

# Everyday Activities and Energy Consumption: How Families Understand the Relationship

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## ABSTRACT

Energy consumption is a growing concern and it is important to inform families of their consumption and how they might reduce it. We conducted an interview study that focuses on the existing routines of families and how they currently understand their power and gas consumption based on standard utility bills. We also investigated how this understanding ties to their everyday activities as might be recorded on their calendars. This allowed us to assess calendars as an artifact for energy consumption awareness. Our results show that many people relate changes in energy consumption to high-level effects such as weather and temperature and not necessarily their own everyday activities. Events on calendars may aid this understanding but people do not currently record enough information on their calendars to make a strong tie. This suggests that if calendars are to be used as artifacts to aid energy consumption understanding, digital calendars need to provide support to include more energy-related information, including both activities and patterns of consumption.

## Author Keywords

Energy consumption; calendars; families

## ACM Classification Keywords

H5.3 [Information interfaces and presentation]: Group and Organization Interfaces – *Computer Supported Cooperative Work*;

## INTRODUCTION

A key issue in energy and water conservation involves our homes and the ways we use them [2]. Humans are beginning to understand the effects of consumption, including issues such as climate change, air pollution, and a lack of renewable natural resources. As a result, many researchers are investigating new ways to provide families with knowledge of their consumption in such a way that they might change their everyday consumption practices. The standard way to provide this information is through the canonical utility bill [7,14]. These summaries are typically

only aggregates, providing at best some related seasonal temperature information or comparisons to similar times (e.g., the same period last year), and people are very poor at understanding these bills [29]. However, a critical issue in understanding depends on how well reporting is tied to patterns of everyday activity. Residential energy reporting cannot be simply presented in aggregate; the use of certain devices reduces demands for others, and use patterns rather than singular appliance profiles need to be considered to enhance understanding [2].

Given this, we were interested in understanding how families tie their everyday routines to their understanding of energy consumption. Specifically, we wanted to investigate family routines and activities surrounding utility bills and how they might use other existing domestic artifacts to aid in this understanding. Research has shown that one of the most common tools for documenting family activities is a calendar [23,27]. As such, we were interested to see if the activities that people typically record on their calendars might aid in their understanding of energy consumption.

To better understand this, we conducted interviews with sixteen people where we focused on their understanding of their consumption based on their everyday activities, utility bills, and calendars. Our results showed that people think about their consumption at a high level, not often recognizing that small changes in routine may affect consumption. Knowledge of consumption is not typically shared amongst household members unless surprising situations occur. We also found that currently calendars are not able to play a large role in understanding consumption given their lack of consumption-specific content. Yet their role as an information-sharing artifact in the home suggests that with additional information about everyday activities placed in them (either automatically or by people), calendars may provide additional support for people to better understand their energy consumption.

## RELATED WORK

There is a large emphasis in the related literature on the design of eco-feedback technologies to provide household members with an awareness of their consumption [8,26]. This is natural given that psychology research shows that feedback is a central aspect of motivating resource conservation in the home [1]. We also know that people have different understandings and motivations for

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conserving resources and design solutions must be tailored accordingly [12]. Given this, there have been a large number of feedback technologies and visualizations created for home inhabitants. These include commercial web sites like Google PowerMeter™ and Microsoft Hohm™. There also exist in-home displays such as Blueline's Power Cost Monitor™, which shows total electricity consumption in terms of kWh hours and money spent, or Kill A Watt™, which can be attached to particular appliances or outlets to provide numerical electrical and financial expenditures. While these help by showing power usage, the information is not tied to a person's broader routine and activities that might aid in understanding consumption.

Research prototypes have similarly attempted to provide household members with an awareness of their consumption. For example, the Power-Aware Cord is an ambient information display that shows electricity passing through a working power strip [11]. Some designs even couple awareness with remote control over home appliances. For example, Weiss et al. developed a web-based application for monitoring home energy use that allows residents to monitor consumption on a smart phone and turn individual appliances on or off [35]. The challenge with all of these designs, however, is that the awareness information being presented is again not tied to a person's broader everyday routines and activities.

Studies show people generally have incomplete and inaccurate models of energy consumption [34]. Kempton and Layne studied how people read and processed their utility bills in 1994 [14]. They suggest that because bills are typically processed as part of a batch of mail/bills, people are more concerned with a dollar amount than energy conservation. They also found that people do not typically compare bills or investigate their amounts unless they see an unusually high bill. Seventy percent of respondents reported discussing electricity bills with others, including neighbors or friends (they do not comment on sharing within a household though; this is our focus). Nearly everyone felt that the weather had a very important effect on their consumption. People also typically overestimated the energy effects of social events like Christmas lights or baking. Our study builds on this to explore whether or not this understanding has changed over the past 18 years.

