One Size Does *Not* Fit All: Applying the Transtheoretical Model to Energy Feedback Technology Design

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ABSTRACT
Global warming, and the climate change it induces, is an urgent global issue. One remedy to this problem, and the focus of this paper, is to *motivate* sustainable energy usage *behaviors* by people. One approach is the development of technologies that provide real-time, continuous feedback of energy usage. However, there is one problem - most technologies use a "one-size-fits-all" solution, providing the *same* feedback to *differently* motivated individuals at different stages of readiness, willingness and ableness to change. In this paper, we synthesize a wide range of motivational psychology literature to develop a *motivational framework* based on the Transtheoretical (*aka* Stages of Behavior Change) Model. For each stage, we state the motivational goal(s), and recommendation(s) for how technologies can reach these goals. Each goal and recommendation is supported by a rationale based on motivational literature. Each recommendation is supported by a simple textual example illustrating one way to apply the recommendation.

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Sustainability, feedback, motivational theory, design.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI)

General Terms
Design, Human Factors, Theory

INTRODUCTION
Global warming, and the climate change it induces, is an urgent global issue. Moving towards an environmentally sustainable lifestyle is recognized as a partial solution to this problem. The development of energy-efficient technology (e.g. cars, homes, appliances) is one approach. While important, this is only a *partial* solution as people do not always use this technology in energy-efficient ways [46]. We must also focus on a *people* solution: understanding how and why people use energy [46], so we can develop technologies that can motivate sustainable energy behavior.

Within products and HCI, one approach to motivating sustainable energy usage behaviors is the development of technologies that provide real-time, continuous feedback of one's energy usage. Feedback is often presented as raw energy use (e.g., watts), personal cost (e.g., money), or environmental impact (e.g., CO_2). While feedback can be effective [4], most technologies are limited as they use a "one-size-fits-all" solution – that is, they provide the *same* feedback to *differently* motivated individuals, at different stages of readiness, willingness and ableness to change. Unless the energy consumer *already* holds a strong goal to use energy sustainably [36], feedback only *informs*, but does not necessarily *motivate* sustainable energy action.

Motivating sustainable energy behavior change is a psychologically, socially, and culturally complex problem [46]. While all perspectives offer important insights, we approach this problem from the *psychological* perspective.

From this perspective, we explore the following question: ***How can energy feedback technologies leverage existing techniques and theories within motivational psychology to more effectively motivate sustainable energy usage behaviors?*** In approaching this question, we argue that designers of such technology need to consider two points:

1. Different people hold different *attitudes, beliefs* and *values* [5], and are motivated by different things.
2. Intentional behavior change does not occur as an event, but rather, as a *process* in a series of stages as defined by the Transtheoretical Model [38]. Individuals move from being unaware or unwilling to acknowledge the problem, to considering the possibility of change, to preparing to make the change, to taking action, and finally, to maintaining the desired behavior over time [38].

We make three contributions: 1) we frame motivational psychology literature as key notions for designers of technology that aim to motivate sustainable energy behavior change, 2) we show how these notions can be used to assess existing feedback technologies from a motivational perspective, 3) we offer a motivational framework based on the Transtheoretical Model where we propose specific strategies that aim to target individual *attitudes, beliefs* and *values* held at each *stage* of behavior change.

DEFINING MOTIVATION
Motivation is "an inquiry into the *why* of behavior" [16]. It is "an internal state or condition (sometimes described as a need, desire, or want) that serves to activate or energize behavior [31]. Motivation is closely tied to emotional processes [29]. Emotions may be involved in the *initiation* of behavior (e.g. the emotion of loneliness might motivate the action of seeking company). Alternatively, the desire to

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experience a particular emotion may also motivate action [29] (e.g. the decision to run a marathon may be motivated by the desire to experience a sense of accomplishment).

CONSTRUCTS OF MOTIVATION

Attitudes, beliefs and values are "learned psychological constructs that motivate and influence behavior" [5]. Within these constructs, attitudes are the *least enduring* (most likely to change), and values are the *most enduring* (least likely to change) [5]. We discuss these constructs within the context of sustainable energy behavior.

Attitudes are "learned predispositions to respond to a person, object, or idea in a favorable or unfavorable way" – reflecting what one likes or dislikes [5]. For example, John holds a favorable attitude towards water conservation: in particular, taking short showers.

