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Sustain Water Conservation Behaviors Using Nonparametric Ranking and Social Marketing

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SUSTAIN WATER CONSERVATION BEHAVIORS USING NONPARAMETRIC

RANKING AND SOCIAL MARKETING

by

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ABSTRACT

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Voluntary water conservation programs involving generic feedback and water-saving tips usually have temporary effects because these programs lack personalized recommendations specific to the customer's end-uses of water and conservation intent. We reviewed past conservation studies (n=55) and found that the effects of conservation campaigns waned over time. This thesis combined water end use and conservation intent data to create personalized messages for users to sustain water-saving behaviors. First, rank users based on water use to identify the end-use behavior(s) that can be improved. Next, assess the household's conservation intent. Third, segment users based on their water-saving potential and conservation intent. Finally, create customized visual messages to help users in each group adopt and sustain water-saving habits. We illustrate the methods using disaggregated water data from the Residential End-Uses of Water-2016 study. We found that more than 90% of users can adopt water-saving behaviors and potentially save up to 25% of total water use volume. A next step is to field test the method.

(159 pages)

PUBLIC ABSTRACT

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Mahmudur Rahman Aveek

Circulation of water use feedback and conservation messaging are strategies implemented to reduce water demand on a short-term (seasonal) basis. Often considered a less impactful strategy than other tactics such as price increments and usage restrictions, authorities mostly use feedback in informational campaigns with a focus to apprise users about their water use. Such conservation programs have had limited success that has been attributed to the fact that the information provided with the feedback campaigns was generic and did not motivate users enough to sustain their water-saving behaviors. However, the advent of disaggregation technologies that can provide appliance-wise water use data to households can drastically upgrade prior feedback and normative messaging approaches. Nevertheless, usage information is not enough to encourage users to adopt water-saving actions. Message selection should depend on its motivational potency, and users' understanding of water conservation, which requires careful psychological analysis that feedback campaigns often ignore. Using the community-based social marketing strategy—a system that combines usage information and behavioral psychology to develop user-specific interventions—we developed a conceptual framework for a customized strategic messaging system that will provide household-specific water use information, behavior-specific water-saving tips, with strategic messages to motivate households adopt and sustain their water-saving habits.

Result of this study will be beneficial to water managers who intend to use feedbacks and normative messaging for conservation purposes.

DEDICATION

To my

Wife Nuzhat Azra, whose continued support is the prominent source of my motivation,

Parents, Anjuman Ara Chowdhury and Mizanur Rahman, for always believing in me and for their blessings,

Sister Maisha Rahman, who unknowingly helps me become a better person.

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CHAPTER 1

INTRODUCTION

Water use among single-family residential households in the United States has decreased by more than 11,000 gallons/year since 1978 (Rockaway et al., 2011). Plumbing codes, installation of efficient appliances, and decreasing household size have contributed to this decline. The Energy Policy Act of 1992 (DOE 1992) and seasonal restrictions on outdoor usage have helped cut water use even further (Inman & Jeffrey, 2006; Syme et al., 2000). Yet, domestic water usage in the United States is still notably high compared to many other western countries. Furthermore, researchers anticipate that drought that has already devastated the western United States will become more severe (Hao et al., 2018). Hence, managers need to develop approaches to encourage users to curtail their excessive water use and sustain conservation behaviors (Levin & Muehleisen, 2016).

Prior studies indicate that demand-side management strategies involving price increment and seasonal restriction can reduce water use (Cahill & Lund, 2013; Cooper et al., 2011; Kenney et al., 2008; Olmstead, 2009; Richter et al., 2020). But such strategies are restrictive, coercive, and users eventually try to subvert the rules (De Young, 1993). Contrary to such forced strategies, voluntary programs try to reduce demand by asking or requesting that users to reduce their water-use through awareness-building programs, information, and educational campaigns. Furthermore, review articles, such as Inman & Jeffrey (2006) posited that voluntary strategies must run parallelly with other demand-management approaches to reach the maximum reduction in water demand. Feedback in the form of water bills rarely helped users improve their end-use behaviors or encouraged users to adopt conservation actions (Levin & Muehleisen, 2016), and awareness building approaches work better with school-going children than with adults (Thompson et al., 2011). Hence, many studies investigated and reported the effects of feedback campaigns that used strategic messaging components, such as social comparison, instantaneous water use, information about leakage, reward, rebate, etc., to encourage users to adopt and retain water-saving behaviors (Brick et al., 2017; Erickson et al., 2012; Ferraro & Price, 2013; Fielding et al., 2013; Katz et al., 2016; Liu et al., 2016; Schultz et al., 2016). For instance, Ferraro & Price (2013) reported a water-use reduction of 25% among users who received feedback messages as compared to a control group, while Mitchell & Chesnutt (2013) observed that both high and low water users retained their efficient behaviors over a year after receiving strategic conservation messages. However, most research has reported that the voluntary strategy's effect starts to disappear very soon after the intervention period ends (Fielding et al., 2013; Koop et al., 2019). Messaging strategies lose their potency over time because they lack 1) specificity , 2) psychological drivers that encourage and sustain efficient water use behaviors, and 3) two-way communication between consumers and water providers (Sønderlund et al., 2016; Syme et al., 2000). Messages can be improved by combining water end-use information with behavioral psychology data to provide appliance and behavior-specific tips (Berkman, 2002; Koop et al., 2019; Sønderlund et al., 2016). One such tactic that can be applied is community-based social marketing—a behavior modification tactic—to improve water conservation behavior. This approach theorizes that users shy away from efficient behaviors due to different types of barriers, which vary from user to user (Mckenzie-Mohr, 2000). Some examples of barriers—in the case of water conservation—are a lack of clarity on why conservation actions are required, which end-use behaviors to focus on, how to act to save the optimum water volume, etc. Hence, to help users improve their behaviors, community-based social marking suggests a thorough analysis of users' conservation psychology and behavior (water use) to identify these barriers and address them through personalized user-specific interventions. Previously, the tactic has been successfully used to change smoking and alcohol habits (Stead et al., 2007), promote physical activities (Drury, 2009), and promote community composting (Boivin et al., 2016).

This research is possible because we can now inexpensively collect appliance-specific data with research (Cominola et al., 2015; Horsburgh et al., 2017; Pacheco et al., 2020) or commercially (Flume, 2021). Customers can access their data by mobile phone or web-based platforms. Hence, to help water users adopt and sustain conservation behaviors through messaging and feedback, this research first identifies the most effective messaging components field-tested by prior empirical studies. Next, the research develops a framework to facilitate water managers' design of conservation campaigns that combines disaggregated water use information with effective messaging components as reported by prior studies along with psychology data such as users' attitudes, susceptibility to peer pressure, and the perception of control over water behavior. Furthermore, to target end-uses with the highest conservation potential, we use a ranking system that is easy to employ and removes dependency on modeled data. This research answers the following questions:

1. Which messaging components, i.e., statements, plots, visual aids, etc., were most effective in promoting water-saving actions among users?

2. How may a ranking approach be used to target end-use behaviors with high conservation potential and quantify water-savings potential?
3. How to segment users based on their water use and psychological standing to maximize the effects of voluntary feedback strategies?
4. What messages to deliver to particular user groups to encourage them to adopt and sustain water-saving measures?

Chapter 2 reviews and synthesizes 80 articles from behavioral science, water, and energy conservation fields to identify messaging components for encouraging conservation behaviors. The identified components are used in Chapter 3 to presents a framework that combines disaggregated data from the Residential end-uses of water study (DeOreo et al., 2016) with psychology data to create household-specific strategic messages. Chapter 4 summarizes the study’s main findings.

References

Berkman, P. A. (2002). Ecosystem Conservation. *Science Into Policy*, *279*(April), 157–181. https://doi.org/10.1016/b978-012091560-6/50013-5

Boivin, M., Gagné, E., & Saint-Arnaud, V. C. (2016). Using Segmentation and Theory to Design Better Promotion and Prevention Campaigns: A RECYC-QUÉBEC Case Study. In *Segmentation in Social Marketing: Process, Methods and Application*. https://doi.org/10.1007/978-981-10-1835-0

Brick, K., Martino, S. De, & Visser, M. (2017). *Behavioural Nudges for Water Conservation : Experimental Evidence from Cape Behavioural Nudges for Water Conservation : Experimental Evidence from Cape Town*. (February 2018). https://doi.org/10.13140/RG.2.2.25430.75848

Cahill, R., & Lund, J. (2013). Residential Water Conservation in Australia and California. *Journal of Water Resources Planning and Management*, *139*(1), 117–121. https://doi.org/10.1061/(asce)wr.1943-5452.0000225

Cominola, A., Giuliani, M., Piga, D., Castelletti, A., & Rizzoli, A. E. (2015). Benefits and challenges of using smart meters for advancing residential water demand modeling and management: A review. *Environmental Modelling and Software*, *72*, 198–214. https://doi.org/10.1016/j.envsoft.2015.07.012

Cooper, B., Burton, M., & Crase, L. (2011). Urban water restrictions: Attitudes and avoidance. *Water Resources Research*, *47*(12), 1–13. https://doi.org/10.1029/2010WR010226

De Young, R. (1993). Changing Behavior and Making it Stick: The Conceptualization and Management of Conservation Behavior. *Environment and Behavior*, Vol. 25, pp. 485–505. https://doi.org/10.1177/0013916593253003

DeOreo, W. B., Mayer, P., & Kiefer, J. (2016). Residential End Uses of Water, Version 2: Executive Report. In *Water Research Foundation*. https://doi.org/4309b

Drury, R. (2009). Reducing urban demand for wild animals in Vietnam: examining the potential of wildlife farming as a conservation tool. *Conservation Letters*, *2*(6), 263–270.

Erickson, T., Podlaseck, M. E., Sahu, S., Dai, J. D., Chao, T., & Naphade, M. (2012). The Dubuque Water Portal: Evaluation of the uptake, use and impact of residential water consumption feedback. *Conference on Human Factors in Computing Systems - Proceedings*, 675–684. https://doi.org/10.1145/2207676.2207772

Ferraro, P. J., & Price, M. K. (2013). *Using Non-Pecuniary Strategies to Influence Behavior : Evidence from a Large Scale Field Experiment*. (December). https://doi.org/10.2307/23355650

Fielding, K. S., Spinks, A., Russell, S., McCrea, R., Stewart, R., & Gardner, J. (2013). An experimental test of voluntary strategies to promote urban water demand management. *Journal of Environmental Management*, *114*, 343–351. https://doi.org/10.1016/j.jenvman.2012.10.027

Flume. (2021). Flume. Retrieved from https://flumewater.com/product/

Hao, Z., Hao, F., Singh, V. P., & Zhang, X. (2018, December 1). Changes in the severity of compound drought and hot extremes over global land areas. *Environmental Research Letters*, Vol. 13. https://doi.org/10.1088/1748-9326/aaee96

Horsburgh, J. S., Leonardo, M. E., Abdallah, A. M., & Rosenberg, D. E. (2017). Measuring water use, conservation, and differences by gender using an inexpensive, high frequency metering system. *Environmental Modelling and Software*, *96*, 83–94. https://doi.org/10.1016/j.envsoft.2017.06.035

Inman, D., & Jeffrey, P. (2006). A review of residential water conservation tool performance and influences on implementation effectiveness. *Urban Water Journal*, Vol. 3, pp. 127–143. https://doi.org/10.1080/15730620600961288

Katz, D., Grinstein, A., Kronrod, A., & Nisan, U. (2016). Evaluating the effectiveness of a water conservation campaign : Combining experimental and field methods Evaluating the effectiveness of a water conservation campaign : Combining experimental and fi eld methods. *Journal of Environmental Management*, *180*(October 2017), 335–343. https://doi.org/10.1016/j.jenvman.2016.05.049

Kenney, D. S., Goemans, C., Klein, R., Lowrey, J., & Reidy, K. (2008). *RESIDENTIAL WATER DEMAND MANAGEMENT : LESSONS FROM AURORA , COLORADO 1*. *44*(1). https://doi.org/10.1111/j.1752-1688.2007.00147.x

Koop, S. H. A., Dorssen, A. J. Van, & Brouwer, S. (2019). Enhancing domestic water conservation behaviour : A review of empirical studies on influencing tactics. *Journal of Environmental Management*, *247*(March), 867–876. https://doi.org/10.1016/j.jenvman.2019.06.126

Levin, T., & Muehleisen, R. (2016). *Saving Water through Behavior Changing Technologies*. 1–12.

Liu, A., Giurco, D., & Mukheibir, P. (2016). Urban water conservation through customised water and end-use information. *Journal of Cleaner Production*, *112*, 3164–3175. https://doi.org/10.1016/j.jclepro.2015.10.002

Mckenzie-Mohr, D. (2000). *Promoting Sustainable Behavior : An Introduction to Community-Based Social Marketing*. *56*(3), 543–554.

Mitchell, D. L., & Chesnutt, T. W. (2013). *Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports*. Retrieved from https://www.financingsustainablewater.org/sites/www.financingsustainablewater.org/files/resource_pdfs/MCubed-Watersmart_evaluation_report_FINAL_12-12-13%2800238356%29.pdf

Olmstead, S. M. (2009). Reduced-form versus structural models of water demand under nonlinear prices. *Journal of Business and Economic Statistics*, *27*(1), 84–94. https://doi.org/10.1198/jbes.2009.0007

Pacheco, C. J. B., Horsburgh, J. S., & Tracy, J. R. (2020). A low-cost, open source monitoring system for collecting high temporal resolution water use data on magnetically driven residential water meters. *Sensors (Switzerland)*, *20*(13), 1–30. https://doi.org/10.3390/s20133655

Richter, B. D., Benoit, K., Dugan, J., Getacho, G., Laroe, N., Moro, B., … Townsend, A. (2020). Decoupling urban water use and growth in response to water scarcity. *Water*

(Switzerland), *12*(10), 1–14. https://doi.org/10.3390/w12102868

Rockaway, T. D., Coomes, P. A., Joshua, R., & Barry, K. (2011). Residential water use trends in North America. *Journal / American Water Works Association*, *103*(2), 76–89. https://doi.org/10.1002/j.1551-8833.2011.tb11403.x

Schultz, P. W., Messina, A., Tronu, G., Limas, E. F., Gupta, R., & Estrada, M. (2016). Personalized Normative Feedback and the Moderating Role of Personal Norms : A Field Experiment to Reduce Residential Water Consumption. *Environment and Behavior*, *48*(2), 686–710. https://doi.org/10.1177/0013916514553835

Sønderlund, A. L., Smith, J. R., Hutton, C. J., Kapelan, Z., & Savic, D. (2016). Effectiveness of smart meter-based consumption feedback in curbing household water use: Knowns and unknowns. *Journal of Water Resources Planning and Management*, *142*(12). https://doi.org/10.1061/(ASCE)WR.1943-5452.0000703

Stead, M., Gordon, R., Angus, K., & McDermott, L. (2007). A systematic review of social marketing effectiveness. *Health Education*.

Syme, G. J., Nancarrow, B. E., & Seligman, C. (2000). The Evaluaion of Information Campaigns to Promote Voluntary Household Water Conservation. *Evaluation Review*, *24*(6), 539–578.

Thompson, R. R., Coe, A., Klaver, I., & Dickson, K. (2011). *Applied Environmental Education & amp ; Communication Design and Implementation of a Research-Informed Water Conservation Education Program Design and Implementation of a Research-Informed*. *0389*. https://doi.org/10.1080/1533015X.2011.575728

CHAPTER 2

SUSTAINING WATER CONSERVATION: A SYNTHESIS OF RESEARCH ON MOTIVATORS, MESSAGE TAILORING, AND TACTICS

Key points

- Synthesized 80 papers from behavior sciences, psychology, resource management, and health communication fields to identify factors that encourage and sustain conservation behaviors.
- 8 strategic message types reduced water demand by 0.6% to 88%.
- Social comparison and public plea reduced water demand the most (8-26%).
- To maximize motivational effect, include public plea, social comparison, tips, and share additional resources.

2.1 Introduction

This paper's goal is to synthesize research from behavior sciences, environmental psychology, resource conservation, and health communication to identify the motivators, message tailoring, and tactics that sustain water conservation behavior. Feedback and strategic messages are used to encourage voluntary reduction in water use. A water bill showing consumption information is the most common form of feedback. Beyond just consumption information, there is a need to help users adopt and sustain conservation behaviors (Berkman, 2002; Koop et al., 2019).

Some examples of strategic messaging are social and self-comparison (Mitchell & Chesnutt, 2013), public plea (Brick et al., 2017), and appealing to one's conscience (Katz et al., 2016). While some studies reported that voluntary approaches reduce water use (Brick, Martino, & Visser, 2017; Katz et al., 2016; Mitchell & Chesnutt, 2013; Schultz et al., 2016; Schultz et al., 2019), others questioned their potency. They pointed out that price penalties and seasonal restrictions are more effective to reduce demand (Fielding et al., 2013; Geller et al., 1983). At the same time, water use behaviors revert after price penalties or restrictions are lifted.

Past studies showed the strengths and weaknesses of messages to encourage voluntary conservation (Inman & Jeffrey, 2006; Koop et al., 2019; Sønderlund et al., 2016; Syme et al., 2000). For example, Syme et al. (2000) pointed out that most voluntary campaigns achieved an approximate 10-25% reduction in water usage. They concluded that prior studies failed to provide enough evidence to justify the long-term effect of voluntary campaigns and recommended incorporating psychological data to form interventions. Inman & Jeffrey (2006) reviewed different demand-side management tools, such as price increments (block price increase), technologies (application of metering and efficient appliances), and voluntary approaches (educational and informational). They posited that a combination of voluntary and mandatory tools are required to achieve maximum water savings. They also emphasized that consumer participation is the most crucial factor in the success of any demand-side management tactic. Engage consumers in different water-savings-related activities to sustain conservation behaviors. Build awareness and relay motivational support in parallel with other demand-side management policies.

Sønderlund et al. (2016) investigated the effectiveness of using high-frequency data for feedback purposes by examining 21 studies. They tested the effectiveness of using granular data along with, self and social comparison information for prompting conservation actions. However, they did not provide guidance on when to use message components because a similar component may not incite similar motivation in a different group of users. For example, Brick et al., (2017) reported a 0.6-2% decrease in consumption from social comparison interventions, while Ferraro & Price (2013) reported a decrease of more than 25% after employing similar approaches. Recently, Koop et al. (2019) examined the effectiveness of different messaging components and suggested to combine components to improve the success rate of behavior-changing interventions. They gave no specific guidance on how to incorporate components into a customer-specific message to reduce water use.

This paper synthesizes 80 articles from behavioral sciences, water conservation, energy conservation, environmental psychology, and health communication to identify factors that motivate and sustain conservation behaviors. The work answers three research questions:

1. How to select and tailor motivational contents for strategic messaging campaigns?
2. What is the long-term effectiveness of feedback and strategic messaging campaigns?
3. How to construct effective messages for water conservation campaigns to reduce and sustain conservation behaviors?

The next section describes the selection of articles while subsequent sections synthesize lessons about psychological motivators, message construction, messaging components, feedback medium, frequency, and duration. A penultimate section recommends how water managers can construct and deploy messages to reduce water and sustain conservation behaviors. A final section concludes.

2.2 Selection of articles

This research first looked into water conservation reviews (n=7) from 2000 to 2019 to gain insight into recent voluntary approaches. While this research provided valuable information on the feedback campaigns and generic suggestions for future improvement, we found that managers might require more direct and specific recommendations when it comes to suggestions regarding the selection of messaging contents, feedback intensity, feedback duration, and feedback medium. Due to the similar nature of feedback messaging, we also considered the energy sector by reviewing papers related to voluntary energy conservation (n=3). Next, we investigated the behavioral sciences field to clearly understand motivation and factors affecting behavioral intentions using keywords "motivation," "intrinsic motivation," "extrinsic motivation," "behavioral intention," and "behavioral sustenance." Among the search results, only the studies focused on environmental behavior, water, energy, or environmental conservation were selected (n=21). These studies helped us assess how different messaging components could influence user conservation behaviors. Next, we looked into different water and energy conservation studies that used feedback or strategic messaging (n=2,579). We narrowed our search using keywords "behavioral nudges," "social comparison," "feedback," "conservation message," and finally selected thirty-two water conservation studies and thirteen energy conservation studies. Finally, to better understand how the messages should be constructed to target different motivational drivers, we searched for message tailoring in water and energy conservation. Unfortunately, we could not find articles relevant to our studies. Hence, we looked into the health communication field, which has a vast collection of studies on messaging and communication strategies. We selected four studies related to message framing and tailoring that used behavioral improvement approaches often used by environmental and water conservation campaigns. A summary of our selected articles is presented in Table 2.1.

Table 2.1: The number of articles reviewed in this research

Topic	Reviewed articles
Behavioral science	21
Water conservation review	7
Energy conservation review	3
Water conservation	32
Energy conservation	13
Health communication	4
Total	80

2.3 Psychological motivators

All studies involving feedbacks and normative messaging clearly showed a noticeable decrease in energy and water consumption (Ferraro & Price, 2013; Fielding et al., 2013; Mitchell & Chesnutt, 2013; P. W. Schultz et al., 2016). Yet, as the intervention ceased, users returned to their initial usage levels. One probable cause is that users perceive information differently, and the same type of intervention, although helping users start conservation actions, cannot provide enough motivation to retain those behaviors in the long term. Therefore, managers could be more successful if they understood user psychology and selected tailored motivational content before launching voluntary conservation campaigns. This section discusses these generic motivation types and includes some factors affecting motivations.

2.4 Types of motivation

Generally, there are two types of motivation: internal or external (Bénabou & Tirole, 2003). Internal motivators stimulate an individual to achieve something for his/her own sake. For instance, when a person wants to do something because he/she finds the act enjoyable, exciting, or because the individual wants to attain an abstract or spiritual satisfaction, then the motivation is termed internal motivation. Self-determination theory—a psychological theory concerning internal motivation—argues that three factors influence internal motivation (Ryan & Deci, 2000). The first is “autonomy” or the belief that the user owns and controls the behavior in question. Next is “competence” which is something the user achieves by repeating a behavior multiple time. And last is “relatedness” which occurs when the user assumes a bond with his/her community. Providing water use information to help users improve their end-use behaviors, urging consumers to reduce water use for nature or a community suffering severe drought—are some examples of prompting internal motivation for conservation purposes.

On the other hand, when a person commits an act to achieve an external goal, i.e., a reward, the motivation is referred to as external motivation. The theory of planned behavior (TPB), which explains how external motivation works, argues that intention is the best predictor of behavior (Ajzen, 1991). And the intention is dependent upon three factors: attitude, subjective norm, and perceived behavioral control. "Attitude", as defined by TPB, is the rationale regarding the new behavior. In other words, the individual weighs the pros and cons of the new behavior and evaluates how the behavior may affect the individual. "Subjective norm" is the evaluation of the society or the individual's peers regarding the behavior. And "perceived behavioral control" is the individual's perception of a new behavior's difficulty level; in other words, the evaluation of how easily the individual can incorporate the new behavior into their daily life. Comparative water use statements to prompt peer pressure (Mitchell & Chesnutt, 2013), messages stating how an efficient household uses their water (Sønderlund et al., 2016), and public recognition for conserving water (Brick et al., 2017), are some examples of prompting water conservation through external motivation.

Past studies related to water conservation could not decisively state which motivational agent is more effective for encouraging users. Studies in other fields, such as environmental psychology, suggest that individuals with intrinsic/internal motivations are better at sustaining environmental behaviors—behaviors that cause less harm to the environment (Monroe, 2003). However, intrinsic motivation is often gained from life experience (De Young, 1993). Hence it is hard for a third party—such as a water manager—to identify a suitable intrinsic motivator and utilize it to improve a consumer's behavior. Conversely, although external goals or motivating agents only temporarily affect the human psyche (Bénabou & Tirole, 2003), their numbers are plentiful and they are usually better at engaging users to adopt new behaviors (Monroe, 2003). However, the application of different motivational agents does not have to be exclusive. In fact, some studies suggested that using different motivational agents simultaneously may increase the probability of encouraging and sustaining user's (conservation) behaviors (Delmas et al., 2013).

2.5 Additional factors affecting motivation

The factors mentioned earlier—autonomy, competence, relatedness, attitude, subjective norm, and perceived behavioral control—are only the core ones identified by the two behavioral models. However, there are more influencers (Aitken et al., 1994; Brick et al., 2017; Jorgensen et al., 2009; Lam, 2006; Schultz et al., 2016):

- Cognitive dissonance is a psychological process where information tells the user they are behaving opposite to what the user thought they were doing (Festinger, 1957). The inconsistency between belief and behavior can trigger a behavioral change to conform with the belief. Aitken et al. (1994) reported a 4.3% drop in daily water use among users due to a messaging intervention using cognitive dissonance principles. Such an approach can be effective because many people have wrong perceptions regarding their water use practices (Beal et al., 2011).
- Personal norm—an individual's belief as they think about how everyone else should behave in a particular situation—is a significant predictor of how they may behave when provided with specific types of feedback messaging (Schultz et al., 2016). Personal norms are shaped by experience and moral obligations (Cialdini et al., 1991). Although not a behavior-influencing motivator per se, the degree of personal norm affects a person's susceptibility to the persuasive powers of social motivators, such as peer pressure (Chaudhary et al., 2017). Schultz et al. (2016) posited that someone with a high/strong personal norm is less likely to be encouraged or dissuaded by the activities of others. In their experiment, they found that users with low/week personal norms reduced their water use by 16-26% when provided with normative messaging—

statements showing how efficient households behave—as feedback. On the other hand, users with high personal norms continued their pre-intervention behaviors.

- Trust refers to user’s faith in authority/utility/water manager’s sincerity to reduce water-loss (Jorgensen et al., 2009). If users believe the authority is sincere in reducing water loss and is undertaking different conservation efforts, i.e., constructing new reservoirs, launching feedback campaigns, updating legislation, etc., then the users reciprocate by adopting water-saving behaviors.
- Response efficacy refers to the user’s belief in how their efforts help the community to reach the collective conservation goal (Lam 2006). Simply put, when a user believes that their contribution, i.e., water-saving measures, are helping the community to achieve their conservation target, the user will be more motivated to adopt and sustain conservation behaviors (Lam, 2006; Lowe et al., 2015; Warner et al., 2015).
- Contextual factors: Russell & Fielding (2010) posited that any physical component (e.g., availability of efficient appliances) or financial component (rebate or incentive) that can motivate users' water behavior, can be contextual factors. Unfortunately, the effect of such factors has not been fully studied in the water conservation field, but in environmental conservation studies, such factors are often considered as catalysts to internal and external motivational drivers (Monroe, 2003).

2.6 Messaging

2.6.1 Message construction

This section discusses some significant aspects of message construction. Seemingly minute details can vastly improve the effectiveness of messages sent to customers (Pope, Pelletier, & Guertin, 2018). Here, we focus on message framing, and norm activating messaging.

2.6.1.1 Message framing

Framing is the process of constructing the message to make it more salient by stating why a conservation action is good or how over-use may harm the environment (Warner et al., 2015). A "gain-framed" statement tells users about an action's benefit or advantage. For instance, "Fixing your leaks will prevent damage to your house and save you $__ in one year." Conversely, a "loss-framed" statement emphasizes the consequences or disadvantages if the users do not change their current behavior. For example, "Fix your leak; otherwise, you will lose approximately $___ in the upcoming year, and leaks will also damage your house's foundation."