More recent studies of households reveal several things. In 2009, Chetty, Tran, and Grinter [5] studied energy management in the home and found that some people do not see their household utility bills and, as a result, are less motivated to reduce consumption. They also found that people are willing to make minor changes to their home to reduce consumption, such as switching to energy efficient light bulbs or installing programmable thermostats, yet motivations for such changes are first and foremost related to comfort and cost. This study and others also showed that people find the units of information presented in energy bills to be confusing, e.g., kilowatts [5,33]. We also know

that people have limited understanding of what uses the most energy in their homes [5,28]. In a study of computer power saving features, Chetty et al. [4] found that people generally did not utilize the power saving features on their computers because of ease of use and accessibility issues. Moreover, most people did not understand how much energy they could save by using such features. Desjardins and Wakkary [6] looked at how children represent sustainability in the home where they found that children have a nuanced and diverse understanding of sustainability. Our study builds on this to show that children do not get told about energy consumption information by their parents despite them understanding sustainable practices.

To foreshadow, our study of households and their utility bills is similar in scope and intent to these previous studies, though we dive more deeply into particular aspects with a focus on everyday activities and family calendars. As such, it is important to understand how calendars are used by families and what information they typically record.

To this end, studies have shown that family calendars are critical domestic artifacts for providing family members' with an awareness of family activities [20,22]. By recording activities on one or more calendars, and routinely checking these calendars, family members learn about the household's activities and can use this knowledge for coordination [20,22]. Along a similar thread, studies of workplace calendars have also shown that the routine and repeated way that people check their calendars is actually critical for reflecting on past activities and remembering upcoming ones [16,17,24]. In both the workplace and at home, calendars have also been found to be shared artifacts that are useful for sharing and informing multiple people about upcoming activities [16,17,20,22,23,27]. When it comes to events recorded on family calendars, families typically include sports events, school activities, work events, social outings, holidays, and birthdays [20]. Some of these events could certainly affect consumption. Together, these studies suggest that calendars may be important artifacts for understanding and even sharing energy consumption information. We explore this idea.

## **STUDY METHODOLOGY**

We conducted semi-structured interviews to understand people's existing practices and understanding around the viewing and sharing of their power and natural gas bills.

### **Participants and Contextual Setting**

We recruited participants through snowball sampling and ads on Facebook, Twitter, and Craigslist. We self-selected sixteen participants (9 female) from twelve households where our goal was to get participants with a variety of backgrounds. Table 1 shows participant demographics including gender, age, type of household composition, type of home, and the participant's role in paying the utility bills or not. All participants resided within Vancouver, British Columbia, Canada, or a neighboring city. This area sees moderate fluctuations of temperature throughout the year

	Sex	Age	Household Type	Home Type	Role
P1	M	61-70	Couple	House	Pays Bills
P2	F	51-60	Couple	House	Doesn't Pay
P3	F	31-40	Parents + Kids	Townhouse	Pays Bills
P4	F	20-30	Couple	Apartment	Doesn't Pay
P5	M	51-60	Parents + Kids	House	Doesn't Pay
P6	F	51-60	Parents + Kids	House	Pays Bills
P7	F	20-30	Roommates	Apartment	Pays Bills
P8	F	20-30	Adult Kids/Parents	House	Doesn't Pay
P9	M	20-30	Roommates	Townhouse	Pays Bills
P10	M	41-50	Couple	House	Pays Bills
P11	M	41-50	Couple	House	Doesn't Pay
P12	F	31-40	Couple	House	Doesn't Pay
P13	F	31-40	Roommates	Townhouse	Pays Bills
P14	M	41-50	Roommates	House	Doesn't Pay
P15	F	41-50	Parents + Kids	House	Doesn't Pay
P16	M	41-50	Parents + Kids	House	Pays Bills

**Table 1: Participant demographics.**

typically varying in a range of 32 to 95 F (0 to 35 C). Electricity is hydro-based and natural gas is used for home and water heating. Stoves can be either electric or gas-based. Power bills are sent to customers once every three months and gas bills are sent monthly. In some months, the utility company estimates consumption.

#### Interview Method

We conducted semi-structured interviews with each participant individually. Interviews lasted between 30 and 60 minutes and occurred in the participant's home or the researcher's office. Interviews contained four stages where we iteratively learned about the participants' understanding of their consumption where they progressively had more detailed information about their activities to rationalize.

