

The Dubuque Water Portal: Evaluation of the Uptake, Use and Impact of Residential Water Consumption Feedback

Thomas Erickson, Mark E. Podlaseck, Sambit Sahu, Jing D. Dai, Tian Chao, Milind Naphade

IBM T. J. Watson Research Center

P.O. Box 704, Yorktown Heights, NY 10598 USA

{snowfall | podlasec | sambits | jddai | tian | naphade}@us.ibm.com

ABSTRACT

The Dubuque Water Portal is a system aimed at supporting voluntary reductions of water consumption that is intended to be deployed city-wide. It provides each household with fine-grained, near real time feedback on their water consumption, as well as using techniques like social comparison, weekly games, and news and chat to encourage water conservation. This study used logs, a survey and interviews to evaluate a 15-week pilot with 303 households. It describes the Portal's design, and discusses its adoption, use and impacts. The system resulted in a 6.6% decrease in water consumption, and the paper employs qualitative methods to look at the ways in which the Portal was (or wasn't) effective in supporting its users and enabling them to reduce their consumption. The paper concludes with a discussion of design implications for residential feedback systems, and possible engagement models.

Author Keywords

Water, smart meters, sustainability, behavior change, water and energy feedback systems, social comparison, games

ACM Classification Keywords

H.5.2 [Information Interfaces And Presentation]: User Interfaces - Graphical user interfaces (GUI);

General Terms

Design, Experimentation, Human Factors.

INTRODUCTION

Lack of fresh water is a worldwide problem: a billion people lack access to clean water, and 3 million die every year due to water-related diseases [18]. Water use is growing twice as fast as the population [19]. Even where plentiful, surface water is being increasingly polluted and aquifers depleted [3]. According to the UN, *“By 2025 1.8 billion people will be living in countries ... with absolute water scarcity, and two-thirds of the world population could be under conditions of water stress.”* [19, p10]

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

CHI '12, May 5–10, 2012, Austin, Texas, USA.

Copyright 2012 ACM 978-1-4503-1015-4/12/05...\$10.00.

Water is also important in producing energy [10]. It is critical to hydroelectric, geothermal and nuclear power generation. It is used to extract natural gas and oil from shale, to produce ‘clean coal’ and to grow biofuels. Many of these uses chemically alter the water, or disrupt natural systems that depend on water, requiring further energy to ameliorate. In sum, the increasing scarcity of fresh water is a problem that requires global attention.

Water scarcity is a complex problem, with many ways of addressing it. This study is concerned with a system for promoting water conservation among residential users in a U. S. city. While residential water consumption is far from the heaviest use in the U.S. (power plant cooling uses 50%, and irrigation 35%), it nevertheless costs \$33 billion a year, with an equivalent amount required to manage the resulting wastewater [9]. Finally, as per capita U.S. water use is the highest in the world, twice that of Japan and over four times that of most northern European countries, it would appear that there are considerable savings to be had.

This paper evaluates a 15-week pilot deployment of a system aimed at supporting voluntary reductions of water use among 303 households in a mid-sized U.S. city. The system collected data from ‘smart’ water meters, analyzed it, and used a variety of techniques – usage graphs, alerts, incentives, games and chat – to encourage water conservation among residential users. This paper offers an in-depth, multi-method evaluation of the system.

PREVIOUS WORK

Over the last decade HCI has devoted increasing attention to sustainability (cf., [2]). Much of this has focused on resource conservation, and especially on energy. Space precludes a comprehensive review of this literature, but fortunately there are several excellent review papers. DiSalvo et al. [7] review of sustainability research within HCI, identifying axes along which work differs and highlighting emerging issues. Froehlich et al. [11] do a superb review of eco-feedback technologies that encompasses work in both HCI and environmental psychology, noting that the two literatures rarely refer to each other, and calling out differences between the fields. Pierce et al. [15] classify eco-visualizations, discuss design rationales and identify new challenges and opportunities. Finally, Darby [4] reviews the environmental psychology literature on energy feedback, finding that direct feedback can reduce energy consumption by 5% to 15%.

Eco-feedback also has its critics. Strengers [17] argues that such systems assume that their users will act as rational resource managers, and that this assumption is challenged by the fact that water and energy use is part of daily practices that are shaped by social and cultural norms (e.g., daily showering as a hygienic practice) and often viewed as largely non-negotiable. Similarly, Pierce et al. [15, 16] argue that much everyday energy use is not the result of conscious and motivated action, and that feedback may reinforce norms by reifying a household's "baseline" usage (which users may try to avoid exceeding but don't consider trying to reduce).

This paper addresses two issues that have been noted as deserving further attention. Froehlich, et al. [11] note that environmental psychology has used large, long-term field studies to quantify the effect of feedback, but pays little heed to the design of the feedback mechanisms, "*while HCI has concentrated on the production of the eco-feedback artifact and rarely on conducting field studies to actually study behavior change*" [11, p. 2,003]. This paper bridges this gap with a 15-week field study of a complex eco-feedback portal. Further, researchers from both HCI and environmental psychology (e.g., [6, 16]) have called for work that, rather than treating the household as a black box, looks at "*how individuals engage or do not engage with feedback*" [16, p 244]. This work addresses this as well.

While energy has gotten the most attention, water has received some notice. Most work on water feedback has focused on point of use feedback at the tap and the showerhead [1, 12, 13]. These studies are limited by the fact that they are short-term, with small numbers of subjects, and have produced mixed results. The most positive result was a reduction in water consumption during showering of about 10% [12]. While feedback at the point of use seems, *a priori*, the most effective approach, a practical limitation is that the costs of purchasing and installing such devices city-wide seem formidable in an era of increasingly-constrained spending on urban infrastructure. Alternatives would be useful.