There have been many studies on message framing in the health communication field, and most of these indicate that gain-framed messages are better at helping users adopt preventative measures and sustaining healthy behaviors (O'Keefe & Jensen, 2007). However, Latimer et al. (2007) provided examples where loss-framed messages were better at helping users adopt healthy behaviors. For sustenance purposes, i.e., continuing the healthy behavior for a prolonged time, gain-frame messages prevailed. Unfortunately, there have not been many studies concerning this topic in the water field. Syme et al. (2000), in their review, was the first to note that personal loss-framed messages—the message that focuses on what the user is losing as an individual—are better at helping users adopt water conservation behaviors. Indeed, personal loss-framed messages might be better for water conservation purposes, as Britton et al. (2013) reported that 74% of the users in their study wanted to learn about leaks and the approximate cost associated with losses if leaks were not fixed. However, the results from Warner et al. (2015) indicated that gain-framed personal messages were better at improving users' water conservation outlook, i.e., users were showed more enthusiasm to adopt water-saving actions in the future. Furthermore, when stating what users could gain or lose as a community, Warner et al. (2015) found that gain-framed messages performed better than loss-framed messages for motivational purposes.

2.6.1.2 Norm activating message

Norm activating messages try to establish behaviors, such as conservation or water-saving habits, as praise-worthy or socially desirable behaviors. When a message focuses on a household's current water use behavior and then tells them what to do to improve the behavior—such statements are referred to as descriptive norm statements (Groot & Steg, 2009). Most of our reviewed studies used this technique by showing the water-use comparison between households and their neighbors and then providing end-use tips for improving behaviors. As discussed earlier, these studies reported a significant decrease during the intervention period (Ferraro & Price, 2013; Fielding et al., 2013; Liu, Giurco, & Mukheibir, 2016b). However, Schultz et al. (2007) noted that users who were already consuming less energy than their neighbors tended to increase their consumption once such comparative messages were delivered. Aitken et al. (1994) also reported that lower water consumers started to increase water use (an average of 12%) after receiving information that they were using less than they initially anticipated. This phenomenon where a low consumer gravitates towards the larger consumption behavior is called the boomerang effect (Schultz et al., 2016).

To negate or reduce the boomerang effect, Cialdini et al. (1991) proposed creating messages using the injunctive norm technique where users are notified of what is expected from them instead of directly stating what to do. Katz et al. (2018) reported that water-users preferred messages constructed with suggestive and gentler tones over assertive language, and such messages were also more effective at convincing users to adopt water-saving behaviors. However, as most conservation campaigns had already started designing messages using social comparisons and tips, Schultz et al. (2007) proposed to include visual aids, more specifically emoticons, to help users realize whether their behavior was conservative (smiling green-faced emoticons) or wasteful (frowning red-faced emoticons). Later studies validated this finding. For example, Otaki et al. (2017) experimented on user groups from similar environmental, climatological, and socio-economic statuses and reported that high water users reduced their water use and low users did not increase their water use after receiving messages with emoticons. The use of emoticons has been adopted by recent conservation campaigns as well (Allcott, 2011; Mitchell & Chesnutt, 2013; Schultz et al., 2019).

2.6.2 Message components

Here we review the prior studies that used feedback and strategic messaging for conservation or demand reduction purposes. We reviewed 32 studies from the water resources field and 13 studies from the energy conservation field (Table 1). We also briefly discuss some theories from behavioral sciences. Our primary goal was to report the efficacy of different messaging components, especially their effectiveness in prompting different internal and external motivational factors. We reviewed the studies not only from the water resources field but also from energy conservation because the energy field has been employing strategic messages since the early 1970s for conservation purposes. The summary of these reviewed studies is provided in the Appendix.

2.6.2.1 Consumption information

Consumption information is the most common form of feedback. A practical example is the water bill that shows usage and the associated billing information. Depending on the data type, i.e., aggregated and disaggregated, there are different ways utilities may choose to show consumption information to their customers, such as simple one-line statements (Ferraro & Price, 2013) or plots of usage (Liu et al., 2016; Mitchell & Chesnutt, 2013; Schultz et al., 2016).

Users generally prefer volumetric (gallon/liter) and financial information ($/gallon or $/liter) as opposed to figurative values such as buckets of water (Liu et al., 2016b). Some studies suggested adding block prices to bills (Brick et al., 2017). However, others determined that it was better to use visual aids instead of statements to attract users' to their water use information if aggregated data was circulated (Fischer, 2008). Typically, time-series data showing monthly water use for the past few months is provided in water bills (Barnett et al., 2020). Sometimes additional visual aids, such as emoticons (Mitchell & Chesnutt, 2013; Otaki et al., 2017) or color-coded scales (Pereira et al., 2013) are added to indicate users' usage efficiency status. If high-frequency water data were collected, then time-series graphs illustrating hourly, weekly, and monthly water use were circulated (Alberts et al., 2016; Erickson et al., 2012; Mitchell & Chesnutt, 2013).

When disaggregated data were used as feedback, studies included appliance-wise bar charts (Froehlich et al., 2012) or pie charts combining all appliances to show the comparative use of different appliances (Liu et al., 2016b). This information was often supplemented by time series plots to provide an overall picture of water use (Froehlich et al., 2012). However, Froehlich et al. (2012) found that bar graphs were the most intuitive way to convey usage information, and most users preferred bar graphs over pie charts in a post-intervention survey. We also investigated some feedback studies from the energy field that provided end-use specific information as feedback and observed that here too bar graphs were the most effective method of conveying appliance-wise energy-use information to users (Benders et al., 2006; Dobson & Griffin, 1992; Ueno et al., 2006).

Circulation of consumption information may function as a self-motivating tool, i.e., users may change end-use behaviors after seeing their consumption record, but such approach rarely helps water users to improve their behavior. First, the main reason why such feedback information rarely worked as a behavior improvement tool is that the water price was relatively inelastic, meaning the price of water was too low to make any noticeable impact on a household's finances (Cahn et al., 2020; Geller et al., 1983; Inman & Jeffrey, 2006; Liu & Mukheibir, 2018). Secondly, Levin & Muehleisen (2016) posited that users usually get such billing information after a significant time has passed—making the effect of such feedback passive and also meaning that the user cannot relate the information directly to their behavior. However, while investigating the effects of instantaneous feedback for a prolonged time period (one year) in the energy field, Pereira et al. (2013) noted that even instantaneous feedback did not help reduce the overall energy consumption. This indicates that additional messages must be circulated for promoting conservation behavior with consumption information, such as comparative statements (Ferraro & Price, 2013; Mitchell & Chesnutt, 2013), authority's appeals to cut back water use to tackle droughts (Brick et al., 2017; Katz et al., 2016a), and information on how an efficient households use their water (Schultz et al., 2016; Schultz et al., 2019).

There are cases where simple consumption data have been used to motivate users to change their behaviors, primarily when a cognitive dissonance tactic was employed. Cognitive dissonance theory posits that if a user is confronted with the evidence that they are consuming more than they initially believed, then inner disharmony or tension occurs, and the user will try to change their behavior to alleviate this dissonance (Festinger, 1957). To create dissonance through messages, a manager would first have to survey users to determine what they think about their water use, i.e. daily water use (Aitken et al., 1994) or shower duration (Dickerson et al., 1992). Next, the manager would have to monitor water use and provide tailored messaging in which actual water use is elaborated to anyone who is using more water than they were initially thinking. Indeed, this dissonance-centric approach can be very effective for improving conservation behaviors. For instance, Beal et al. (2011) conducted a study comprised of 222 households to assess users' perceptions regarding their daily water use and found that more than 40.5% of the users who thought they were using water efficiently were using more water daily than the average population. Aitken et al. (1994) conducted a paper-based feedback study involving cognitive dissonance in which participants were divided into three groups and only members of the dissonance group were asked about their water use practices as environmentally cautious citizens before the actual feedback program. During the intervention period, the dissonance group was provided with information that they were using more than an environmentally concerned citizen, which resulted in an average 4.3% reduction in water use.

2.6.2.2 Leak information

Smart metering technology can help identify leaks. For example, by identifying minimum night flow (MNF) a utility can detect leaks by analyzing high-frequency data of any household fitted with smart meters (Farah & Shahrour, 2017). Studies posited that leak identification was the most sought-after information by users who used or intended to use smart-meters (Cahn et al., 2020; Liu et al., 2017; Liu & Mukheibir, 2018) and most commercial smart-meter companies provide leakage detection features (Flume, 2021). From a psychological perspective, this information targets attitude—the factor that helps users decide whether an action is beneficial or detrimental to them. For example, if a user thinks that fixing leaks will reduce long-term damage to his/her home, then he/she will fix the leak.

Liu et al. (2017) reported that almost 80% of users are interested in seeing leakage information in portal-based feedback systems where they can check for leaks through an internet-based portal. Even with paper/mail-based systems, it is possible to apprise users of leaks in their water systems. Britton et al. (2013) reported that in their study—which used a mail-based approach to apprise users about leaks—an approximate 89% reduction in leakage rate was observed. Once MNF was identified, the study then communicated with their experimental groups in four stages through postal mailings which included informing users about leaks over three months (through three separate mailings) and finally offering a rebate of almost $70 (AUD$100) in a fourth mailing, if users repaired leaks. For clarification purposes, a daily time-series chart was provided to users with detection reports showing the timing and volume of leaks. The study also conducted a post-intervention survey where it was revealed that 93% of the users contacted fixed the leaks to prevent further damage to their infrastructure (attitudinal factor), while 72% mentioned money-savings as an added motivation (contextual factor). The users also provided suggestions regarding their preferred content for such leak detection reports. Some of the suggestions were: total water loss volume and price of the leaked water in graphical form, leak types (if possible), where leaks were located, and predicted cost of repairs.

While not a behavior-improving process per se, due to its high popularity, the inclusion of leak detection may be used to draw users' attention to their daily water use which is an indirect way of engaging users in conservation behaviors. Some studies have suggested a more instantaneous system, preferably through text alerts or mobile phone applications, to notify users about leaks (Cahn et al., 2020). The time-series data, and users' preferences mentioned in the Britton et al. (2013) study, can be used to improve the leakage reports.

2.6.2.3 Social comparison

Social comparison is a messaging tactic where a household's water use information is juxtaposed with that of neighbors (Brick et al., 2017; Ferraro & Price, 2013) or an efficient household (Mitchell & Chesnutt, 2013) from the same community. This tactic effectively reduces water demand because it utilizes peer pressure and implicitly displays the norm regarding water use. From the TPB perspective, such a method influences the subjective norm as it tries to establish efficient water use as a praise-worthy trend. As users are informed about how inefficient they are compared to others in the community, they try to improve their behaviors to fit in with the community. Unfortunately, the opposite also happens (Schultz et al., 2016).

Past studies have used statements and bar charts (Brick et al., 2017; Ferraro & Price, 2013; Mitchell & Chesnutt, 2013; Schultz et al., 2019; WaterSmart, 2014) and sometimes ranks (Otaki et al., 2017) when providing such comparisons. The statements usually cover the volume of water the household was using, the average volume of water used by the household's neighbors, and what the household should do to save water in the form of generic tips. In addition, some studies used emoticons to emphasize the efficiency status of households (Mitchell & Chesnutt, 2013). Apart from these, some studies ranked users based on average water use and supplied that information as feedback to evoke peer pressure, but the effect of such feedback was not significant among high users (Otaki et al., 2017).

Schultz et al., (2019) reported that social comparison intervention resulted in an average of 8% water use decrease by the treatment group (8,362 households) than the control group (10,349 households). Schultz et al. (2016) also reported a 16-26% decrease in water use among the users in the treatment group when these users were provided with comparative statements. However, the intervention period of that study was only one week, and the post-study evaluation period was also only one week. Ferraro & Price (2013) also reported an overall 12% decrease in water use among consumers in Atlanta, Georgia who received a comparative statement and a message comprised of water-saving actions adopted by efficient households. In a post-intervention evaluation after two years, the researchers found that the effect of treatments dissipated slightly, as a 2% increase in consumption was noted as compared to the control group. However, the intervention groups who received comparative statements were still more efficient at using household water than control group participants. Both Ferraro & Price (2013) and Mitchell & Chesnutt (2013) reported that the treatment's effect varied with financial standing, as relatively poorer populations were more receptive of such intervention than affluent populations. However, Brick et al. (2017) reported a similar reduction (1.2-1.6%) in usage by all financial groups who received comparison statements. Hence, it is fair to say that comparative statements work in reducing water demand.

Among studies from the energy field, Allcott (2011) evaluated the effectiveness of messaging intervention using comparative statements in energy conservation. The author used consumption information recorded by the Opower company, which provided energy consumption data and self and social comparison reports (Home Energy Report) to approximately 600,000 users. The results indicated that high and low users decreased consumption by 6.3 and 0.3%, respectively, because of the feedback and social comparison. The feedback continued for two years, and the treatment group did not go back to their baseline behavior during the observation period. The effect of comparison was also found by Andor & Fels (2018) as they examined 24 social comparison papers and reported that social comparison worked in more than 90% of cases and energy use reduction achieved by social comparison ranged from 1.2 to 30%.

Only one study from the energy field postulated that peer pressure as a feedback tool is ineffective without financial motivation (Myers & Souza, 2019). Other than that, most studies found such intervention efficacious. However, the long-term effect is yet to be examined as treatment effects dissipate over time (Ferraro & Price, 2013). For messaging purposes, simple comparison statements with volumetric and monetary information, and bar charts with some visual aids pointing to the efficiency status are suggested by most studies.

2.6.2.4 Self-comparison

When a household receives consumption information from multiple time periods as comparative statements, the message is considered self-comparison information. For instance, water-use feedback comparing the average usage information from two to three consecutive months stating how the household improved or decreased their efficiency within this timeframe--can be considered self-comparison statements. Typically, bar graphs are included with the regular bills or feedback reports for self-comparison purposes, where each bar represents the total or average water use per month or billing cycle (Barnett et al., 2020; Mitchell & Chesnutt, 2013; WaterSmart, 2014).

The effect of self-comparison has not been assessed by previous studies in the water resources field, but some studies in the energy sector have found that such information could target internal factors such as competence and perceived behavioral control, which helped users reduce specific consumption. However, there are some considerations (Petkov et al., 2011). First, the effect increases when a single end-use is used instead of aggregated total use or when the information is constructed in a way that focuses explicitly on how much the user has deviated from their usual (past) consumption. Next, such information is more effective when the users are skeptical about social-comparison information, believing that the neighbor's or efficient home's data used for comparison purposes was inappropriate due to differences in appliances' efficiency level or household sizes. Finally, this type of self-comparison information works best in goal-setting campaigns, i.e., when the utility sets a conservation goal and requests that users help to achieve it. For example, Becker (1978) reported that in a conservation study in New Jersey, United States, users were asked to reduce their energy consumption by 20% during the summer. The treatment group that received self-comparison information three times per week and successfully reduced consumption by 13% compared to the control group. Similar strategies may be applied in the water sector, as high-frequency and disaggregated data are becoming more accessible to users.

2.6.2.5 Request from the authority for public good

Most conservation studies used messaging to inform users why conservation was necessary. Brick et al. (2017) termed such messaging interventions as “public good” requests, and Schultz (2010) referred to such messages as “pleas”. Usually, depletion of local reservoirs or other water sources (Ferraro & Price, 2013) and drought information (Brick et al., 2017; Katz et al., 2016; Schultz et al., 2019) were used to construct messages to help users grasp the seriousness of the shortage issue. Besides trying to justify the need for conservation, these messages were tailored using local infrastructure or depletion scenarios to help users connect to something they knew very well and could easily relate to. The motivational driver utilized for such messages is called "relatedness". It helps users assume a bond with the community and appeals to their altruistic nature (Ryan & Deci, 2000). This type of message has other implications as well. By mentioning the water shortage situation and the water manager’s measures to address it, users are assured of the administration's sincerity regarding conservation. This also reinforces users' trust in authorities—another motivational driver (Jorgensen et al., 2009).

When constructing such "public good" requests, studies have used the name of a known place (e.g., city, or reservoir) with a current depletion situation, conservation, or water reduction target (Brick et al., 2017; W. Schultz et al., 2019) and the impact of water shortage on wildlife or human health (Ferraro & Price, 2013). In addition, the county or city logo is usually attached to the message to ensure users that the message is coming from the authority.

Brick et al. (2017) reported the effectiveness of "public good" requests. In their experiment, which involved 400,000 users in Cape Town, South Africa, one of the treatment groups received such pleas from the utility. The results indicated that the effect of this type of intervention was more prominent among the wealthy user groups, as they reduced their consumption by 1.9%. Ferraro & Price (2013) directed social comparison messages in addition to such requests to one of the treatment groups. They reported that this treatment group saved 53% more water than the control group, retaining their efficient behaviors even after two years. However, the study credited the comparison information as the primary factor for this reduction, not the "public good" request.

2.6.2.6 Conservation tips

Water-saving tips are distributed during conservation campaigns and are often available on utility websites. However, such conservation tips do not trigger any motivational driver, but instead are primarily circulated for educational purposes.

In most cases, circulated tips were generic, i.e., tips mentioned different end uses and a list of measures that the household could take to reduce the water loss through those end-use behaviors. Our review reveals that the most circulated tips were: how to detect toilet leaks, recommendations on plant selection for landscaping, irrigation system tuneup, and requests to save water by cutting back shower time (Brick et al., 2017; Ferraro & Price, 2013; Fielding et al., 2013; Liu et al., 2016; Mitchell & Chesnutt, 2013; Schultz et al., 2019; Tiefenbeck et al., 2013). In addition, plumbing leak detection (Brick et al., 2017; Britton et al., 2013), retrofitting households with efficient appliances (Brick et al., 2017), timing of lawn watering (Brick et al., 2017), benefits of covering swimming pools (Brick et al., 2017), taking smaller (lower volume) baths, and reducing faucet run times (Brick et al., 2017) are some of the types of information shared as water-saving tips in recent studies. Contrary to generic tips, customized tips target specific end-use behavior that the household is performing inefficiently and provide guidance on how to improve particular behaviors.

Some studies assessed the standalone effect of tips. Schultz et al. (2016) found that treatment groups that received only water-saving tips did not reduce their water use significantly. Brick et al. (2017) also reported that a "tips only" treatment group reduced their water use by 0.6%–the least of any other treatment group. One probable reason that tips alone cannot improve the end-use behavior is that adults are less responsive to educational approaches than school-aged children (Thompson et al., 2011). Furthermore, users are less likely to try recommendations when the suggested steps to save water are perceived as too difficult to employ or cost more than users can afford (Geller et al., 1983; Hayden et al., 2015). Contrary to these experiments, when tips were circulated in addition to other motivational agents such as social comparisons, the effect was much more significant, as households saved 5-20% water on average and, in some cases, retained the behaviors for a prolonged time (Ferraro & Price, 2013; Mitchell & Chesnutt, 2013; Schultz et al., 2019).

Among all the reviewed studies, only Fielding et al. (2013) provided customized tips to one treatment group. However, the treatment group only received three postal mails comprising tips over a four-month period, and each time only one end-use behavior was targeted. Although an average decrease between 8-15% was observed across all treatment groups, growth-curve modeling revealed that the effect would eventually decrease within a year. The researchers cautioned that the effects of different interventions should not be compared because the selection of the different treatment groups was based on geography. As a result, the climatologic conditions and drought severity were different, which influenced users' responses to different treatments.

Our review of energy-related conservation studies revealed that tips also proved to be most effective when circulated with social comparison information (Allcott, 2011; Andor & Fels, 2018). For instance, Dolan & Metcalfe (2015) found that tips with comparison information resulted in an 11% decrease in energy usage on average as compared to comparison information intervention, which resulted in a 4% decrease.

In summary, the effect of conservation tips individually is not very substantial, but its effect increases significantly when applied with other behavior influencing strategies, notably social comparisons. Although the specificity of "conservation tips" was deemed necessary and was repeatedly suggested by previous reviews (Sønderlund et al., 2016; Syme et al., 2000), very few studies have used disaggregated data to devise customized, household-specific tips. Nonetheless, tips should be provided for educational purposes. Managers should also share tips that are straightforward to implement, low cost, and include the consequences in terms of money, time, and water loss if the recommendations are not employed.

2.6.2.7 Social recognition

Social recognition or commendation is a form of reward in which users are praised publicly for exhibiting environmentally friendly behaviors. Although considered an external motivator due to its reward-centric approach, social recognition can also help users sustain their environmentally friendly behaviors because once users are publicly praised, they feel obligated to continue the behaviors (Lockton, 2012).

Seaver & Patterson (1976) was one of the earliest studies reporting the effectiveness of social recognition in the energy field. The research assessed the effect of fuel savings after the authority declared a fuel crisis in 1973 and reported that the treatment group that received a decal saying "we are saving oil" along with consumption feedback reduced their usage significantly compared to the control and other treatment groups. In water conservation studies, Brick et al. (2017) in their recent research involving 400,000 households in Cape Town, South Africa observed a 2.3% decrease in water use among financially prosperous high-water users after the city offered to post photos of any citizen who conserved 10% every month on the city website as a form of recognition. This study had also employed other interventions such as social comparison, tips, and consumption information, and reported that social recognition was the most influential motivator among the wealthy consumer group.

Despite its behavior influencing power, social recognition was utilized by only a few conservation studies. Nonetheless, social recognition is considered an important motivator for promoting physical activities; for instance, Rivers (2020) found that Strava, an online platform where users can post their health-related outdoor activities, motivated many users to conduct physical activities once they were notified that a peer/friend had achieved a remarkable physical feat. Similar tactics can be utilized for promoting conservation behaviors once high-frequency and disaggregated data become readily available to users and managers (Levin & Muehleisen, 2016).

2.6.2.8 Additional components

Apart from the methods previously mentioned, additional information featuring rebate notifications (Mitchell & Chesnutt, 2013; Schultz et al., 2019), availability of mobile phone applications (Schultz et al., 2019), customer helpline information for establishing direct communication between utilities and customers (Allcott, 2011; Brick et al., 2017; Mitchell & Chesnutt, 2013), website information comprising water-saving tips (Ferraro & Price, 2013), and information focusing on efficient appliances (Brent et al., 2016) have been attached to strategic messages. Individually, this information does not provide noteworthy motivation, but when coupled with behavior influencing methods such as social comparison, self-comparison, and local water-shortage information, these types of notices can vastly increase the messages' potency (Monroe, 2003). Russell & Fielding (2010) referred to these types of drivers as the contextual factors. In addition, behavior improvement tactics such as community-based social marketing specifically suggest using such information to nudge users towards adopting conservation actions (Mckenzie-Mohr, 2000).

As a summary of our review, Figure 2.1 illustrates how different messaging components were used to target different motivating factors.

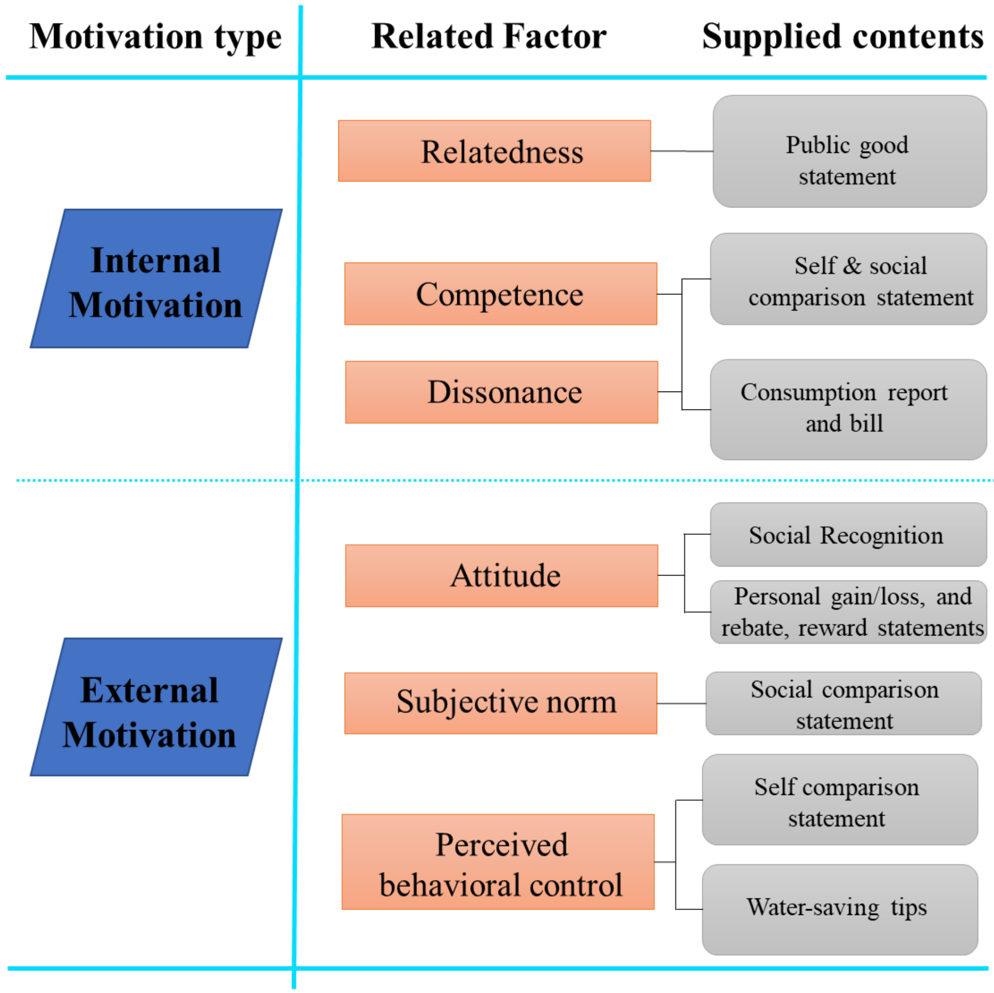


Figure 2.1: Messaging components targeting specific psychological factors that were used by prior feedback and strategic messaging studies

2.6.3 Feedback medium

Historically, most feedback campaigns have used paper-based reports to apprise users of their water use; however, paper-less communication through emails, in-home-displays (IHD), and web portals are also being used more recently. We found six distinct methods of communication: 1) paper-based feedback (Brick et al., 2017; Britton et al., 2013; Ferraro & Price, 2013; Katz et al., 2016; Liu et al., 2016; Mitchell & Chesnutt, 2013; Schultz et al., 2016; Schultz et al., 2019; Tiefenbeck et al., 2013), 2) electronic reports through emails (Schultz et al., 2016), 3) feedback through fax (Otaki et al., 2017), 4) web portals (Erickson et al., 2012; Mitchell & Chesnutt, 2013; Petersen et al., 2007), 5) IHD (Froehlich et al., 2012; Willis et al., 2010), and 6) mobile phone applications (Schultz et al., 2019). We note that some studies used both paper and electronic-based feedback simultaneously and reported the effectiveness of both mediums (Mitchell & Chesnutt, 2013; Schultz et al., 2016). Schultz et al. (2019) only provided high-frequency water use information through ta mobile application, but the feedback report was mainly delivered through postal mailings.

Most paper-based feedback used aggregated water use data collected through water bills or manually reading water meters (Brick et al., 2017; Ferraro & Price, 2013; Schultz et al., 2016) and others used smart meters or other smart monitoring devices to collect the data (Fielding et al., 2013; Katz et al., 2016; Liu et al., 2016; Mitchell & Chesnutt, 2013; Schultz et al., 2019). In the case of electronic feedback, the studies primarily used digital meters and data loggers. Only one paper-based study (Fielding et al., 2013) and IHD-based studies used disaggregated data for feedback purposes.

In terms of content, there have not been any distinct differences in paper or electronic-based feedback. All the mediums provided consumption information, social comparison information, and generic tips for cutting back water use. Except for Fielding et al. (2013), most provided generic water-saving tips.

Despite using high-frequency datalogger or smart monitoring techniques that had a near-real time data collection frequency (5-10 seconds), the feedback intensity was not delivered in a real-time format, ranging instead from monthly (Fielding et al., 2013; Schultz et al., 2019) to bi-annually (Liu et al., 2016b). Studies that used web portals were provided feedback more frequently, with data refreshed every couple of hours (Erickson et al., 2012) to a 1-week (Petersen et al., 2007). Furthermore, the most instantaneous feedback was provided by IHD, where users could check their usage right after a particular end-use (Froehlich et al., 2012; Willis et al., 2010).