1. **Background.** We first asked participants to describe the typical routines of their household along with descriptions of their home, their heating and gas fixtures, appliances, electronics, etc. We wanted to get an understanding of what might consume the most power and gas in their home.

2. **Energy Usage Reflection.** We next asked participants to describe which month of the year they thought consumed the most power and natural gas and also which consumed the least over the past year. At this point, answers were based on only their perceptions and existing knowledge; they were not allowed to look at their utility bills. We also asked them to describe their rationale. Our goal was to see at what level they thought about their consumption when presented with a situation similar to the frequency of receipt for their energy bills. That is, when receiving bills (and thinking about energy consumption) on a monthly basis, how did they think about and understand their consumption.

3. **Utility Bill Analysis.** We asked participants to look at their power and gas bills over the past year and assess their previous predictions with the data. We were interested in understanding how they understood their bills and what information on the bills they used to deduce the consumption level. We also asked about the household's routines for sharing information on the bills.

4. **Calendar Activities.** We asked participants to show us the primary calendar that they used to keep track of their own activities and events. We discussed the events on it with them and whether or not they felt the calendar events contributed to their understanding of their utility consumption. Our goal was to understand how their knowledge of their everyday activities may or may not allow them to better understand their energy consumption.

#### Data Collection and Analysis

We kept handwritten or typed notes and audio-recorded all interviews. All interviews were transcribed and we inductively analyzed the transcriptions using open, axial and selecting coding [30]. The goal of our analysis was to understand each household's practices around the viewing, understanding, and sharing of their utility bills. We were less concerned about whether their understanding or rationalization about consumption was accurate. Next, our results step through the various stages of our study and the general themes we found in our participants' responses.

#### UNAIDED EXPLANATIONS OF CONSUMPTION

We first asked participants to tell us which months during the past year they thought their household had consumed the most power and gas and also which months consumed the least (without looking at their utility bills). Responses varied, but what was most interesting was the participants' rationale for their choice, described next.

#### Seasonal Weather and Lighting

Nearly all participants explained high or low consumption periods as being a result of large seasonal effects such as temperature, weather, and the amount of resulting daylight. For example, many participants felt they consumed more natural gas to heat their home in the winter and less in the summer because of the temperature outside.

*"I would think in the winter months, mainly December, would be the most gas consumption. July would be the lowest consumption, because it would be much hotter outside, the weather would be hot. Although you'd use the air conditioner more." – P2*

In terms of power, several participants described how various seasons affected the amount of natural light, in terms of weather as well as the length of the day. They felt that in months where there was more sunny weather or longer days, they used less power.

#### Seasonal Activities

Beyond weather and lighting, participants also described other seasonal effects on their consumption and these related to the activities they did in various seasons.

**Travel.** Seven people described fluctuations to their energy consumption as a result of either traveling themselves, or having people travel and stay with them. This typically occurred only at certain times in the year, such as the summer or Christmas season. With more people in the home as a result of guests, participants described an increased amount of hot water usage, additional lighting usage, and increased electronic usage. Similarly, they felt that when they themselves were traveling, their consumption went down.

*“December [would be the highest for power]... Could probably have more company over in that month...” – P2*

*“Well we used to travel. We used to travel like around July. So we used be able to travel before [our son] came along. We used to be able to take a couple of weeks off...But uh, yeah and then you know, we don’t use any usage in that month. Hardly because we’re not home.” – P5*

**Holidays.** Five participants described the effects of a holiday season (e.g., Christmas) on their consumption. At this time, participants typically said they felt they consumed more power than other months in the year. This was beyond simply having additional people in the home and reflected additional lighting, decorations using power, etc.

*“The only time I’d think there’d be more power would be in December because of Christmas lights.” – P1*

**Cooking.** Four participants said that the amount they cooked varied throughout the year, which could affect power consumption or natural gas, depending on the type of cooking appliance used. Some described the summer months as being ones where they would cook less because it would heat up the house. Therefore, they thought they used less energy in summer months.

*“We also BBQ in the summer a lot because it gets really hot in our place and we like BBQs. So we think it tastes better so we tend to BBQ as much as possible.” – P4*

Others described the winter months as having increased cooking in the home and, thus, higher consumption.

*“Uhm, winter time, aside from the cold. Um, maybe wanting to eat more warm food and we use more, I dunno, as opposed to the Summer time...” – P5*

Some described increased cooking because of holidays, which ties together the current and previous categories.

**Hot Water.** Four participants felt they used different amounts of hot water during the year. This related to their consumption of natural gas for heating the water. For example, some felt they used more hot water in the summer because they would take more showers to clean themselves.

