report, Austing: University of Texas, Center for Energy Studies.

Wilhite, H., E. Shove, L. Lutzenhiser, and W. Kempton. 2001. "The Legacy of Twenty Years of Energy Demand Management: We Know More About Individual Behavior But Next to Nothing About Demand" pp. 109-126 in E. Jochem, J. Satha ye and D. Bouille, eds. *Society, Behaviour and Climate Change Mitigation.* Dordrecht, Netherlands: Kluwer Academic Publishers.

Willis, Scott (2008) *My Turn: Why AEL&P is rebuilding above ground* in the Juneau Empire, May 12, http://www.juneauempire.com/stories/051208/opi_278160535.shtml.

Woods, J. (2008) What people do when they say they are conserving electricity, *Energy Policy* 36, 1945-1956.

Yang, Y.Y. (1978) Temporal stability of residential electricity demand in the United States, *Southern Economic Journal* 45(1), 107-115 July.

Young, T., Stevens, T.H., Willis, C. (1983) Asymmetry in the residential demand for electricity, *The Energy Journal* 4, 153-162.

California Measurement Advisory Committee (CALMAC), website http://www.calmac.org

Appendix A: the Survey Tool

Juneau Energy

Who is the respondent?

Please have the person who knows the most about your household or business energy use respond to this survey.

*** 1.1: For what type of energy user are you responding? (note, you may complete the survey multiple times, representing a different entity each time)**

Please choose *only one* of the following:

☐ Household
☐ Small business (fewer than 15 employees)
☐ Large business (more than 15 employees)
☐ Seasonal business (open fewer than 8 months per year)
☐ Government, municipal
☐ Government, state
☐ Government, federal
☐ Other

*** 1.2: How many people in this household or organization are located in Juneau, including you?**

Please choose *only one* of the following:

☐ 1
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6 to 10
☐ 11 to 20
☐ 21 to 50
☐ 51 to 100
☐ More than 100

*** 1.3: What term(s) best describes your position in this household or organization?**

Please choose *all* that apply:

☐ Head of household
☐ Husband
☐ Wife
☐ Son
☐ Daughter
☐ Owner / Chief Executive
☐ Manager
☐ Employee
☐ Maintenance
☐ Operations
☐ White Collar
☐ Blue Collar

*** 1.4:**

Please briefly describe your occupation.

Please write your answer here:

☐

1.7: Which of the following space heating systems do you have in your home/business?

Please choose *all* that apply:

☐ Electric baseboard
☐ Electric space heater
☐ Oil furnace
☐ Wood stove
☐ Pellet stove
☐ Diesel Monitor-type heater
☐ Propane
☐ Other

*** 1.5: Is electricity the <u>primary</u> source of space heat for your home/business?**

<u>Please choose *only one* of the following:</u>

- ☐ Yes
- ☐ No
- ☐ Electricity and other sources
- ☐ Don't know

1.8: Which of the following WATER heating systems do you have in your home/business?

<u>Please choose *all* that apply:</u>

- ☐ Electric
- ☐ Propane
- ☐ Oil
- ☐ Dual-fuel
- ☐ Other

*** 1.6: Is electricity your <u>primary</u> source of WATER heating?**

<u>Please choose *only one* of the following:</u>

- ☐ Yes
- ☐ No
- ☐ Electricity and other sources
- ☐ Don't know

Awareness of the crisis

*** 2.1: Did you know that Juneau lost its primary electric energy supply for a period of 45 days between April 16, 2008 and June 1, 2008?**

<u>Please choose *only one* of the following:</u>

- ☐ Yes
- ☐ No

*** 2.2: What alternative source provided power during this period?**

Please choose *only one* of the following:

☐ Diesel generators
☐ Coal-fired powerplant
☐ Natural gas turbines
☐ Power brought in from outside Juneau
☐ Other
☐ Don't know

*** 2.3: Was Juneau in danger of running out of electricity during this period?**

Please choose *only one* of the following:

☐ Yes
☐ No
☐ Don't Know

*** 2.4:**

From which of the following did you get information regarding Juneau's electricity supply?

Please choose *all* that apply:

☐ Radio
☐ Newspaper (printed)
☐ Newspaper (website)
☐ Power company website
☐ City government website
☐ Word of mouth (community conversation)
☐ Legislator's newsletter
☐ Statements from elected officials
☐ Pamphlets in the mail
☐ Internet blog / chat
☐ Service agency / non-profit
☐ Other

*** 2.5: From which of the following did you get information regarding what you could do to reduce your energy use?**

Please choose *all* that apply:

☐ Radio
☐ Newspaper (printed)
☐ Newspaper (website)
☐ Power company website
☐ City government website
☐ Word of mouth (community conversation)
☐ Legislator's newsletter
☐ Statements from elected officials
☐ Pamphlets in the mail
☐ Internet blog / chat
☐ Service agency / non-profit
☐ Other

*** 2.6: Who provided the most leadership during this crisis?**

Please choose *only one* of the following:

☐ Mayor
☐ Legislators
☐ Local government agencies
☐ State government agencies
☐ Federal government agencies
☐ Power company
☐ Other businesses
☐ Friends & Neighbors
☐ Citizen Groups
☐ University / schools / researchers
☐ Service agency / non-profit
☐ Media
☐ Other
☐ Don't know

2.8: Please indicate whether you agree or disagree with the following statements.
The temporary loss of hydroelectric power and associated increase in electricity price had an important impact on...
(1 = strongly disagree 3 = unsure 5 = strongly agree)

Please choose the appropriate response for each item:

...me and other members of my household/business.	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
...the people living in Juneau	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
...the businesses in Juneau	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
...the economy of Juneau	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2.9: Please indicate whether you agree or disagree with the following statements.
I was willing to exercise restraint in my use of electricity during the energy crisis because...
(1 = strongly disagree 3 = unsure 5 = strongly agree)

Please choose the appropriate response for each item:

...I felt personally concerned about the electricity shortage	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
...there may have been consequences for others	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
...it was not difficult for me to reduce my electricity use	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2.10: Please indicate whether you agree or disagree with the following statements.
(1 = strongly disagree 3 = unsure 5 = strongly agree)

Please choose the appropriate response for each item:

Before the crisis, I was already using as little electricity as possible.	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Before the crisis, I conserved electricity because I was concerned about the environment.	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Before the crisis, I conserved electricity because I was concerned about my electricity bills.	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

What you did during the 2008 energy crisis

This sections asks questions about your actions during the 45-day period from April 16 to June 1, 2008 when the connection to hydroelectric power was down.