Work on water consumption feedback at the residential scale is rare. Petersen et al. [14] staged a two-week "energy reduction" contest at Oberlin during which they delivered feedback on water and energy consumption to 18 student dorms. Feedback was either delivered in near real time or once a week, and was delivered via student-accessible web pages and kiosks located in the dorms. The results were mixed: energy use dropped by 32%, but water use only by 3%. Although the students' 32% reduction in energy use considerably exceeded the 5–15% reduction usually achieved by energy feedback systems, the 3% reduction in water consumption is very small. It raises the question of whether residential-scale water feedback would be effective at all under circumstances more ordinary than an inter-dorm competition among college students.

In summary, it is clear that providing energy feedback, particularly in near real-time, can reduce resource consumption; it is less clear whether that is true in the realm of water. This study provides a data point – derived from a longer study of a broader population – that will provide a useful supplement to Petersen et al's [14] work. Finally, and more generally, as called for by other researchers, it would be valuable to have a deeper understanding of how feedback mechanisms are used, understood and experienced so as to be able to more effectively design such systems.

BACKGROUND: SITE, SYSTEM, PILOT AND PORTAL

The Site

The system this study evaluates was deployed in Dubuque Iowa. The choice of Dubuque was opportunistic, due to a convergence of factors including: Dubuque had established a strong sustainability agenda; Dubuque was in the process of switching from traditional water meters to smart water meters; and the researchers' organization had developed a good working relationship with the City. Dubuque does not have water scarcity problems: water is cheap.

The System

The system was designed for the City of Dubuque, and responded to their requirements both in specific features (e.g., showing water consumption in gallons, dollars and pounds of CO₂), and at a general level (e.g., a strong focus on maintaining privacy). In brief, the system worked as follows: Smart meters recorded consumption every 15 minutes. Each home's data was sent to a cloud-based repository every 4 hours where it was analyzed, typically with a 2-3 hour delay. The resulting feedback was provided (in aggregate, anonymized form) to the City's Water Agency, and (privately) to individual homes. Further details of the system architecture, data collection and analyses can be found in [4] and the final project report [8].

The Pilot Project

The portal was deployed to 303 volunteer households located in a few contiguous neighborhoods (due to constraints on proximity to data collection points) in early September. The deployment had two phases. During the first 9 weeks, half the participants were given access to the Portal, and half were not, allowing a controlled comparison of its impact on water consumption. Phase 2 started after a 1-week break, and during its 6 weeks everyone used the Portal. Because the pilot ran into the year-end holiday season, interviews were carried out in early December and the survey ran from late December into January.

The pilot project involved more than just turning on a web portal: sustained efforts were made to publicize the project and engage participants. The Mayor wrote letters to recruit participants and to update them on the pilot's progress. Dubuque 2.0, a non-profit sustainability organization, held various events to encourage participation. Training classes gave participants hands-on experience with the Portal.

Weekly prizes were awarded for participation, and weekly emails announced winners, prizes and tips. Web sites run by the City and by Dubuque 2.0 also provided publicity.

The public nature of the pilot project had consequences. Its stakeholders, particularly elected officials, were aware that problems could reflect back on them. Thus, it was not acceptable to recruit volunteers for the pilot and then tell half that they could not use the Portal at all because they needed to serve as controls. Nor was it acceptable to make water consumption data from the pilot public (even though water usage data is, legally, public, and available to anyone who asks). Strict user ID and password requirements were enforced out of concern that users might expose their usage. In general, concerns of this sort sometimes drove the design of the system and the pilot in ways that were not ideal for research, particularly with respect to the more social features of the system.

The Water Portal User Interface

Each household had a private portal, as shown in Figure 1. Just below the user ID (①), the timeline shows the daily water usage for the last year (②). Moving a ‘thumb’ along the timeline, shows a graph of the hour-by-hour usage for each day (③). The “Weekly Usage” tab displays a bar graph that shows usage for the week, each day broken into 4 periods. The “Compare” tab displays a bar graph that

contrasts usage per day of the week for the last 3 weeks.

The last tab, “This Week’s Game,” provides two means of socially shaping behavior. The first (④) shows the ongoing results of a weekly game. Each week teams of 4 to 6 households were automatically created by the system. Each team was matched against another team that was expected – based on previous consumption patterns – to use about the same amount of water during the upcoming week. The goal was, of course, to use less water than the opposing team. The results were updated throughout the week (with each household being able to see how it and each of its (anonymous) teammates were performing (via the segments in the bar in the graph). Finally, the farthest bar to the right (⑤) shows the amount of water used by “Neighbors Like You,” to which users can compare to their own usage. At the top right are statistics that provide various metrics of how the household is doing such as rank, and a menu bar that provides access to chat and news functionality (⑥).

THE STUDY

The Portal was deployed to 303 households for 15 weeks. Multiple measures – logs, a survey and interviews – were used to evaluate its effects on its users’ behavior, beliefs and experience. The study examines the following areas:

- **Degree of usage.** How many households made use of the Water Portal, and what usage patterns did they exhibit?