Apart from providing feedback at a higher frequencies, web portal and IHD-based systems also provided users with the option to customize their visual settings, through which the users were able to see their water use in hourly, daily, weekly, and monthly timeframes (Erickson et al., 2012). The IHD system evaluated by Froehlich et al. (2012) could provide appliance-wise daily consumption (individual and grouped) as well as hot and cold water use data (by volume). Furthermore, the entire interface was customizable, as users could see daily, weekly, and monthly consumption for individual appliances.

Despite having such an overwhelming advantage regarding feedback frequency and data customization power, web-based and IHD-based feedback studies were not as successful at reducing water demand as conventional paper-based studies. The studies that used electronic and paper-based systems reported users' general disinterest in accessing websites. For instance, Schultz et al. (2016) reported that only 18% of eligible participants accessed websites to check their water use information during the study. Furthermore, the reduction in usage reported by paper-based feedback ranged from over 5% (Mitchell & Chesnutt, 2013) to over 25% (Ferraro & Price, 2013), whereas the reduction reported by web portals ranged from 3% (Petersen et al., 2007) to slightly more than 6% (Erickson et al., 2012). Willis et al. (2010) used alarming visual displays—a form of IHD—which notified users when their shower duration exceeded 5-minutes or 10.5 gallons (40 L) and reported an average 27% reduction in water usage. However, the average volumetric reduction was only 4 gallons per shower, whereas Mitchell & Chesnutt (2013), with an average 5% reduction, observed a reduction of more than 14 gallons/day. This observation differs from the findings reported in energy-related feedback studies, where interactive systems were reported to be more effective at reducing energy usage and better at engaging users in conservation actions (Karlin et al., 2015; Petkov et al., 2011). Figure 2.2 summarizes the findings. One crucial observation is that intervention potency diminishes over time regardless of the type of communication medium, which underscores the finding that the influence of messaging content outweighs the influence of the communication medium.

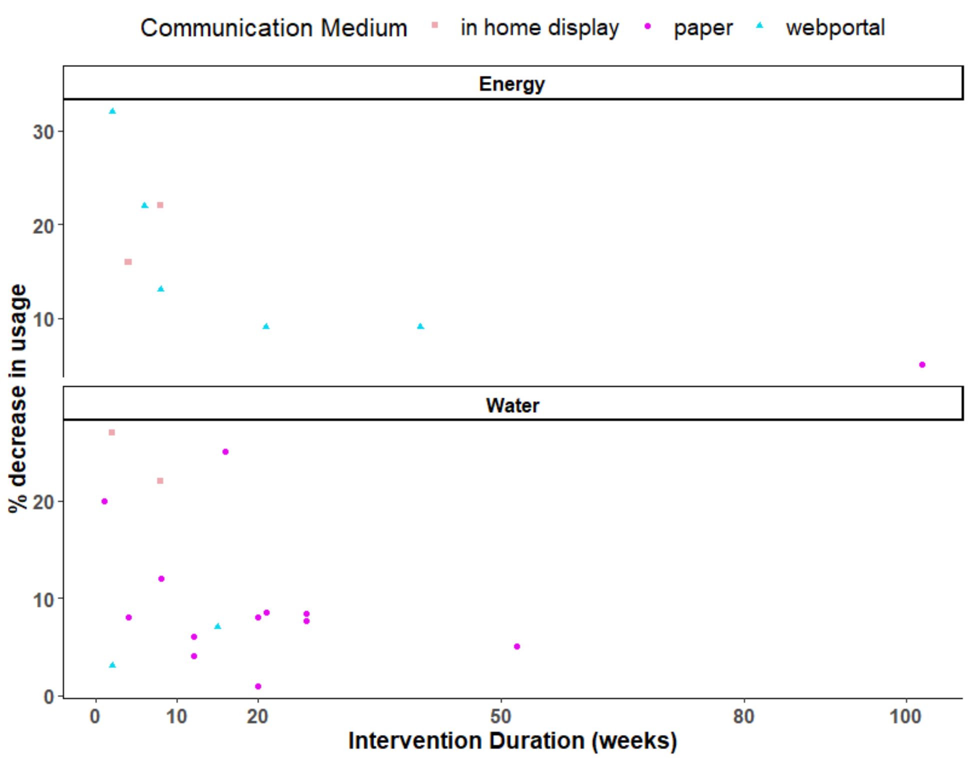


Figure 2.2: Different communication medium and intervention duration of the reviewed studies involving voluntary feedback and messaging strategies in water and energy fields.

Liu & Mukheibir (2018) posited that paper-based feedback, or systems where information was pushed to consumers (e.g., through text messages), had better chances of engaging users because users readily noticed the feedback and took action. Conversely, users had to pull information from web portals or IHDs and, in most cases, they were not motivated enough to do so. This was also the case in the Erickson et al. (2012) study where 49% of the users who did not access the portal reported that they "kept forgetting" about the portal, whereas some of the other participants responded that it did not give them any goal or motivation to work on. However, the small percentage of users who used the portals regularly engaged themselves in other activities offered by the portals, such as chats and friendly games. This type of engagement was also reported in the Liu et al. (2017) study and many other energy-feedback studies that used web portals (Karlin et al., 2015; Petkov et al., 2011). Past review studies of water conservation (Inman & Jeffrey, 2006b; Syme et al., 2000) and studies from behavioral science (Pope et al., 2018; Sofoulis, 2005) have pointed out that engaging users in different water-saving activities is a pre-requisite for sustaining conservation behaviors. Hence, although paper-based systems have proved to be more effective for reducing water use, the application of web portals and IHDs should not be disregarded as they have potential to sustain the improved behavior.

2.6.4 Feedback Frequency

Feedback frequency or intensity refers to the amount of feedback users receive in a given timeframe. The gap between action and feedback determines the effect of feedback (Levin & Muehleisen, 2016). Hence, it is assumed that the higher the feedback intensity, the better the probability of improving consumption behaviors (Fischer, 2008). Unfortunately, while studies from the medical field indicate that real-time feedback can improve behavior (Lee & Dey, 2014), there has not been any study in either the water resources or energy fields that has evaluated optimum feedback frequency.

Fischer (2008) posited that efficient behavior could result if users received feedback right after an action. Indeed, from the Willis et al. (2010) study, we noticed that an alarming visual display—a form of in-home-display—reduced users' shower times from 7.19 minutes to 5.86 minutes, and an average 27% reduction was achieved through that instantaneous feedback. In the energy field, Tiefenbeck et al. (2018) also reported that instantaneous feedback on energy consumption while taking a shower could reduce energy use by 22%. However, Karlin et al. (2015) contradicted these findings by stating that while a single end-use can be improved through such feedback, the effectiveness diminishes when multiple end-uses come into play. They argued that users do not usually pay attention to instantaneous feedback because they have to perform multiple end-uses throughout the day and it is not practical for them to pay attention to feedback continuously. Furthermore, after reviewing contemporary feedback studies in the energy field, Karlin et al. (2015) reported that a direct connection did not exist between increased energy feedback and consumption efficiency. Pereira et al. (2013) also reached a similar conclusion after providing instantaneous feedback on energy consumption to research participants (n=12) for a year, as it did not result in significant changes in energy use behavior.

When it comes to coarse feedback frequencies, i.e., once every two hours or once every months, our review revealed that the number of feedbacks received by treatment groups varied considerably. In the case of paper-based feedback studies, users received as few as one feedback (Schultz et al., 2016) or up to 6 feedbacks (Schultz et al., 2019) during the entire intervention period, which spanned a couple of months. When online portals were used, feedback intensity varied from 2-3 hours (Erickson et al., 2012) to 1 week (Petersen et al., 2007). As with results in the energy field, we were unable to find a relationship between feedback intensity and consumption reduction. For example, Erickson et al. (2012) reported a 6.6% decrease in water use from 2-3 hour feedback intensity, Tiefenbeck et al. (2013) reported a 6% decrease from weekly feedback intensity, and Mitchell & Chesnutt (2013) reported a 5% decrease from bi-monthly feedback, indicating higher feedback frequency may result in better savings. But Liu et al. (2016) reported achieving an 8% decrease in water use from biannual feedback, which again disputes the effectiveness of increased frequency on higher savings. Therefore, the effect of feedback frequency on behavioral improvement remains unclear.

2.6.5 Feedback Duration

Intervention duration is the timeframe between the first and the last message/feedback that users receive. Post-intervention occurs when users are not provided with any feedback or messaging but are observed to assess the effects of the intervention. Our investigation revealed that the duration of intervention ranged from 1 week (Schultz et al., 2016) to 52 weeks (Mitchell & Chesnutt, 2013), and most studies initiated their intervention just before or during summer and ended just before fall (Brick et al., 2017; Fielding et al., 2013; Katz et al., 2016a). These studies reported that a significant reduction in consumption had resulted, ranging from 0.6% (Brick et al., 2017) to more than 25% (Ferraro & Price, 2013) during the intervention period. However, there have been only a few post-intervention studies, and all reported users returning to their pre-intervention use levels when the intervention ended (Ferraro & Price, 2013; Fielding et al., 2013; W. Schultz et al., 2019). Ferraro & Price (2013) reported that although the effect of intervention dissipated, the treatment group that received social comparison information was still using less volume than other experimental groups, suggesting that some content may have a prolonged temporal effect than others. However, Fielding et al. (2013) reported that all treatment groups returned to their pre-intervention level behaviors regardless of the type of intervention.

Past review studies from the energy field indicate that any intervention lasting three months or more had significantly reduced energy consumption (Fischer, 2008). However, Karlin et al. (2015) indicated that 3 to 6 month long studies achieved the highest savings, and posited that prolongation of intervention might be counterproductive, as the studies that ran more than six months reported the effect of feedback reducing over time. But this finding was based on empirical data that used only information and tips for feedback purposes, and it was not clear whether other behavior influencing techniques were involved. Studies have shown that the continued application of motivational drivers, i.e., messaging interventions, can help users retain their efficient behavior for a prolonged time. For instance, in their year-long experiment involving smart water monitoring techniques, Mitchell & Chesnutt (2013) reported that users retained their conservation behaviors and attained a reduction in use of approximately 5% throughout the intervention period. The experiment used social comparison as one of its primary motivators. Similar results were reported by Allcott (2011) as he investigated the effect of strategic feedback messaging that used social comparison, tips, and consumption information for improving energy behavior over two years and reported that all users retained their energy-efficient behaviors and high users managed to save more than 6% of energy use. However, from Figure 2.2, we observe that the reduction reported by these prolonged studies is comparatively less than others, indicating that repetition of the same content loses its motivational power over time.

2.7 Recommendations

2.7.1 Messaging strategy for temporary reductions

Here we provide our recommendations for the managers who intend to use messages to encourage water conservation. We suggest using components that target internal and external motivational factors. Figure 2.3 presents a schematic of a strategic message that contains all the components that we found were the most effective. The left part of the Figure 2.3 mentions the contents, and the right part lists the required information that have the highest potential to motivate users. Note that including all this information may overwhelm users, and some of the information will only be available when digital data loggers and smart meters are used for data collection purposes or special rebate programs are offered. Hence, we indicated the most important ones in blue, which can be included without requiring any unique technology (i.e., data logger and smart metering technology) or rebate programs. In summary, managers should include contents that focus on:

- Internal motivation by relaying information regarding the depletion or shortage condition of local infrastructure (reservoir, canal, river, etc.) to connect users with the community and give them a charitable purpose to conserve.

- Reinforcing users' trust in their water authority by highlighting its continued efforts to save water.
- External motivation, by showing social comparison information to provide users with information on whether they are efficient or inefficient users.
- Improving users' behavioral control by suggesting conservation tips that are economical and easily implementable.
- Engaging users in conservation activities by sharing additional information, such as rebates, efficient appliance listings, availability of web portals, water authority's web page, complaint page, and help lines.

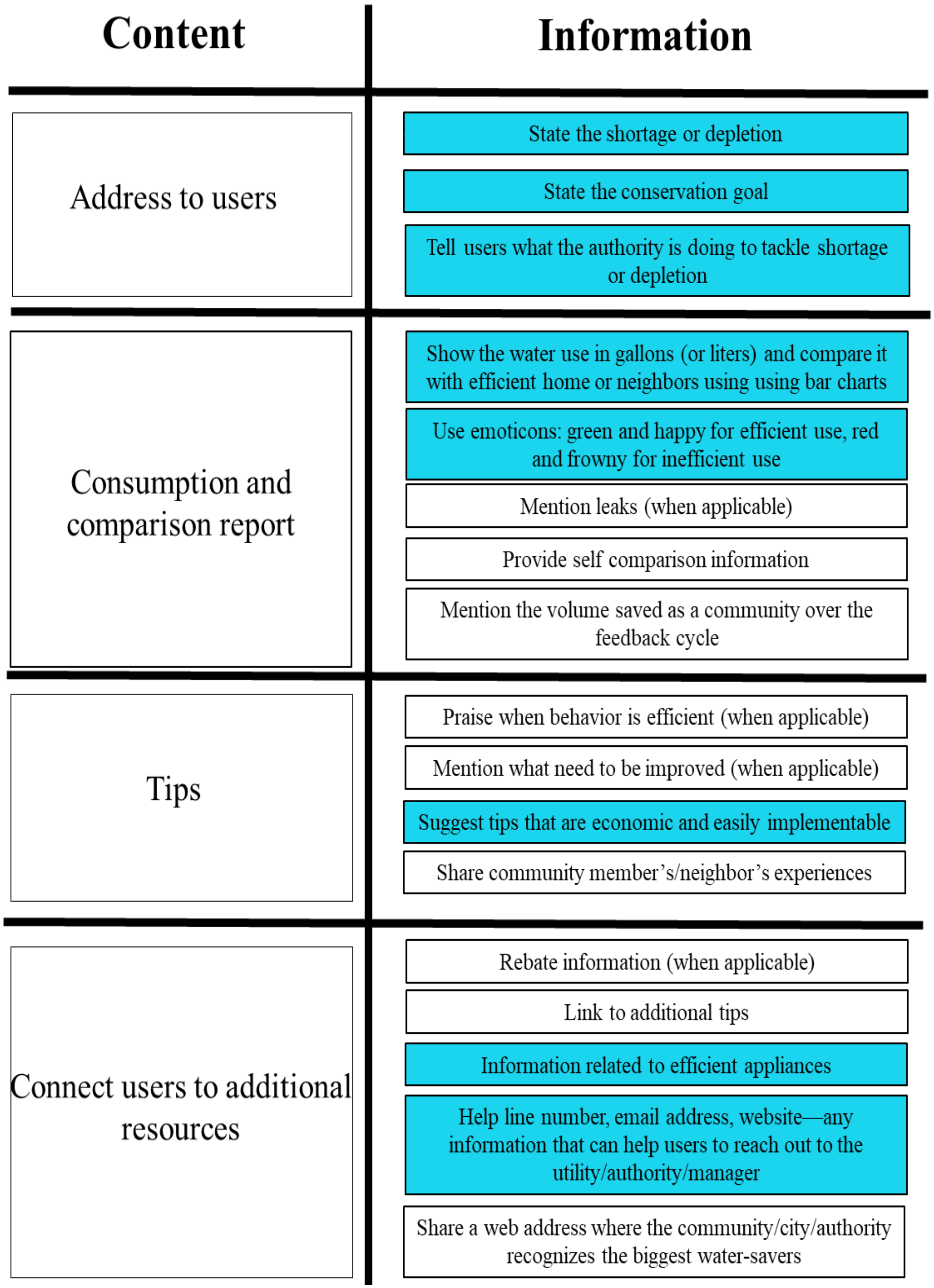


Figure 2.3: Recommended feedback contents. The most important contents are marked in blue.

2.7.2 Messaging strategy for long-term reduction

Few studies performed year-long interventions and reported that users continued to perform efficiently during the intervention period (Allcott, 2011; Mitchell & Chesnutt, 2013). Although the reduction reported by these studies was not as high as some others (those tended to bring down seasonal demand, 0.3-6.6% vs. 0.6-25% reduction), uninterrupted intervention can potentially keep demand at a relatively lower level. If a manager chooses to follow this path of uninterrupted intervention, then the recommendations provided in the previous section are applicable. Here we provide some additional recommendations to make messages' effects more significant for a prolonged period.

1. Conduct a survey and group users based on their socio-psychological preference: The purpose of the survey is twofold: a) to start a conversation with consumers to understand what their understanding and intention regarding water conservation is, and b) to identify their information preferences because not all users will respond to the same type of content. Furthermore, grouping users will help managers immensely because instead of reaching out to individual users separately, managers can create group-specific content. Examples of groupings could be: Degree of conscience regarding the environment, sensitivity to peer pressure, heightened personal norms, past conservation behavior, financial capability, and responsiveness to rewards or monetary incentives.
2. Launch feedback program during shortage conditions: To make the necessity of conservation more salient, launch the campaigns during shortage conditions. Drought conditions will act as a significant internal motivator.

3. Set the correct feedback frequency: If aggregated data is available, set a feedback frequency of not less than once per week (can also try bi-weekly or monthly). If disaggregated data is available, the manager can choose to focus on changing one behavior at a time. Under such consideration, intensifying the frequency, i.e., once per day or notifying right after the event, can improve the effectiveness of the message. On the other hand, if a manager decides to provide feedback on multiple end-uses, we suggest setting a coarser feedback schedule, e.g., once per day (for outdoor use) or week (for indoor use).
4. Select the right message content: A socio-psychological survey should indicate users' outlook, attitude, and information preferences. Select the appropriate contents from Figure 2.3 by using the results of the survey. In doing so, the chances of overwhelming consumers with the least preferred messages will diminish.
5. Keep both paper-based and internet-based communication options available for the consumers: Past studies suggest that paper-based feedbacks are still the most popular form of communication. However, digital platforms are becoming more available, and it is equally essential to help users acclimatize to mobile and web-based applications to engage them in water-related activities such as checking for leaks, engaging in group chats, and friendly games where users save water as a group. The best course of action, for the time being, is developing paper-based feedback that can be circulated with regular water bills, with options to access both web and mobile-based applications.
6. Constantly update the feedback message: Regularly change the contents, especially water-saving tips. Do not use the same tip for more than three months.

7. Encourage users to make a public commitment to conserve water: This is not the feedback per se, however, this type of initiative can help sustain water-saving behavior in the long run, especially if feedback is developed using cognitive dissonance (Aitken et al., 1994; Dickerson et al., 1992). Research indicates that users who made a public commitment to conserve water and encourage others to adopt water-saving actions are more likely to sustain their behavior.
8. Socially recognize the water savers: Share a web address where the community/city/authority recognizes the biggest water-savers. This type of recognition is exclusively popular among financially wealthy users who are also, in most cases, the highest water consumers.
9. Share a neighbor's experience with conservation: Syme et al. (2000) first proposed including such messages with feedback. Jorgensen et al. (2009) also posited that including such messages could improve a household's trust in their neighbors and boost their motivation to conserve.

2.7.3 Sustaining conservation behavior

Commercial companies now provide internet and mobile phone-based applications for monitoring water use, and in many areas, the utilities are working together with such companies. In some major cities, the utilities are providing such services now a days. Hence, managers can use these platforms to relay conservation messages (Erickson et al., 2012; Liu & Mukheibir, 2018). Such an approach can address two issues identified by previous reviews as core requirements for behavioral sustenance, 1) constant user-to-manager connectivity and 2) provision of customizable content (Inman & Jeffrey, 2006;

Sønderlund et al., 2016; Syme et al., 2000). However, managers need guidelines to make messages customizable for individual households. Here, we briefly discuss one such tactic called community-based social marketing, suggested explicitly by some prior studies (Beal et al., 2013; Fielding et al., 2013). Community-based social marketing is a tactic that utilizes both internal and external factors to devise interventions based on user behavior (i.e., water use) and psychology (i.e., motivation and intention to conserve).

The social marketing approach has five distinct steps. The first step is understanding the reasons behind users' behaviors. The next step is to select which behavior to target. This step may involve a research survey, focus group discussions, and close monitoring of behaviors. The third step is where the users are divided into several groups based on their behavioral and psychological profiles. The fourth step in the social marketing process is designing a program to help users change their behavior. The main objective of this step is to reduce any barriers hindering the user from performing in an environmentally friendly manner. Finally, the fifth step is to create a pilot project involving a few users before the intervention's big-scale implementation and evaluation of the pilot through direct (not self-reported) and repeated measurements of the behavior.

Although community-based social marketing has been used for promoting environmentally friendly behaviors since the early 1990s (Mckenzie-Mohr, 2000; Monroe, 2003), its application has spread rapidly in the health and environmental sectors in recent years. For example, Boivin, et al. (2016) provided a detailed illustration of the segmentation process used for a successful campaign promoting community composting; Stead et al. (2007) provided evidence of using social marketing for reducing alcohol and tobacco use; Gordon et al. (2006) showed the application of social marketing for promoting physical activity, and Drury (2009) showed its use in species conservation. In addition, some of our reviewed studies suggested that the social marketing approach can improve users' perception of their water use and eventually improve user behavior (Beal et al., 2013; Beal et al., 2011). In fact, Lowe et al. (2015) discussed the effect of a state-wide campaign called "Project Hydro" in Australia that used social marketing to develop a water conservation program. The project used all the required steps to segment users and used television and radio commercials, roadside signs, and billboards to deliver motivational messages. The study reported that Project Hydro was able to achieve a 25% reduction in daily water use with this method. Furthermore, a 2-year post-intervention evaluation study reported that all the households under Project Hydro retained their conservation behavior (Lowe et al., 2015)

2.8 Discussion and conclusion

Voluntary water conservation campaigns still need to sustain users’ conservation behaviors in the long term. This paper synthesized 80 research studies from behavioral sciences, water conservation, energy conservation, environmental psychology, and health communication to learn how prior studies used strategic messages to encourage and sustain water conservation behaviors. The paper examined the effects of feedback duration, frequency, and communication medium.

Foremost, customize messages for individual households based on their behavioral and psychological standing. When near real-time end use data are available, notify users to improve a single shower or faucet behavior immediately after the event. To make messages have a longer effect, change message content every three months. Combine electronic-based communication systems and paper-based systems even though consumers' do not use web portals because web portals provide immense opportunities for customization and notification. Customization and notifications help engage users. Finally, to increase the long-term efficacy of conservation messages:

1. Tell users about the problem and conservation goal.
2. Provide consumption and comparison reports that contain easy to read bar charts and emoticons.
3. Give praise when behavior is efficient and suggest conservation tips that are easy to implement.
4. Connect users to additional resources.

Future work can improve the efficacy of conservation messages by constructing messages from disaggregated water end-use and psychological intent data and share messages with customers on smart-phone and web platforms. Water providers can also apply community-based social marketing to design messages to sustain user conservation behaviors for longer.

Data availability

No data was generated for this study.

References

Aitken, C., McMahon, T., Wearing, A., & Finlayson, B. (1994). Residential Water-Use - Predicting and Reducing Consumption. *Journal of Applied Social Psychology*, *24*(2), 136–158.

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–221. https://doi.org/10.1080/10410236.2018.1493416

Alberts, G., Gurguc, Z., Koutroumpis, P., Martin, R., Muûls, M., & Napp, T. (2016). Competition and norms: A self-defeating combination? *Energy Policy*, *96*, 504–523. https://doi.org/10.1016/j.enpol.2016.06.001

Allcott, H. (2011). *Social norms and energy conservation*. *95*, 1082–1095. https://doi.org/10.1016/j.jpubeco.2011.03.003

Andor, M. A., & Fels, K. M. (2018). Behavioral Economics and Energy Conservation – A Systematic Review of Non-price Interventions and Their Causal Effects. *Ecological Economics*, *148*(July 2017), 178–210. https://doi.org/10.1016/j.ecolecon.2018.01.018

Barnett, M. J., Jackson-Smith, D., Endter-Wada, J., & Haeffner, M. (2020). A multilevel analysis of the drivers of household water consumption in a semi-arid region. *Science of the Total Environment*, *712*, 136489. https://doi.org/10.1016/j.scitotenv.2019.136489

Beal, C. D., Stewart, R. A., & Fielding, K. (2013). A novel mixed method smart metering approach to reconciling differences between perceived and actual residential end use water consumption. *Journal of Cleaner Production*, *60*, 116–128. https://doi.org/10.1016/j.jclepro.2011.09.007

Beal, C., Stewart, R. A., Spinks, A., & Fielding, K. (2011). *Using smart meters to identify social and technological impacts on residential water consumption*. 527–533. https://doi.org/10.2166/ws.2011.088

Becker, L. J. (1978). Joint effect of feedback and goal setting on performance: A field study of residential energy conservation. *Journal of Applied Psychology*, *63*(4), 428–433. https://doi.org/10.1037//0021-9010.63.4.428

Bénabou, R., & Tirole, J. (2003). Intrinsic and extrinsic motivation. *Review of Economic Studies*, *70*(3), 489–520. https://doi.org/10.1111/1467-937X.00253

Benders, R. M. J., Kok, R., Moll, H. C., Wiersma, G., & Noorman, K. J. (2006). New approaches for household energy conservation-In search of personal household energy budgets and energy reduction options. *Energy Policy*, *34*(18), 3612–3622. https://doi.org/10.1016/j.enpol.2005.08.005

Berkman, P. A. (2002). Ecosystem Conservation. *Science Into Policy*, *279*(April), 157–181. https://doi.org/10.1016/b978-012091560-6/50013-5

Boivin, M., Gagné, E., & Saint-Arnaud, V. C. (2016). Using Segmentation and Theory to Design Better Promotion and Prevention Campaigns: A RECYC-QUÉBEC Case Study. In *Segmentation in Social Marketing: Process, Methods and Application*. https://doi.org/10.1007/978-981-10-1835-0

Brent, D. D. A., Cook, J. H., & Olsen, S. (2016). Erratum: Social comparisons, household water use, and participation in utility conservation programs: Evidence from three randomized trials (JAERE, (2015) 2 (4), 10.1086/683427). *Journal of the Association of Environmental and Resource Economists*, *3*(2), 523–524. https://doi.org/10.1086/687270

Brick, K., Martino, S. De, & Visser, M. (2017). *Behavioural Nudges for Water Conservation : Experimental Evidence from Cape Behavioural Nudges for Water Conservation : Experimental Evidence from Cape Town*. (February 2018). https://doi.org/10.13140/RG.2.2.25430.75848

Britton, T. C., Stewart, R. A., & O'Halloran, K. R. (2013). Smart metering: Enabler for rapid and effective post meter leakage identification and water loss management. *Journal of Cleaner Production*, *54*, 166–176. https://doi.org/10.1016/j.jclepro.2013.05.018

Cahn, A., Katz, D., & Ghermandi, A. (2020). Analyzing Water Customer Preferences for Online Feedback Technologies in Israel: A Prototype Study. *Journal of Water Resources Planning and Management*, *146*(4), 06020002. https://doi.org/10.1061/(asce)wr.1943-5452.0001179

Chaudhary, A. K., Warner, L., Lamm, A., Israel, G., Rumble, J., & Cantrell, R. (2017). Using the Theory of Planned Behavior to Encourage Water Conservation among Extension Clients. *Journal of Agricultural Education*, *58*(3), 185–202. https://doi.org/10.5032/jae.2017.03185

Cialdini, R. B., Reno, R. R., & Kallgren, C. A. (1991). A focus theory of normative conduct.pdf. *Journal of Personality and Social Psychology*, *58*(6), 1015–1026.