Beliefs are "the ways in which people structure their understanding of reality" – in other words, "what is true and what is false" [5]. Most beliefs are based on previous experience [5], e.g. recycling helps the environment.

Values are "central to our concept of self" [5], and can be conceptualized as "behavioral ideals" or "preferences for experiences" [38]. As *behavioral ideals*, values function as "enduring concepts of good and bad, right and wrong" [38], e.g. it is wrong to litter. As *preferences for experiences*, "values guide individuals to seek situations in which they may experience certain emotions" [38], e.g. I bike to work because it makes me feel good. Throughout this paper, we draw upon a *subset* of values defined by Rokeach and Maslow (See Table 1). Both proposed that people hold *value systems* – "a value hierarchy or priority structure based on the relative importance of the individual values" [22]. Rokeach believed that differences in behavior occur due to differences in the *ranking* of value importance [43] – e.g. Kim, an energy auditor, values being "logical" more than she values being "imaginative" during an audit. Maslow's value system is a hierarchical structure, where he believed humans seek to satisfy the lower level values (i.e. physiological, safety) before the higher ones (i.e. love/belongingness, esteem, self-actualization) [35].

Behavioral Ideals (Rokeach)	Preferences for Experiences (Rokeach)	Preferences for Experiences - Low to high level (Maslow)
Capable: Competent, effective **Helpful**: Working for the welfare of others **Honest**: Sincere and truthful **Imaginative**: Daring and creative **Independent**: Self-reliant; self-sufficient **Intellectual**: Intelligent and reflective **Logical**: Consistent; rational **Obedient**: Dutiful, respectful **Responsible**: Dependable and reliable	**A comfortable life**: a prosperous life **Freedom:** independence and free choice **Health:** physical and mental well-being **Inner harmony:** freedom from inner conflict **A sense of accomplishment:** a lasting contribution **Social recognition:** respect and admiration **Wisdom:** a mature understanding of life **A world of beauty**: beauty of nature and the arts	**Physiological:** Homeostasis and appetites **Safety:** Security of body, employment, resources, family, health, property **Love/belonging:** Affection and belongingness, be accepted **Esteem:** Self-respect, self-esteem, esteem of others **Self-actualization:** To find self-fulfillment and realize one's potential

Table 1. Values proposed by Rokeach and Maslow

HOW BEHAVIOR CHANGE OCCURS

The Transtheoretical Model (TTM), also known as the "Stages of Change" Model, is an established theory of behavioral change processes [41]. It states that intentional behavior change is a *process* occurring in a series of *stages*, rather than a single event [38]. *Motivation* is required for the focus, effort and energy needed to move through the stages [38]. The stages progress as follows.

Precontemplation. The individual is unaware, uninformed, unwilling or discouraged to change the problem behavior [38]. They are not intending to take action in the foreseeable future, usually measured as the next 6 months [41].

Contemplation. Individuals acknowledge their behavior is a problem [38], and *intend* to change in the next 6 months [41]. Contemplators are open to information about the problem behavior, though may be far from making an actual commitment due to feelings of ambivalence [38].

Preparation. The individual is ready to take action in the immediate future (usually measured as the next month), and aims to develop and commit to a plan [38]. At least one 24-hour change attempt was made in the past year [41].

Action: The individual takes action by overtly modifying their behavior, usually within the past 6 months [41].

Maintenance, Relapse, Recycling: The individual works to sustain the behavior change, and struggles to prevent relapse [41]. If relapse occurs, individuals regress to an earlier stage and begin to progress through the stages again [38].

FACILITATING BEHAVIOR CHANGE

Motivational Interviewing (MI) is a client-centered counseling style often used in conjunction with the TTM that aims to facilitate behavior change [38]. In MI, motivation to change is elicited from the *client* [38]. Three principles summarize MI [38]: 1) build client *self-efficacy*, 2) develop *intrinsic* attributions to successful behavior, and 3) develop discrepancies between *values* and current behavior.

ASSESSING PERSUASIVE ENERGY FEEDBACK TECHNOLOGIES - WHY ONE SIZE DOES *NOT* FIT ALL

We now show the value of the above constructs and theories by assessing selected persuasive energy feedback technologies from this motivational perspective. First, however, we discuss the goal of motivating *durable* sustainable energy behavior change, and define the concepts of extrinsic and intrinsic motivation. We then introduce commonly-used techniques that aim to motivate sustainable energy behavior. Finally, we draw upon a sample of work in persuasive energy feedback technologies and classify them according to their best fit to particular motivational theories

(this is *our* classification - the actual systems were not necessarily designed with these explicit theories in mind). From this, we discuss the technology's potential effectiveness in motivating sustainable energy behavior.