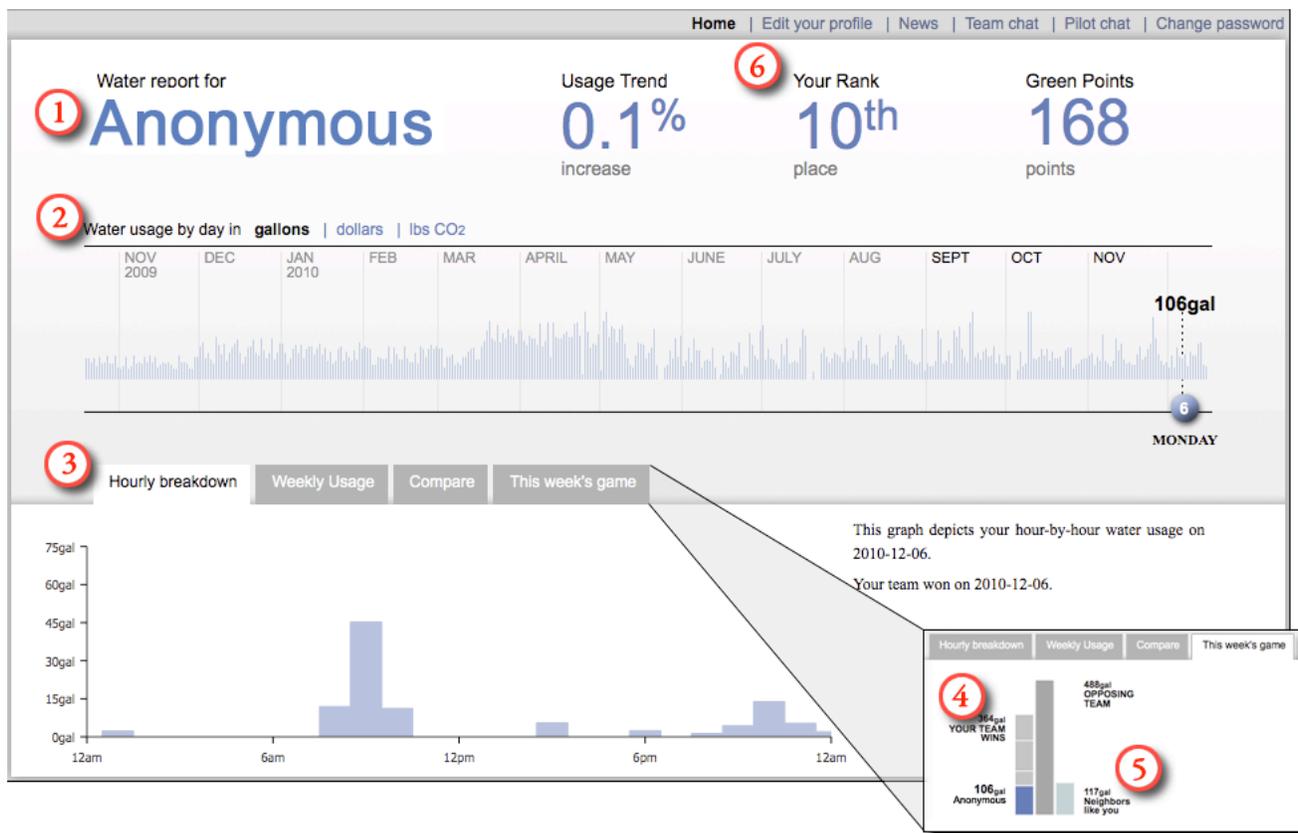


Figure 1. The Water Portal.

- **Manner of usage.** Which features of the Water Portal did participants use, and how and why did they use them?
- **Impacts of use.** What kind of impact did using the Water Portal have? Did users learn things from the information presented? Did they change their behavior, or make changes to their water appliances, to reduce their water consumption? And so on.

Participants

Because of privacy concerns, participants were identified only by anonymized IDs. Because the pilot was restricted to one area of the city, we can infer that participants were mostly middle class and lived in single-family dwellings.

Limitations

Our ability to generalize from this study is limited by two factors. First, as noted above, participants were not a random sample of the city population, but were primarily middle class residents of single-family dwellings. Second, participants were volunteers. On the one hand, it can be argued that as a consequence they are highly motivated and will be more inclined to use the Portal than the general populace. On the other hand, it can be argued that the same attitudes that led them to volunteer may mean that they have already taken actions to conserve water and thus there is little more they can do – i.e., the low hanging fruit is already picked. The study will shed more light on this.

While it is important to keep these factors in mind when generalizing from this research, it should be noted that issues like this are characteristic of most *in situ* studies of this type. Thus readers should draw conclusions, keep the limitations in mind, and over time, as more deployments of this type of technology occur, the field as a whole will develop a more general understanding of this domain.

Usage Logs

Two types of usage information were logged. Throughout the pilot Portal usage was tracked via login records. During phase 2, fine-grained logging was added to track use of individual user interface components.

The Survey

The survey consisted of 36 questions, 1 open-ended and the rest a mix of multiple choice and Likert scale questions, with valences mixed where appropriate. It took about ten minutes to complete. Participants received an email with a link to an online survey; two reminders were sent.

The survey began asking about the frequency of Water Portal usage. Those who rarely or never used it were asked about barriers to their usage; the others were asked which components of the Water Portal they used, how they used (and whether they understood) those components, and what impact they believed using the Water Portal had on them. After that, all participants answered questions about their attitudes and actions with respect to water usage.

The survey received 89 responses (2 other responses in which only 1 question was answered were omitted), which is a 29% response rate. With respect to the focus of this evaluation – the use of the Water Portal – 62 of the respondents reported using the Portal at least once, which, since the logs show that 106 distinct users logged onto the Portal, gives a 58% response rate for Water Portal users. Thus the survey provides a good picture of those who used the Portal; it has much less to say about non-users.

The Interviews

Interviews were conducted near the end of the deployment; their purpose was to provide illustrations and context and to inform the design of the survey. The 10 informants (3 women, 6 men, and 1 couple) were diverse in age, attitudes towards water conservation, and in the degree and ways in which they used the Portal. Semi-structured interviews were conducted in a city office and lasted about 45 minutes. They were digitally recorded, with permission, and later roughly transcribed. Interviews enquired about issues such as motivation, degree and manner of use of the Portal (using screenshots as prompts), and the impacts of using it.