*“Well when it’s too hot then you’ll start doing other things that factor into it. Like you’ll you know maybe you end up taking two showers a day because you’re sweaty, you know.” – P11*

Interestingly, and in complete contrast, others felt they used more hot water in the winter because they wanted to “warm up” during showers.

**Electronics.** Five participants described varying usage of electronics during the year. For some, work on computers occurred more at particular times during the year relating to busy work months or periods when school was in session.

*“June maybe [is the lowest month for power]... we’re probably not using the computers as much... school’s winding down so there’s not as many projects to do and work’s probably not as busy.” – P3*

*“I’m wondering if maybe we’d use more energy in [busy work months] because you’re using the computer more and the printer.” – P2*

Another participant described the winter as being a time when you wanted to stay inside more, given the cooler temperature. This resulted in increased television usage.

*“Because we’re inside the most and it’s colder so the heats always on. I don’t really feel like going outside so yeah watch TV or something.” – P9*

**Laundry.** Three participants described changes to their consumption based on their laundry habits. In the summer months, one participant would reduce the usage of a dryer in favor of drying clothes outside.

*“The only other thing I can only think of is in summer month it’s really hot so we don’t use a dryer.” – P14*

Another participant felt she did more laundry when returning from a holiday trip.

*“Usually because I’m returning from an annual vacation trip in December, from December, like I’m gone in December so January is usually when I come back and wash, do a few loads of wash from cleaning out the entire place.” – P13*

### **Daily and Weekly Variations**

We had wondered if participants’ responses were affected by the fact that bills came monthly and therefore they were only thinking at that level of detail. This would explain their focus on larger seasonal affects for their consumption. For this reason, we also asked them if they felt there were any variations in their consumption over the past few weeks or days. Again, responses related to larger effects such as weather or time spent at home.

*“Gas consumption may have declined slightly because moderately warmer weather reduced the need for heat during the past two weeks... I put the air conditioner in the front window today, so I expect our power consumption to increase once the air conditioner is turned on, and our gas consumption to go down a little.” – P1*

*“I don’t think power consumption has changed between the weeks as I have spent about the same amount of time at home over the last three weeks.” – P13*

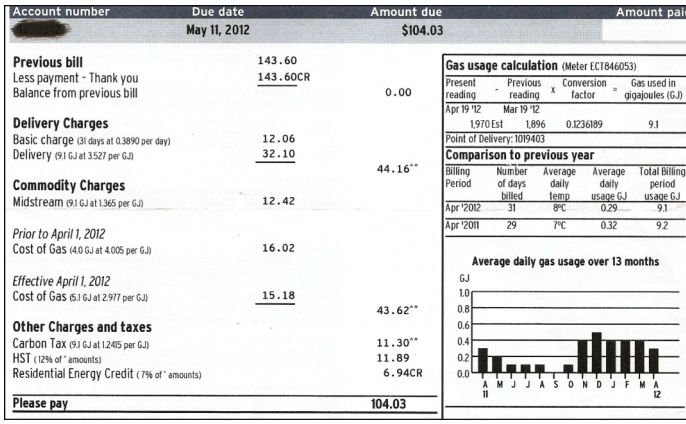


Figure 1. An example natural gas bill.

**ACTUAL UNDERSTANDING OF CONSUMPTION**

As can be seen, many people think about their consumption at a relatively high level, typically related to seasonal effects. Our analysis revealed that within seasons it can be more difficult for participants to deduce which particular month had higher or lower consumption levels. And, most participants did indeed have a difficult time figuring out which particular month in a season would have the highest or lowest consumption. For example, many would say that they consumed more natural gas for heating their home in the winter, but they did not necessarily know which month in the winter. Thus, their specific answers about their consumption were often a month or two off of the correct responses when they actually looked at their bills.

In the next stage of the study, participants actually looked at their power and gas bills to determine if they were correct in their previous explanations. To contextualize their responses, Figure 1 shows the relevant portion from a sample natural gas bill. Natural gas bills show the cost of gas per Gigajoule, the total cost for the billing period, the average temperature each month, and a bar chart showing average daily gas usage over the past thirteen months. Figure 2 shows the relevant portion from a sample power bill. Power bills provide a numerical value for Kilowatt hours of electricity used, a price for this usage, a meter reading (or label stating it was estimated), as well as a small bar graph that compares the daily average usage per billing period over the past seven months. In cases where participants had not been accurate in their previous assessments of consumption, we noticed several things.