Durability of sustainable energy behavior change

When motivating sustainable energy behavior, one important goal is *durability* of behavior change [13]. *Durability* is behavior that is "self-sustaining without the need for repeated interventions" [13]. To achieve this goal, *intrinsically* motivated behavior is ideal [13].

Intrinsic motivation is "the doing of an activity for its inherent satisfactions rather than for some separable consequence" [18]. Intrinsic satisfactions include interest [42], curiosity [42], competence [2] and enjoyment [42]. *Extrinsic motivation* is "the doing of an activity in order to attain some separable outcome" [18]. Examples include material incentives or social reinforcement.

Commonly-used motivation techniques

The *Attitude Model* assumes that "pro-environmental behavior will automatically follow from favorable attitudes towards the environment" [46]. This model appeals to Rokeach's value of "a world of beauty", assuming if one values nature, then they will act to protect it.

The *Rational-Economic Model (REM)* assumes "people will make pro-environmental decisions based on economically-rational decisions" [46] - that is, monetary cost is the primary motivator. This model appeals to Maslow's value of "safety" - specifically, "security of resources", and Rokeach's values of being "logical" and "responsible".

The *Information Model* provides information to a problem, why it is a problem, and action steps to solve the problem [46]. It appeals to Rokeach's value of being "obedient", assuming once you know what to do, you will do it.

Positive reinforcement (PR) occurs when "a response is followed by the *addition* of a reinforcing stimulus which "increases the likelihood that the response will be repeated in similar situations" [29] (e.g. receiving money for recycling cans positively reinforces future recycling behavior).

The *Elaboration Likelihood Model (ELM)* [39] proposes two routes of cognitive processing. The central route processes arguments according to logic, rationale, and quality of the argument. The peripheral route uses emotional persuasion, where one is influenced by factors unrelated to the argument's validity, such as emotional responses.

A motivational perspective assessment of energy feedback technologies

Caveat: Assessing existing feedback technologies from the author's descriptions of them solely from a motivational perspective is not really 'fair'. Our intent, rather, is to reflect on these designs, where we reconstruct, how well a particular design is justified (or not) as a motivational device. Regardless of how well the design fits this somewhat narrow motivational view, we recognize that the device's overall effectiveness as a feedback technology may be heavily influenced by other design considerations not discussed in this assessment.

Attitude Model: Almost all current feedback technologies employ the Attitude Model. We illustrate using two examples. The 'Power-Aware Cord' [28] (Figure 1, left) is an electrical cord that visualizes electricity consumption by varying the pulse, flow, and intensities of light using electroluminescent wires. It assumes that visualizing electricity alone suffices in motivating individuals to reduce their consumption. '7000 Oaks and Counting' [30] (Figure 1, right) visualizes a building's energy consumption by equating trees to carbon dioxide emissions. The lower the energy usage, the more trees shown. The higher the energy usage, the more buildings and appliances shown. This work assumes that showing energy usage in relation to carbon offsets suffices to motivate action.

There are two limitations to this model. First, it does not consider the stages of behavioral change. Specifically, the assumption of a pro-environmental attitude does not hold for *precontemplators* who have not yet acknowledged their behavior is problematic. For *contemplators*, feelings of ambivalence may indicate that a pro-environmental attitude does not lead to commitment or action. While the Attitude Model may be effective in the *preparation* stage, it does not provide individuals with specific energy actions they can take. In the *action* and *maintenance* stages, individuals have already acted, and thus motivations based on attitude alone may have no further effect. Secondly, this model does not consider factors such as situational circumstances (e.g. time, convenience, comfort, aesthetics), social influences, government regulations, and so on that often override the decisional influence of a pro-environmental attitude [46].