FINDINGS

Of the 303 households in the pilot, 106 (35%) logged onto the Portal at least once. (Note: 28 households lacked internet access and received their results on paper; we do not report on these households). We discuss the results in three sections: the degree to which the Portal was used; the manner in which it was used; and the impacts it had. We also note implications for design, to which we return later.

How Often was the Portal Used?

Those who used the Portal Little or Not at All

The survey asked users who didn't use the Water Portal (at all or very much) the reasons for their lack of use. Significantly, only 4% of the respondents said that they found the Portal too difficult or complex to use; respondents had only minor suggestions for improving the user interface of the Portal. The most frequent reason for non-use was that they "kept forgetting" (49%). While some users reported difficulties with managing user IDs (random strings of digits) and passwords (sent on paper by U.S. mail), we believe that there is a larger issue of how (and whether) tracking water consumption fits into people's daily lives. We will return to this issue later.

Of the 32 respondents who used the Portal infrequently, 41% choose the response "After looking at it a few times I'd learned all I wanted." In the interviews, users spoke of wanting to 'establish a baseline.' One informant said "*I probably used it more frequently at the beginning – more interested in what the baselines were, and once I knew that, my access to it probably dropped off.*" Another said: "*I was looking at it every day just out of curiosity, but it doesn't do anything... <laughs> You know, it gets kind of boring after a while. I decided once a week I'd just check it and see*

what the past week was like.” Both made it clear that initially they found the Portal quite interesting, and learned some things about their water usage, but after a while they ‘figured out’ what they did, and that was sufficient. With regard to designing future systems, this raises the question of how to best engage users over longer periods.

Those who Used the Portal More Frequently

About 27% of the survey respondents reported that they were using the Water Portal regularly – about once a week or more frequently. While some of these might still have been in the process of establishing a baseline and would subsequently reduce their frequency of use, it was clear from the interviews that some of participants ‘got into’ using the Water Portal. One said: *“I would say [I use it] maybe 2 or 3 times a week. I mean I don’t check it every day cause I kind of know what’s going to be there. But it’s interesting to see the game and how I stack up against other users and how many green points I got today.”* Another said, *“I check it religiously every day. [...] I do look at kind of the team thing. I usually check first thing in the morning – I get up around 6 and the numbers are low. And then when I come home I also look to see what’s going on.”*

The existence of this set of more frequent users raises the question of why they kept returning to the Portal and what they did while they were there, which we will turn to next.

What Parts of the Portal were Used, and Why?

This section focuses on the 56 survey respondents who used the Portal multiple times, hereafter referred to as “the Portal Users.” This section also draws on the interviews.

Table 1 shows the user interface components that users reported most frequently looking at. This largely corresponds to the fine-grained usage logs that tracked time per component, except that they indicated that more time was spent using news and chat than looking at “Neighbors Like You” and the weekly game. This discrepancy between what people “usually did” and “time spent” is not troubling since both news and chat involve switching to another page and reading text, which might be expected to take more time than looking at bars on a graph for the “Neighbors Like You” and the weekly game results. This ordering is also consistent with our impressions from the interviews.

Table 1: What users reported that they usually looked at

I usually looked at	N	%
The hourly graph of water usage	49	88%
How I compared with Neighbors Like You	37	66%
The weekly game results	27	48%
The news	23	41%
The chat	17	30%

The Hourly Usage Graph

The hourly usage graph is among the most looked at elements of the Water Portal. One question going into the study was to what extent users would be able to connect what they saw in their usage graphs to their actual water use. This was a key question because the Water Portal did not indicate which appliances – showers, sinks, toilets – had used the water, and there was a 2-3 hour delay before usage was reflected in the Portal. Another question was whether this information would be useful. From the two survey questions shown in Table 2, it’s evident that almost all respondents found the hourly usage graph understandable, and half reported learning surprising things from it.

Table 2. Questions about the hourly water usage graph

Question	Agree-Neutral-Disagree (NA)	% agreed
<i>When I looked at the graph of my hourly water usage, I could usually understand what the peaks in the graph corresponded to</i>	51- 2- 2 (1)	91%
<i>I was surprised by some of the things I saw in my water usage graph</i>	28-17- 8 (3)	50%

While the Portal did not show which appliances contributed to water consumption, users found this easy to infer by mapping their recent experience to the peaks they saw in the hourly usage graph. One said he could see that one toilet used twice as much as the other, and another that it was nice to see that his new energy star dishwasher really was efficient. Other interviewees provided more details: *“I was knock-your-socks-off impressed at the detail that you could see. Wow! Here’s the shower I took this morning. Here’s the shower [my wife] took this morning. Here’s where I came home during the middle of the day and washed my hands and used the toilet. Here’s where I filled the dog’s dish.”* Another said *“When I look at it you can tell alright this is when we’ve gotten up and are getting ready, and [this is] when I get home and I start doing laundry or baking or cooking and running a dishwasher.”*

A recurrent theme was the power of visualization. It was clear that informants not only found the graph useful but also enjoyed looking at it and seeing their activities reflected in it. This suggests that visualizations can play a dual role: they are powerful communications mechanisms, and they are also effective ways of engaging people. One informant said, *“I know I have a leak in my house ...it’s a leaky faucet. ... I just never took the time because I never saw a graphical representation. ... You can really picture – I mean a gallon is a gallon of milk, and you can see fifteen of those going down your drain! That makes a heck of a difference!”* Another said, *“When I wash I can really see the spike!”* and wondered aloud whether a new washer might be a good idea. Informants made similar comments about the year-long timeline, one noting a huge peak on thanksgiving when she had 25 people over and saying that

“it was nice to be able to connect [the peak] with something and see that it was going to be tracked.” Others commented on the big peaks that signified the start of summer with the watering of new grass and the filling of the swimming pool.