Retrieved from http://media.cbsm.com/uploads/1/AFocusTheoryofNormativeConduct.pdf

De Young, R. (1993). Changing Behavior and Making it Stick: The Conceptualization and Management of Conservation Behavior. *Environment and Behavior*, Vol. 25, pp. 485–505. https://doi.org/10.1177/0013916593253003

Delmas, M. A., Fischlein, M., & Asensio, O. I. (2013). Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012. *Energy Policy*, *61*, 729–739. https://doi.org/10.1016/j.enpol.2013.05.109

Dickerson, C. A., Thibodeau, R., Aronson, E., & Miller, D. (1992). Using Cognitive Dissonance to Encourage Water Conservation. *Journal of Applied Social Psychology*, *22*(11), 841–854. https://doi.org/10.1111/j.1559-1816.1992.tb00928.x

Dobson, J., & Griffin, J. (1992). Conservation effect of immediate electricity cost feedback on residential consumption behavior. *Proceedings of the 7th ACEEE Summer Study on …*, 33–35. Retrieved from https://www.aceee.org/files/proceedings/1992/data/papers/SS92_Panel10_Paper06.pdf

Dolan, P., & Metcalfe, R. D. (2015). Neighbors, Knowledge, and Nuggets: Two Natural Field Experiments on the Role of Incentives on Energy Conservation. *SSRN Electronic Journal*, (1222). https://doi.org/10.2139/ssrn.2589269

Drury, R. (2009). Reducing urban demand for wild animals in Vietnam: examining the potential of wildlife farming as a conservation tool. *Conservation Letters*, *2*(6), 263–270.

Erickson, T., Podlaseck, M. E., Sahu, S., Dai, J. D., Chao, T., & Naphade, M. (2012). The Dubuque Water Portal: Evaluation of the uptake, use and impact of residential water consumption feedback. *Conference on Human Factors in Computing Systems - Proceedings*, 675–684. https://doi.org/10.1145/2207676.2207772

Farah, E., & Shahrour, I. (2017). Smart water for leakage detection: Feedback about the use of automated meter reading technology. *2017 Sensors Networks Smart and Emerging Technologies, SENSET 2017*, *2017-Janua*, 1–4. https://doi.org/10.1109/SENSET.2017.8125061

Ferraro, P. J., & Price, M. K. (2013). *Using Non-Pecuniary Strategies to Influence Behavior : Evidence from a Large Scale Field Experiment*. (December). https://doi.org/10.2307/23355650

Festinger, L. (1957). Cognitive dissonance theory. *1989) Primary Prevention of HIV/AIDS: Psychological Approaches. Newbury Park, California, Sage Publications*.

Fielding, K. S., Spinks, A., Russell, S., McCrea, R., Stewart, R., & Gardner, J. (2013). An experimental test of voluntary strategies to promote urban water demand management. *Journal of Environmental Management*, *114*, 343–351. https://doi.org/10.1016/j.jenvman.2012.10.027

Fischer, C. (2008). Feedback on household electricity consumption: A tool for saving energy? *Energy Efficiency*, *1*(1), 79–104. https://doi.org/10.1007/s12053-008-9009-7

Flume. (2021). Flume. Retrieved from https://flumewater.com/product/

Froehlich, J., Findlater, L., Ostergren, M., Ramanathan, S., Peterson, J., Wragg, I., … Landay, J. A. (2012). The design and evaluation of prototype eco-feedback displays for fixture-level water usage data. *Conference on Human Factors in Computing Systems - Proceedings*, 2367–2376. https://doi.org/10.1145/2207676.2208397

Geller, E. S., Erickson, J. B., & Buttram, B. B. (1983). Attempts to Promote Residential Water Conservation with Educational , Behavioral and Engineering Strategies. *Population and Environment*, *6*(2), 96–112.

Gordon, R., McDermott, L., Stead, M., & Angus, K. (2006). The effectiveness of social marketing interventions for health improvement: what's the evidence? *Public Health*, *120*(12), 1133–1139.

Groot, J. I. M. D. E., & Steg, L. (2009). *Morality and Prosocial Behavior : The Role of Awareness , Responsibility , and Norms in the Norm Activation Model*. *149*(4), 425–449. https://doi.org/10.3200/SOCP.149.4.425-449

Hayden, L., Cadenasso, M. L., Haver, D., & Oki, L. R. (2015). *Landscape and Urban Planning Residential landscape aesthetics and water conservation best management practices : Homeowner perceptions and preferences*. *144*, 1–9.

Inman, D., & Jeffrey, P. (2006). A review of residential water conservation tool performance and influences on implementation effectiveness. *Urban Water Journal*, *3*(3), 127–143. https://doi.org/10.1080/15730620600961288

Jorgensen, B., Graymore, M., & Toole, K. O. (2009). Household water use behavior : An integrated model Household water use behavior : An integrated model. *Journal of Environmental Management*, *91*(1), 227–236.

https://doi.org/10.1016/j.jenvman.2009.08.009

Karlin, B., Zinger, J. F., & Ford, R. (2015). *The Effects of Feedback on Energy Conservation : A Meta-Analysis*. *141*(6), 1205–1227.

Katz, D., Grinstein, A., Kronrod, A., & Nisan, U. (2016). Evaluating the effectiveness of a water conservation campaign : Combining experimental and field methods Evaluating the effectiveness of a water conservation campaign : Combining experimental and fi eld methods. *Journal of Environmental Management*, *180*(October 2017), 335–343. https://doi.org/10.1016/j.jenvman.2016.05.049

Katz, D., Kronrod, A., Grinstein, A., & Nisan, U. (2018). Still Waters Run Deep: Comparing Assertive and Suggestive Language in Water Conservation Campaigns Enhanced Reader. *Water*, *10*(3), 275.

Koop, S. H. A., Dorssen, A. J. Van, & Brouwer, S. (2019). Enhancing domestic water conservation behaviour : A review of empirical studies on influencing tactics. *Journal of Environmental Management*, *247*(March), 867–876. https://doi.org/10.1016/j.jenvman.2019.06.126

Lam, S. P. (2006). Predicting intention to save water: Theory of planned behavior, response efficacy, vulnerability, and perceived efficiency of alternative solutions. *Journal of Applied Social Psychology*, *36*(11), 2803–2824. https://doi.org/10.1111/j.0021-9029.2006.00129.x

Latimer, A. E., Salovey, P., & Rothman, A. J. (2007). The effectiveness of gain-framed messages for encouraging disease prevention behavior: Is all hope lost? *Journal of Health Communication*, Vol. 12, pp. 645–649.

https://doi.org/10.1080/10810730701619695

Lee, M. L., & Dey, A. K. (2014). Realtime Feedback For Improving MedicationTaking. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2259–2268.

Levin, T., & Muehleisen, R. (2016). *Saving Water through Behavior Changing Technologies*. 1–12.

Liu, A., Giurco, D., & Mukheibir, P. (2016). Urban water conservation through customised water and end-use information. *Journal of Cleaner Production*, *112*, 3164–3175. https://doi.org/10.1016/j.jclepro.2015.10.002

Liu, A., Giurco, D., Mukheibir, P., Mohr, S., Watkins, G., & White, S. (2017). Online water-use feedback: household user interest, savings and implications. *Urban Water Journal*, *14*(9), 900–907. https://doi.org/10.1080/1573062X.2017.1279194

Liu, A., & Mukheibir, P. (2018). Digital metering feedback and changes in water consumption – A review. *Resources, Conservation and Recycling*, *134*(March), 136–148. https://doi.org/10.1016/j.resconrec.2018.03.010

Lockton, D. (2012). Affordances, Constraints and Information Flows as “Leverage Points” in Design for Sustainable Behaviour. *SSRN Electronic Journal*, (1999), 1–34. https://doi.org/10.2139/ssrn.2120901

Lowe, B., Lynch, D., & Lowe, J. (2015). Reducing household water consumption: a social marketing approach. *Journal of Marketing Management*, *31*(3–4), 378–408. https://doi.org/10.1080/0267257X.2014.971044

Mckenzie-Mohr, D. (2000). *Promoting Sustainable Behavior : An Introduction to Community-Based Social Marketing*. *56*(3), 543–554.

Mitchell, D. L., & Chesnutt, T. W. (2013). *Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports*. Retrieved from https://www.financingsustainablewater.org/sites/www.financingsustainablewater.org/files/resource_pdfs/MCubed-Watersmart_evaluation_report_FINAL_12-12-13%2800238356%29.pdf

Monroe, M. C. (2003). *Two Avenues for Encouraging Conservation Behaviors*. *Human Ecology Review, 10*(2), 113-125.

Myers, E., & Souza, M. (2019). *Social Comparison Nudges Without Monetary Incentives: Evidence from Home Energy Reports*. (March).

O'Keefe, D. J., & Jensen, J. D. (2007). The relative persuasiveness of gain-framed and loss-framed messages for encouraging disease prevention behaviors: A meta-analytic review. *Journal of Health Communication, 12*(7), 623–644. https://doi.org/10.1080/10810730701615198

Otaki, Y., Ueda, K., & Sakura, O. (2017). Effects of feedback about community water consumption on residential water conservation. *Journal of Cleaner Production, 143,* 719–730. https://doi.org/10.1016/j.jclepro.2016.12.051

Pereira, L., Quintal, F., Barreto, M., & Nunes, N. J. (2013). Understanding the limitations of eco-feedback: A one-year long-term study. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 7947 LNCS,* 237–255. https://doi.org/10.1007/978-3-642-39146-

0_21

Petersen, J. E., Shunturov, V., Janda, K., Platt, G., & Weinberger, K. (2007). *Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives*. (June 2014). https://doi.org/10.1108/14676370710717562

Petkov, P., Foth, M., Road, V. P., & Köbler, F. (2011). Motivating Domestic Energy Conservation through Comparative , Community-Based Feedback in Mobile and Social Media Queensland University of Technology Chair for Information Systems. *In Proceedings of the 5th International Conference on Communities and Technologie*, 21–30.

Petkov, P., Köbler, F., Foth, M., & Krcmar, H. (2011). Motivating domestic energy conservation through comparative, community-based feedback in mobile and social media. *C and T 2011 - 5th International Conference on Communities and Technologies, Conference Proceedings*, 21–30. https://doi.org/10.1145/2103354.2103358

Pope, J. P., Pelletier, L., & Guertin, C. (2018). Starting Off on the Best Foot: A Review of Message Framing and Message Tailoring, and Recommendations for the Comprehensive Messaging Strategy for Sustained Behavior Change. *Health Communication*, *33*(9), 1068–1077. https://doi.org/10.1080/10410236.2017.1331305

Rivers, D. J. (2020). Strava as a discursive field of practice: Technological affordances and mediated cycling motivations. *Discourse, Context and Media*, *34*, 100345. https://doi.org/10.1016/j.dcm.2019.100345

Russell, S., & Fielding, K. (2010). Water demand management research: A psychological perspective. *Water Resources Research*, *46*(5), 1–12. https://doi.org/10.1029/2009WR008408

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Schultz, P. W. (2010). *Changing Behavior With Normative Feedback Interventions : A Field Experiment on Curbside Recycling Changing Behavior W ith Normative Feedback Interventions : A Field Experim ent on Curbside Recycling*. *3533*. https://doi.org/10.1207/s15324834basp2101

Schultz, P. W., Messina, A., Tronu, G., Limas, E. F., Gupta, R., & Estrada, M. (2016). Personalized Normative Feedback and the Moderating Role of Personal Norms : A Field Experiment to Reduce Residential Water Consumption. *Environment and Behavior*, *48*(2), 686–710. https://doi.org/10.1177/0013916514553835

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The Constructive , Destructive , and Reconstructive Power of Social Norms. *Psychological Science*, *18*(5), 429–434.

Schultz, W., Javey, S., & Sorokina, A. (2019). Social Comparison as a Tool to Promote Residential Water Conservation. *Empirical Study*, *1*(July). https://doi.org/10.3389/frwa.2019.00002

Seaver, W. B., & Patterson, A. H. (1976). DECREASING FUEL-OIL CONSUMPTION THROUGH FEEDBACK AND SOCIAL COMMENDATION. *Journal of Applied Behavior Analysis*, *9*(2), 147–152.

Sofoulis, Z. (2005). Big Water, Everyday Water: A Sociotechnical Perspective. *Continuum*, *19*(4), 445–463. https://doi.org/10.1080/10304310500322685

Sønderlund, A. L., Smith, J. R., Hutton, C. J., Kapelan, Z., & Savic, D. (2016). Effectiveness of smart meter-based consumption feedback in curbing household water use: Knowns and unknowns. *Journal of Water Resources Planning and Management*, *142*(12). https://doi.org/10.1061/(ASCE)WR.1943-5452.0000703

Stead, M., Gordon, R., Angus, K., & McDermott, L. (2007). A systematic review of social marketing effectiveness. *Health Education*.

Syme, G. J., Nancarrow, B. E., & Seligman, C. (2000). The Evaluaion of Information Campaigns to Promote Voluntary Household Water Conservation. *Evaluation Review*, *24*(6), 539–578.

Thompson, R. R., Coe, A., Klaver, I., & Dickson, K. (2011). *Applied Environmental Education & amp ; Communication Design and Implementation of a Research-Informed Water Conservation Education Program Design and Implementation of a Research-Informed*. *0389*. https://doi.org/10.1080/1533015X.2011.575728

Tiefenbeck, V., Goette, L., Degen, K., Tasic, V., Fleisch, E., Lalive, R., & Staake, T. (2016). Overcoming salience bias: How real-time feedback fosters resource conservation. *Management Science*, *64*(3), 1458–1476. https://doi.org/10.1287/mnsc.2016.2646

Tiefenbeck, V., Staake, T., Roth, K., & Sachs, O. (2013). For better or for worse ? Empirical evidence of moral licensing in a behavioral energy conservation campaign. *Energy Policy*, *57*, 160–171. https://doi.org/10.1016/j.enpol.2013.01.021

Ueno, T., Inada, R., Saeki, O., & Tsuji, K. (2006). Effectiveness of an energy-consumption information system for residential buildings. *Applied Energy*, *83*(8), 868–883. https://doi.org/10.1016/j.apenergy.2005.09.004

Warner, L. A., Rumble, J., Martin, E., Lamm, A. J., & Cantrell, R. (2015). The Effect of Strategic Message Selection on Residents ' Intent to Conserve Water in the Landscape. *Journal of Agricultural Education*, *56*(4), 59–74. https://doi.org/10.5032/jae.2015.04059

WaterSmart. (2014). *Tapping into the Power of Behavioral Science*. Retrieved from http://www.watersmart.com/wp-content/uploads/2014/11/WSS_TappingintoBehaviorScience.pdf

Willis, R. M., Stewarta, R. A., Panuwatwanich, K., Jones, S., & Kyriakides, A. (2010). Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households. *Resources, Conservation and Recycling*, *54*(12), 1117–1127. https://doi.org/10.1016/j.resconrec.2010.03.004

APPENDICES

Appendix

Tables

Table: List of reviewed studies that used feedback and strategic message for conservation.

Field	Communication medium	Study	Intervention duration	Post-intervention	Sample Size (number of households)	Year	Percent (%) reduction in usage
Energy	In home display	Seligman et al. 1978	4-weeks	ns	20	1976	16%
Energy	Electronic/computer-based	Dobson & Griffin, 1992	8-weeks	ns	25	1991	13%
Energy	Electronic/computer-based	Benders et al., 2005	21-weeks	ns	190	2002-2003	8.50%
Energy	Electronic/computer-based	Ueno, Inada, Saeki, & Tsuji, 2006	40-weeks	ns	19	2003	9%
Energy	Paper-based	Allcott, 2011	102-weeks	ns	600,000	2009-2010	0.3-6.3%
Energy	In home display and computer-based	Tiefenbeck et al., 2016	8-weeks	2-weeks	697	ns	22%
Energy	Electronic/computer-based	Alberts et al., 2016	6-weeks	2-weeks	466 post-graduate students	2013	22%
Energy	In home display	Tifenbeck er al., 2018	8-weeks	ns	636	ns	22%
Water	Paper-based	S. C. Thompson & Stoutemyer, 1991	8-weeks	8-weeks	171	1991	6-18%
Water	Paper-based	Aitken et al., 1994	12-weeks	ns	226	1991	4.30%

Field	Communication medium	Study	Intervention duration	Post-intervention	Sample Size (number of households)	Year	Percent (%) reduction in usage
Water and energy	Electronic	Petersen et al., 2007	2-weeks	ns	1,612	2005-06	32% decrease in energy use 3% decrease in water use
Water	Electronic	Willis et al., 2010	2-weeks	2-weeks	151	2008	
Water	Electronic	Erickson et al., 2012	15-weeks	ns	303	ns	
Water	Paper & electric	Mitchell & Chesnutt, 2013	52-weeks	ns	10,000	2012	4.4-6.6%
Water	Paper-based	Fielding et al., 2013	21-weeks	52-weeks	221	2010-11	8-15%
Water	Paper-based	Ferraro & Price, 2013	16-weeks	ns	100,000	2007	7.41-53.38%
Water	Paper-based	Tiefenbeck et al., 2013	12-weeks	2-weeks	154	2011	6%
Water	Electronic and Paper-based	WaterSmart, 2014	ns	ns	ns	2014	5%
Water	Electronic, Paper, Billboard, Road Signs	Lowe, Lynch, & Lowe (2015)	104-weeks	ns	535	2007	25%
Water	Paper & electric	Schultz et al., 2016	1-week	1-week	296	ns	16-26%

Field	**Communication medium**	**Study**	**Intervention duration**	**Post-intervention**	**Sample Size (number of households)**	**Year**	**Percent (%) reduction in usage**
Water	Paper-based (post card)	Katz et al., 2016	26-weeks	5-weeks	934	ns	7.60%
Water	Paper-based (post card)	Liu et al., 2016	20-weeks	4-weeks	57	2012-14	20.30%
Water	Paper-based	Brick et al., 2017	20-weeks	ns	400,000	2015	0.6-1.3%
Water	Electronic	Otaki, Ueda, & Sakura, 2017	24-weeks	ns	246	ns	reduction reported through Mann-Whitney and Kruskal-Wallis test, and no actual values were used
Water	Paper-based	Nayar & Kanaka, 2017	4-weeks	ns	74	ns	5.02-10.6%
Water	Paper-based	Schultz et al., (2019)	26-weeks	60-weeks	18,711	2015-17	8.35%

CHAPTER 3

COMBINE PSYCHOLOGICAL AND WATER END USE DATA TO CREATE INDIVIDUALIZED MESSAGES TO SUSTAIN CONSERVATION BEHAVOIR

Key points

- Developed household-specific water conservation messaging system to sustain water conservation behavior.
- System constructs user messages by combining psychological intent and water end use data.
- Illustrated method with Residential End Uses of Water 2016 data and showed 93% of users can reduce use by 25%.
- Feedback from ten graduate students, university faculty, and homeowners and made messages more intuitive.

3.1 Introduction

This paper's purpose is to combine data about a user's intent and their end use behaviors to create individualized messages to encourage and sustain water conservation behaviors. In prior voluntary or mandatory conservation campaigns, the water volume saved and duration of savings varied (Inman & Jeffrey, 2006; Sønderlund et al., 2016). For instance, Brick, Martino, & Visser (2017) reported a consumption decrease of 0.6%, while Ferraro & Price (2013) observed a 53% decrease. Water savings may last from a couple of months (Fielding et al., 2013) to a year (Mitchell & Chesnutt, 2013). When price penalty withdrawn or seasonal water restrictions lapsed, water use rebounded

(Kenney et al., 2008). Managers and authorities are challenged to motivate users to voluntarily follow their messages and sustain water-saving behaviors.

Studies repeatedly suggested that behavior modification approaches can improve the effectiveness of voluntary campaigns (Chaudhary et al., 2017; Fielding et al., 2013; Warner et al., 2015). For example, managers can develop messages that use cognitive dissonance theory to change a person’s behavior by directing them to information that shows that they are behaving differently (e.g., using more energy or water) than they believe (Festinger, 1957). The inconsistency between belief and behavior can trigger behavior to change to conform with the belief. However, some customers/users may consider such an approach confrontational and ignore the message (Taddicken & Wolff, 2020). Furthermore, the water manager still needs clear directions to tailor the tips to guide the user/customer to adopt conservation actions. Social comparison is another popular technique applied by many studies that provides comparative statements showing how the user/customer consumed water relative to their neighbor. For instance, Ferraro & Price (2013) reported a 26% decrease in water consumption among users who received comparative statements. However, Schultz et al. (2016) pointed out that some user groups, such as users who are confident about their actions and believe their consumption habit is appropriate, are not influenced by comparative statements. Other conservation message components included water use, climate (drought) information, and water-saving tips.

Because different user groups process information differently, managers can benefit from a dynamic system to identify the right message components to prompt effective conservation actions. Furthermore, if users' informational preferences are met, the user can sustain the changed behavior in the long term (Inman & Jeffrey, 2006; Koop et al., 2019; Sønderlund et al., 2016).

To overcome these issues, we combine behavioral information with psychology to devise voluntary conservation interventions. This approach follows community-based social marketing (Mckenzie-Mohr, 2000). Mckenzie-Mohr (2000) posited that as users get the required and preferred information through customized interventions to fulfill their motivational needs, they will better adopt and sustain conservation behaviors. The approach has helped users change smoking and alcohol habits (Stead et al., 2007), promote physical activity (Drury, 2009), and promote community composting (Boivinn et al., 2016). Use for water-saving tips was challenged because granular, high-frequency, disaggregated end-use data were not available. Because commercial companies now provide high-frequency and disaggregated data (Flume, 2021; Mitchell & Chesnutt, 2013), water utilities, authorities, and managers now have an opportunity to use community-based social marketing to develop customized feedback messages.

The next 2 sections provide a theoretical framework and describe how to combine psychological intent and end use data, segment users into groups with similar psychological and behavioral characteristics, and tailor messages to each group. Subsequent sections illustrate the approach with the Residential End Uses of Water, Version-2 (REU-2016) dataset (DeOreo et al., 2016), share feedback from testing messages with ten graduate students, university faculty, and homeowners, and list limitations. A final section concludes.

3.2 Theoretical Framework

3.2.1 Community-based social marketing

Community-based social marketing utilizes behavioral and psychology data to create interventions that improve one behavior at a time. Interventions can be conservation tips circulated through mailings (Boivin et al., 2016) or educational commercials broadcasted through TVs, radios, and newspapers (Lowe et al., 2015). The customized interventions always target a specific behavior and a specific population or user group. The entire social marketing process can be divided into three broader stages, the pre-intervention data collection stage, the intervention and evaluation stage, and the full-scale implementation stage.

3.2.1.1 Pre-intervention stage

3.2.1.1.1 Setting conservation goal

The manager/authority must first define the goal, i.e., reduce water use by a certain volume. An example of goal setting was discussed by Lowe et al. (2015), where the authors reported a case study in Australia that used community-based social marketing tactics to create radio, television, and newspaper commercials for water conservation. The conservation goal set by that study was 25% reduction in average daily water use. This specific value was selected to keep a reservoir water level above the critical draw.

3.2.1.1.2 Data collection

Once a goal is set, water managers collect behavioral and psychology data. For water conservation, behavioral data is the water use information that is collected through meter reading. Commercial companies now collect high frequency aggregated (Mitchell & Chesnutt, 2013) and disaggregated data (Flume, 2021) and relay the information to their customers, i.e., water users. The collected behavioral data must be accurate because interventions are directly connected to the behavioral data. Therefore, inaccurate behavioral data will diminish the credibility of customized interventions.

Psychology data refers to information collected through household surveys that identify users' informational and motivational preferences and conservation outlook. The questions used for collecting psychology data depend on the behavioral model implemented—models or theories that are used to determine motivating factors and how a user might act once those motivations are provided. For instance, the theory of planned behavior (TPB)—a behavioral model that postulates that a user's intention is the prime controller of the user's behavior (Ajzen, 1985)—was repeatedly used by earlier studies that used community-based social marketing for developing behavior-specific interventions (Boivin et al., 2016; Chaudhary et al., 2017; Lowe et al., 2015). As per TPB, the behavioral intention is motivated by factors, such as attitude (users outlook), subjective norms (social pressure), and perceived behavioral control (the perception of ease or difficulty of incorporating the changed behavior into day-to-day life). Hence, if TPB is selected as the behavioral model for analyses, then a specific set of questions targeting the user's attitude, subjective norms, and perceived behavioral control must be developed and circulated, and the responses must be recorded before producing feedback and strategic messaging interventions. One important note here is that the questions should be tailored to the behaviors (Clark & Finley, 2007). If a single end-use is being targeted for improvement, it is imperative to create questions specific to that end-use. Appendix 1 provides some guidance on the construction of TPB questions.

3.2.1.2 Intervention phase

In the intervention phase, first, managers carefully examine behaviors and select a behavior based on its inefficiency. For instance, some behaviors, such as lawn irrigation, are skewed meaning only a few households exhibit inefficient behaviors and by targeting these behaviors, managers can maximize their demand reduction instead of targeting every end-use behavior. Next, by combining this behavior data with the psychology data collected during the pre-intervention stage, managers segment users into meaningful groups with similar inefficiency and socio-psychological standings. Afterward, customized interventions are developed for each group, focusing on inefficient water application, customized suggestions for improving the behaviors, and any other motivational messages to keep users engaged in conservation behaviors (Chapter 2). Finally, water use is strictly monitored simultaneously with the application of the intervention. If behavior is improved, then intervention ends. Otherwise, the intervention keeps repeating. Note that the entire intervention is tested by performing a small-scale pilot study.

3.2.1.3 Full-scale implementation

Full-scale implementation follows similar steps to those used in the pilot testing. However, managers concentrate on the entire community instead of a few households. Figure 3.1 provides a simplified flowchart of the whole process.

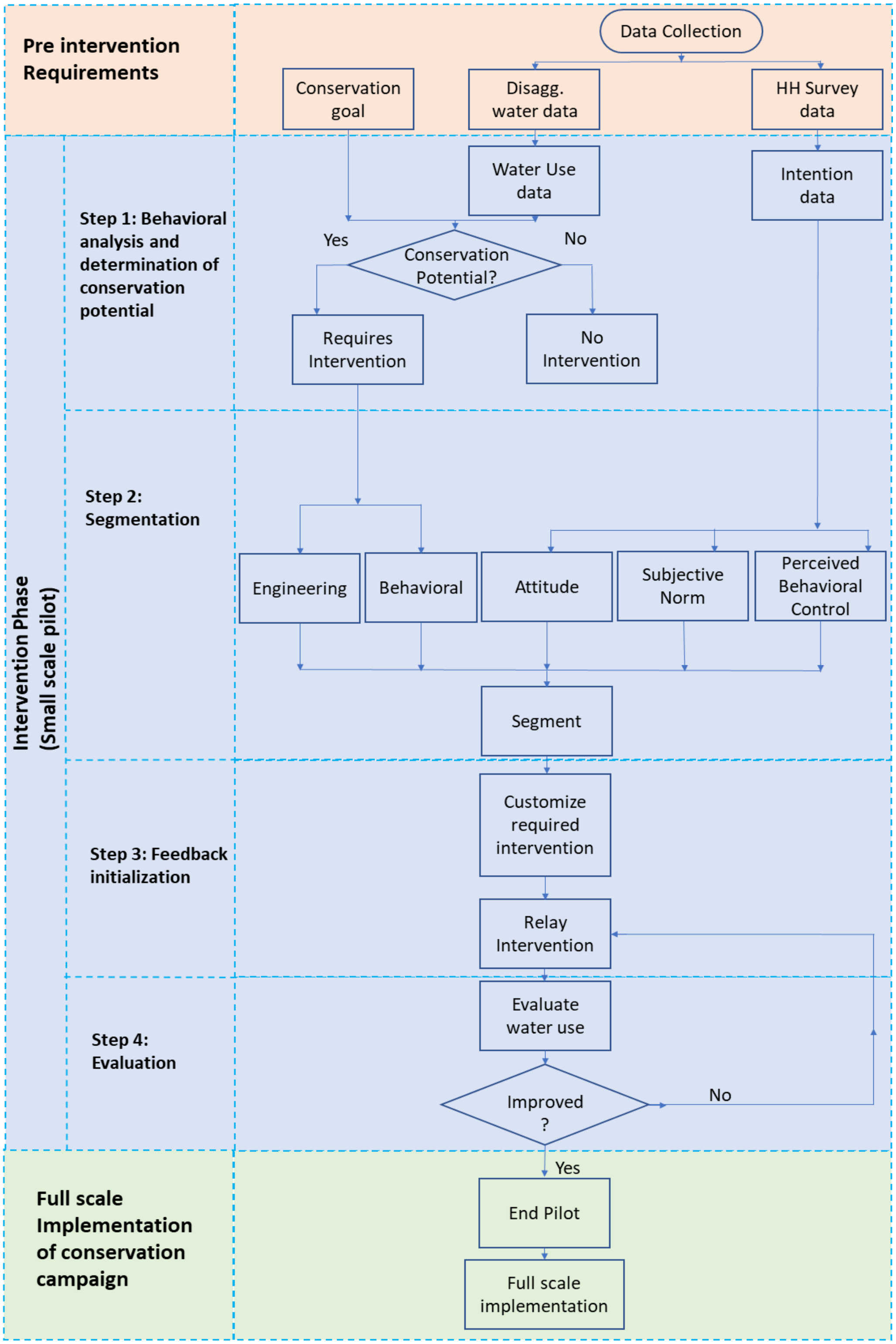


Figure 3.1: Community-based social marketing process to develop conservation campaigns.