*** 3.1: Which of the following actions did you take to reduce electricity use during the period when the power lines were being repaired?**

Please choose *all* that apply:

- ☐ I took no action
- ☐ Used electrical devices less often
- ☐ Replaced normal light bulbs with compact fluorescent bulbs
- ☐ Installed water heater blanket(s)
- ☐ Installed insulation in attic, walls, or floor
- ☐ Installed low-flow shower head(s)
- ☐ Turned my thermostat down
- ☐ Only heated rooms which were in use
- ☐ Turned my water heater down
- ☐ Took shorter showers
- ☐ Took fewer showers
- ☐ Switched to an alternative energy source for space heating
- ☐ Switched to an alternative energy source for water heating
- ☐ Had fewer lights on than I normally would
- ☐ Reduced the number of bulbs in light fixtures
- ☐ Reduced the light output of bulbs in fixtures (e.g., 60 Watt vs. 100 Watt)
- ☐ Turned off lights more frequently
- ☐ Turned off appliances (television, computers, etc.) when not in use
- ☐ Unplugged appliances not in use
- ☐ Hung clothes to dry
- ☐ Used power-saving settings on appliances (e.g., dishwasher)
- ☐ Washed full loads of laundry and/or washing in cold water
- ☐ Sealed and/or weather-stripped windows and/or doors
- ☐ Turned off my hot tub and/or sauna
- ☐ Other

3.6: For which of the following reasons did you take these actions to save electricity?

Please choose *all* that apply:

☐ To save money

☐ It's what my friends were doing

☐ To reduce environmental impact

☐ To help others / the community

☐ Don't know / no particular reason

☐ Other reasons

[Only answer this question if you answered 'Replaced normal light bulbs with compact fluorescent bulbs' to question '3.1 ']

3.1.1: Please tell us more about your replacement of normal light bulbs with compact fluorescent. Approximately how many compact fluorescent bulbs did you buy and install?

Please write your answer here:

[Only answer this question if you answered 'Installed water heater blanket(s)' to question '3.1 ']

3.1.2: Please tell us more about your installation of water heater blankets. Approximately how many water heater blankets did you install?

Please write your answer here:

[Only answer this question if you answered 'Turned my thermostat down' to question '3.1 ']

3.1.4: Please tell us more about your thermostat settings.

Please write your answer(s) here:

Approximately how many degrees Fahrenheit, on average, did you turn your thermostat down during the crisis?:	
What average temperature setting did you maintain after turning the thermostat down (degrees Fahrenheit)?:	

[Only answer this question if you answered 'Took shorter showers' to question '3.1 ']

*** 3.1.5: Please tell us more about your change in shower time. Approximately how many minutes shorter were your showers?**

Please write your answer here:

[Only answer this question if you answered 'Took fewer showers' to question '3.1 ']

3.1.6: Please tell us more about your shower frequency. Approximately how many fewer showers per week did you take?

Please write your answer here:

[Only answer this question if you answered 'Switched to an alternative energy source for space heating' to question '3.1 ' *and* if you have NOT answered 'Electricity and other sources' to question '1.5 ']

3.1.7: Please tell us more about your change in space heating. To what source did you switch your space heating?

Please write your answer here:

[Only answer this question if you answered 'Switched to an alternative energy source for space heating' to question '3.1 ' *and* if you answered 'Electricity and other sources' to question '1.5 ']

3.1.8: Please tell us more about your change in space heating. You indicated that you use more than one source of energy for space heating.

Please write your answer(s) here:

Approximately what percentage of your space heating came from each source BEFORE the energy crisis (please write source, percentage; source, percentage):	
Approximately what percentage of your space heating came from each source DURING the energy crisis (please write source, percentage; source, percentage):	

[Only answer this question if you answered 'Switched to an alternative energy source for water heating' to question '3.1 ' *and* if you have NOT answered 'Electricity and other sources' to question '1.6 ']

3.1.9: Please tell us more about your change in water heating. To what source did you switch your water heating?

Please write your answer here:

[Only answer this question if you answered 'Switched to an alternative energy source for water heating' to question '3.1 ' *and* if you answered 'Electricity and other sources' to question '1.6 ']

3.1.10: Please tell us more about your change in water heating. You indicated that you use more than one source of energy for water heating.

Please write your answer(s) here:

Approximately what percentage of your water heating came from each source BEFORE the energy crisis (please write source, percentage; source, percentage):	
Approximately what percentage of your water heating came from each source DURING the energy crisis (please write source, percentage; source, percentage):	

[Only answer this question if you answered 'Had fewer lights on than I normally would' to question '3.1 ']

3.1.11: Please tell us more about the number of lights you generally had on. Approximately how many fewer lights did you have on than you normally would?

Please write your answer here:

[Only answer this question if you answered 'Unplugged appliances not in use' to question '3.1 ']

3.1.12: Please tell us more about the appliances you unplugged. Which appliances did you unplug when not in use?

Please write your answer here:

[Only answer this question if you answered 'Used power-saving settings on appliances (e.g., dishwasher)' to question '3.1 ']

3.1.13: Please tell us more about the power-saving settings on your appliances.

Please write your answer(s) here:

For which appliances did you use the power-saving setting?:	
In general, did you use these settings before the energy crisis?:	

*** 3.2: When did you FIRST take an action in response to the HIGHER electricity prices DURING the crisis, and what was this action? Note, the avalanches broke Juneau's connection to hydroelectric power on April 16, 2008 (16,04,08).**

Please write your answer(s) here:

Date of first action (DD,MM,YY):	☐
Description of the action:	☐

*** 3.4: By how much do you think your energy use decreased as a result of the actions you took?**

Please choose *only one* of the following:

☐ Less than 10%
☐ 10%
☐ 20%
☐ 30%
☐ 40%
☐ More than 40%
☐ Don't know

3.5:

Please provide your thoughts on the following three questions.