“Neighbors Like You” and “This Week’s Game”

“Neighbors Like You” and “This Week’s Game” both involved comparisons or competitions with others – but (because of privacy concerns) *anonymous* others. Thus, unlike many gaming situations, users didn’t know who was on their team, or against whom they were competing. Would the Portal Users find these ‘invisible’ competitions and comparisons interesting and engaging?

Interestingly enough, 66% (37) of the Portal Users reported usually looking at the “Neighbors Like You” comparison, and 48% (27) reported usually looking at the weekly game. Given that the team and neighbors comparisons are side by side, it is interesting that some users paid attention to “Neighbors Like You” but not “This Week’s Game,” and *vice versa* – in fact, a total of 16 users followed one but not the other, with more favoring “Neighbors Like You.”

The interviews provide some insight here. Two of the informants were engaged by the game. One said, “*That’s the one I concentrate on [pointing to “This week’s game”], I guess because I’m competitive and trying to see what my team is doing... And um, it would be kind of nice to know who your team was.*” Another explained that he had turned the Portal over to his kids: “*I think the competition was a perfect thing to do. ... I saw it as an opportunity to get my kids excited. Because they can earn points and they can win stuff.*” And this had ramifications: “*I did notice an impact right away. That the kids were – either jokingly or seriously, it’s hard to tell – that ‘you’re going to make our usage go up and we’re going to lose again!’*”

Interestingly, three other informants explained that they “followed” the game, even though they didn’t actually care about winning and said they didn’t change their behavior to try to win the game. One said “*it’s interesting to compare myself against neighbors like myself – households with four people of a certain size and a certain makeup.*” Another said “*This down here [pointing to the “This Week’s Game” graph] ...my team always loses! ... I’m like, ‘We’re doing our part people, come on!’*” These informants liked seeing their household compared against others, perhaps in contrast to “Neighbors Like You” in which they were compared to an average.

Finally, although the sample is too small to draw firm conclusions from, it is telling that of the 15 survey respondents who reported logging on more than once a week, all but one reported that they “looked to see how my team was doing,” and/or “made an effort to reduce my water consumption to help my team.” While the game only engaged a minority of the Portal Users, playing or following the game is highly correlated with frequent visits.

News and Chat

News and Chat saw the least usual use (41% and 31%). This corresponds with our impressions from the interviews, where informants said little about either function, except that some looked at them and occasionally saw things of interest. With respect to chat, none of the informants reported seeing any content in the team chat; for pilot chat (the chat open to all users), while some reported posting comments or reading, they felt it was not well attended, and no one reported having real back-and-forth conversations.

These impressions are reinforced by an analysis of the system’s chat logs. Team chat was very lightly used. Eighteen comments were posted by 11 people, 7 of whom posted only one comment. The most common posts were those intended to encourage or congratulate the team such as “*good job team!*” and “*OK team, are you ready to win!!*,” (further illustration that some users were engaged by the game). No comments directly responded to others.

Pilot chat was used more than team chat. Fifty-seven distinct comments were posted by 18 people, twenty-four of these by the project administrator (e.g., answering questions, thanking users for input, and offering “tips of the day”). Besides the administrator, only 3 people posted three or more comments, 5 posted two, and 7 posted one. Except for the administrator, only 2 users replied to others; most non-administrative posts were general comments about water use (15), questions about water use (11), or questions or suggestions relating to the web site (7).

In summary, although Pilot chat was used more than team chat, it was used for informational purposes. Virtually no conversation, in the sense of users responding to one another, took place in either chat room. One reason may be that users were anonymous, and thus there were few openings for conversation. Another may be that there were few users online at any one time: the Water Pilot may have fallen short of the “critical mass” needed for robust online conversation. A third reason is that conversations are most apt to start when there is something to talk about. Several informants commented that they just didn’t have much to say about their water use. Regardless of the reason, examining ways of encouraging conversation in systems like this seems like an important area for further work.

Impact of Use

About the Users

Before examining the impact of the Water Portal, we will look more closely at the participants in the pilot. Recall that the pilot participants were all volunteers, and therefore may have been exceptional. And indeed, the survey indicates that the Portal Users were already attuned to water conservation: 73% reported that before the pilot started they had made at least one change to their behavior to conserve water (e.g., shorter showers, running dishwashers only with full loads, etc.), and 57% reported that they had made at least one change to their water infrastructure (e.g., installing

low-flow showerheads, efficient toilets, etc). So, for Pilot participants it seems that much of the low hanging fruit was already gone.

That makes the actual finding of a water consumption reduction quite impressive. As reported elsewhere [8], during the first 9 weeks of the deployment, when Group 1 was using the Portal and Group 2 was not, Group 1's water normalized water consumption was reduced 6.6% compared to that of Group 1. This is similar to that achieved by residential energy feedback systems (5 – 15%), and better than that observed for water by Petersen [14].

So what accounts for this reduction?

Increased Understanding

The survey asked a number of questions about the impact using the Water Portal had on users (Table 3). Large majorities of the Portal Users agreed that it increased their understanding of how they use water (77%) and enabled them to see the effects of changes they made (70%). As we've described earlier in this section, the ten informants described ways in which the Portal – especially the hourly water usage graph – did this: from seeing how much water a particular appliance used, to seeing that an appliance that claimed to be water efficient actually was.