REM and Attitude Models: The Attitude Model is often used in conjunction with the REM. Early works employing these models include textual LCD displays that present energy usage in relation to cost. Examples include the 'Energy Detective', 'Power-Cost Monitor', and 'Kill-A-Watt' (Figure 2, top row). Other systems add persuasive prompts (through changes in color or graphics) to encourage less usage during peak hours when energy costs are high. Examples include the 'Wattson', 'Energy Orb', and 'Energy Joule' (Figure 2, bottom row). Works employing

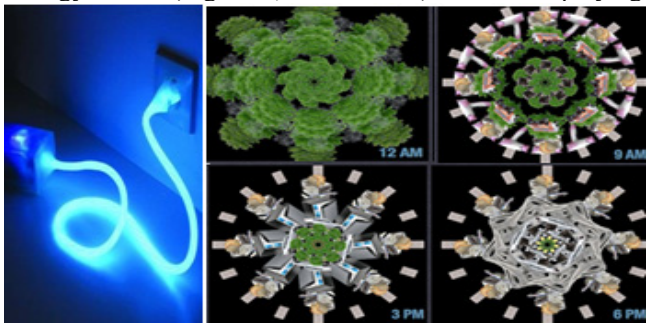

Figure 1. ***Left:*** Power-Aware Cord. ***Right:*** '7000 Oaks and Counting': 4 snapshots over the day

these models have three limitations. First, the motivating effect of material incentives (such as money) is non-durable; just as the behavior is quickly started using material incentives, their removal likewise terminates behavior change [13]. Second, when the cost of energy is low in proportion to one's income, feedback is not as effective [25]. Third, similar to the Attitude Model, the REM does not consider situational circumstances that may override the logistics of cost, or the positive influences of pro-environmental attitude [50].

Information, Rational-Economic and Attitude Models: Some systems supplement these earlier models with an Information Model. 'Ecomagination' and 'Energy Tree' (Figure 3, top left and bottom) are two examples. They provide complex feedback visualizations for energy used, cost and CO_2 emissions, summarize trends over days to months, and provide action steps for more efficient usage. These help to explain why current energy use is problematic and how more efficient usage can be achieved.

While the combination of these models improves upon the previous categories, limitations remain from a motivational perspective. First, information *alone* rarely motivates action [46] as information is only effective if the user *already* holds a strong goal to act based on that information [36]. Second, humans have a psychological tendency to *avoid* non-supportive and *seek out* supportive information [6]. Specifically, individuals in the contemplation stage may hold ambivalent feelings [38], and thus may psychologically discount information that contradicts with their current energy behaviors. In contrast, the Information Model can be very effective in the *preparation* and *action* stages, improving upon the Attitude Model by providing specific actions one can take. In *maintenance*, Information Models can be effective if the information provided changes over time to match with the individual's deepening knowledge.

Positive Reinforcement, Emotional Persuasion (through the ELM) & Values: 'Ubigreen'[24] (Figure 3, top right) employs these techniques. It is a mobile phone visualization that uses semi-automatic sensing technologies to provide feedback of transportation behaviors. It uses a series of *emotionally persuasive* icons [24] (i.e. a polar bear standing on an iceberg) as *positive reinforcement*. The more "green" one's transportation behaviors, the further in the progression of icons one gets (i.e. the iceberg grows and the ecosystem improves) until one reaches the final stage (i.e. sun sets and Northern Lights appear). Icons also represent "auxiliary benefits", including a piggy bank to represent money savings, a person meditating to represent relaxation, a book representing the opportunity to read and a weightlifter to represent exercise [24]. We classify these respective icons as appealing to the following *values*: Maslow's "safety", Rokeach's "inner harmony", "intellectual", and "health".

In 'Ubigreen', the relation of green transportation behaviors to other benefits of value is promising as it provides a range of personal *benefits* [46] while minimizing the individual's

Figure 2. ***(Clockwise)*** Kill-A-Watt, Power Cost Monitor, Energy Detective, Energy Joule, Energy Orb, Wattson.

perception of personal *cost* [10]. An improvement would be to consider the *specific values* and *value systems* of each individual. For example, Person A holds a high value on exercise and fitness, and a lower value on money savings. As such, the visualization could provide *personalized* feedback of the positive impacts of green transportation behaviors on Person A's fitness level (e.g. heart rate, calories burned, etc.). In contrast, the visualization could highlight different benefits for Person B who (say) highly values money savings.