3.2.2 Application of non-parametric ranking approach using Lorenz curve and Gini index

To utilize community-based social marketing for conservation purposes, managers need to target specific end-uses or end-use attributes (e.g., duration of an end-use event or occurrence of an end-use event). The Lorenz curve and Gini index are approaches that use a simple ranking method for analyzing the end-use inequality. Economists have long been using Lorenz curves and Gini indices to quantify income inequality among different countries. These methods were established by Corrado Gini (Gini, 1912). Recently, Lorenz curves and Gini indices have been used outside the field of economics to identify inequality of carbon emissions among countries (L. Groot, 2010) and seasonal variability of domestic radon gas emission (Groves-Kirkby, Denman, & Phillips, 2009).

The Lorenz curve sorts users from smallest to largest (or vice-versa) according to the cumulative share (%) of a particular attribute (income, water use, etc.) and the approach works on any dataset regardless of the units of measurement. When plotted, both the x- and y- axes go from 0 to 100% representing percent of total population (x-axis) and ranked cumulative share of total resource use (y-axis). If every user uses the same amount of a resource, then a straight one-to-one line from (0,0) to (1,1) occurs known as the 'line of equality'. In most cases, however, the resource is not equally distributed, and the Lorenz curve drops below the 1:1 line. The Gini index (G, unitless) is the area between the line of equality and the Lorenz curve (A) and the area under the Lorenz curve (B):

$$G = \frac{A}{A + B}$$

The Gini index measures the skewness of the data, and its value ranges from 0 to 1. The more the Lorenz curve pulls away from the 1:1 line, the higher the Gini index, and the greater the skewness of the data. Plotting multiple Lorenz curves on the same plot allows managers to identify which dataset is most skewed.

Figure 3.2 demonstrates the versatility of Lorenz curves and Gini indices. Country-wise carbon emission data (kt), population (persons per country), and income data ($/capita) for the year 2014 are plotted (World Bank, 2021). In the same figure, Lorenz curves for the daily average bathtub, shower, indoor, and outdoor water use (gallons/ household/ day) (DeOreo et al., 2016), and per capita water use data for Utah municipalities (Utah Division of Water Resources, 2021) were plotted. The figure shows that the most skewed dataset, with a Gini index of 95%, is carbon emission and that 25% of the countries (including the U.S.) emit more than 95% of the carbon in the world. The lowest Gini index among the six data sets is REU-2016 indoor water use, which is 0.3, which indicates that indoor water use is more equal across households, although the highest 30% of water using households still use almost 50% of the total indoor water used.

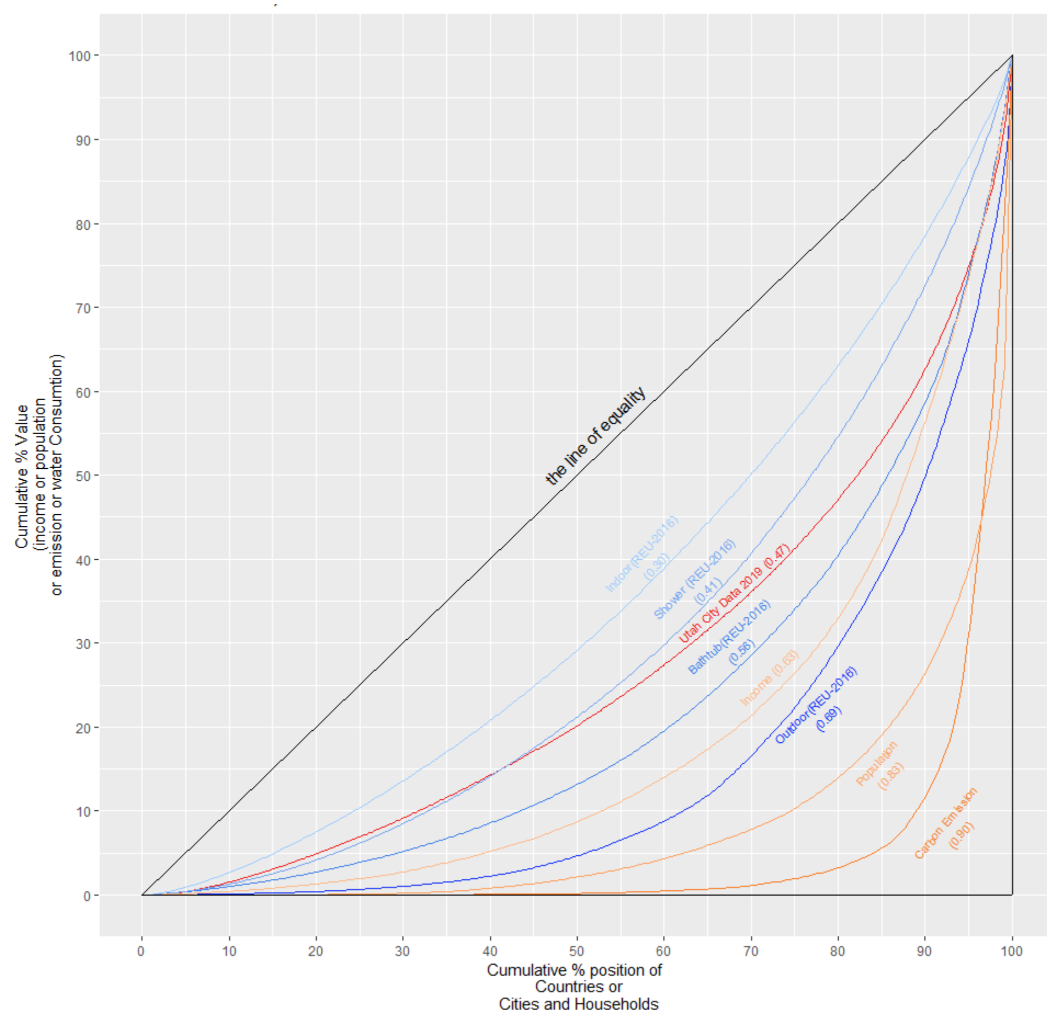


Figure 3.2: Lorenz curves for carbon emission (kt), population, and income data by country for 2014, and REUS-2016 daily bathtub, shower and indoor water use by household.

Like standard deviation, the Gini index provides a good idea of the dispersion of the dataset. However, Gini is bounded by the ranks (0 to 100) as every dataset item is sorted from lowest to highest by the values. Also, the Gini index does not retain the scale of the dataset. Hence, we can plot multiple Lorenz curves (of varying units) in the same graph to get a comparative perspective of inequality or spread different datasets. Unlike standard deviation, where the maximum value is reached when half the data points live at the extreme minimum and maximum zones, the Gini index reaches its maximum value when one data point lives at the extreme maximum zone. In other words, the outliers provide more skewness to the curve and we can identify which data points are responsible for the skewness. Hence, this process offers a unique way to look into the behavioral and usage inequality of households. For example, if end-use data for a region is available, a water manager can create Lorenz curves for each end-use and calculate the Gini indices to target the most skewed water behavior. In this manner, the manager will be able to target the least number of households with the highest water use behavior for that particular end-use.

3.3 Methods

The purview of this research is to create a framework that managers may use to construct household-specific customized strategic messages for water conservation purposes. Hence, our methods will only focus on the intervention phase stage of community-based social marketing and its required four stems (Figure 3.1). The steps from pre-intervention stage and full-scale implementation stage will not be discussed.

Step 1: Behavioral analysis and determination of conservation potential

Managers need to understand the end-use behaviors and users’ outlook/intention towards conservation to provide comprehensive and personalized feedback. This step, therefore, is divided into two sub steps.

Step 1(a): Understanding user's end-use behaviors and potential to conserve

This sub-step utilizes the information collected through high-frequency smart water monitoring systems. The details of the data disaggregation process are provided in DeOreo et al. (2016), Attaallah (2018), and Pacheco et al. (2020).

I. Compute water savings through behavioral intervention

a. Select a water conservation target for the community [gallons/day].
b. For each appliance (of each household), compute behavioral attributes such as intensity of use [events/day, events/person/day] and duration of use [minutes/event, minutes/person/day]. Also, compute technology attributes such as flowrate [gallons/event] and volume per event [gallons/event] for each appliance.
c. For each appliance, plot Lorenz curves and compute Gini indices for all behavioral attributes.
d. For each appliance, select the behavioral attribute with the highest Gini index. This selection encourages managers to work with the most skewed attribute and the fewest number of households to reach the target.
e. Solve for the behavioral threshold value so that when users reduce their behavior to that threshold value, the households will save the target water volume specified in step 1(a).I.a. This step assumes the appliance technology will stay the same.

f. Separate households with behavioral values higher than the threshold defined in Step 1(a).I.e.

g. Compute appliance-wise total cumulative volume that can be potentially conserved if households with higher behavioral values adopt the behavioral conservation action.

h. For irrigation water use, mark the time of water application.

II. Compute appliance wise water savings through technology opportunity

a. Use the USEPA WaterSense criteria (USEPA, 2020) as listed in Table 3.1 to identify appliances that use more water per event than the attribute values listed in the table. A household may have multiple inefficient appliances.

Table 3.1: Criteria used for identifying inefficient appliances. The values are taken from USEPA guidelines lists fixture standards for the United States.

Appliance	**Criteria**
Clothes washer	14 gallons/load
Dishwasher	4 gallons/load
Faucet	1.5 gallons/minute
Shower	2 gallons/minute
Toilet	1.6 gallons/flush

b. Compute appliance-wise total potential volume (cumulative) that can be saved if all households with inefficient appliances are retrofitted with WaterSense labeled appliances.

Step 1(b): Evaluate user conservation intentions

For customizing messages, managers need to understand users' intentions towards conservation. To do so,

- Use the question constructs provided as samples in Appendix 1 and create end-use specific questions to evaluate user attitude, subjective norm, and perceived behavioral control.
- For each decision variable (i.e., attitude, subjective norm, perceived behavioral control, etc.), calculate the total response score by summing the responses.
- Calculate the median value for each decision variable.
- Identify the households that scored more than or equal to the median scores.

Studies reveal that some users are highly enthusiastic about the environment and score high points in the survey questions. Unfortunately, the opposite is also true. Furthermore, the distribution of the scores often follows a skewed pattern. Hence, using the median is a better metric than using the mean of the scores, as it reduces the effect of outliers and provides a better estimation of the central tendency.

Step-1 has two direct implications if managers use community-based social marketing for feedback. First, managers will be able to quantify the cumulative volume of water that consumers can save if different behavioral and engineering interventions are implemented. Second, managers can use this step for segmentation purposes which will eventually lead to the selection of messaging contents.

Step 2: User segmentation and intervention planning

Here, we propose a hybrid segmentation system based first on the required intervention type and second on users' responses to the psychological evaluation questions.

I. Segmentation based on prospective intervention

There will be two intervention groups: behavioral intervention (BI) and engineering intervention (EI). Users in the BI group will save the largest water volume by changing behaviors such as taking a shorter shower. Users in the EI group will save water by retrofitting the house with efficient appliances. Households may have multiple behaviors that will require improvements or multiple appliances that will require upgrading. Social marketing targets a single behavior at a time.

- Select a household, determine the number of behaviors (identified in step 1.a) and the number of appliances that require improvement. This number will determine how many intervention-phases the household will need if managers focus on one behavior or one inefficient appliance at a time.
- Select the behavior or the inefficient appliance with the largest water-saving potential.
- If it is a behavior, put the household in the BI group.
- Conversely, put the household in the EI group.
- Keep the household in that intervention group until its behavior improves or the inefficient appliance is replaced.

- Once the household has improved its behavior or retrofitted with an efficient appliance, select the subsequent behavior or inefficient appliance with the second-highest water-savings potential and put it in the relevant intervention group.
- Repeat steps until all the behaviors are improved or all the inefficient appliances are removed or replaced.
- Repeat this process for every other household.
- Group the households based on their intervention phases and intervention requirements.

Once this sub-step is completed, managers will know how many intervention phases to develop and will have specific households grouped by intervention requirements. In the first intervention phase, managers will focus on behaviors with the most significant water use volume. Subsequently, once that behavior has improved, managers can start the next intervention, and so on.

II. Segmentation based on psychological responses

The next step is to group users based on their responses to the baseline survey questions. As mentioned earlier, three psychological factors are targeted: attitude, subjective norm, and perceived behavioral control.

Consider just one of these factors (for now), say, subjective norm—the factor that sheds light on the user's perception of how other users (e.g., neighbors, loved ones, influential persons in his/her life) are conducting conservation actions. If a household's score is less than the median value computed in step 1.b for subjective norm questions, it will be assumed that the household does not know that the other users are conserving water through various water-saving activities. Therefore, providing comparative usage information (of neighbors or similar-sized households) may motivate them to conserve water. Conversely, if the household scores higher than the median value and has opportunity to save water by changing behaviors or replacing inefficient appliances, then providing a comparative statement detailing how neighbors use their water will not improve their efficiency. This method of using median values for separating users is called the median split method (Galotti et al., 1999).

As there are three psychological factors, there will be eight total psychological groups (Table 3.2). For example, the households who scored higher than the median scores in attitude, subjective norm, and perceived behavioral control questions will be in one group. The users who scored lower than the median score in at least one of the evaluation sections will be placed in another group and so on. Previous studies did not provide any consistent system for naming these groups.

Table 3.2: Psychological grouping criteria

Group name	Attitude	Subjective norm	Perceived behavioral control
Has all intention factors	✓	✓	✓
Missing attitude factor		✓	✓
Missing subjective norm factor	✓		✓
Missing perceived behavioral control factor	✓	✓	
Only has Perceived behavioral control factor			✓
Only has subjective norm		✓	
Only has attitude	✓		
Has no intention factors			

For any given intervention phase, managers will have two intervention groups and each group will have eight different psychological groups. Grouping users based on the intervention requirement helps managers target a specific end-use, and segmenting users helps managers decide which messages to send.

Step 3: Feedback

The efficacy of components was discussed in detail in chapter 2, where 80 research articles from the behavioral science, environmental, water, and energy conservation, and health communication fields were reviewed and synthesized. Based on the articles reviewed, we propose having multiple sections in the message (Table *3.3*) which can be organized any way the manager or water utility sees fit.

Table 3.3: Distinct sections of the customized message and their purpose.

Section	Content	Purpose
1	Appeal from utility or water manager for conservation	Provide internal motivation for water conservation
2	Appliance-specific water use information and social comparison	Help user assess their end-uses (also, this is the most sought-after information among users)
3	Customized feedback, strategic messages, and appliance-specific tip for individual household	Help user focus on the end-use that has the highest potential to save water
4	Any additional information mentioned by the social marketing that may help user to improve their behavior	To inform users about rebates, efficient appliances, and emphasize to communicate with the manager or the utility to improve the message contents.

Below, we describe the sections in detail. Examples are provided in the illustration section.

a) Section 1: Announce utility's current conservation initiatives and urge users to "conserve" (build user's trust)

The likelihood of adopting water-saving actions increases if a utility helps users realize that the utility has taken all necessary efforts to maximize water conservation. In this way, the utility earns users' trust while emphasizing how water-saving actions can protect the community from future calamities.

- Describe the current water crisis.
- State the utility's or water authority's initiatives that exists to reduce water loss.
- State the water authority's goal, i.e., how much water the administration plans to save in a given period.

- If applicable, mention that other community members have also started to conserve.
- Finish with a concise statement that summarizes what the authority wants the user to do.
- The statements should be gain-framed, i.e., state how the authority is improving the situation—because gain-framed messages are more effective for encouraging users than loss-framed statements (Warner et al., 2015).

b) Section 2: Provide appliance-specific water use information (prompt internal satisfaction or cognitive dissonance)

This section aims to inform the user about their end-uses and also points out whether the consumer is efficient or inefficient in their water use. Some suggestions for creating this section are:

- Group households based on household size, i.e., number of permanent residents.
- Provide appliance-wise comparisons between the household and their neighbors or another efficient household using a bar chart.
- Use emojis: green for efficient use, red for inefficient use.
- For outdoor use, use a line or bar graph where the x-axis is the time of day and the y-axis represents the volume used. Also, note the desired times of day for irrigation.

- Mention how much the household has reduced or increased their overall water uses since the last feedback.

c) Section 3: Provide specific water saving tips using strategic messages that improve attitude, prompt peer pressure, and reinforce customer confidence to sustain conservation behaviors.

The selection of messages will depend on the type of intervention and psychological grouping discussed in step 2. Each message includes a normative portion and end-use specific recommendations.

I. Normative messaging construct

A user may have attitude, subjective norm, and/or perceived behavioral control deficits. Messages will show why water conservation may be beneficial (attitude development), how neighbors are performing (subjective norm development), and how easily can they be incorporated into daily life by accomplishing small achievable goals.

Messages to increase conservation outlook (attitude)

Attitudinal messages highlight conservation benefits, either social or financial. Some suggestions on the types of messages that can be used are:

- By practicing conservation actions, the user will be considered a role model in society (Brick et al., 2017; Warner et al., 2015).

- Inefficient appliances and poor irrigation techniques can cost the user more money in the long term (Warner et al., 2015).
- The user will pay more for higher use with block pricing techniques (Brick et al., 2017).

Messages to improve subjective norm deficit

These messages tell a user that other community members are saving water to the best of their ability:

- State how many users (or fraction of users) from the community have already adopted that water-saving behavior or replaced inefficient appliances.
- Share positive statements by adopters of water-saving behaviors.

Messages to improve perceived behavioral control deficit

These messages tell users adopting and sustaining a conservation action is easy:

- Tell the customer that many users practice the conservation action without disrupting their daily routine.
- Actions are easy to implement.
- Tell users where to purchase replacement appliances.

Note that for users with no psychological deficit (type 1) this section is entirely optional. The manager must choose the contents discussed above based on the deficits mentioned in Table *3.2*.

II. Feedbacks and customized tips

Make tips end-use specific. Concentrate on one new tip or habit at a time.

- Use the analysis from step 2 to identify the necessary intervention (behavior or engineering) and select the appliance or behavior that needs improvement.
- Insert a picture of the appliance to draw the user's attention to the recommendation.
- If the household is from an engineering intervention group, state the current technology problem (i.e., the toilet uses more than 1.6 gallons/flush, the washing machine uses more than 14 gallons/cycle, etc.), and recommend that they install an efficient model of that appliance.
- If the household is from a behavioral intervention group, recommend a behavioral reduction value slightly below their daily average. Once the household is accustomed to this new behavior, suggest they decrease the shower time by another two minutes. Repeat the process until the household reaches the population mean.
- State how much water (volume) the household can save over one year if they change their habit or install a newer, more efficient appliance.
- State the main recommendation in bold letters.

- For outdoor use, mark the usage graph showing appropriate times for irrigation and inappropriate times using pink and blue colors and urge users to recalibrate their irrigation devices (for automated irrigation systems) or to change their watering practices.
- Identify the behaviors that household residents are doing efficiently (better than median value) or the appliances using less water than the standard (from the disaggregated data) and praise them as a part of positive feedback (Deci, 1971; E S Geller, 1989).

d) Section 4: Providing information relevant to social marketing tactics (for providing additional motivation, and removing obstacles through information)

Help users set a goal or simply guide users to resources that may take excessive effort to find.

Announce the usernames of the highest water-savers

This tactic usually influences wealthier populations who are eager to receive social recognition (Brick et al., 2017). Nonetheless, acknowledging users for their water-saving efforts can motivate users from all socio-economic groups.

- Insert a logo or a picture to attract users' attention to this panel.

    - Highlight the names of users with the most water savings. The number of names will depend on the size of the panel.
    - Request efficient users share their success stories on the utility website. Include a URL in the feedback for other users to access later.

Help users access efficient appliances:

Social marketing strategies also suggest providing as much information as possible to help users access specific products (e.g., low flush toilet or low flow showerhead) or information on rebate programs that can influence users' decisions.

- Include URLs for appliances or stores to purchase efficient products.
- If applicable, provide information on rebates or exchange programs where users can exchange inefficient appliances for efficient ones.

Information on how to contact the utility and to access disaggregated data

Studies suggest that the probability of sustaining users' environmental behaviors increases if users can communicate freely with the authority that encourages them to change their behavior (Sofoulis, 2005). One way to establish this communication is to ask for feedback from users. Also, proactive users often want to access their usage data in detail (Erickson et al., 2012) so utilities should also provide the option to access detailed end-use data to interested users.

- Encourage users to communicate with the utility by requesting their suggestions (systematic interaction). For example, put the number, website, or email address in a panel. Ask what additional information they want to see.
- Include a URL to allow users to access their water use information in detail.

The contents presented in this step are selected from past studies involving voluntary strategies that used feedback and normative messaging for conservation in both the water and energy sectors. The primary purpose was to customize and personalize strategic messages using these contents by utilizing the disaggregated water data from step 1 and the segmentation completed in step 2. While previous studies have attested to the motivational potency of these contents, we advise performing field tests before using them in full-scale campaigns.

Step 4: Evaluation of strategic messages

The evaluation step assesses the effect of feedback, i.e., measures the changes in behavior or quantity of water used by appliances once messages are circulated and compares the new water use behavior and end-use with the threshold value selected in step 1(a). If household use is below the threshold, then managers will target the next end-use with the most water-savings potential. Conversely, messages should continue until use is below the threshold level.

Conduct steps 1 through 4 through small-scale pilot projects before undertaking full-scale implementation (Mckenzie-Mohr, 2000).

Feedback medium and frequency

The communication medium and feedback frequencies are two of the most critical aspects of strategic feedback. Although web-based platforms were more successful than paper-based feedback systems in the energy field, studies reveal that water users still value paper-based communication through mailings more than web-based platforms (Schultz et al., 2016). To address these complexities, we prepared contents that could be used for both electronic and paper-based communication mediums.

The frequency of delivering messages depends on the communication medium and technology utilized. If an IHD is used, then such technology has the capability to notify users of their end-use right after the event (Froehlich et al., 2012; Tiefenbeck et al., 2016). Alternately, feedback frequency can be as high as once every couple of hours (Erickson et al., 2012), if web-based platforms are used, or as little as once every couple of months (Fielding et al., 2013; Katz, Grinstein, Kronrod, & Nisan, 2016b) if mail-based systems are used. The method discussed above was created to target one inefficient end-use behavior at a time. Therefore, as discussed in Chapter-2, section 2.6.4 (Feedback Frequency), higher feedback frequency, i.e., feedback immediately after the event or at least once per day, is suggested when web-based or other types of electronic communication are used. Conversely, if mail-based communication is used, then feedback frequency should be at least once per week.

3.4 Illustration

In this study, we used Residential End Uses of Water, Version-2 (REU-2-16) (DeOreo et al., 2016) data to illustrate the feedback system based on community-based social marketing. The example includes both indoor and outdoor water uses.

3.4.1 Residential End Uses of Water Version, 2 (2016) data set background

We used data from REU-2-16 to apply our method. The REU-2-16 was conducted at the residential household level to assess appliance-wise water demand of single-family households in the United States and Canada. Thirty utility companies participated in the project during the 2012-13 fiscal year and the results were published in 2016. In total, 762 households were monitored for approximately two weeks. The study collected end-use data at a 10-second frequency (40 pulses per gallon) using Meter-Master flow recorders. The logged data was later disaggregated using Trace Wizard Software, which could also separate and analyze hot and cold-water use. End-use data of six major indoor appliances—bathtubs, clothes washers, dishwashers, faucets, showers, and toilets–was recorded. Also, two primary outdoor water uses—irrigation and swimming pool filling—were traced, where irrigation was the highest outdoor water use activity and was performed during the summer months in most cases.

In addition to water use data, a household baseline survey was also conducted. Questions were asked about demography, household income, education, condition of appliances, irrigation practices, past and present conservation behaviors, and conservation attitudes. Responses to the questions were related to past conservation experiences, present water use behaviors, and attitudes and were scored using a Likert scale (Likert, 1932). Unfortunately, psychological data such as susceptibility to peer pressure and perception of control over water use, which are necessary to determine users' conservation intentions, was not collected as the study was focused on end-use behavior only.

3.4.2 Illustration using REU-2016 data

3.4.2.1 Indoor

We make two assumptions.

Assumption 1: Conservation target

This example uses a community-wide water reduction target of 25%. This target compares to 10% in South Africa (Brick et al. 2017) and 25% in Australia (Lowe et al., 2015).

Assumption 2: Psychological evaluation strategy

We used REU-2-16 survey questions numbers M, N, and O to evaluate household attitudes (Appendix 3, Table A3-1). The REU-2-16 survey did not include any subjective norm or perceived behavioral control questions. Thus, we assumed that each household had both subjective norm and perceived behavioral control deficits.

Evaluating user attitude towards conservation

Respondents were allowed only 5 choices to respond to attitudinal questions M, N, and O, which ranged from "Strongly disagree," "Somewhat disagree," "Not applicable," "Somewhat agree" to "Strongly Agree". The median score for attitudinal evaluation was 13 (out of 15). Any household with total attitude scores lower than 13 was considered to have attitudinal deficit.

Calculate water savings potential

We considered a 25% reduction target for this study as illustration, whereas actual conservation targets are region and utility specific. A 25% reduction target means that REU-2-16 households in aggregate will save approximately 24,000 gallons/day. Considering shower end-use and the five shower attributes, shower duration (minutes/person/day) has the highest Gini coefficient meaning it is the most skewed behavior (Figure 3.3). Considering all end-uses and attributes, the bathtub, clothes washer, and dishwasher have attributes with very high Gini indices that are more skewed than faucet, shower and toilet attributes (Table 3.4). By focusing on the behavioral attributes (duration and intensity) listed in Table 3.4 that have the highest Gini index for each appliance, a water manager can target fewer households with higher water usage.