**Bill Information**

First, reviewing the information provided in their utility bills often did not aid participants' understanding of their consumption. That is, the numerical data provided on the bill did not help them know why their consumption was not as they had expected.

*"It does not make sense at all. Because the highest consumption is in April."* – P6

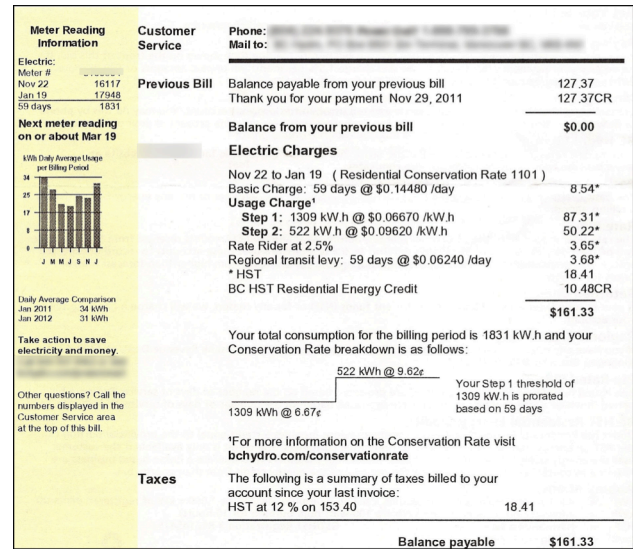


Figure 2. An example power / electricity bill.

*"I'm not sure how to read this. Because I thought this was the highest. Because I'm reading it. So this is January \$89, right?... 89 and then where's March. <looks for the March bill> Ok March is 58?... And then May, oh April, 68 for April. Ok May is 100. And then June also 100. And July is the highest 151. Oh, I had no idea.... I am totally in shock. That's strange."* – P15

In some cases, the review of their bills caused them to question what they previously thought they knew.

When reviewing their bills in the study, participants nearly always looked at the amount owing on each bill and compared this across their bills. Most participants did not notice if there were fluctuations in the actual cost of the energy on a per unit scale. A small number of participants actually looked at more specific details on their bills like the actual consumption level rather than dollar amount, yet the terminology used was typically confusing to them (this validates Chetty et al. [1]).

*"The billing date is Feb 24 and it's 7.6 Giga Joules...I guess it's how they measure how much heat they use, or gas. <looks closely at the bill and notices something> I'm wrong, [the highest consumption month] was January. They changed something in the bills... Something about midstream. The actual cost of gas is 8.6 Giga Joules and February is 7.6."* – P3

*"I mean a kilowatt hour to the average person does not mean, doesn't say a lot, it doesn't say much to them, it's not tangible. So uh yeah, I don't know how you would put it back in a way that people would, could an average person could understand."* – P11

Another person described how looking at a bar chart comparing months did not help explain her exceptionally high bill one month. In fact, it caused more confusion to see that one month was higher than all previous months.

*"...it shows you the bars of how much you used. So looking at that, it was just really surprising and just insanely big... it was crazy high and we had no idea why." – P4*

For one participant, additional data on temperature helped better understand why a particular month was high.

*"Maybe we had a cold April. Yeah apparently...hmm let me see, they even give you the temperature, yea that's right, that's right. March's average daily temperature is 4 degrees and April is 8 degrees and then the rest of the year is higher temperatures than 4 degrees actually." – P6*

### **Recalling and Replaying Events**

For some participants, seeing the bill and realizing they were wrong caused them to 'replay' the events in their head that happened during a particular time period. In these cases they tried to remember what had happened during that time period. Without any aids that described their activities, this was often particularly difficult to do.

*"There's like a jump in August, I don't know why. It's like it more than doubled. That's weird. How come August of last year? Right? Like low, low, low, low like 190. What happened? Oh, we may have had... Did we have a flood downstairs? Would that of contributed to anything? Extra usage of power? Maybe. We had the construction worker? It may have been in August of last year. A construction crew came to help for a week to help with the flood, we had a flood downstairs..." – P5*

### **SHARING OF ENERGY CONSUMPTION KNOWLEDGE**

We also asked participants who in the household was responsible for receiving, viewing, and paying the power and gas bills and how consumption information was shared, if at all. We wanted to understand if others in the household may help understand why consumption may be higher or lower during particular billing cycles.

#### **Utility Manager**

In all participant households, there was always one person who was designated as the person responsible for viewing and paying the utility bills. We refer to this person as the 'utility manager.' This role was roughly evenly distributed between men and women participants in our study. This person would review the amount of the bill and then pay it. Sometimes other household members would retrieve the bills from the mail at which point they would simply give them to the person responsible for them, typically without their own review.