Table 3. Questions on the general impact of the Portal

Question	Agree-Neutral-Disagree (NA)	Summary
<i>Using the Water Portal increased my understanding of how I use water</i>	43- 7- 5 (1)	77% agreed
<i>The Water Portal allowed me to see that changes I've made do affect my water usage</i>	39-13- 3 (1)	70% agreed
<i>The Water Portal helped our household conserve water</i>	27-21- 8 (0)	48% agreed
<i>I discussed water usage information from the Water Portal with other members of my household</i>	12 (Never) 6 (Once) 29 (A few times) 9 (Once a week or more)	79% discussed at least once
<i>I discussed water usage information from the Water Portal with people who do NOT live in my household</i>	21 (Never) 6 (Once) 23 (A few times) 6 (Once a week or more)	62% discussed at least once

Water Conservation: Reinforcing Existing Practices

Yet, in the third question, a smaller proportion of the Portal Users (48%) said that the Water Portal actually helped them conserve water. Why is this? A number of the interviewees commented that while they liked the Water Portal and the information it provided, they were, in the words of one couple, “pretty frugal anyway.” Another said, “*This, for us, reinforces what we're doing and keeps us doing it, rather than changing the mode of operation in our house.*” Still others reported taking a wait and see approach – “*It's just*

got us thinking about it. And put it into focus that this is real, we have some control over this, and in the end our faucet controls how much is going down the drain” – sometimes because they are contemplating major appliance purchases that they don't want to rush in to.

Talking with Others

We were interested in the extent to which the Portal Users discussed their experiences with others. Such talk within the household is crucial to enabling collective discussion and decision-making about household water use. And talk beyond the household can be important in encouraging system adoption and shifting public norms.

A large majority (79%) of the Portal Users discussed their water use with others in their household (note that some members of the pilot group lived by themselves). For instance, one informant recounted how looking at the hourly usage graph led to “*some comedic banter with [my wife] about how come your shower has such a bigger bar than my shower has. And that kind of caught her attention.*” In another instance, the kids in the family, motivated by winning the weekly game, nagged their father: “*My kids said 'Dad, you gotta fix that faucet, it's dripping so much!'*”

A majority of The Portal Users (62%) also reported discussing their results with those outside of the household. One informant described giving out his user ID and password to his extended family so they could log in and see his results. Another printed out screenshots to show people. And still others mentioned carrying on discussions with their co-workers. No doubt some of this is due to the novelty of the Water Portal, but nevertheless this can facilitate adoption.

Water Conservation: Changes to Appliances and Behaviors

The survey asked the Portal Users about changes they had made *during the pilot*, or *planned to make in the future*. Although many of the Portal Users had made such changes before the pilot began, many also reported making other changes during the pilot, or planning to in the future.

- 39% of the Portal Users reported making at least one change to their water infrastructure, with the most frequent being fixing a leak (29%). 45% reported plans to make such changes, with the most frequent planned alteration being to purchase a water efficient toilet (18%).
- 45% of the Portal Users reported making at least one change in their water consumption behavior during the pilot. The most popular of these behavioral changes was to avoid unnecessarily running the faucet – e.g., while washing dishes or brushing teeth – and was reported by 33% of the Portal Users. Only 20% of the Portal Users reported plans to make further behavioral changes, perhaps because, unlike making changes to water appliances, advance planning is not so necessary.

Overall, a total of 61% of the Portal Users reported making a change to either a water appliance or the ways in which

they used water (or both) during the pilot, and 48% reported plans to do so. These reports are consistent with the observed reductions in water use.

DISCUSSION AND CONCLUSION

A web-based Water Portal was deployed to 303 volunteer households in Dubuque Iowa for 15 weeks. The system, designed to be deployed city-wide, was intended to reduce water consumption by providing near real time feedback, social comparisons, a weekly game, and news and chat. Portal Users reported that feedback, social comparisons and the game had impacts on their behavior (in that order); majorities reported increased understandings of their consumption, seeing that changes they made had an effect, and discussing their consumption with those within and outside their households. Quantitative measures showed a 6.6% reduction in water use during an experimental/control contrast for the first 9 weeks of the pilot study; this is striking, since most participants reported that they'd taken measures to reduce their use long before the pilot began.

Degree of Use

The aggregate usage pattern for the Water Portal is an initial burst of logons followed by a gradual decline to a lower and steadier pattern of use. It is evident from both survey and interview responses that a portion of the users were interested in gaining an understanding of their water usage patterns, but once they'd done that they lost interest in the Portal. In the interviews, those who fit this pattern commented that they were already quite frugal in their use of water. This is in line with other reports [16, 17], and consistent with concerns that eco-feedback systems may, in part, work to reify existing norms. On the other hand, the Portal did result in a reduction in consumption, and some users engaged with the Portal throughout the deployment.

What of the households that rarely or never used the Portal? That is more difficult to say. Of the relatively small proportion of those users who responded to the survey, the most frequently cited reason for their infrequent or non- use was that they "kept forgetting." This is a curious response, and it raises two possibilities, both of which we suspect have some truth to them. First, users had to navigate to a web page that was not part of their usual routine, and that required a special ID and password. This may be too much to expect, and as we discuss later, the engagement model may need to be re-thought. Second, it may be that, in line with criticisms of eco-feedback systems, many users are not interested in acting as "managers" of their consumption, and thus feedback is beside the point. In this view, progress lies in the re-design of point-of-use appliances and services.

User Experience

In an ideal world, this study would have been much larger, and different versions of the Portal could have been deployed to different groups, allowing a crisp assessment of the relative importance of various user interface

components. That was not the case, and so the best we can do is rely upon users' reports as uncovered by the survey and interviews.