Please write your answer(s) here:

Did anything prevent you from taking other energy-saving actions during the energy crisis?:	☐
What is the next thing you would have done if the crisis had been "bigger" in some way? (e.g., longer in duration, higher electricity price):	☐
If the crisis were to happen again, what would you do differently?:	☐

What you did after the 2008 crisis ended

This section asks questions about your actions several months after the connection to hydroelectric power was repaired (on June 1, 2008), when you had settled into normal routines and patterns of energy use.

*** 4.1: Which of the following actions did you STOP doing when the crisis was over? (Mark actions that were, in your judgment, more stopped than continued)**

Please choose *all* that apply:

☐ I have not stopped doing any energy-saving actions since the energy crisis ended
☐ I stopped using electrical devices less often (i.e., returned to normal use)
☐ I stopped replacing normal bulbs with compact fluorescent
☐ I stopped using water heater blanket(s)
☐ I stopped installing additional insulation in attic, walls, or floor
☐ I returned my thermostat back to what it was before the energy crisis
☐ I stopped only heating rooms which are in use (i.e., returned to heating the whole building)
☐ I returned my water heater thermostat back to what it was before the energy crisis
☐ I stopped taking shorter showers than before the energy crisis
☐ I stopped taking fewer showers than before the energy crisis
☐ I stopped using an alternative energy source for space heating
☐ I stopped using an alternative energy source for water heating
☐ I stopped having fewer lights on than I normally would
☐ I returned the number of bulbs in light fixtures back to normal
☐ I stopped keeping bulbs with lower light output in fixtures (e.g., 60 Watt vs. 100 Watt)
☐ I stopped turning lights off more frequently
☐ I stopped turning off appliances (television, computers, etc.) when not in use
☐ I stopped unplugging appliances when not in use
☐ I stopped hanging clothes to dry
☐ I stopped using the power-saving setting on appliances (e.g., dishwasher)
☐ I stopped washing full loads of laundry and/or washing with cold water
☐ I stopped sealing and/or weatherstripping windows and/or doors
☐ I turned my hot tub and/or sauna back on
☐ I have stopped doing other energy-saving actions

4.7: Which of the following <u>new</u> actions have you taken since the energy crisis ended?

<u>Please choose *all* that apply:</u>

☐ I have taken no new actions
☐ Replaced windows with more insulating ones
☐ Replaced appliances with more energy efficient ones
☐ Installed additional insulation
☐ Switched to an alternative source for space heating
☐ Switched to an alternative source for water heating
☐ I took other new actions

4.8: For which of the following reasons are you continuing to take actions to save electricity?

<u>Please choose *all* that apply:</u>

☐ I am not continuing to take actions to save electricity
☐ To save money
☐ It's what my friends are doing
☐ To reduce environmental impact
☐ To help others / the community
☐ Don't know / no particular reason
☐ Other reason

[Only answer this question if you answered 'Replaced normal light bulbs with compact fluorescent bulbs' to question '3.1 ' *and* if you have NOT answered 'I stopped replacing normal bulbs with compact fluorescent' to question '4.1 ']

4.1.1: Please tell us more about how you replace light bulbs.

<u>Please write your answer(s) here:</u>

Do you replace light bulbs before they burn out?:	
Approximately how many light bulbs do you replace per month?:	
Approximately what percentage of bulbs in your house/business are now fluorescent?:	

[Only answer this question if you answered 'Turned my thermostat down' to question '3.1 ' *and* if you have NOT answered 'I returned my thermostat back to what it was before the energy crisis' to question '4.1 ']

4.1.3: Please tell us more about your thermostat settings.

Please write your answer(s) here:

Approximately how many degrees Fahrenheit lower, on average, was your thermostat set after the energy crisis ended than before it started?:	
At what average temperature did you keep your thermostat set after the energy crisis ended (degrees Fahrenheit)?:	

[Only answer this question if you answered 'Took shorter showers' to question '3.1 ' *and* if you have NOT answered 'I stopped taking shorter showers than before the energy crisis' to question '4.1 ']

4.1.4: Please tell us more about your shower time.

Please write your answer(s) here:

Approximately how many minutes shorter were your showers after the energy crisis ended than they were before it started?:	
Approximately how many minutes long was your average shower after the energy crisis ended?:	

[Only answer this question if you answered 'Took fewer showers' to question '3.1 ' *and* if you have NOT answered 'I stopped taking fewer showers than before the energy crisis' to question '4.1 ']

4.1.5: Please tell us more about your shower frequency.

Please write your answer(s) here:

Approximately how many fewer showers per week did you take after the energy crisis ended than you did before it started?:	
Approximately how many showers per week did you take after the energy crisis ended?:	

[Only answer this question if you answered 'Switched to an alternative energy source for space heating' to question '3.1 ' *and* if you have NOT answered 'Electricity and other sources' to question '1.5 ' *and* if you have NOT answered 'I stopped using an alternative energy source for space heating' to question '4.1 ']

4.1.6: Please tell us more about your space heating. What energy source were you using after the energy crisis ended for space heating?

Please write your answer here:

[Only answer this question if you answered 'Switched to an alternative energy source for space heating' to question '3.1 ' *and* if you answered 'Electricity and other sources' to question '1.5 ' *and* if you have NOT answered 'I stopped using an alternative energy source for space heating' to question '4.1 ']

4.1.7: Please tell us more about your space heating. You indicated that you use more than one source of energy for space heating.

Please write your answer(s) here:

Approximately what percentage of your space heating came from each source after the energy crisis ended? (please write source, percentage; source, percentage):	

[Only answer this question if you answered 'Switched to an alternative energy source for water heating' to question '3.1 ' *and* if you have NOT answered 'Electricity and other sources' to question '1.6 ' *and* if you have NOT answered 'I stopped using an alternative energy source for water heating' to question '4.1 ']

4.1.8: Please tell us more about your water heating. What energy source were you using after the energy crisis ended for water heating?

Please write your answer here:

[Only answer this question if you answered 'Switched to an alternative energy source for water heating' to question '3.1 ' *and* if you answered 'Electricity and other sources' to question '1.6 ' *and* if you have NOT answered 'I stopped using an alternative energy source for water heating' to question '4.1 ']

4.1.9: Please tell us more about your water heating. You indicated that you use more than one source of energy for water heating.