*"Um it's under my name and it comes to our mailbox. Um, I usually don't open it, but my partner usually pays it because its setup with her, well, our TP account, she's got it all set up...She's kind of in charge of paying all of the bills." – P4*

*"They're in my name and I pay them ... Actually I don't really share that information with [my wife]. It's really not important for making any decisions." – P1*

### **Sharing of Consumption Information**

Across all households, the utility manager typically did not share information about the power and gas consumption with other household members. Other household members sometimes had access to see the bills if they were sitting on a counter, desk, or had recently arrived in the mail. Yet despite having this opportunity, household members who were not the utility manager did not look at the bills. In general, there was a sense of trust in the utility manager that the job was being done and there was no need to look. In some cases, participants felt that looking may simply cause confusion.

*"No, generally I don't see the bills at all unless I happen to see them on his desk ... I would try to look at them to try and see how much energy is consumed, how much power we use, but I really wouldn't understand it all." – P2*

*"I don't find out because I don't need to find out. I never think about it. ... Because my husband pays the bill right so I don't even look at the bill." – P7*

One participant described a situation where his mother would give him the bill because she did not understand English. He would pay the bill and as long as it was reasonably priced, she would not ask him any questions.

*"Like she pays attention, but like she would never ask why. She's more like worried about like why's it so much money, why do I have to spend so much money, yeah. Like we don't ever call and ask... Because like if she doesn't really care, then I don't really care. I don't ask her like 'Why's it so expensive?' I'm never really that certain; I just pay what she gives me." – P8*

In families with pre-teen and teenager children, parents did not share the information on the bills with their children though they felt it was information that the children should be made aware of. Others commented that they simply may not understand the information if shared with them.

*"I don't tell them how much, but I tell them to save the energy. To save the world." – P15*

Utility managers told us that while they normally did not include other family members in the process of viewing and paying the utility bills, they did alert them in problem situations. Similarly, participants who were not utility managers told us that their household members would consult them if bills were unusually high.

*"Well I know, I had a conversation with my partner a couple weeks ago because we got the bill and it was really, really high in July or June and we were really surprised because there's nothing new that would cause that." – P4*

*"Usually no, usually we don't discuss that, we just pay. Unless it's very exceptional high cost but over the years since I pay attention to it, not extra high." – P15*

## EXPLAINING CONSUMPTION WITH CALENDARS

We also asked participants to show us the calendar that they used most often and talk about the activities on it and how they might (or might not) relate to their energy consumption. All participants referred to their own personal calendar—as opposed to a shared family calendar—and discussed the activities on it with us. The types of activities that people put on their calendars varied heavily. Some recorded nearly every activity that they participated in (e.g., work hours, kids' school activities), while others only recorded exceptions to their typical schedule. Routine activities were typically left off people's schedules. These findings reflect those found in [22].

### Events Recorded on the Calendar

We had participants look at the months in their calendars that they felt were the highest and lowest for energy consumption and describe each calendar event to us and whether they affected their consumption. Most participants initially felt that events on their calendar did not typically relate to how much energy they consumed.

*“Uh, no, uh, it's the calendar, so for the calendar I just write down stuff, personal appointment stuff, there's nothing related to what [energy] we use.” – P10*

*“Yeah, I just have personal appoints, like meetings and stuff. Either dinners or lunches. I was out of town for 4 days. But that doesn't really explain high usage.” – P13*

For other participants, as they began discussing events on their calendar, they began to explain how certain events could help aid their understanding of energy consumption or cause them to think of other activities that might affect it. The most prominent example of this related to knowing when household members were at home or when guests were visiting from out of town.

*“I know if I'm not going to be [home] most of the time then I know I'm not the one using the energy... Such as when I'm not doing anything then I'm sitting at home playing on my computer. You know if there's nothing on my calendar then it's a lazy day and I'm at home that means I'm automatically using energy because I'm at home.” – P9*

*“Well there's nothing unusual [on my calendar]. Just work appointments and things for me to remember to do so there isn't anything that would spike it. But I guess another thing is the emptiness of the calendar shows that we're actually home, we're not hanging out. So we may not be consuming less, we're at home, so we're actually consuming at home.” – P11*

One participant explained that she recorded when her sons had hockey games and practices on her calendar. She felt that because this information showed when they would be away from home, it could show times when she used less energy (e.g., not using the television, computer, etc.).

Another participant talked about having a birthday party written down on her calendar; this signaled that lots of

people would be at their house, with the potential to increase consumption. She also described additional 'get-togethers' that were similarly recorded on her calendar.