The hourly usage graph received the most attention. Most importantly, Portal Users reported that it was easy to map their daily experience to the hourly usage graph, and thus make inferences about the impacts of particular appliances and practices on their consumption. Because they were able to draw such inferences, they got value from the hourly usage graph in several ways. It enabled identification of the activities (e.g., showers, watering the lawn as part of a grub control treatment) and appliances (e.g., washing machines, toilets) that were consuming larger than expected quantities of water. It allowed them to compare activities (my shower versus your shower) and appliances (downstairs versus upstairs toilet) *vis a vis* their consumptions. It provided validation that some appliances (e.g., the energy star dishwasher) actually did use small amounts of water. It enabled visualization of the cumulative impact of leaks (e.g., the leaky faucet that accounts for 15 gallons a day).

Of the Portal Users, 66% usually looked at "Neighbors Like Me," and 48% followed the results of the weekly games. Although both these techniques involve social comparison, it is worth noting that they appealed to somewhat different sets of users. The attention devoted to the weekly games is of interest because the 'teams' were composed of anonymous households, and although teammates could in principle chat with one another, no such conversations took place. Apparently, even something that lacks many of the characteristics of online games can still succeed in engaging people. Finally, of the 15 participants who used the system more than once a week, 14 followed the weekly game, suggesting that although not for everyone, games may be of value for encouraging frequent use.

The other social aspects of the Water Portal – News and Chat – saw the least "usual" use according to the survey (41% and 31%), which corresponds to impressions from the interviews. While users appreciated these functions, and gained useful information from them, analysis of the chat logs and comments in the interviews show that the chat function was not used for conversations among ordinary users: it was instead used as a place for posting information, and supporting Q&A between users and the administrator.

Impact

As noted earlier, use of the Water Portal resulted in a reduced consumption of water. This is striking in view of the fact that 70% of the Portal Users noted that they'd tried to conserve water for a long time, and 79% had made some kind of change to their water appliances or the ways they used water before the pilot began.

While this study does not have the data to reveal which aspects of portal use led to a reduction in water consumption, much of what participants reported in the surveys and interviews could have contributed. The 56

Portal Users reported seeing the most benefits. 77% reported that using the Portal increased their understanding of their water use, and interviewees gave examples ranging from understanding the amount of water wasted by a leak to realizing how much water a washer or dishwasher used. And informants reported that these realizations led to changes in behavior – fixing leaks, running dishwashers and washers only with full loads, and contemplating the purchase of more water efficient appliances. More generally, 61% of Portal Users reported making changes either to a water appliance (e.g., 29% reported fixing a leak) or their water use behavior (e.g., 33% reported letting the faucet run less) during the pilot study, and 48% stated they planned to make other changes in the future.

Design Implications and Issues

This examination of how Portal Users used and experienced the Water Portal suggests areas for future work.

The Value of Aggregate Visualizations

There is value in providing near real time graphs of water consumption, even if it does not show what is responsible for the consumption. The finding that participants could make sense of their graphs – mapping the graphs’ peaks and valleys to their practices and appliance use – is an important finding. This is useful to know because the additional instrumentation needed to tie usage to particular appliances is quite expensive when scaled up to the number of households in a city. Furthermore, the enjoyment that users exhibited when interpreting their water graphs suggests that they might also serve as motivational mechanisms.

Social Comparisons

The “Neighbors Like You” comparison and the weekly games were effective as well, albeit for a smaller set of Portal Users. It was interesting to note that although the comparison and game graphs were shown side by side, some users only paid attention to one or the other. This suggests that it is useful to provide a variety of mechanisms to have the best chance of engaging the broadest array of users. Of particular interest were those who “followed” the game but didn’t care about winning – the comments of these users suggest that they liked seeing themselves compared against individual households, even though those households were anonymous. This distinction, between comparisons with an average and comparisons with similar but anonymous households would be interesting to understand more deeply. Regardless, there appears to be considerable opportunity for future development of both comparisons and games.

Chat

While the chat was used for posting information and Q&A, there was almost no conversation among participants. This is disappointing, because such discussion could provide a channel for participants to share practical knowledge and

even to question the existing norms that underlie consumption (as suggested by Strengers [17]).

This merits further exploration because there are many examples of online communities that sustain rich and varied conversations, and thereby attract and retain participants. If the difficulty is simply lack of a critical mass of conversants, the problem may solve itself as the technology is deployed city-wide. Conversation might also be encouraged by providing a richer interaction model than the Portal’s simple chat-in-a-single-window. One that allowed users to create and monitor separate topics with practical orientations – e.g., “How to save water in the summer,” or “Are front loading washers worth it” – might encourage chat. Finally, encouraging participants to use real identities rather than anonymous ID’s might provide more grounds for discussion, particularly among neighbors.

Identity and Anonymity, Privacy and Visibility

Real identities could be usefully surfaced not only in chat but in other parts of the Water Portal. This, of course, raises a number of issues having to do with privacy and visibility. Interestingly enough, individual water usage information is not private in Dubuque: in theory, anyone can call up the city water department and request the water usage data for any address. While this policy was understandable when water usage data consisted of monthly consumption, it clearly needs to be revisited given the detailed and intimate picture of household activity made possible by the per-hour-usage view provided by the Portal.

At the same time, majorities of consumers discussed their water usage with others outside their households. While some of this is no doubt a function of the novelty of the Portal, and of the fact the pilot participants were enthusiastic volunteers, enabling the sharing of some degree of usage information seems crucial to promoting discussion of everything from community norms to city policy. One approach could be to share data aggregated at the neighborhood, parish, or school district level. Another approach could be to make it easy for individual users to publish their water usage on social networking systems.