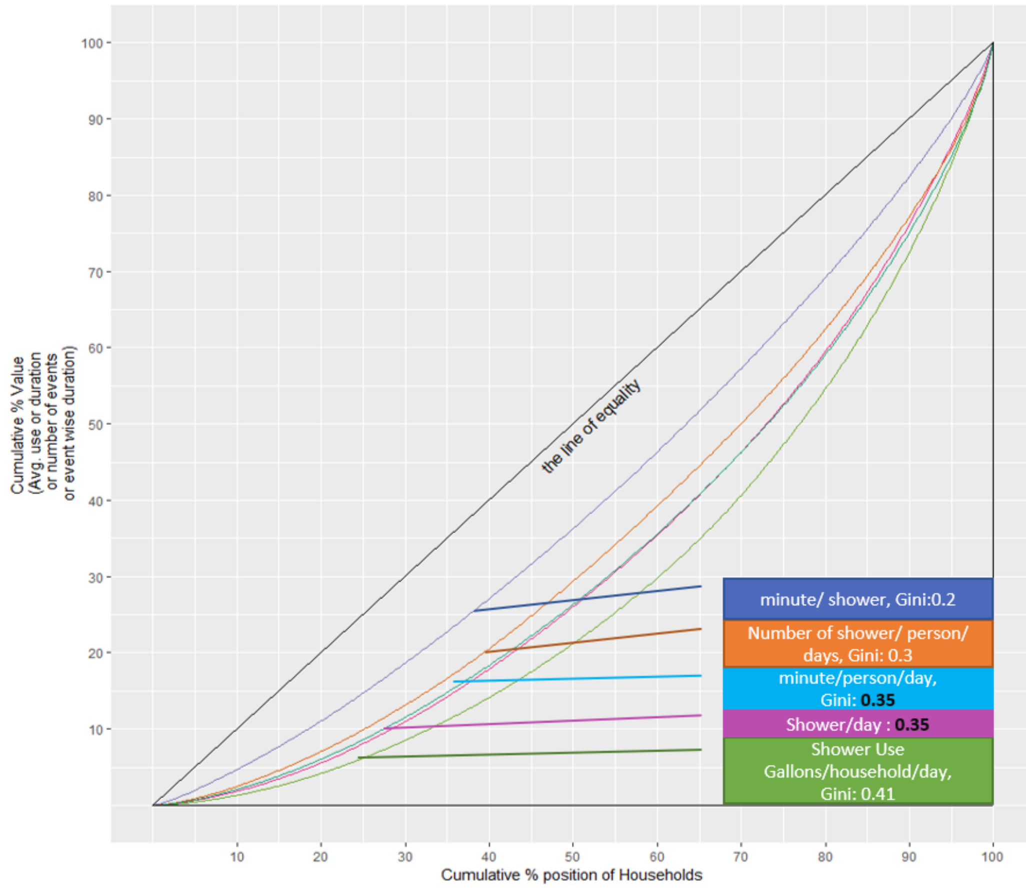


Figure 3.3: Lorenz curves for different shower behavior attributes.

Table 3.4: The behaviors with the highest Gini coefficient for different indoor water end-uses.

Appliance	Attribute with highest Gini Index	Gini Index
Dishwasher	Events/week	0.53
Bathtub	Events/person/week	0.52
Clothes washer	Events/week	0.50
Faucet	Duration/person/day	0.36
Shower	Duration/person/day	0.35
Toilet	Events/person/day	0.27

To identify adequate threshold values for different end-uses, we have developed figures similar to Figure 3.4, which was created for shower end-use. Figure 3.4 shows that if 45% of the population that currently takes a shower for longer than 5 minutes/person/day reduced their shower time to 5 minutes/person/day, they would save approximately 5,500 gallons/day, which is almost 7.5% of the total water use by all households in REU-2-16. Other reductions in use, such as 8 shower minutes/person/day, would target fewer households (less than 20%), and the cumulative water-savings potential of these households–by changing their shower end-use behavior–is almost 3% of total daily consumption.

As our total conservation goal was to reduce use by 25%, we chose 7 minutes/person/day as the shower end-use threshold behavior, targeting less than 25% of the population with the potential to conserve 3,000 gallons/day or 4% of total daily use. We used a similar approach (Appendix-2, Figure A2- 1) for other end-uses, and the behavioral thresholds and the potential volume that may be saved are listed in Table 3.5.

We used USEPA WaterSense guidelines and Energy Star recommended values to identify households with inefficient appliances and the volumes of water they would conserve if those households were retrofitted with efficient appliances (almost 12,500 gallons/day; Table *3.6*).

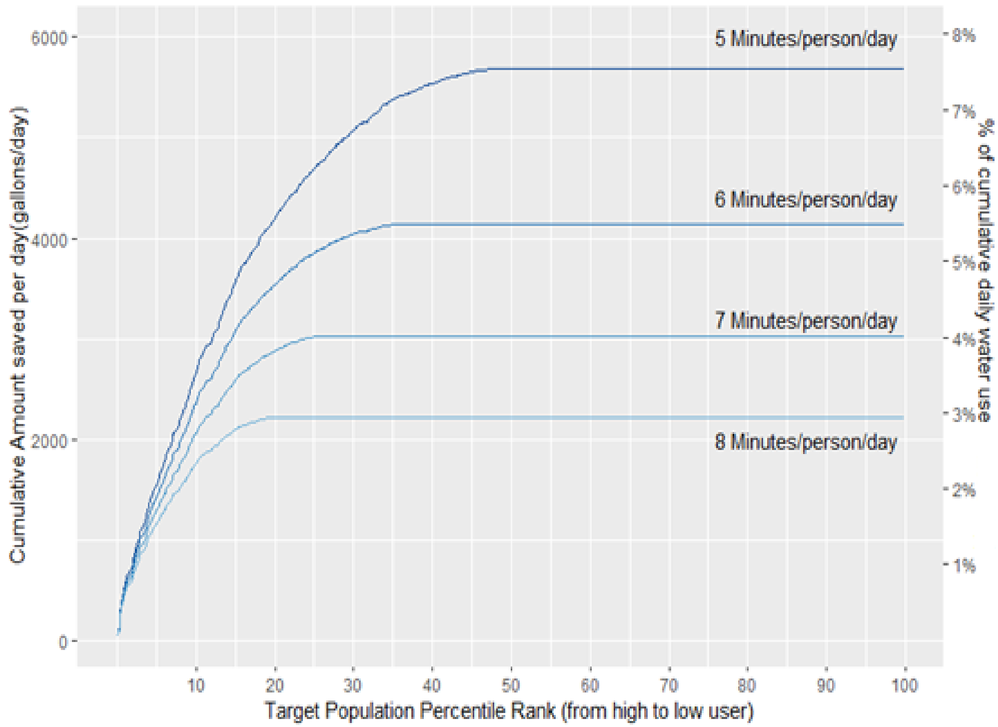


Figure 3.4: The relationship between shower end-use behavior and the percentage of the population that should be targeted to achieve a specific reduction in water use. Lines represent the potential volume that could be saved if users curtailed their shower habits to different levels.

Table 3.5: Selected behavioral threshold values and potential water use reduction when those values are adopted.

Appliance	**Behavioral Threshold Value**	**% of Total Households with the behavioral opportunity**	**Maximum Reduction Volume (Gallons/ Day) that can be achieved by all 771 households of the REU-2-16 dataset**
Bathtub	1 bath/person/week	37%	987
Clothes washer	6 loads/week	44%	2,497
Dishwasher	7 loads/week	19%	103
Faucet	15 minutes/person/day	34%	3,388
Shower	7 minutes/person/day	49%	3,030
Toilet	7 flushes/person/day	25%	2,024
Total			12,029

Table 3.6: The amount of water that could be saved if the households in the REU-2-16 dataset were retrofitted with efficient appliances.

Appliance	**Criteria**	**% Of Total Households with opportunity**	**Maximum Volume saved(gallons/day)**
Bathtub	No criteria available	0	0
Clothes washer	14 gallons/load	43%	997
Dishwasher	4 gallons/load	0	0
Faucet	1.5 gallons/minute	0	0
Shower	2 gallons/minute	47%	2,112
Toilet	1.6 gallons/flush	86%	9,394
Total			12,503

The analysis of daily water use data indicated that 93% of households could save water either by changing behavior or by retrofitting their households with more efficient appliances. Households with low cumulative daily average values also had opportunities to conserve water. This finding aligns with previous research that found conservation potential among both high and low users (Fielding et al., 2013). The cumulative water-savings potential of these families (almost 25,000 gallons/day) was slightly above the conservation goal (25% of daily aggregated water use; Figure 3.5). Managers could theoretically reach the targeted reduction objective by encouraging users to bring their behaviors to the threshold values provided in Table 3.5 or by encouraging them to retrofit their households with efficient appliances. The number of ways (behavioral or technological) these households could improve their water use habits varied from 1 to 8 out of 11 possible intervention scenarios, meaning these households were already practicing at least one or more water-saving actions (Appendix 2, Figure A2- 2).

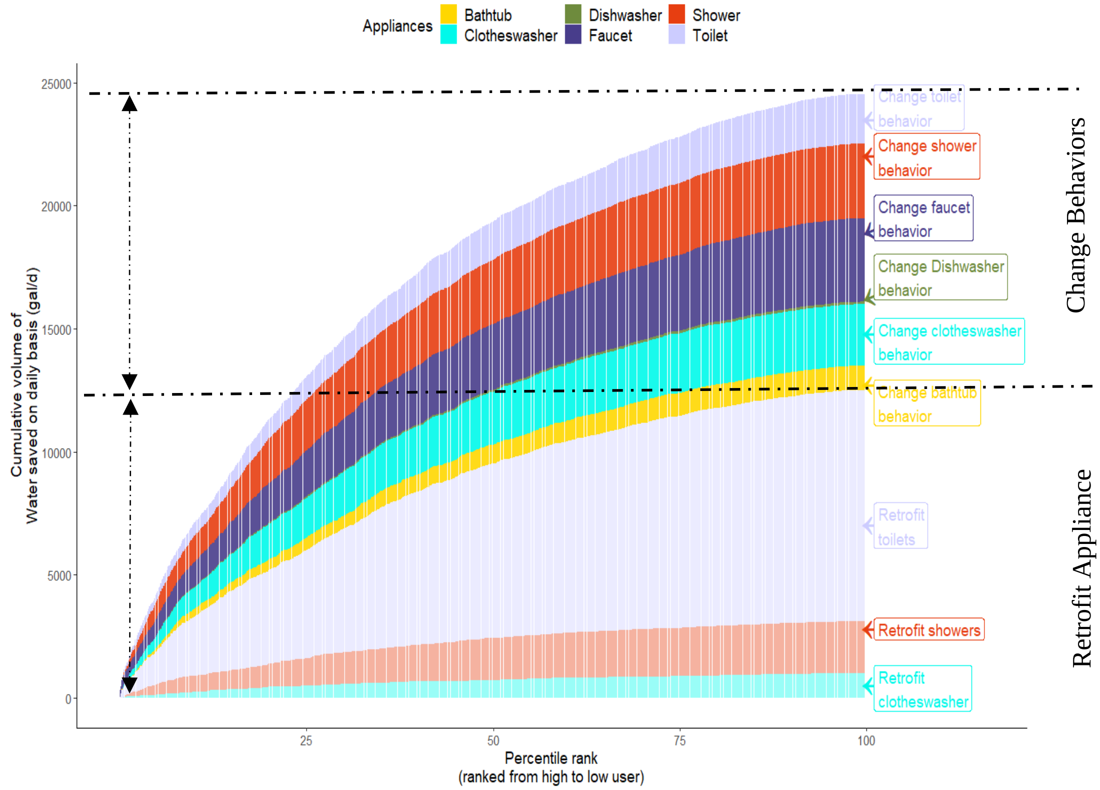
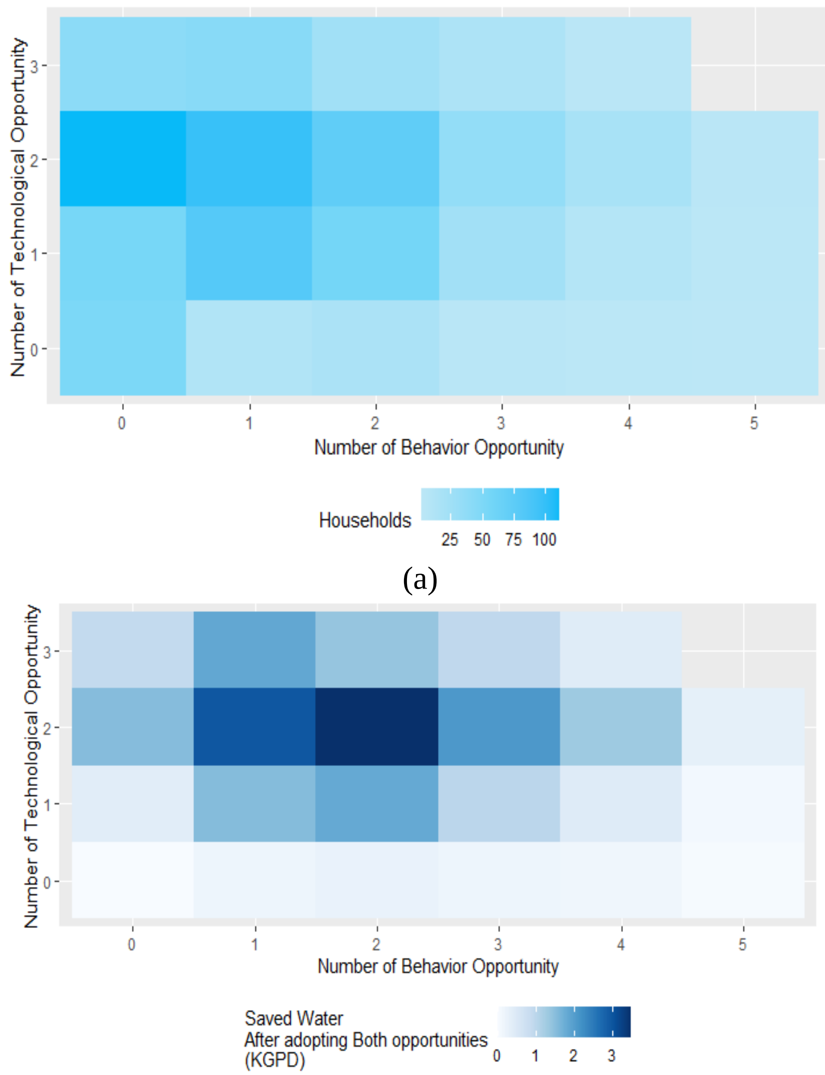


Figure 3.5: Cumulative conservation potential of the REU-2-16 households by changing behavior (darker shades) or retrofitting inefficient appliances (lighter shades).

Figure 3.6 illustrates 73 REU-2-16 participants with at least two behavioral and two technological opportunities that could save the most significant quantity of water (almost 3,500 gallons/day) by changing behaviors or appliances. The average water-savings potential of this group of 73 users is 48 gallons/household/day. From a manager's perspective, directing interventions to improve these households might seem a very targeted approach for improving end-use behaviors. However, a substantial number of other opportunity combinations existed with an even higher value of average water-savings potential. For instance, three households had seven ways to improve their water use with a potential for saving almost 100 gallons/day. But the combined water-savings potential of these three houses was 300 gallons/day. So, it is difficult for managers to target groups due to this varied opportunity dilemma.



(a) (b)

Figure 3.6: Relationship between technology and behavior opportunities, number of households in each opportunity group and the volume of water saved per day.

User segmentation

At first, managers can segment users based on their intervention requirements. As 93% of the users had some type of water-saving opportunities, Figure 3.7 illustrates the potential volume that households could have saved if authorities had implemented phase-wise intervention. Note that the water-saved volume is significantly higher in the first few intervention phases than in later phases. For instance, if authorities had implemented such an intervention system, the managers could help households save almost 20,000 gallons/day in the first two phases, which was 80% of the conservation target. Figure 3.7 depicts the intervention-wise segmentation of each end-use, the number of phases, and the potential volume that households could save during each intervention phase. A more detailed appliance-wise segmentation is provided in Appendix 2 (Figure A2- 3).

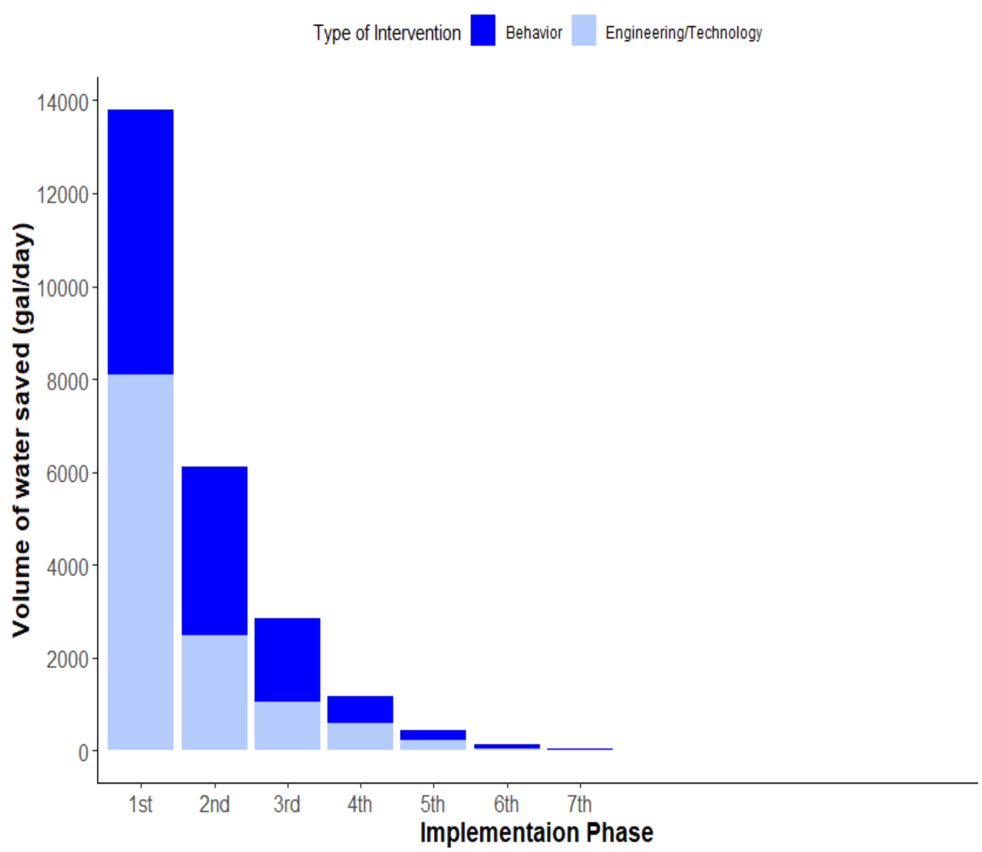


Figure 3.7: Intervention-wise segmentation for different implementaion phases.

Segmentation based on psychological criteria

Our analyses showed that users from both high and low attitude groups used almost the same amount of water per day and that users with lower attitudes could save slightly more water if they chose to improve their behaviors (Figure *3.8*; Appendix 2, Figure A2- 4). If subjective norm and perceived behavioral control data were available, managers could use a similar approach to segment users as per the steps defined in the methodology section and to put users into different groups based on their conservation potential and psychological deficits.

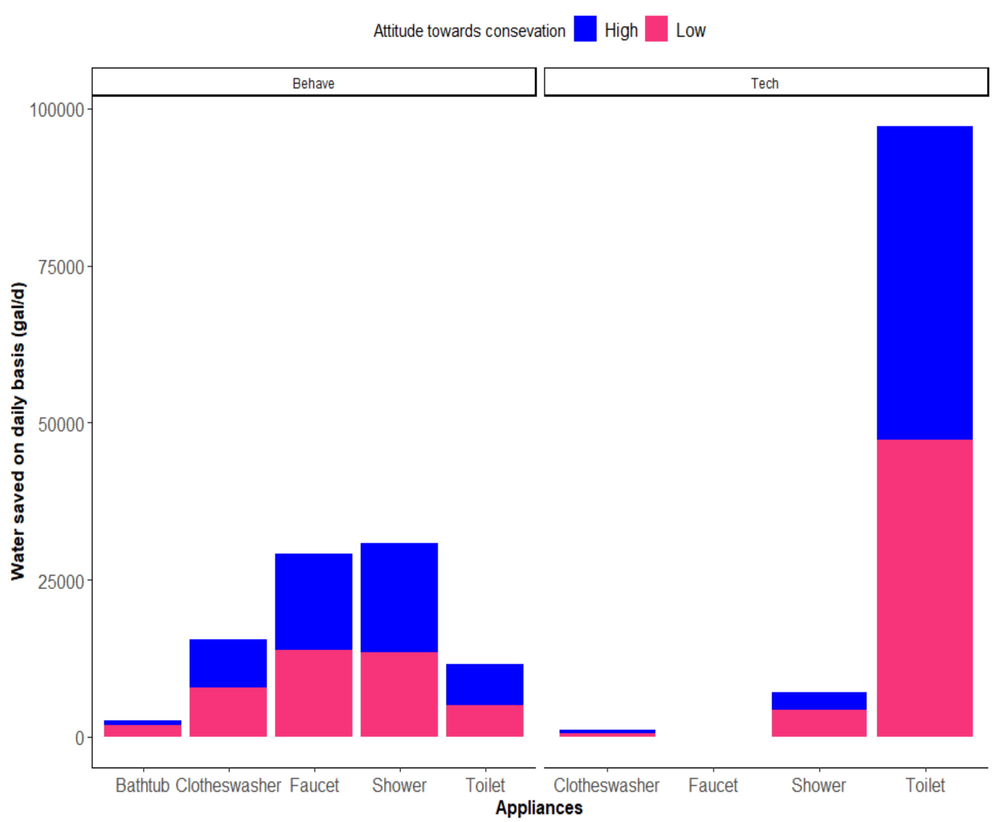


Figure 3.8**:** Pyschological segmentaion of households.

Create customized messages to encourage households to adopt conservation actions

Figure 3.9 shows a sample customized message for a single household. This household had attitude, subjective norm, and perceived behavioral control deficits and was from the engineering/technology intervention group that could save most water by replacing its toilets. Panel-1 builds trust in the water utility as it assures that the utility launched an initiative to improve water efficiency. It also provided internal motivation by requesting the user join their water-saving cause. Panel-2 provides appliance-wise water use information for self-assessment purposes and also provides a comparison between the household and a neighbor (with same household size) to illicit peer pressure. These two panels are the same for all households regardless of their water use behavior.

Panel-3 starts with a dialogue to improve the household's attitude toward conservation by suggesting an external reward, the chance of becoming a water ambassador. Next, the panel provides positive feedback by stating that the faucet and dishwasher meet the standards. Afterward, it provides one specific water-saving tip (retrofitting the toilet) customized for this particular household. Furthermore, to motivate the household through peer pressure, the panel also states that many neighbors have already switched to low-flow toilets.

Panel-4 contains all the additional information that is suggested by studies that used community-based social marketing for behavioral change purposes. First, it lists the name of the highest water-saver of the month, which works as an external motivator. Next, it shows the volume of water the household had saved since the previous month—a motivational input to help users assess their progress in successive months. Also, a sub-panel is attached to inform the household where to find efficient appliances (in this case, the low-flow toilet). Furthermore, to establish one-on-one communication, another sub-panel is included where the user can find the contact information for the water utility.

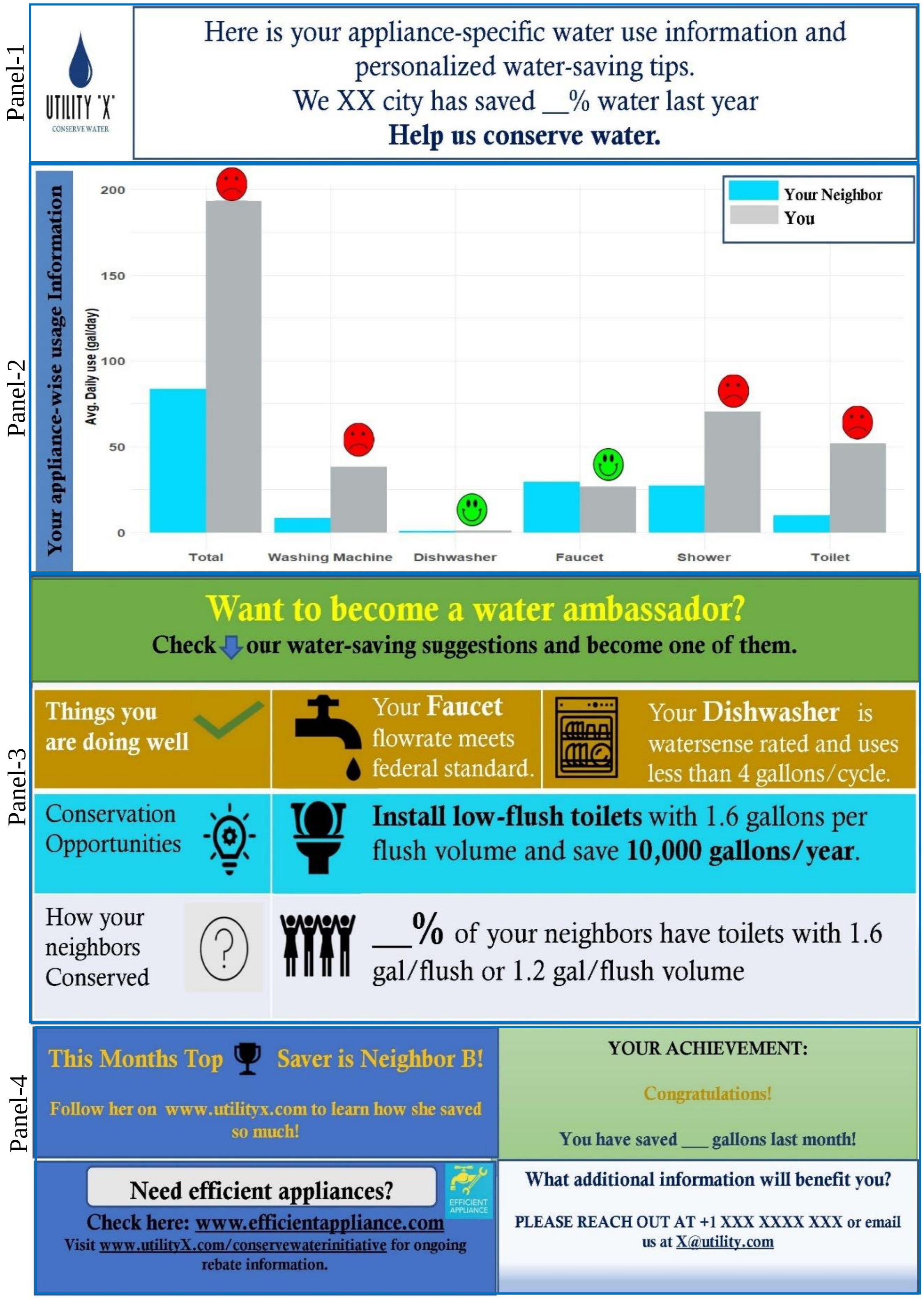


Figure 3.9: Customized message which may be circulated with utility bills.

3.4.2.2 Outdoor

We made the following assumptions to use community-based social marking for feedback for outdoor water use.

Assumption 1: We work with 200 households (these were monitored for at least a week) and assume that the data is for the summer period with an imagined sunrise and sunset time of 6:00 AM and 6:00 PM, respectively.

Assumption 2: We use the same attitude questions (Appendix 3, Table A3-1) for attitudinal evaluation.

Identifying behavior that requires improvement:

By analyzing daily irrigation water use data, we identified a significant number of users that were watering their lawns during the daytime hours, potentially increasing evaporative water loss. Only a few households were applying water during nighttime hours. By changing the habit of watering lawns from daytime to nighttime, there was the potential for households to save a substantial volume of water. Figure 3.10 shows the average hourly irrigation of the households. The points in the figure signify the average hourly water application and the error bars denote the highest and lowest volume of water applied during that time of the day.