Please write your answer(s) here:

Approximately what percentage of your water heating came from each source after the energy crisis ended? (please write source, percentage; source, percentage):	

[Only answer this question if you answered 'Had fewer lights on than I normally would' to question '3.1 ' *and* if you have NOT answered 'I stopped having fewer lights on than I normally would' to question '4.1 ']

4.1.10: Please tell us more about the number of lights you generally have on. Approximately what percent fewer lights do you keep on than you did before the energy crisis?

Please write your answer here:

[Only answer this question if you answered 'Unplugged appliances not in use' to question '3.1 ' *and* if you have NOT answered 'I stopped unplugging appliances when not in use' to question '4.1 ']

4.1.11: Please tell us more about the appliances you unplug when not in use. Which appliances did you unplug when not in use after the energy crisis ended?

Please write your answer here:

[Only answer this question if you answered 'Used power-saving settings on appliances (e.g., dishwasher)' to question '3.1 ' *and* if you have NOT answered 'I stopped using the power-saving setting on appliances (e.g., dishwasher)' to question '4.1 ']

4.1.12: Please tell us more about the power-saving settings on your appliances.

Please write your answer(s) here:

For which appliances did you use the power-saving setting after the energy crisis ended?:	
In general, did you use these settings before the energy crisis?:	

[Only answer this question if you answered 'Replaced appliances with more energy efficient ones' to question '4.7 ']

4.1.13: Please tell us more about your appliance purchases.

Please write your answer(s) here:

Which appliances have you replaced with more efficient ones?:	
Did you plan to replace these appliances before the energy crisis occurred?:	
Would you have replaced these appliances with more efficient ones even if the energy crisis had not occurred?:	

*** 4.2: When did you FIRST take an action in response to the LOWER electricity prices AFTER the crisis had passed and what was this action? Note, the connection to hydroelectric power was restored on June 1, 2008 (01,06,08).**

Please write your answer(s) here:

Date of first action (DD,MM,YY):	
Description of the action:	

*** 4.4: By how much did your energy use AFTER the crisis differ from what it was BEFORE the crisis (approximately)?**

Please choose *only one* of the following:

☐ 40% more
☐ 30% more
☐ 20% more
☐ 10% more
☐ About the same
☐ 10% less
☐ 20% less
☐ 30% less
☐ 40% less
☐ Don't know

*** 4.5: By how much did your energy use AFTER the crisis differ from what it was DURING the crisis (approximately)?**

Please choose *only one* of the following:

☐ 40% more
☐ 30% more
☐ 20% more
☐ 10% more
☐ About the same
☐ 10% less
☐ 20% less
☐ 30% less
☐ 40% less
☐ Don't know

Relativity

5.5: Please indicate whether you agree or disagree with the following statements.
(1 = strongly disagree 3 = unsure 5 = strongly agree)

Please choose the appropriate response for each item:

I now use less electricity than before the crisis	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
The shortage did not change my use of electricity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
My attitude to using electricity changed since the crisis	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I now use more electricity than before the crisis	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

*** 5.1: Do you think you reduced energy consumption more than your neighbors during the period when the power lines were being repaired?**

Please choose *only one* of the following:

☐ A lot more
☐ More
☐ About the same
☐ Less
☐ A lot less
☐ Don't know

*** 5.2: Who should have done the most to reduce energy use during the energy crisis?**

Please choose *only one* of the following:

☐ Homeowners
☐ Apartment renters
☐ Businesses
☐ Government
☐ Everyone equally
☐ Other
☐ Don't know

*** 5.3: Did anyone not do enough to reduce energy use?**

Please choose *all* that apply:

☐ Homeowners
☐ Apartment renters
☐ Businesses
☐ Government
☐ No one did enough
☐ Everyone did enough
☐ Don't know

*** 5.4: Would you have benefitted if others had reduced energy use more?**

Please choose *only one* of the following:

☐ Yes
☐ No
☐ Don't know

Sociodemographic information

*** 6.1: To help us evaluate whether we get responses that represent all of Juneau, please provide the cross streets for the intersection nearest to your home / business.**

Please write your answer(s) here:

First street name : ______

Second street name: ______

6.2: Your gender

Please choose *only one* of the following:

- ☐ Female
- ☐ Male

6.3: Your date of birth

Please enter a date:

/ /

6.4: Marital status

Please choose *only one* of the following:

- ☐ Married
- ☐ Never married
- ☐ Widowed
- ☐ Divorced

6.5: Your highest level of education

Please choose *only one* of the following:

- ☐ 5th grade
- ☐ 8th grade
- ☐ High school diploma
- ☐ 1 year of college
- ☐ Associate degree
- ☐ Bachelor's degree
- ☐ Master's degree
- ☐ Professional degree
- ☐ Doctorate degree

[Only answer this question if you answered 'Household' to question '1.1 ']

6.6: Total household income

Please choose *only one* of the following:

☐ $0 to $25,000
☐ $25,001 to $50,000
☐ $50,001 to $75,000
☐ $75,001 to $100,000
☐ $100,001 or more

6.7: Did you participate in any financial assistance programs specifically for the energy crisis?

Please write your answer(s) here:

Yes / No:	
If so, which program(s):	

[Only answer this question if you answered 'Small business (fewer than 15 employees)' or 'Large business (more than 15 employees)' or 'Seasonal business (open fewer than 8 months per year)' to question '1.1 ']

6.8: Approximate building area occupied by your business (square feet)

Please write your answer here:

[Only answer this question if you answered 'Government, state' or 'Government, municipal' or 'Government, federal' to question '1.1 ']

6.9: Approximate building area occupied by your government agency (square feet)

Please write your answer here:

[Only answer this question if you answered 'Household' to question '1.1 ']