*“Well, [my husband] had his fortieth [birthday], go figure... So we had um, maybe 20 people over to celebrate.... Oh and they're nice, we entertained guests until like 2, 3 in the morning. And the guys come over and play poker. They have like all the lights on upstairs.” – P5*

In contrast, however, two participants felt that events on their calendar that showed when they were not at home would have little effect on consumption because they were only for short durations.

*“...these events outside of the house are only like an hour or two, a couple hours, so it's not, I would say it's substantial to eliminate the cost that much. Yeah.” – P5*

### Events Not on the Calendar

We also asked people about activities that were not written in their calendar (but could be) that they thought would affect their consumption. Again, people talked about when they would not be at home, however, in these cases, this information was not recorded on the calendar. In many cases, it was 'spur of the moment.'

*“In summer there's a lot of BBQs where people host so we're going out, so we're not home consuming. Those things are more spur of the moment you know 'Hey I'm having a BBQ on Saturday' and people just go over, you know. But again because we're out we're not running on the air conditioning.” – P11*

Others similarly talked about vacations and travel as being times when they were away from home and would consume less energy. Yet not everyone recorded this information on their calendar. Instead, it represented tacit knowledge.

*“Oh, so when we go on our trips, we go out of town. This I know right and I don't write it down.” – P15*

Several participants said that they felt knowing when visitors were at their house could affect knowledge of their consumption levels. However, they did not record this information on their calendar always. One participant said this was because visitors typically come over 'last minute.'

*“No because it's usually last minute like with hockey or friends just coming over for the evening. Like 'We're coming over pick me up at the ferry' kind of thing.” – P4*

## DISCUSSION

We now compare our findings to the related work and explore the ways in which designs may better support people in understanding their energy consumption. In particular, we discuss potential roles for calendars.

### How People Understand Consumption

Our study revealed that many people know little about what actually affects their consumption and when provided with their utility bills, they are often still left guessing. Thus,

utility bills that provide numerical values for consumption with basic comparison data between billing months certainly are not providing people with enough information. Participants' explanations about what consumes the most energy typically related to high-level effects such as weather and temperature that are basically out of the control of home residents. We also see high-level rationalizations relating to seasonal activities, such as holidays, travel, and cooking, but less of a tendency to think about the everyday things that people do which may affect consumption.

Comparing this to Kempton and Layne's study done in 1994, eighteen years ago, little has changed: People still think 'high-level' about consumption, overestimate the effects of large social events, and mostly look for unusual moments of consumption [14]. Given the variety of campaigns that have occurred over the last two decades to promote better energy consumption, it is somewhat surprising to see similar results to Kempton and Layne.

In some ways, we feel that utility bills have trained and continue to train people to think at a high-level about their consumption. None of the participants in our study had special awareness displays or eco-visualizations and we would expect that typical households would similarly not. Instead, the only real indicator of consumption comes from utility bills that come to the home at a monthly or seasonal level. As a result of this billing frequency, most of the data received by household members is at a high-level. Moreover, there is little to no information on the bills that is actually tied to one's everyday activities, which could have an effect on consumption. This is important for it is largely the everyday activities that we engage in that we actually have control over.

Certainly an implication is that designers should think of ways to tie everyday activity details to the consumption information provided to typical households. Of course, next-generation awareness displays are already trying to do this, yet there are possibilities for more near-term solutions relating to utility bills. For example, companies could overlay utility usage on a blank weekly or monthly calendar within the bill so people can think about their likely routines and activities on those days. The context of the calendar could help family members think about that time period where the calendar would serve as memory trigger (as found in our study). Companies could also change the distribution frequency of energy information (e.g., send it between bills via email if consumption is unusual). This would allow them to better relate consumption to their everyday activities because they would more likely remember what they did recently. Some utility companies provide detailed information online about energy consumption; however, our study showed that most family members are too busy to check the information on their own accord. Sending it to them could alleviate this concern, though there is a risk of information overload.

### **Sharing Consumption Information**

Our study also elaborated on Chetty et al.'s finding that most people do not see their household utility bills [1]. Here we found that there is one person whom we call the utility manager that is responsible for 'taking care of' the bill. This information is not shared with others—both adults and children in the home—unless there is an issue where things do not look 'normal.' In the study's location, and certainly more broadly, utility companies are transitioning to online billing mechanisms where utility bills arrive in a household member's email. As part of this, we suggest designers think about ways of making these bills or the information contained within them easily shared amongst family members for viewing. The reality is that not all family members will care to see this information, especially all the time. Research has shown that couples implicitly take on different roles in a relationship where one partner may be assigned to a certain 'role' [32]. Given this natural routine, it is unlikely we are going to change it nor want to.