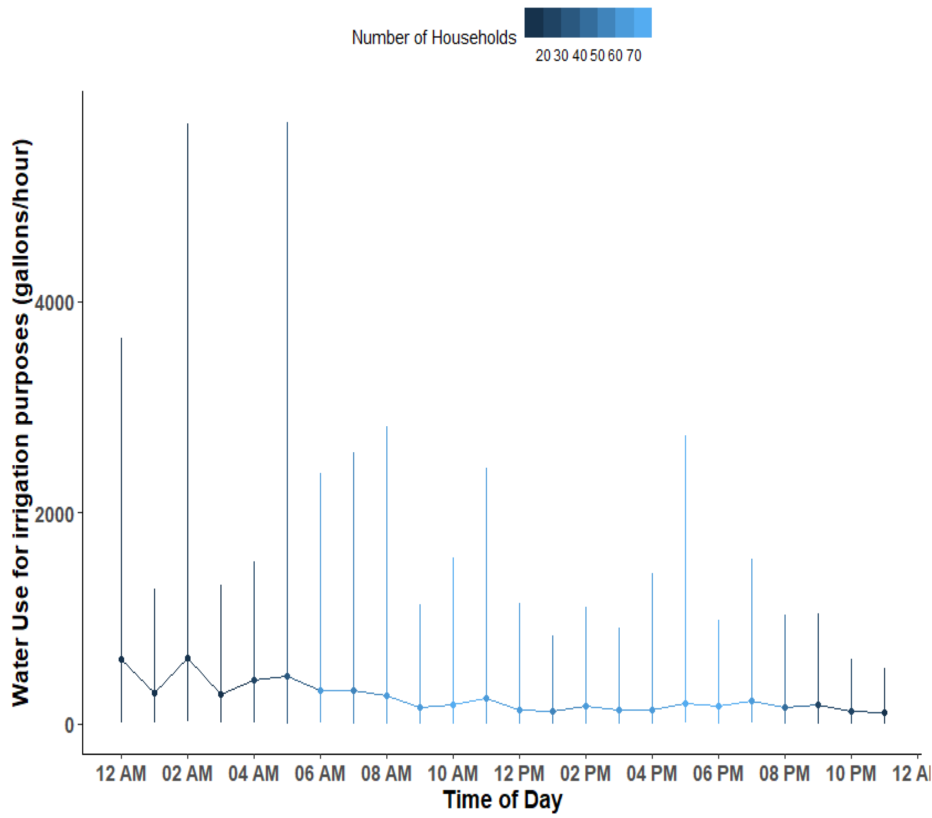


Figure 3.10*:* Hourly time-series graph showing daily irrigation applications.

Segmentation

For behavioral segmentation, we used irrigation application time. Results indicated that 180 of 200 households had daytime irrigation applications, even though water authorities typically suggested nighttime application to reduce evaporative losses (DeOreo et al., 2016). Hence, a manager could target water application time and apply social marketing strategies to improve this behavior. It should be noted, though, that daytime application volumes were significantly lower than the nighttime volumes (Figure 3.11). For our illustration, the goal of feedback was to reduce irrigation water application between the hours of 6:00 AM and 6:00 PM.

For psychological segmentation, we used attitudinal response scores and found that the median score for the 200 outdoor users evaluated was 12. Therefore, any user with a response score higher than 12 was considered to have a high conservation attitude and vice versa. We plotted users based on their irrigation time, total application volume, and attitude (Figure 3.11) but could not observe any significant pattern. In this case, a lack of psychological data hindered our attempt to simulate proper segmentation process.

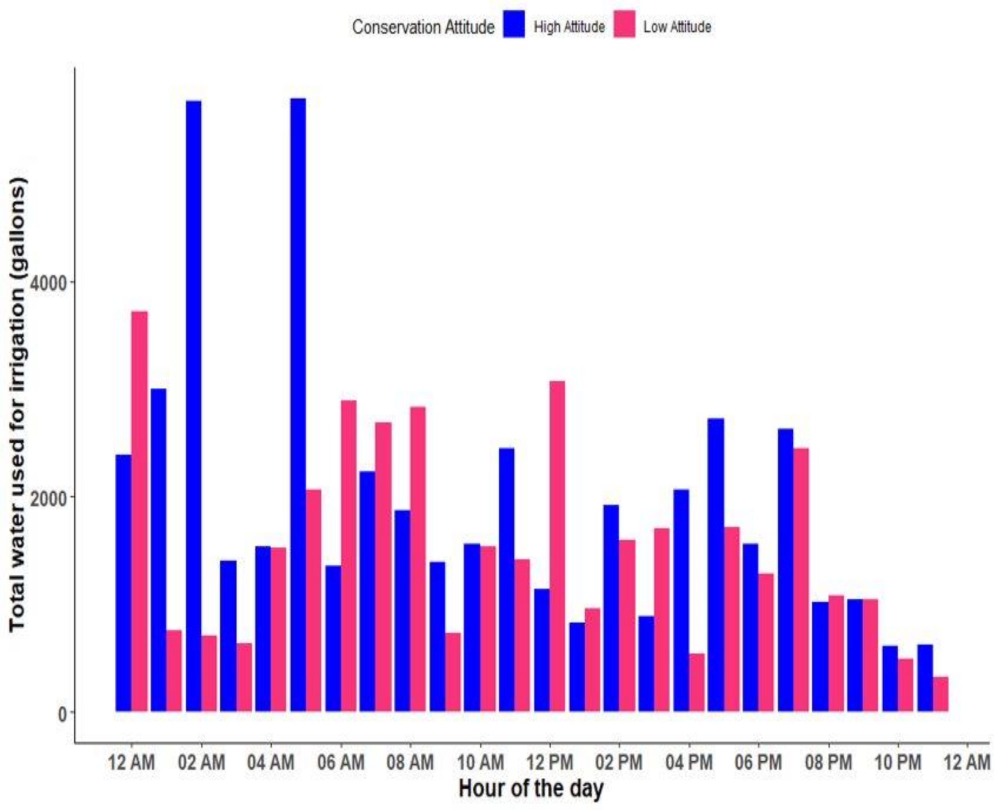


Figure 3.11: Total water applied by high and low attitude users over the day.

Feedback generation

The outdoor message (Figure 3.12) contained four panels, each targeting a specific psychological deficit.

Panel-1 repeated as a page header. Panel-2 contains a simple bar chart illustrating when the household usually applies water for irrigation purposes and indicates appropriate and inappropriate irrigation timing. This panel is included for self-assessment purposes.

Panel-3 starts by stating that the daytime water use for irrigation causes additional evaporative loss–a simple message to draw the household's attention. The following statement provides positive feedback by saying that their house is leak-free and then provides a customized tip to water the lawns between 6 PM to 6 AM to reduce evaporative losses. The final statement of this panel stimulates peer pressure by stating that a significant number of users are currently watering their lawns only during nighttime hours.

Lastly, panel-4 simply states that the household can become a water ambassador by cutting their average water use by 10%. This form of social recognition works as an external motivator and is an excellent way to improve user attitudes towards conservation.

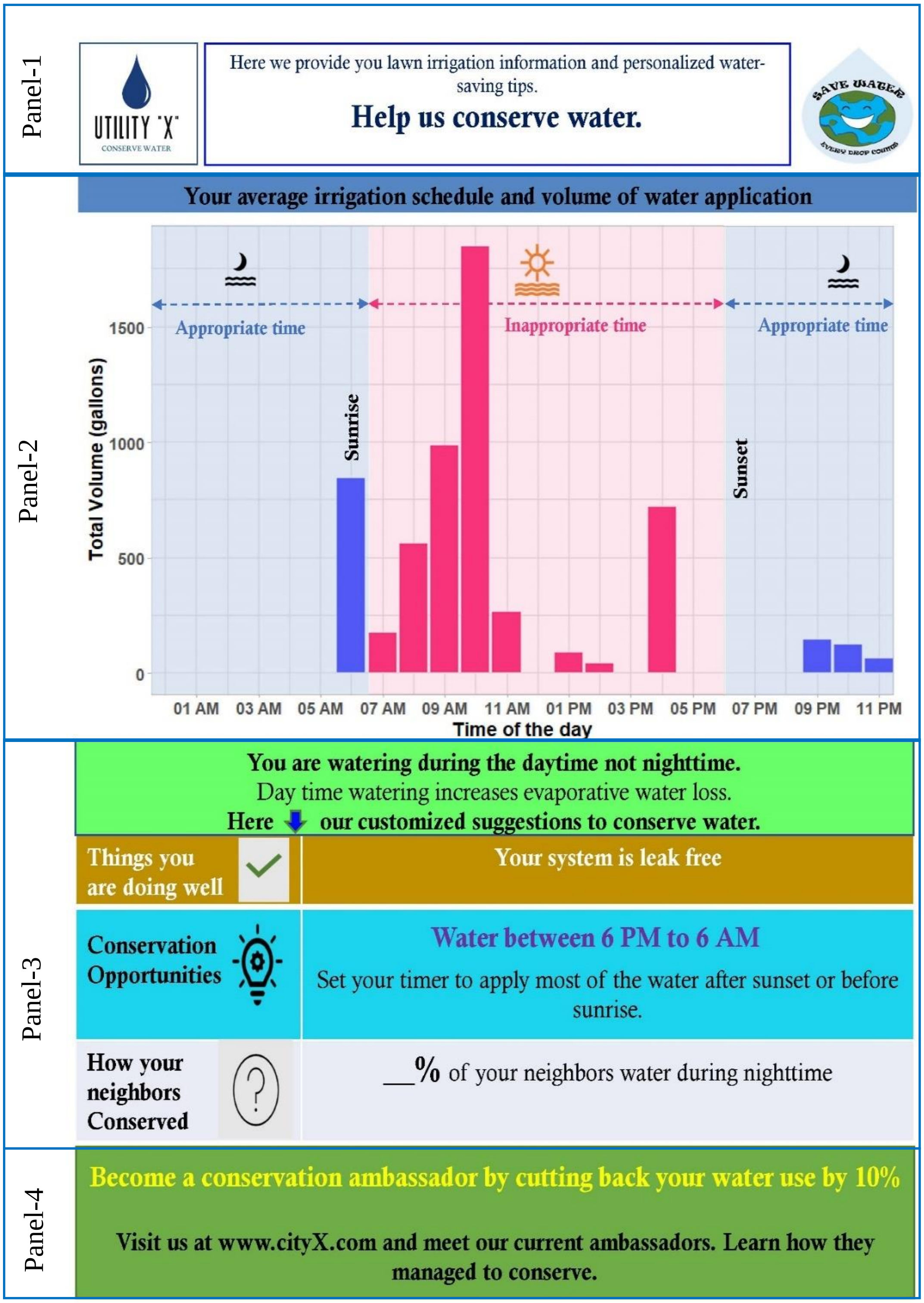


Figure 3.12: Sample of customized message for outdoor water use.

3.5 Feedback on customized strategic messages

We shared an older version (Appendix 2, Figure A2- 5) of the strategic message via online virtual calls and emails with ten graduate students, university professors, and homeowners to test its appeal and intuitiveness. Feedback included:

- Panel 1 provided the goal or encouragement for conservation but needs some figures, i.e., logos or decorations, to make the statements more prominent.
- Panel 2 was informative but not intuitive. The suggestions for improvement included:
    - Show appliance-wise data as a bar chart instead of a radar plot.
    - Use actual water volume when providing appliance-wise usage information of the household instead of rank.
- Panel-3 was very noticeable because of the graphs and for providing comparative information, but not very intuitive. The suggestions for improvement included:
    - Use simple statements instead of plots when providing comparative information.
    - Separate the behavioral suggestions from engineering recommendations.
    - Use gain-framed messages.
- Panel-4 was informative and would not require any changes

Overall, the message was well-received, especially the information and motivational statements, and most suggestions were related to improving the figures. We incorporated these suggestions into our current illustrations. Detailed reviews are included in the appendix.

3.6 Limitations

Study limitations included limited psychology data, study efficacy, difficulties in setting targets, difficulties in evaluating outcomes, and the use of alternative behavior-change models instead of TPB. We also discuss the need for follow-up studies.

3.6.1 Limited psychology data

Unfortunately, due to a lack of psychological information in the REU-2-16 dataset, we could only group by attitude and not social norm or opportunity. Furthermore, the REU-2-16 attitudinal questions did not explicitly ask why conservation was beneficial to the user. Therefore, the attitudinal analysis we included did not completely capture the user's behavioral intention.

3.6.2 Efficacy of the proposed normative messaging system

We cannot validate the effectiveness of the proposed messaging at this point, as utilities do not collect disaggregated end-use data. However, we circulated one of the earlier versions of our customized message among six graduate students, two university professors, and two homeowners to check the intuitiveness of the content and we used their feedback to adjust the message design. However, the revised message was not circulated for field testing.

3.6.3 Defining a target behavior

This study targeted one conservation action at a time where managers could target multiple actions simultaneously. If a behavior and behavioral improvement goal is clearly defined, such approaches are valid from a social marketing standpoint. However, the additional tips or suggestions may distract some users from focusing on the end-uses that cause the highest volume of water loss. Nonetheless, we provide a sample of a customized message that lists multiple customized suggestions (Figure A2- 6, Appendix 2) as an example to illustrate how managers can use disaggregated data if they choose to provide feedback targeting multiple appliances and behaviors simultaneously. The message was created for the same household for which we developed the feedback in Figure 3.9, but in this particular case we provided suggestions for multiple end-uses (shower, clothes washer, and toilet).

3.6.4 Selection of behavioral model

This work used TPB to define the determinants that control the behavior, however, there are other models. A manager can choose the model for developing strategic feedback contents and that affects the questions and number of factors used in Steps 2 and 3. Alternative model choices include cognitive dissonance (Festinger, 1957), self-determination theory (Ryan & Deci, 2000), social cognitive theory (Bandura, 2005), self-efficacy theory (Bandura, 1977).

For instance, unlike TPB which uses three factors, social cognitive theory suggests that outcome expectancy, the probable outcome or consequence of one behavior, and self-efficacy, the perception of ease or difficulty of incorporating changes into day-to-day life, are the two major factors influencing behavior (Yazdanpanah et al., 2015). Hence, if a manager chooses to use social cognitive theory for strategic messaging purposes, the questions should focus on which type of reward will persuade the user to change their behavior and how confident the user is in incorporating the changes in their life. Also, the delivered messages should contain the type of conservation behaviors that may help the users win a reward and statements assuring how easy it is to adopt conservation actions in daily life.

3.7 Follow-up research

A follow-up pilot study is needed to evaluate the effect of feedback intensity on behavioral modification. We also recommend further studies to identify how long conservation behaviors are sustained. Researchers also need to validate those personalized messages target attitude, behavior, and subjective norm effectively to help users build efficient water use behaviors. Additional research should identify which environmental, communal, or pecuniary aspects best improve users' conservation ethics. Furthermore, if enough psychological data is collected, researchers can investigate which deficit group, among the seven groups identified in this study, has the greatest conservation potential.

3.8 Conclusions

This paper's purpose was to combine data about a user's intent and their end use behaviors to create individualized messages to encourage and sustain water conservation behaviors. This combination was not previously possible due to the absence of appliance-specific water use and psychological data. To combine, the paper applied nonparametric rankings based on disaggregated water use data. The rankings identified suggested interventions for each user and water volume(s) a user can save by adopting the suggested interventions. Next, we used psychological data to identify components of intent to provide a user to motivate a user to adopt suggested interventions. Then we used the components of intent and water end uses to select features to include in household-specific strategic messages for water conservation purposes.

Evaluation of REU-2-16 data showed that more than 90% of the users had water-savings potential (indoor). This finding complements prior studies where users with low daily per capita water use still saved water (Fielding et al., 2013). In addition, 180 of 200 households used water for lawn irrigation during daytime. Ten university faculty members, graduate students, and homeowners provided feedback to improve the intuitiveness and contents messages.

A next step is to provide individualized messages that combine psychological intent and water-end use data to a larger sample of homeowners and measure disaggregated water uses for a longer period of time. Additionally, include psychological data about users subjective norms and perceived behavior controls that were not available in the REU-2016 study. Researchers can also investigate different methods to segment users. These improvements can help water providers, authorities, and managers better combine psychological and water end use data to develop more personalized and intuitive conservation messages with feedbacks that users can adopt and sustain for longer.

References

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control: From Cognition to Behavior* (pp. 11–39). https://doi.org/10.1007/978-3-642-69746-3_2

Attaallah, N. A. M. (2018). *Demand Disaggregation for Non-Residential Water Users in the City of Logan , Utah , USA* (Utah State University). Retrieved from https://digitalcommons.usu.edu/etd/7401

Bandura, A. (1977). Self-efficacy theory in human agency. *American Psychologist*, *37*, 191–215.

Bandura, A. (2005). The Evolution of Social Cognitive Theory. *Great Minds in Management*, pp. 9–35.

Bank, W. (2021). World Bank Open Data.

Boivin, M., Gagné, E., & Saint-Arnaud, V. C. (2016). Using Segmentation and Theory to Design Better Promotion and Prevention Campaigns: A RECYC-QUÉBEC Case Study. In *Segmentation in Social Marketing: Process, Methods and Application*. https://doi.org/10.1007/978-981-10-1835-0

Brick, K., Martino, S. De, & Visser, M. (2017). *Behavioural Nudges for Water Conservation : Experimental Evidence from Cape Behavioural Nudges for Water Conservation : Experimental Evidence from Cape Town*. (February 2018). https://doi.org/10.13140/RG.2.2.25430.75848

Chaudhary, A. K., Warner, L., Lamm, A., Israel, G., Rumble, J., & Cantrell, R. (2017).

Using the Theory of Planned Behavior to Encourage Water Conservation among Extension Clients. *Journal of Agricultural Education*, *58*(3), 185–202. https://doi.org/10.5032/jae.2017.03185

Clark, W. A., & Finley, J. C. (2007). Determinants of water conservation intention in Blagoevgrad, Bulgaria. *Society and Natural Resources*, *20*(7), 613–627. https://doi.org/10.1080/08941920701216552

Deci, E. L. (1971). Effects of Externally Mediated Rewards. *Journal of Personality and Social Psychology*, Vol. 18, pp. 105–115.

DeOreo, W. B., Mayer, P., & Kiefer, J. (2016). Residential End Uses of Water, Version 2: Executive Report. In *Water Research Foundation*. https://doi.org/4309b

Drury, R. (2009). Reducing urban demand for wild animals in Vietnam: examining the potential of wildlife farming as a conservation tool. *Conservation Letters*, *2*(6), 263–270.

Erickson, T., Podlaseck, M. E., Sahu, S., Dai, J. D., Chao, T., & Naphade, M. (2012). The Dubuque Water Portal: Evaluation of the uptake, use and impact of residential water consumption feedback. *Conference on Human Factors in Computing Systems - Proceedings*, 675–684. https://doi.org/10.1145/2207676.2207772

Ferraro, P. J., & Price, M. K. (2013). *Using Non-Pecuniary Strategies to Influence Behavior : Evidence from a Large Scale Field Experiment*. (December). https://doi.org/10.2307/23355650

Festinger, L. (1957). Cognitive dissonance theory. *1989) Primary Prevention of*

HIV/AIDS: Psychological Approaches. Newbury Park, California, Sage Publications.

Fielding, K. S., Spinks, A., Russell, S., McCrea, R., Stewart, R., & Gardner, J. (2013). An experimental test of voluntary strategies to promote urban water demand management. *Journal of Environmental Management*, *114*, 343–351. https://doi.org/10.1016/j.jenvman.2012.10.027

Flume. (2021). Flume. Retrieved from https://flumewater.com/product/

Froehlich, J., Findlater, L., Ostergren, M., Ramanathan, S., Peterson, J., Wragg, I., … Landay, J. A. (2012). The design and evaluation of prototype eco-feedback displays for fixture-level water usage data. *Conference on Human Factors in Computing Systems - Proceedings*, 2367–2376. https://doi.org/10.1145/2207676.2208397

Galotti, K. M., McVicker Clinchy, B., Ainsworth, K. H., Lavin, B., & Mansfield, A. F. (1999). A new way of assessing ways of knowing: The attitudes toward thinking and learning survey (ATTLS). *Sex Roles*, *40*(9–10), 745–766. https://doi.org/10.1023/A:1018860702422

Geller, E. S. (1989). Applied behavior analysis and social marketing. *Journal of Social Issues*, *45*(1), 17–36.

Gini, C. (1912). Variabilità e mutabilità. *Reprinted in Memorie Di Metodologica Statistica (Ed. Pizetti E.)*.

Groot, L. (2010). Carbon Lorenz curves. *Resource and Energy Economics*, *32*(1), 45–64. https://doi.org/10.1016/j.reseneeco.2009.07.001

Groves-Kirkby, C. J., Denman, A. R., & Phillips, P. S. (2009). Lorenz Curve and Gini Coefficient: Novel tools for analysing seasonal variation of environmental radon gas. *Journal of Environmental Management*, *90*(8), 2480–2487. https://doi.org/10.1016/j.jenvman.2009.01.003

Inman, D., & Jeffrey, P. (2006). A review of residential water conservation tool performance and influences on implementation effectiveness. *Urban Water Journal*, Vol. 3, pp. 127–143. https://doi.org/10.1080/15730620600961288

Katz, D., Grinstein, A., Kronrod, A., & Nisan, U. (2016). Evaluating the effectiveness of a water conservation campaign: Combining experimental and field methods. *Journal of Environmental Management*, *180*(October 2017), 335–343. https://doi.org/10.1016/j.jenvman.2016.05.049

Kenney, D. S., Goemans, C., Klein, R., Lowrey, J., & Reidy, K. (2008). *RESIDENTIAL WATER DEMAND MANAGEMENT : LESSONS FROM AURORA , COLORADO 1*. *44*(1). https://doi.org/10.1111/j.1752-1688.2007.00147.x

Koop, S. H. A., Dorssen, A. J. Van, & Brouwer, S. (2019). Enhancing domestic water conservation behaviour : A review of empirical studies on influencing tactics. *Journal of Environmental Management*, *247*(March), 867–876. https://doi.org/10.1016/j.jenvman.2019.06.126

Lowe, B., Lynch, D., & Lowe, J. (2015). Reducing household water consumption: a social marketing approach. *Journal of Marketing Management*, *31*(3–4), 378–408. https://doi.org/10.1080/0267257X.2014.971044

Mckenzie-Mohr, D. (2000). *Promoting Sustainable Behavior : An Introduction to Community-Based Social Marketing*. *56*(3), 543–554.

Mitchell, D. L., & Chesnutt, T. W. (2013). *Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports*. Retrieved from https://www.financingsustainablewater.org/sites/www.financingsustainablewater.org/files/resource_pdfs/MCubed-Watersmart_evaluation_report_FINAL_12-12-13%2800238356%29.pdf

Pacheco, C. J. B., Horsburgh, J. S., & Tracy, R. J. (2020). *Collecting High Temporal Resolution Water Use Data*. 1–29. https://doi.org/10.3390/s20133655

Resources, U. D. of. (2021). No Title. Retrieved from https://dwre-utahdnr.opendata.arcgis.com/maps/utahDNR::2019-municipal-and-industrial-water-use/about

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Schultz, P. W., Messina, A., Tronu, G., Limas, E. F., Gupta, R., & Estrada, M. (2016). Personalized Normative Feedback and the Moderating Role of Personal Norms : A Field Experiment to Reduce Residential Water Consumption. *Environment and Behavior*, *48*(2), 686–710. https://doi.org/10.1177/0013916514553835

Sofoulis, Z. (2005). Big Water, Everyday Water: A Sociotechnical Perspective. *Continuum*, *19*(4), 445–463. https://doi.org/10.1080/10304310500322685

Sønderlund, A. L., Smith, J. R., Hutton, C. J., Kapelan, Z., & Savic, D. (2016). Effectiveness of smart meter-based consumption feedback in curbing household water use: Knowns and unknowns. *Journal of Water Resources Planning and Management*, *142*(12). https://doi.org/10.1061/(ASCE)WR.1943-5452.0000703

Stead, M., Gordon, R., Angus, K., & McDermott, L. (2007). A systematic review of social marketing effectiveness. *Health Education*.

Taddicken, M., & Wolff, L. (2020). 'Fake News' in Science Communication: Emotions and Strategies of Coping with Dissonance Online. *Media and Communication*, *8*(1), 206–217. https://doi.org/10.17645/mac.v8i1.2495

Tiefenbeck, V., Goette, L., Degen, K., Tasic, V., Fleisch, E., Lalive, R., & Staake, T. (2016). Overcoming salience bias: How real-time feedback fosters resource conservation. *Management Science*, *64*(3), 1458–1476. https://doi.org/10.1287/mnsc.2016.2646

USEPA. (2020). United States Environmental Protection Agency. Retrieved from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fwww.energystar.gov%2Fsites%2Fdefault%2Ffiles%2FEPA%2520Memo%2520ENERGY%2520STAR%2520Most%2520Efficient%25202021.pdf&clen=343407&chunk=true

Warner, L. A., Rumble, J., Martin, E., Lamm, A. J., & Cantrell, R. (2015). The Effect of Strategic Message Selection on Residents ' Intent to Conserve Water in the Landscape. *Journal of Agricultural Education*, *56*(4), 59–74.

https://doi.org/10.5032/jae.2015.04059

Yazdanpanah, M., Feyzabad, F. R., Forouzani, M., Mohammadzadeh, S., & Burton, R. J. F. (2015). Predicting farmers’ water conservation goals and behavior in Iran: A test of social cognitive theory. *Land Use Policy*, *47*, 401–407. https://doi.org/10.1016/j.landusepol.2015.04.022

APPENDICES

Appendix 1: TPB Question constructs

I. Attitude question construct

Attitude questions are asked to determine how the responder rationalizes behavioral change. Make the questions(s) appliance/end-use specific, and use divergent adjectives (e.g., good-bad) to help the responder easily express his/her thoughts. The steps for making the questions are:

- Select an end-use (shower, toilet, irrigation, etc.).
- Ask what the user thinks about conservation by changing the behavior, changing the appliance, installing specialized devices that may save water.
- Provide six responses with opposing adjectives for each of the questions.
- Ask how much the user agrees with the statement on a scale of 1 to 5.
- Repeat the steps for every other end-uses.

Box 1 includes an example of attitude question.

Box 1: Attitude question example

Taking a shorter shower is a (an) __________ way of reducing water use.

Please select responses those most correctly capture your view on this statement.

Good	5	4	3	2	1	Bad
Excellent	5	4	3	2	1	Stupid
Practical	5	4	3	2	1	Impractical
Easy	5	4	3	2	1	Hard
Clever	5	4	3	2	1	Foolish

II. Subjective norm question construct

Subjective norm questions try to measure what people—close or important to the respondent—think about the behavior in question. More specifically, the question asks how likely or unlikely the people who are important to the respondent are inclined to changing the behavior in question. Like attitude questions, subjective norm questions must be appliance or end-use specific and responses may range from very likely, somewhat likely, unknown, somewhat unlikely, to very unlikely. Box 2 provides an example.

Box 2: Subjective norm question example.

The people whom I value (loved ones or peers) take shorter showers to save water.
How much do you agree with this statement?

Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
1	2	3	4	5

III. Perceived behavioral control question construct

The third TPB factor, perceived behavioral control, tries to capture how easily the user thinks that he/she can incorporate the behavioral changes into daily life. Like attitude and subjective norm questions, it also focuses on one specific behavior at a time. Box 3 shows an example.

Box 3: Perceived behavioral control question example.

I think taking shorter showers is very easy and will not disrupt my daily routines.

How much do you agree with this statement?

Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
1	2	3	4	5

IV. Question construct related to trust

Trust questions ask the user how likely or unlikely it is that their neighbors are conserving water and how likely or unlikely the user believes the authority is trying their best maximize water conservation. The follow-up responses may range from "very likely" to "very unlikely," and scores will range from 1 to 5, respectively (like subjective norm question responses). Box 4 provides an example.