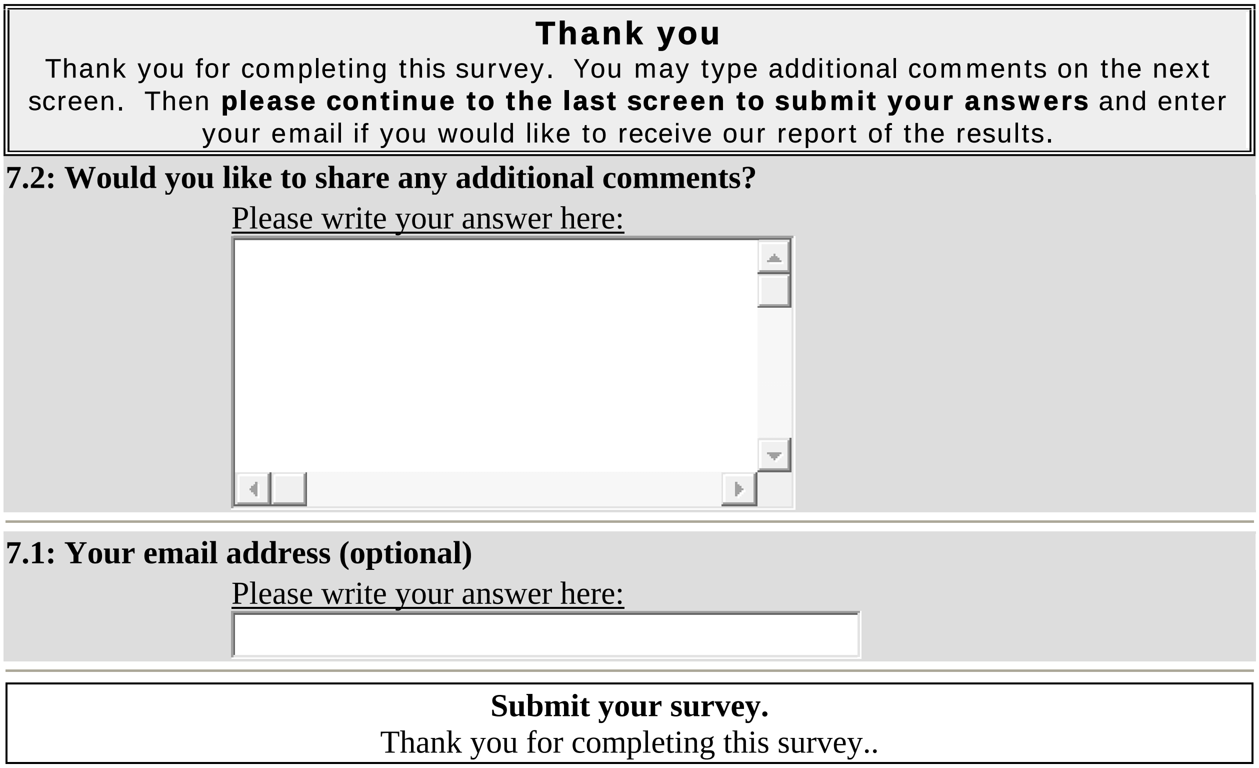
6.10: Approximate total floor area of your home (square feet)

Please write your answer here:

6.11: Do you own or rent this building space?

Please choose *only one* of the following:

☐ Own it
☐ Rent/Lease it
☐ Own some and rent some



Thank you

Thank you for completing this survey. You may type additional comments on the next screen. Then **please continue to the last screen to submit your answers** and enter your email if you would like to receive our report of the results.

7.2: Would you like to share any additional comments?

Please write your answer here:

7.1: Your email address (optional)

Please write your answer here:

Submit your survey.

Thank you for completing this survey..

Appendix B: Maps and Photographs

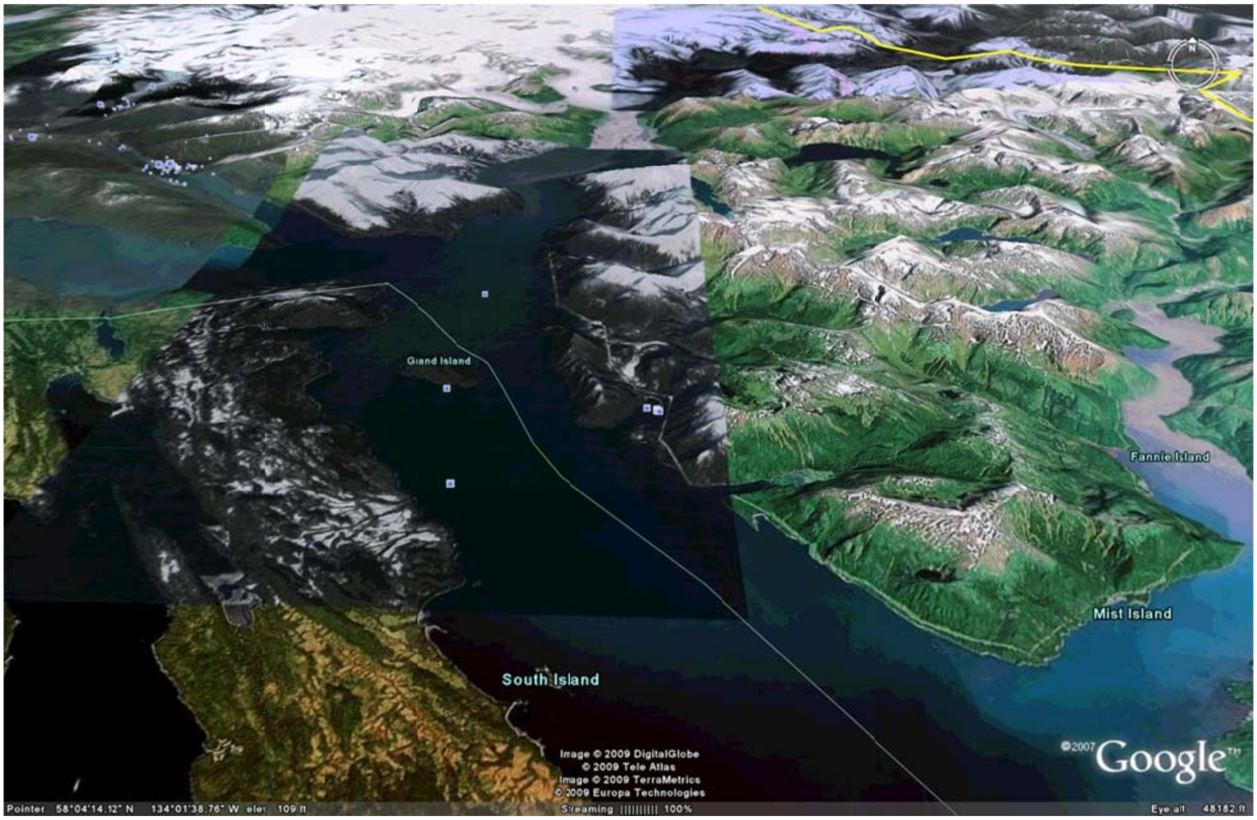


Figure 58: Map showing Juneau (a), Long Lake and the Snettisham Power Station, the route of the 44 miles of 138-kV transmission line connecting Juneau and Snettisham, and the location of avalanche damage to the transmission line (Source: Google Earth).