Engagement Models

Finally, at a more general level, we are interested in the issue of engagement models. It seems unrealistic to envision a world where people wake up every morning and eagerly check their water usage. Perhaps games will engage some users in a persistent way, but engaging the others who most likely constitute the majority remains a challenge.

How might we move beyond the current default, the seek-out-and-use paradigm? Perhaps efforts could be made to periodically re-engage participants. This might be done occasionally, in response to sporadic or seasonal changes that impact water usage. Another approach would be to develop what we refer to as pseudo-ambient displays. While ambient displays at the point of use seem promising,

as we've noted they are expensive when scaled to entire urban populations. We might tap some of the advantages of ambient displays by redesigning the Portal so that portions of it could be embedded in or 'on the way to' a frequently visited site: perhaps a social networking site, or an online bill-paying application. One of our informants, in discussing his vision of the future, sketched out a similar idea: "It's all going to come together and it will probably end up merged in with your television and you'll have a touch screen on your TV and you'll just check everything while you're watching the news at the same time."

A final, more speculative idea has to do with enabling different groups to appropriate feedback technology. While working on this project, we've been struck by the number and diversity of community groups that care about resource conservation. At the same time, not all groups identified themselves as "green;" some were wary of being seen as "tree huggers" and/or being drawn into the global warming debate. Framings of resource conservation ranged from it being an intrinsic part of local (rural) values of frugality, to religiously grounded beliefs about stewardship, to good business sense, to civic-minded promotion of the city's image. And, yes, there was a group of ten ladies who met weekly to talk about how to save the earth. It might be useful to explore ways of disseminating information from government to citizens *via* community groups which can reframe ideas in ways that speak to their constituents. As one informant said, "You just have to find a way to engage folks and then it's fine. So whether that is through newspaper or radio, or by going to their Lions or Kiwanis club, if they hear their friends and their small group of folks say 'this is great and here's how it worked for me.' For folks who may not ordinarily take the plunge that is a better way to get people involved and engaged in the process."

ACKNOWLEDGMENTS

This project would not have been possible with the support of the City of Dubuque, the Dubuque 2.0 NGO, and the 303 households who participated in the pilot study.

REFERENCES

1. Arroyo, E., Bonanni, L., Selker, T. Waterbot: exploring feedback and persuasive techniques at the sink. *Proc. CHI 2005*, ACM (2005), 631-639.
2. Blevis, E. Sustainable interaction design: Invention & disposal, renewal & reuse. *Proc. CHI 2007*, ACM (2007), 503-512.
3. Brown, L. *Outgrowing the Earth: The Food Security Challenge in an Age of Falling Water Tables and Rising Temperatures*. Norton, 2005.
4. Chen, F., Dai, J., Wang, B., Sahu, S., Naphade, M. and Lu, C. Activity Analysis Based on Low Sample Rate Smart Meters. *Proc. Intl. Conf. on Knowledge Discovery and Data Mining*. ACM (2011), 240-248.
5. Darby, S. The effectiveness of feedback on energy consumption. 2006. <http://www.eci.ox.ac.uk/research/energy/electric-metering.php>. Accessed 9-11-11.
6. Darby, S. Social learning and public policy: Lessons from an energy-conscious village. *Energy Policy* 34 (2006), 2929-2940.
7. DiSalvo, C., Sengers, P., and Brynjarsdóttir, H. Mapping the landscape of sustainable HCI. *Proc. CHI 2010*, ACM (2010), 1975-1984.
8. IBM Research. *Smart Water Pilot Report*. June 10, 2011. [Public report] <http://www.cityofdubuque.org/DocumentView.aspx?DID=3116>. Accessed 9-11-11.
9. ICF International. *Water and Energy: Leveraging Voluntary Programs to Save Both Water and Energy*. March 2008. <http://water.epa.gov/scitech/wastetech/upload/Final-Report-Mar-2008.pdf>. Accessed 9-11-11.
10. IEEE. Water Vs. Energy: Special Report. *IEEE Spectrum*, 47:6, June 2010.
11. Froehlich, J., Findlater, L., and Landay, J. The design of eco-feedback technology. *Proc. CHI 2010*. ACM (2010), 1999-2008.
12. Kappel, K. and Grechenig, T. "show-me": Water consumption at a glance to promote water conservation in the shower. *Proc. Pervasive 2009*. ACM (2009), 1-6.
13. Kuznetsov, S. and Paulos, E. 2010. UpStream: motivating water conservation with low-cost water flow sensing and persuasive displays. *Proc. CHI 2010*, ACM (2010), 1851-1860.
14. Petersen, J.E., V. Shunturov, K. Janda, G. Platt, K. Weinberger. Combining real-time feedback on resource use with incentives stimulates dormitory residents to reduce electricity consumption. *Int. J. of Sustainability in Higher Education*, 8, (2007), 16-33.
15. Pierce, J., Odom, W., and Blevis, E. Energy aware dwelling: A critical survey of interaction design for eco-visualizations. *Proc. OZCHI 2008*, ACM (2008), 1-8.
16. Pierce, J., Fan, C., Lomas, D., Marcu, G. and Paulos, E. Some consideration on the (in)effectiveness of residential energy feedback systems. *Proc. DIS 2010*, ACM (2010), 244-247.
17. Strengers, Y. Designing eco-feedback systems for everyday life. *Proc. CHI 2011*. ACM (2011) 2135-2144.
18. UNICEF. *UNICEF Handbook on Water Quality*. 2008. http://www.unicef.org/wash/files/WQ_Handbook_final_signed_16_April_2008.pdf. Accessed 9-11-11.
19. UN Water. *Coping with Water Scarcity – Challenge of the Twenty-first Century*. UN Water, 2007. <http://www.fao.org/nr/water/docs/escarcity.pdf>. Accessed 9-11-11.