Instead, designers should think about making consumption information accessible enough that the household utility manager can easily choose to share consumption information in cases when it is relevant to others (e.g., when there are spikes in consumption). This would allow families to maintain their existing routines with their established household roles while providing new opportunities for sharing relevant consumption information.

Paperless bills found in one's email can be easily forwarded between family members. Yet these emails often only include a price or a link to the full bill on a website. Forwarding such emails to family members will not necessarily help because accessing the information requires a sequence of steps (navigating to the web page) and other family members may not have login credentials. This could be alleviated if designers included more information within email bills, including consumption information, rather than redirecting users to a web page. For family members who look at detailed bill information online, designers could provide tools that allow users to select what information they would like to share with their family members and then input email addresses to send this information. This would allow the utility manager to select the information she thinks the family member needs to know about, e.g., high consumption. Designers could also think about ways of supporting sharing consumption information beyond emails. For example, one could design a tool that allows family members to select consumption information and send it over SMS along with a comment.

### **Calendars and Energy Consumption**

Other studies have shown that the most crucial domestic artifact for recording one's everyday activities is the calendar [21,23]. Thus, it *could* be seen as a fruitful source of information that could be tied to one's energy consumption and provide a historical perspective of why



consumption is high or low. This occurred for some participants where they could pick out certain activities (e.g., traveling, being at home, having visitors) that may have an effect on consumption. Yet in reality, the number of activities on the calendar that people felt affected their consumption was relatively low. Everyday activities that would affect consumption such as showers, laundry loads, use of electronics, etc. simply do not get written on people's calendars. This illustrates that calendars, as they are presently being used, do little to aid people in understanding their energy consumption.

Yet reflections on the calendaring literature coupled with our own study results suggest several ways calendars may be useful as it relates to energy consumption. First, people clearly understand their calendars and the content on them [22,23,27]. We saw in our study that calendars can help people remember specific time periods and the activities that occurred. This can help people to 'replay' certain time periods in their head if they are interested in understanding why energy consumption may be high. Thus, even though a calendar may not contain information illustrating why consumption may be high, they often contain enough information so that people can remember what else may have occurred at a particular point in time. If energy consumption information were displayed within a digital calendar next to one's recorded activities, this act of mental 'replay' could be used in conjunction with the energy information to better understand it.

Second, we know from the literature that calendars are an awareness tool that family members use to share information about household activities [21,22,23]. The person in the household that is responsible for the 'family calendar' tells others about activities on it on an as-needed basis and others may also look at it to gain this understanding [21,23]. If consumption information were embedded within a shared family calendar, it could be yet another piece of awareness information that is easily accessible for family members to see. Digital calendars with this information could also be designed as appliances that could be placed in high traffic areas of the home so people would easily see the information as they pass by and tell others about it. This could make it easier for family members other than the utility manager to stay aware of consumption, if desired.

Third, designers could think about creating digital calendars that automatically place relevant information that helps explain consumption into a family's calendar. Consumption could be shown at hourly, daily, or weekly levels, depending on the calendar view shown and the data available. Hourly or daily time period views may help people to think about their consumption at a finer grained level than people have been 'trained' to do with their utility bills. Yet larger time periods would also be useful. Our results showed that context was especially important for triggering thoughts about consumption. In this case, views

at a higher level of detail are better, e.g., showing multi-days, weeks, or even months. Comparisons could also be visualized across days, weeks, months, or even years. The obvious solution is to display how much energy devices/outlets/appliances are using. Yet there could be logical reasons for high consumption on a particular day given a person's activities. Instead, based on our results, a more clever solution would be to show the information that people relate to their consumption and allow them to understand it. This includes weather patterns, the number of people at home (or gone out), durations of time at home/out, travel information, etc. Some of this information could be easily detected through simple sensors or computer vision techniques.

Certainly these ideas are preliminary and while they suggest possible design avenues, it is critical to test them out through design and actual usage.

## CONCLUSION

Our study has explored the routines that households and family members have for understanding their power and natural gas bills and how this relates to their everyday activities as might be recorded on their calendars. Our main findings illustrate that, even with the aid of artifacts such as their utility bills and calendars, people are still challenged when it comes to understanding their consumption. Some calendar events help people to understand their consumption, but many do not. Nonetheless, given the role calendars currently play in the home, there could be value in coupling energy consumption information with calendars for information sharing.

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