Box 4: Trust question example.

My utility does everything to use water efficiently.

How much do you agree with this statement?

Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
1	2	3	4	5

V. Personal obligation/personal norm

Personal obligation questions will determine the extent of the user's moral conviction towards water conservation efforts. Note that the responses to moral obligation questions do not determine the customized feedback contents but can be used to understand whether subjective norms will influence the user or not. Example questions are listed in Box *5*.

Box 5: Personal obligation/personal norm question examples.

On a scale of 1 (disagree) to 5 (agree), how much do you agree with these statements?

a. **Water is a valuable (or scarce) resource and I need to use it very carefully (Lowe et al., 2015).**

Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
1	2	3	4	5

b. **I feel a personal obligation to minimize my impact on the environment by conserving water (Chaudhary et al., 2017).**

Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
1	2	3	4	5

c. **I must do everything I can to protect water resources (Chaudhary et al., 2017).**

Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
1	2	3	4	5

VI. Past conservation behavior

Past conservation behavior questions simply ask if the user thinks they are practicing any water-saving behaviors. Like others, this question should also be behavior/appliance specific. Use the same divergent scale as mentioned in other question constructs. Box 6 shows examples.

Box 6: Past conservation behavior questions.

On a scale of 1 (disagree) to 5 (agree), how much do you agree with these statements?

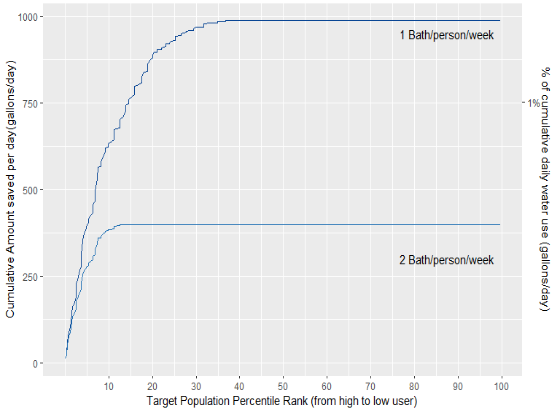
a. **In the past month, I have mostly taken short showers.**

Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
1	2	3	4	5

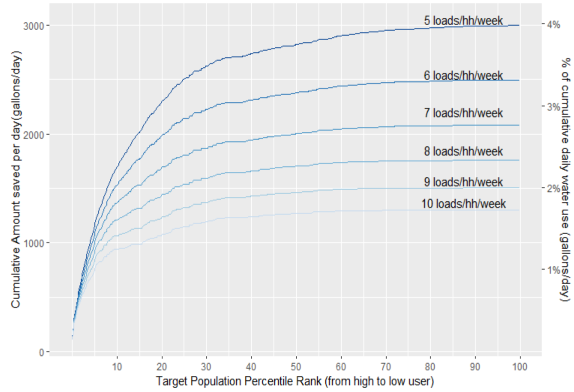
b. **All the showers in my home have low-flow shower heads.**

Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
1	2	3	4	5

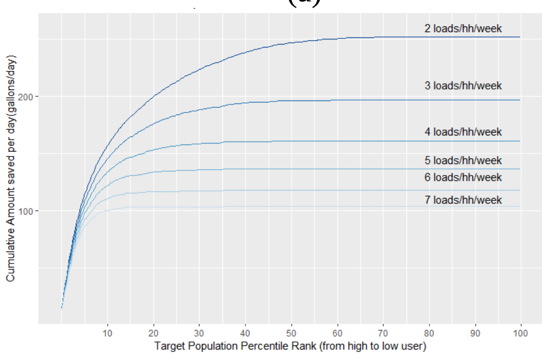
Appendix 2: Figures



(a)



(b)



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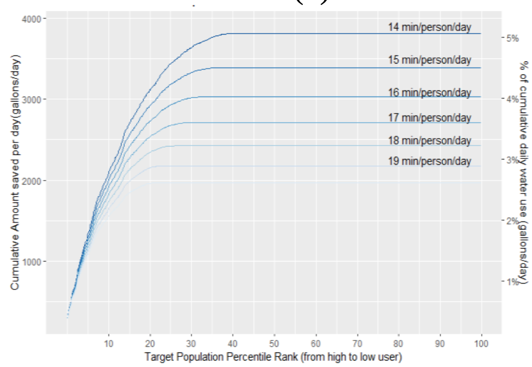

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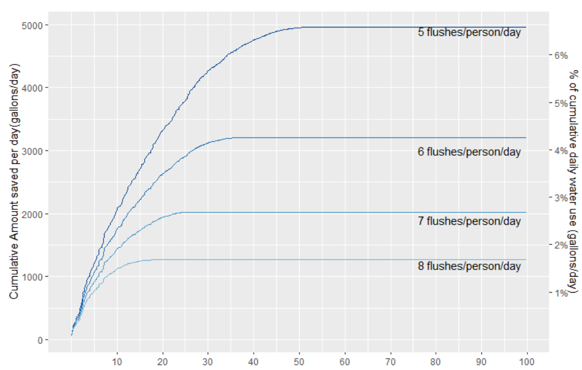


(e)

Figure A2- 1: Plots illustrating the amount of water that could have been saved by behavioral improvement for different threshold values for different end uses –(a) bathtubs, (b) washing machines, (c) dishwashers, (d) faucets, (e) toilets.

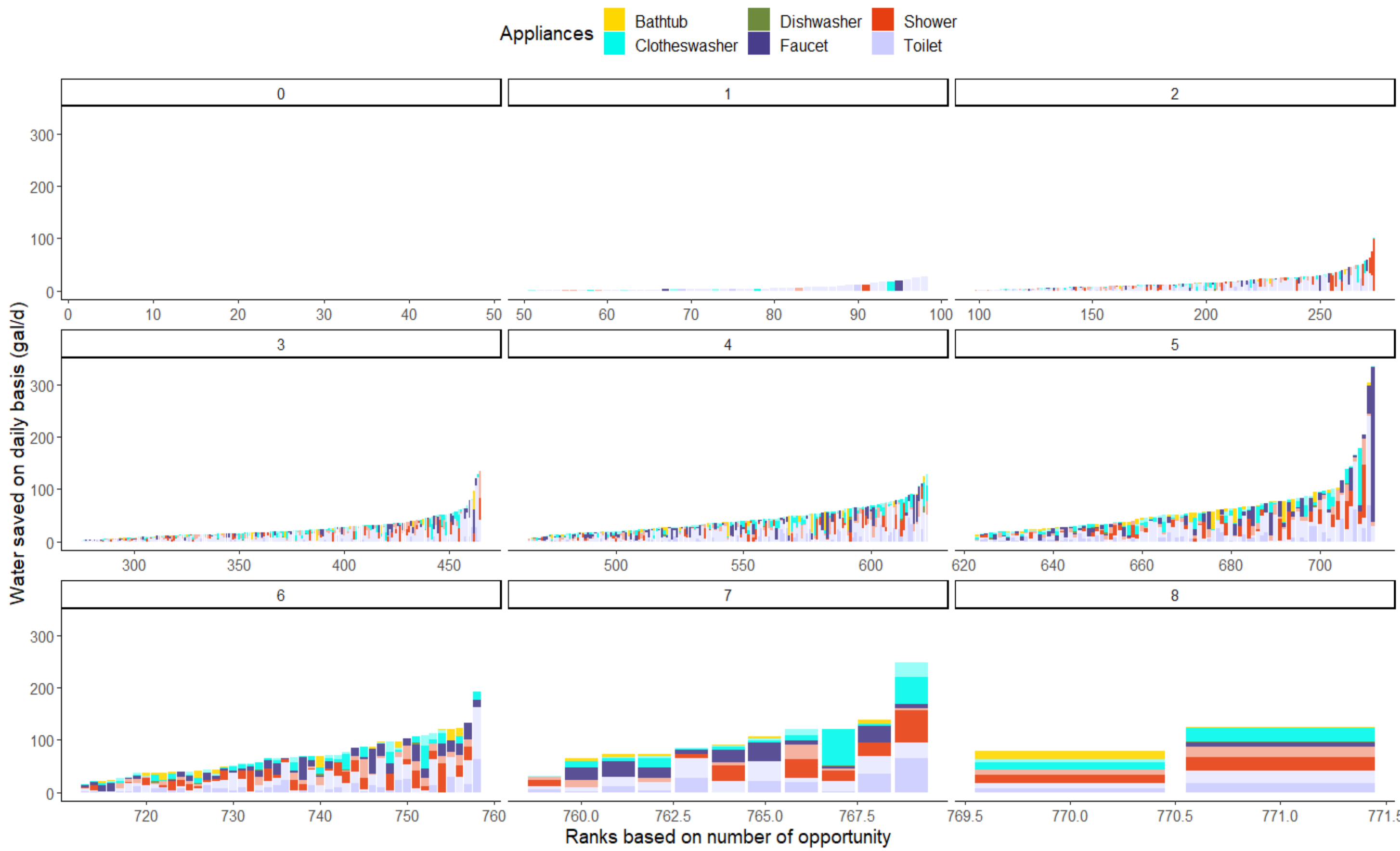
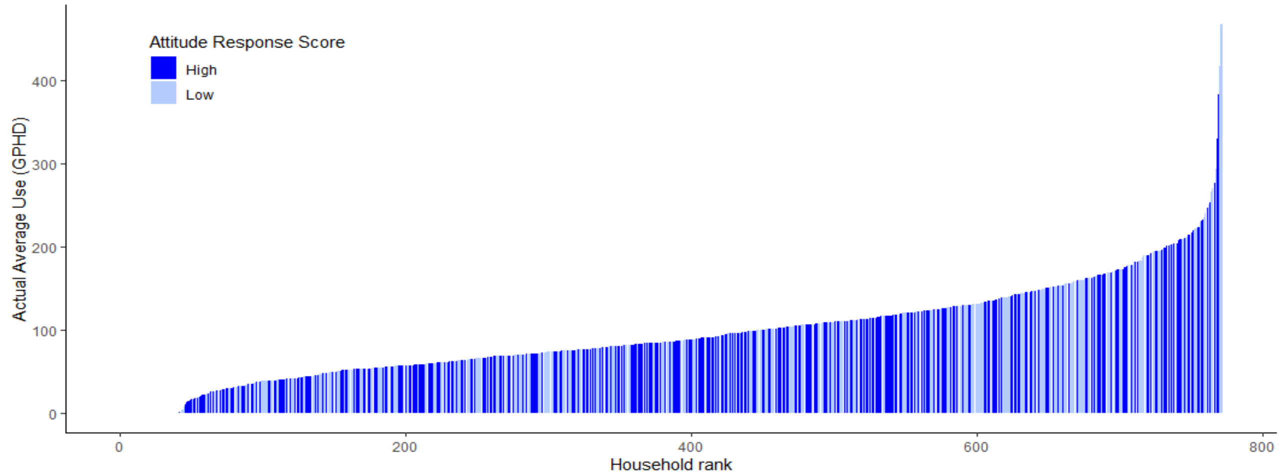
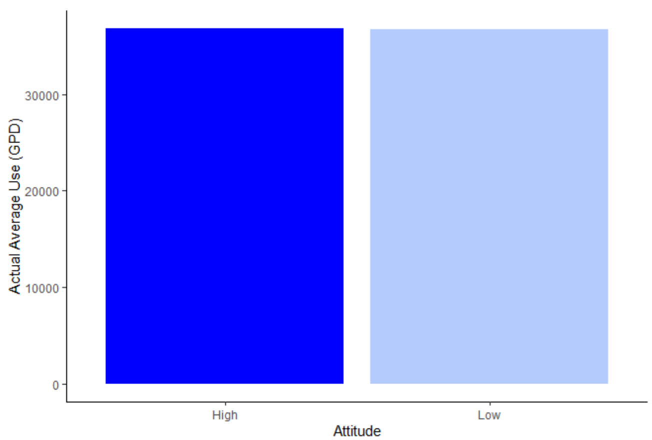


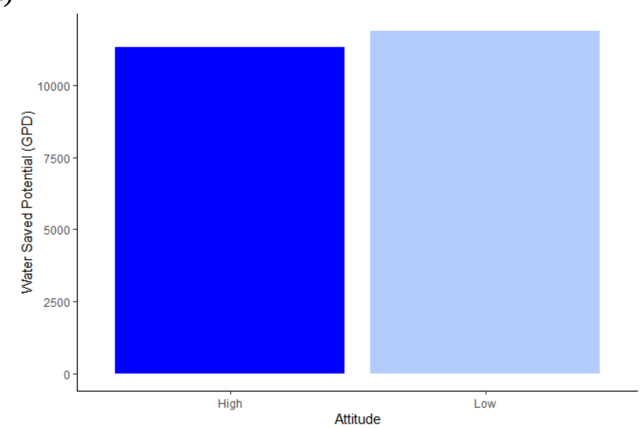
Figure A2- 2: Households grouped by the number of water conservation opportunities. The figure shows that the households with 3 to 8 opportunities have the highest potential for conserving water. The darker shades represent conservation resulting from behavior change while lighter shades of the same color represent conservation resulting from retrofitting inefficient appliances.

Figure A2- 3: Intervention-wise segmentation for different implementation phases if community-based social marketing is employed to reduce water demand of households from the REU-2-16 study.



(a)





(b) (c)

Figure A2- 4: Segmentation based on attitude. (a) The relationship between a household's rank and actual daily water use attitude; (b) cumulative average daily water use of high attitude and low attitude households; (c) and their water savings potential .

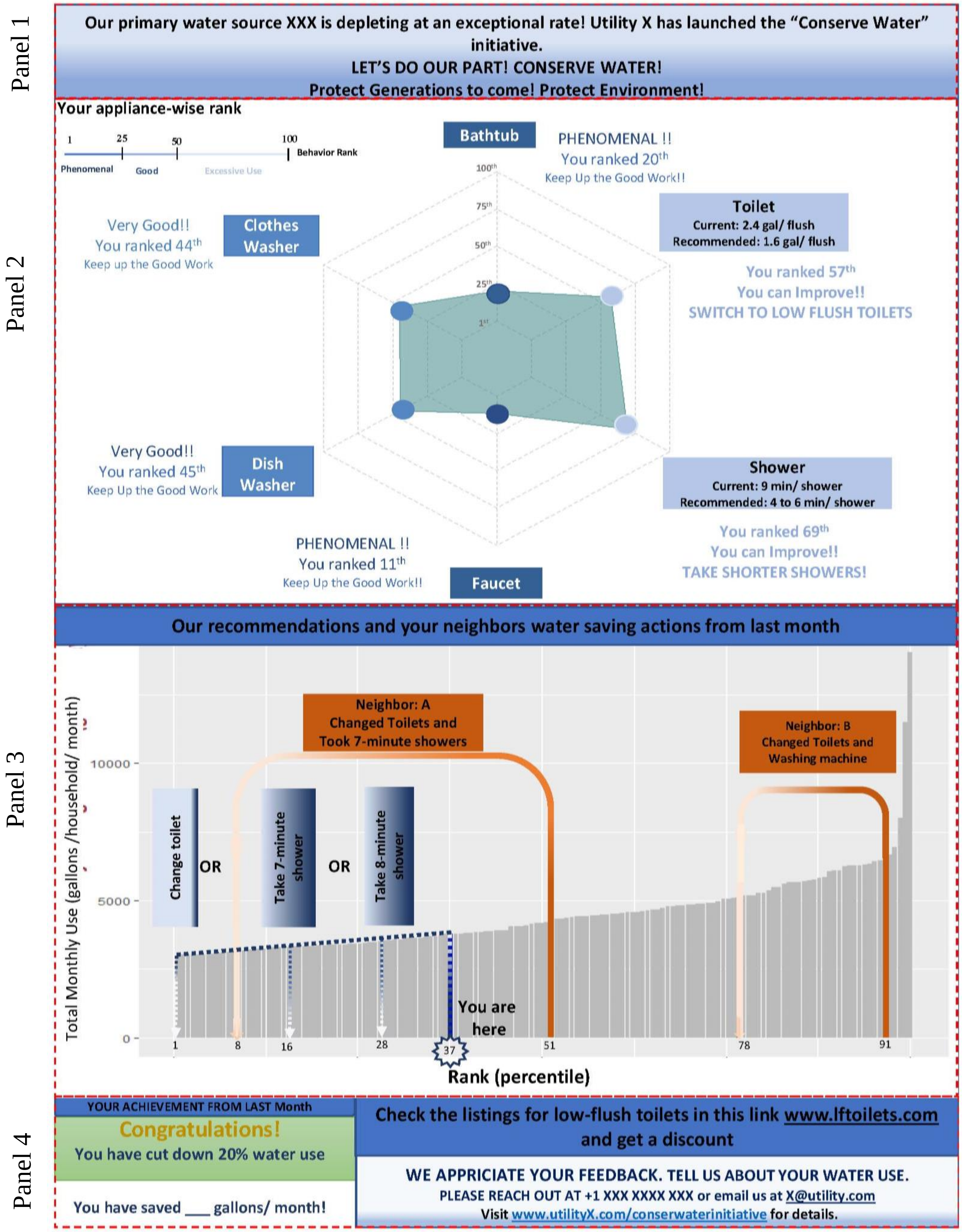


Figure A2- 5: An early version of the customized feedback message which was circulated among university professors, graduate students, and homeowners to evaluate intuitiveness.

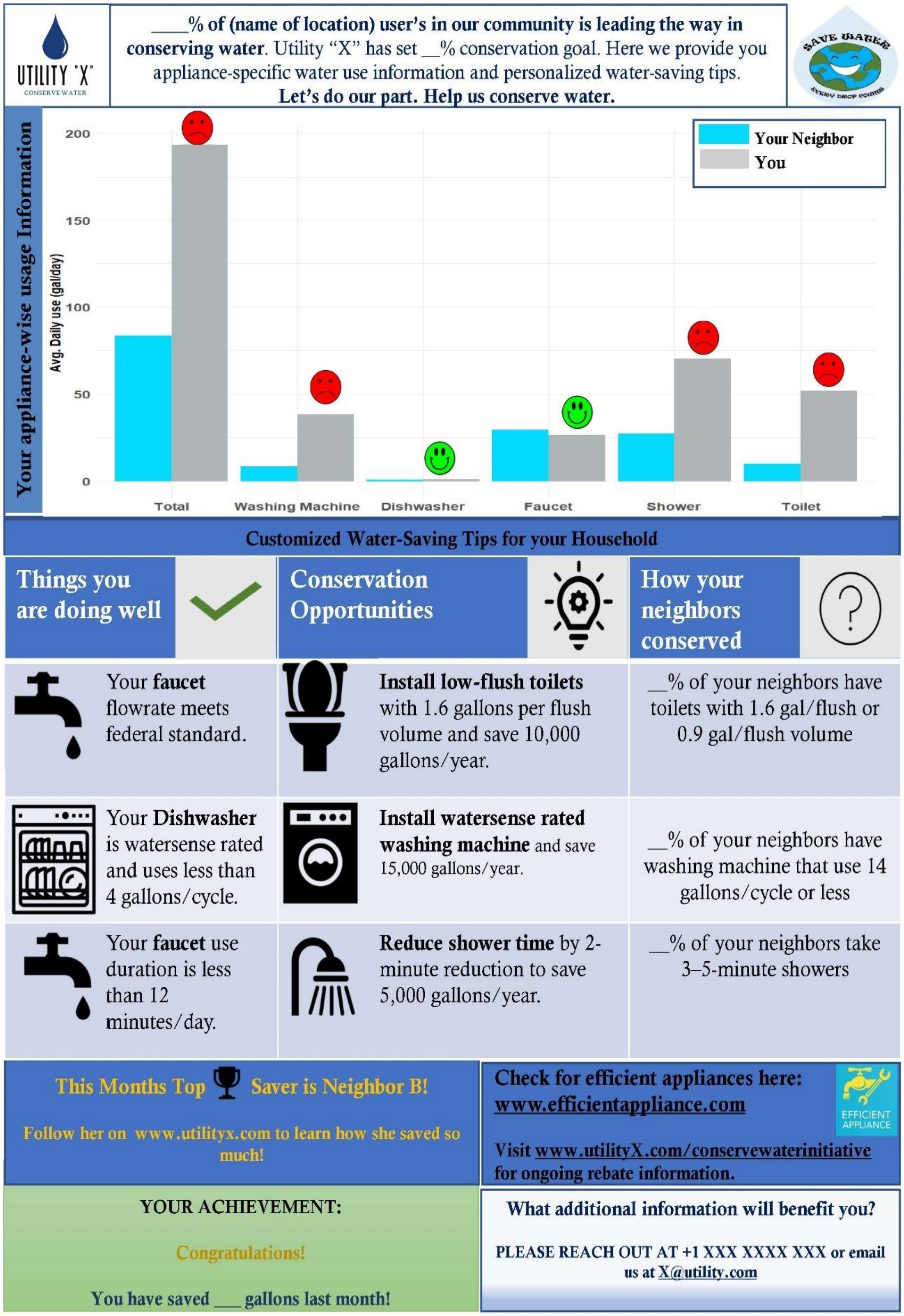


Figure A2- 6: Message sample with customized water-saving tips targeting multiple inefficient end-uses.

Appendix 3: Tables

Table A3-1: Sample survey questions from the REU-2-16 dataset (only the relevant attitude questions are included from the actual survey form).

Question ID	**Question**
REU2-16_attitude_M	I conserve water to save money.
REU2-16_attitude_N	I conserve water to save energy.
REU2-16_attitude_O	I conserve water because it is the right thing to do.

Table A3-2: Mean statistics of REU-2-16 dataset for 6 major indoor appliances.

Appliances	Number of Households using the Appliance	Total Volume of Water Used by the Appliance (gallons/day)	Daily Mean Volume (Gallons/ Household/ day)	Daily Mean Number of Events (Events/ day)	Average Volume Per Event (Gallons/ Event)	Average Duration Per Event (Minutes/Event)	Average Per Capita Volume (Gallons/ person/day)	Average Per Capita Event per Week (Event/person/Week)	Mean Flowrate (Gallons/ Minute)	Average End-use Time per Day (Minutes/ Household/day)
Bathtub	352	2,644	7.73	0.38	20.67		3.22	1.12	4.38	
Clothes washer	707	7,427	10.49	1.19	11.25		4.65	3.57		
Dishwasher	508	436	0.86	0.59	1.56		0.37	1.82		
Faucet	731	19,518	26.66	52.03	0.57	0.68	11.47	160.93	0.75	33.14
Shower	718	20,889	29.07	1.82	15.88	7.81	11.68	5.32	2.06	14.47
Toilet	731	35,437	33.31	13.06	2.57		14.57	39.55		

Table A3-3: The potential water volume that households with attitude response scores higher than 37 (median response score) can conserve.

Number of Behavioral Opportunities	Number of Technology Opportunities	Number of Households with Attitude Response Scores Higher than Median Response Score	Total Water Used (gal/day)	Potential Volume that can be saved by Changing Behavior (gal/day)	Potential Volume that can be saved by Changing Technology (gal/day)
0	0	28	335	0	0
0	1	21	1269	0	128
0	2	50	3472	0	676
0	3	17	1268	0	332
1	0	4	277	33	0
1	1	30	2809	365	365
1	2	52	5217	305	971
1	3	28	2943	263	789
2	0	10	887	224	3
2	1	28	2539	431	308
2	2	49	5580	1006	997
2	3	9	1130	136	271
3	0	5	618	216	0
3	1	14	1477	387	135
3	2	35	4763	1125	939
3	3	12	1815	377	410
4	0	1	217	81	4
4	1	8	899	268	75
4	2	10	1571	543	220
4	3	2	282	79	42
5	1	3	343	75	71
5	2	3	439	193	70
5	3	1	232	53	26
6	0	1	79	38	2
6	2	1	150	81	45

Table A3-4: Recommendations from university professors, graduate students, and homeowners on an earlier version of the strategic-customized message shown in figure A2-5 (Appendix 2),

Panel Number	Synthesis of overall review		Suggestions
	Positive	Negative	
1	Source of water is a good touch	• Not catchy • Gain-framed messaging should be used • No graphic	• Use gain-frame message for motivation • Use loss-framed message for motivation (Most reviewers)
2	Most informative figure	• Color code should provide a sense that high rank is bad and low rank is good (red→green) • Messaging was not good. Make it more general instead of telling good or bad • Messaging did not help user understand whether high rank is a good or a bad thing?	• Add Volume • Specify the number of total users • Include information for both good and bad usage • Use upper and lower bounds of each end use • Use one panel for tech and one for behavior • Use WaterSense information • Show which appliance is using the highest amount of water.
3	Very good at providing comparative information	• Hard to follow	• Use only the action (actions) that is suggested for the user when providing examples related to water-saving action adopted by other neighbors. • Instead of actual rank, make it more general or use a range when addressing high users. • The big arrows should be complied using smaller arrows instead of color gradients. • Also tell how much water the users can save by adopting water-saving actions
4	• Classified information/advertisement was great • Straight forward • Information showing the change in water-saving was great		• Link the saved water to something meaningful, e.g., how many trees or children or locality was benefited by users' sacrifice • Specify what type of feedback you are looking for

CHAPTER 4

SUMMARY AND CONCLUSION

Reducing water demand has become challenging, especially in regions that are becoming more arid and where users may not yet be accustomed to water-saving behaviors. Therefore, managers are looking into innovative ways to maximize water savings that can be run parallelly with other demand management strategies such as price penalties and seasonal water restrictions. One viable option is to use a voluntary messaging strategy, as many recent empirical studies have reported the effectiveness of such an approach. Furthermore, a few commercial companies now provide high-frequency water use information through mobile phones and web-based applications, which managers may use for communication, i.e., sending strategic messages for conservation. However, message components must be selected strategically to maximize conservation and sustain efficient behaviors in the long term–for which the managers need specific guidelines that prior studies have not provided.

Chapter 2 of this manuscript synthesized 80 studies from the behavioral science, health communication, water, energy, and environmental fields to identify how strategic messages may motivate conservation behaviors. The review indicated that four components must be included; a plea to users, consumption and comparison reports, customized tips, and additional information to connect users to available resources. A message constructed using only one strategic component, such as social comparison, may not be enough to encourage users. Nine additional recommendations maximized demand reduction in the longer run, which included the selection of feedback frequency, depending on the data type, shuffling messaging components every three months, and providing a neighbor's conservation experience to improve users' trust in other community members. However, studies from the behavioral sciences suggest that there is still room to improve a strategic message's efficacy, which requires customizing messages to fit the household's informational and motivational needs.

Chapter 3 provided household-specific messages that combined water behavior data with conservation intent data, using a behavior transforming tactic called community-based social marketing. Two conditions of this approach are the availability of disaggregated data and a psychological survey requirement before the messaging campaign's initiation. This approach first targets a household's most inefficient end-use by analyzing water data using a simplified ranking method. This ranking system can be applied to any dataset that has household-specific water use information. Furthermore, the proposed framework introduces the Lorenz curve and Gini Index to identify most inequal end-use attributes to identify households with highest water-saving potential. Next, psychological information data is utilized to tailor strategic messages to meet the household's motivational needs, such as improving conservation attitudes, inciting peer pressure, and building confidence in their own water behaviors by providing end-use-specific tips. The methods are illustrated using a publicly available national dataset, REU-2-16, and showed that 93% of the users have opportunities to save water either by retrofitting their appliances or changing their behaviors. A sample of messages tailored for indoor and outdoor activities was shared with ten graduate students, university faculty members, and homeowners who provided feedback to improve the messages.

The findings from chapter 2 and 3 illustrate how water managers can use commercially available platforms that provide instantaneous, disaggregated water use data to motivate their customers to initiate and sustain water conservation behaviors. Follow-up studies should first test the efficacy of the proposed method. Then, additional research should identify which environmental, communal, or pecuniary aspects best improve users' conservation ethics.