Figure 59: Photograph showing the crown face of the April 16, 2008 avalanche and location of Snettisham transmission line damage that it caused (KTOO, 2009).

Figure 60: Boeing Chinook 234 helicopter lifting replacement asymmetrical tower.

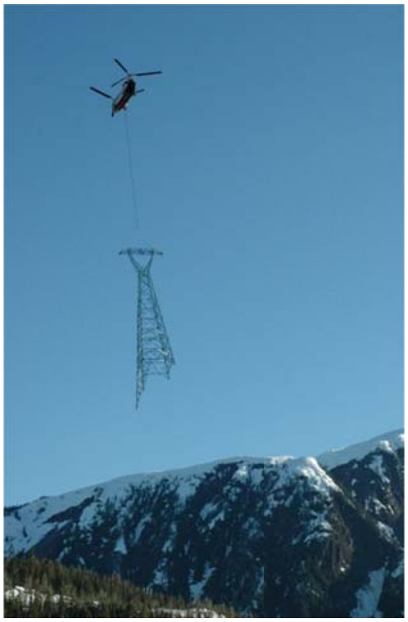


Figure 61: Boeing Chinook 234 helicopter lifting replacement asymmetrical tower.

Figure 62: Boeing Chinook 234 helicopter sets asymmetrical tower replacement onto intact original foundations.

Figure 63: AEL&P employees dig out a helicopter landing pad on Saturday, April 27 near one of the destroyed Snettisham transmission line towers. The snow pictured is natural accumulation, not part of the avalanches of April 16th (Michael Penn, Juneau Empire www.juneauempire.com/stories/042808/loc_273101146.shtml).

Appendix C: the transmission line reconstruction sub-plot

(Adapted from Eriksen et al., 2009 and Willis, 2008)

Immediately AEL&P had finished assessing the damage to the Snettisham transmission line caused by avalanches on April 16, 2008 (three structures destroyed and two others damaged), they began making plans for restoring service. AEL&P gathered T&D consultant POWER Engineers Inc. (Hailey, Idaho, U.S.), utility line contractor City Electric (Anchorage, Alaska), several local barge operators, Bill Glude and colleagues at Alaska Avalanche Specialists, and others to begin identifying possible solutions. The team used maintenance video of the line, photographs, and record drawings while considering everything from routing the transmission line to the upper elevation slopes above the existing line, temporarily routing the line on barges in the fjord, installing submarine cable for the damaged area, spanning the bowls where the worst slides occurred (thereby eliminating the need to replace towers in the most avalanche-prone locations), hauling in and setting up emergency restoration towers, or replacing towers and structures on the same locations for restoration options. Each option was assessed along dimensions like duration of repair, constructability, avalanche danger, meteorological conditions and material availability. Although restoring power inexpensively was a priority, timely restoration was also important because the cost of operating backup diesel generation was $1.5 million per week.

Since the slide had occurred close to the old Snettisham work yard, AEL&P had a nearby staging location for personnel, material and equipment for whichever restoration scenario was pursued. Constructing new towers in the same locations and using the same designs as the towers that had been damaged and destroyed emerged as the fastest and least-expensive solution because the technical data, materials and qualified labor were readily available and existing designs and foundations could be re-used.[55] Preliminary materials lists were ready within days of the avalanches and initial procurement of the necessary line hardware and conductor and tower materials from structure suppliers in the United States and Mexico was underway. Meanwhile, crews began clearing the staging area at Snettisham of 10 ft (3 m) of snow and inventorying materials and equipment at the Juneau yard.

The first barge of materials (tower parts, heavy equipment, fuel supply, camp supplies) departed for Snettisham on April 19, three days after the avalanches. Linemen were instructed in the use of avalanche transponder beacons and how to work in avalanche conditions since the chance of another slide had not entirely abated. The early work crews cleared and caught-off downed cable to protect still-standing structures, using a 30 caliber gun to shatter porcelain insulators in some cases due to the extreme terrain. The next step was uncovering foundations and anchor points for the towers that had been destroyed by lighting 55-gal (208-liter) barrels loaded with charcoal where the team thought anchor points were located. Two mini-excavators were also flown in to the location via helicopter to help dig out the snow, but their mobility was severely limited by the terrain. At the same time, crews at Snettisham began assembling towers, including scavenging and fabricating some of the 800-900 different tower members and hardware assemblies from parts found at the two yards.

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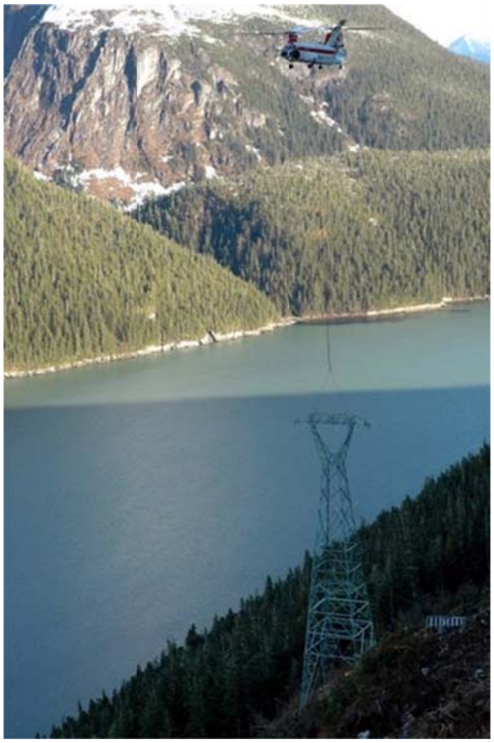
[55] The submarine cable option would have eliminated exposure to future avalanches, but suffered long lead times for manufacture and delivery of the cable as well as engineering and permitting. The buried cable option suffered from the same lead times and expensive access to dangerously steep construction areas.

The first replacement of a destroyed tower occurred on May 18 using a Bell 214 helicopter for lifting the tower into place. The next structure to be replaced, an asymmetrical tower designed to sit on two intact original foundations laid in irregular topography, was lifted into place from Snettisham with a Boeing Chinook 234 helicopter (Figure 64). This same helicopter was used on the following day to lift in the three masts of the other destroyed structure one-by-one. The remaining task of repairing the arms on the other damaged towers was done on-site and did not require special helicopter lifts.

With the towers repaired, cable stringing turned out to be a complex endeavor. The steep terrain high above the Speel Arm fjord left little room for stringing equipment and limited crews to using only smaller, compact equipment. Rope (sockline) pullers, conductor reels, reel stands and the tensioner were placed on relatively flat terrain near one of the towers, but the hardline puller had to be set on a large cargo barge on the water some 1000 ft (305 m) below the towers.

Crews started by stringing rope across a 1600-ft (488-m) span between two towers and slowly pulling in new conductor. Stringing conductor through a total of eight towers over a 6,600 ft (2 km) length ultimately also required the use of an A-Star AS350 helicopter to pull the sockline through the towers and down to the barge on the water below. A total of eight hours over two days was required to pull in the sockline and all three hardlines. Over the following few days, crews manually sagged, dead-ended and clipped the line. Finally, on the Sunday evening of June 1, 2008, AEL&P energized the rebuilt Snettisham line and the diesel generators in Juneau spun down, 45 days after the avalanches slid and a full month ahead of schedule.



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AEL&P recognized that replacing towers on existing foundations could leave the Snettisham transmission line vulnerable to future avalanches. Consequently, AEL&P commissioned an engineering study to consider subsequent steps to mitigate potential damage and interruption by future avalanches, including submarine cable, underground cable, and avalanche diversion or protection structures. The study was to evaluate the capital and operating costs of each alternative and its reliability and effectiveness, as a basis for selecting one option for implementation. The two-stage process of rapid repair to status quo with subsequent work to mitigate potential future avalanche damage was intended to minimize the cost of diesel generation during the supply disruption while also allowing adequate time for thorough consideration of the most cost-effective long-term solution.

But on Friday, Jan. 9, 2009, just seven months after electric service was restored, a winter storm warning for the city of Juneau and surrounding areas forecast up to 30 inches (76 cm) of new snow. Although avalanche-control specialists had been conducting weekly bombing runs to prevent avalanche slabs from forming, the storm grounded them for the weekend and on Monday afternoon the snow turned to rain and the slopes gave way. This time the avalanche destroyed one of the same towers that had been destroyed the previous year.

The avalanche-mitigation program put in place after the previous year's avalanche had cleared lower-elevation slopes of snow which prevented the slide from growing larger as it slid, thereby containing damage to a relatively small area with only one structure destroyed. Another result of the previous year's experience was creation of an emergency preparedness plan by AEL&P. The utility had stocked its inventory yards with replacement parts and material to enable rapid rebuilding of destroyed towers if necessary. Although determining the preferred solution was more straightforward given the recent experience with this scenario, the timing of the slide earlier in the winter season added complication due to challenges in accessing the site and fewer daylight hours available for work. Consequently, AEL&P decided to bypass the downed structure rather than rebuilding it, which also avoided the most avalanche-prone slope on this portion of the line. After making some adjustments to the towers on either side of the downed structure and splicing in the repaired line, the line was reenergized in the evening of February 1, 2009 only 19 days after the avalanche.

under
ission

By October of 2009, construction was underway on an avalanche "diverter" to protect the most vulnerable tower on the Snettisham transmission line (Figure 65). The v-shaped structure, estimated to cost $2 million, is designed to direct the force of an avalanche around to the sides of the tower (Forgey, 2009). "First we had to have an avalanche expert tell us how large an avalanche could happen here and what the forces an engineer would have to design for," said Scott Willis of AEL&P. Much of the cost for the structure was due to the location, where crews and materials had to be helicoptered up the steep mountainside in a remote location. Although the 2008 avalanche was estimated to be a 100- to 300-year event, the diversion structure was engineered for a 50-year event. "With a 100-year [event], the forces are just way too large [to protect against]," said Willis.

Appendix D: Remarkable Comments and Anecdotes

As with any survey, the anecdotes shared by respondents are informative. The following comments are representative of general themes that we found particularly interesting.

Attitudes and Perspective

- Most people were proactive and involved. Go, Juneau!
- In general, we viewed the power crises of 2008 as a good eye-opener for the community, and felt that people reacted in a positive, active and involved way. A wake-up call for all of us!
- I found it to be somewhat of a game to see how little electricity I could use during the time higher rates were being charged.
- Utilities are included in my rent, [but] I took steps to reduce my energy usage to benefit my landlord and the community.
- Seeing the entire community participate in energy conservation put us all on the same team. Having the electric company give us updates on how we were doing in conserving energy was a good motivational tool.
- The initial estimates of monthly impact were terrifying (5 times increase for 3+ months). It actually affected my business as people tried to face a budget bomb that threatened their resources. Very destabilizing for weeks.
- I think Juneau in general did a fairly good job reducing consumption and it brought our community closer. Stores turned off half of their lights and people could be seen helping others find and read things in the dark. It was darker at night while driving through neighborhoods as people turned off more lights in and outside of their homes. You also saw a lot of clothes outside on the sunny days!
- I read a lot of books durning that time and also competed with my co workers to see who could get the lowest bill.
- I'd thought our electric use was relatively low, but I found we could reduce our use by 25 percent without out too much pain.
- I thought I was conserving very well before the crisis, but there were more things I found I could do.
- Money had a lot to do with it. I conserved less this time because I would save less.
- This prompted us to have the Home energy audit done so we have a list of improvements to make so we might be better prepared in the future.
- Having state offices and stores turning off lights and conserving energy was a great motivator and made it feel like a community effort.
- AELP should have had more safeguards to prevent the avalanche from taking out the powerlines... It is unfortunate that the consumers have to bear the brunt of the cost of repairing something that might have been prevented.
- I believe AEL&P people, and the Army Corps of Engineers many years ago, did an outstanding job of risk and cost analysis. I believe they followed the tenets of that analysis.
- It was an interesting time period, in the course of about 5 days it was like we all had taken a giant leap backwards in time. You could see people lighting their homes with kerosene lamps and candles. Folks were burning their woodstoves to cook on and to keep warm. The sun would go down and the whole neighborhood would be dark, hardly an electric light on you could detect. It wasn't hard to imagine that this was what life was like in Alaska 100 or more years ago. Everyone was exchanging ideas on ways to reduce electricity usage around their homes.

- My house is all-electric. My usual wintertime bills are $250 to $300. I could not possibly afford $1250 to $1500. I turned off all my heat and my water heater to profoundly impact my bill. I could not live that way on a continuous basis.
- My electric bill has gone down considerably compared to normal bills before the crisis due to energy saving techniques still used.
- What impressed me the most was that there wasn't even a power outage at my house that I was aware of when the avalanch occurred! It never appeared to me that there was a "power" crisis--there was a "cost" crisis.
- Some vocal environmentalists applauded the way Juneauites were able to reduce their energy comsumption, as if it were proof that we normally use too much power. [But] many of us were and are living with deprivation. I try to be conservative in my use of resources anyway, but this was not a lifestyle that can be maintained indefinitely. We've been living in the dark and the wet.

Fuel Switching

- [Electric] baseboard heat is by far the largest portion of our energy usage. We were fortunate that the crisis occurred during a time of the year when it was feasible to turn down the heat and rely on a pellet stove as a primary heat source.
- It was a double whammy for those of us who use oil also [for heating] as diesel prices of $4.00+ per gallon forced conservation long before the power crisis hit.
- We grilled a LOT more.
- You could have had more questions about wood/coal use for heating and cooking.
- We intentionally have a dual heat system. The electric baseboards are the primary heat source and we installed an oil heater to participate in the AEL&P dual heat system, allowing us to buy surplus hydro electric when available.

Behavioral Changes

- [We] started to notice that family was less diligent on turning off things each night… started to slip back into the habit of leaving electric appliances on.
- My water heater has remained turned down and I do attempt to turn off all items not in use.

Appliances

- We cleaned out our second freezer and closed it down. Many Juneauites keep freezers full of fish and game that often end up just being crab bait.
- Consolidating contents of 2 freezers into one provided greatest savings. Have not gone back to using old upright freezer since.
- I did buy a new energy refrigerator that made a big difference, but I also found out I did not need most of the stuff that was plugged in.

Future Investments

- With consciousness raised about costs and impacts of diesel use, and having just completed state energy audit, we’re seriously exploring investing in major alternatives to current electric baseboard heat – either air source heat pump or gasification wood boiler.
- We participated in the AHFC energy upgrade rebate program during which we added insulation, replaced an old door, replaced the oil furnace, installed setback thermostats and did a lot of

caulking. Our electric usage is down over 50%, much of which is due to the new water heater and refrigerator we bought during the crisis.

- I plan to take several actions this year to improve our home’s energy efficiency, including more insulation, several new windows and installation of a small heat pump.
- This crisis definately tested us. Our highest bill was $179 which is amazing compared to what I heard from other folks here in town. Our governor gave us each an extra $1000 with our dividend checks which we turned around and bought insulation for the attic and new clothes washer and dryer. It also helped pay for the on-demand water heater. Without those dollars those purchases could not have been made.

Information

- [It was] very valuable having on-going graphs of electric useage in [the] paper so we could see impact of our actions.
- We all worked together to reduce our rates and the paper would print our savings in diesel fuel burned each day. This spurred us on.
- I continue to save energy and now know how to. It was a lot to learn and people just need to be told how much we are wasting by leaving everything plugged in at night and how to reduce water heater usage. We all learned from talks in town and articles in [the] paper and on radio.
- One of the most helpful things they did was the power fair where you could learn about saving money.
- The first avalanche there were many questions as to when the high billing period would begin and end. Second time clear info really helped.
- I was very confused about how much my bill would be… I was confused about the billing cycle… I conserved energy when it would not have cost me anything directly.
- In the 2008 incident… nobody really knew how AEL&P was going to recoup those costs, so people were conserving “just in case". In the 2009 incident, everyone understands how the billing process works now. While I did take some actions early on to conserve power for the common good, I held off on the really difficult sacrifices until I knew I was in the billing period where I would be paying higher prices.
- Tips to and from friends and co-workers were most important.

Survey Design

- This survey is toooo long!
- The questions in this survey didn't really allow for certain subtleties of the situation.
- Thanks for doing this.
- Nice survey. Thanks for sharing the results with us. We all learned a lot.
- Your answer options are archaic... for instance we do not have a "head of household" we share all equally and no husband/wife or "married." Please remember that the face of america is changing.
- I was surprised to see the bias with the household owner choices. I have a partner of 18 years, yet the choices were "wife, husband" or "married, never married, divorced, etc.”
- I appreciate your survey questions and interest.
- Your survey can be misleading as comparing energy use after the crisis with "before" the crisis will be inaccurate as the weather was getting warmer and home heating was unnecessary in June.
- Why didn't you ask about condos vs. houses, vs. apts--- I would think that would have been interesting.

Other Miscellaneous

- The timing of the april avalanche was critical to the amount of energy savings we as a community were able to implement: lots of daylight, beginning to warm up outside, that meant it was easier to turn off lights and turn down heat.
- You should have separated government into state and city more… the city conserved a lot, the state appeared less concerned.
- I noticed your survey focused on the period in which the avalanche repairs were being made, but people continued to conserve due to the rate adjustments – so there is [sic] really 4 periods: before, while on diesel, while on higher rates, and after.
- I had a friend who had to replace drywall, carpeting, subflooring because of mildew in an unheated room. Penny proud, pound foolish.
- Imagine the energy we could save if the entire country learned from our experience!