One limitation of 'Ubigreen' from a motivational perspective is the possible *extrinsic* nature of the positive iconic reinforcement (polar bears). Specifically, some participants viewed the visualization to be a "game", where making it to the last screen was the "final level" [24]. This is problematic. When people are only in it to win, it negatively impacts their *intrinsic* motivation [17], and may lead to less durable behavior change [13]. As this work aimed to target "already very green individuals", participants were most likely in the *action* or *maintenance* stages, where intrinsic motivation is required for long-term success [38].

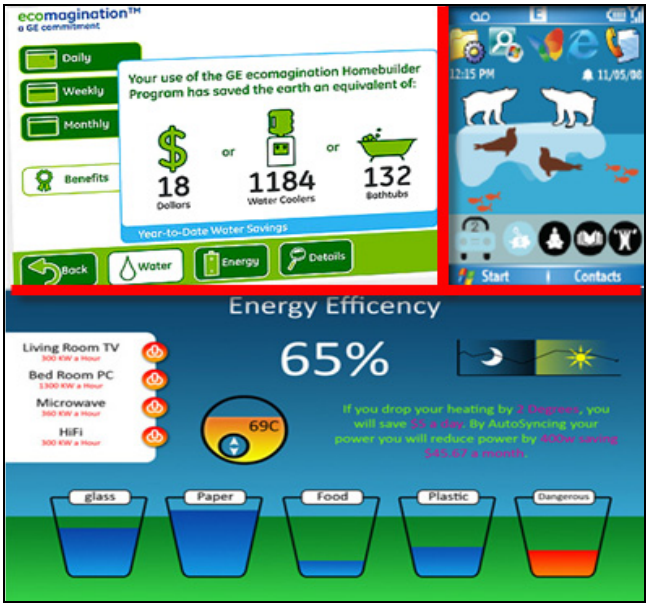

Figure 3. (Clockwise) Ecomagination, Ubigreen, Energy Tree.

A MOTIVATIONAL FRAMEWORK: APPLYING TTM TO ENERGY FEEDBACK TECHNOLOGY DESIGN

Our assessment argued that most feedback technologies tend to design for "one-size-fits-all". To address this shortcoming, we offer a motivational framework based on the TTM's stages of change and MI's counseling principles, to propose strategies that aim to target individual motivations at each stage of behavioral change. To do this, we synthesize the TTM and MI with various motivational literature, including foundational motivation theories, learning theories, social psychology, applied psychology, and environmental psychology. For each stage, we present the motivational **goal(s)**, and **recommendation(s)** for how technologies may reach these goals. Each goal and recommendation is supported by a **rationale** (based on motivational literature). To make the recommendations more vivid, we use a scenario of a particular energy user named Mary, who holds specific attitudes, beliefs and values. We simplify this example to focus on one appliance – the desktop computer. We draw upon the *details* presented in this scenario to provide a simple textual **example** for each recommendation. We do not claim the examples we provide are ideally presented; rather, they illustrate *one* way to achieve a recommendation. Table 2 summarizes the goals of each stage, and can be used as a reference for the following text.

An example scenario: Mary

About Mary: Mary is 36 years old, married, the mother of two school-age children (Logan and Sarah), and lives in Edsen Community. She is a novelist and works on a home desktop computer with two 19" monitors. Due to familial responsibilities (e.g. driving her kids to school and activities), Mary works flexible but long hours. Mary values work and productivity, family, and physical health. Though money is not a problem, Mary is a frugal spender.

Computer usage: Mary uses MS Word, Internet and email. She browses the web for ideas and usually keeps her computer and monitors on so she can readily access her open Internet tabs and work when desired. Mary knows about but does not make use of her computer's automatic power management features. Last month, Mary's computer got a virus, though she is not sure how it was contracted.

Motivational stage: We begin this scenario with Mary as a precontemplator. While Mary is somewhat aware of general environmental problems, she does not believe her personal energy use (and in particular, her computer usage) has much negative effect. In general, Mary does not believe she has the time or energy to make big energy changes.

STAGE 1 – PRECONTEMPLATION

Goal #1: Present information in moderation to "plant the seed" for individuals to acknowledge their current (energy) behaviors are problematic.

Rationale: Precontemplators can be reluctant, resistant, resigned, or rationalizing [38]. Through inertia or lack of knowledge of the effect of the problem behavior, precontemplators do not want to consider change [38]. The goal is to "plant the seed" that unsustainable energy behaviors are problematic. Once planted, precontemplators often need time to let them germinate [38]. Information should be provided in moderation as more intensity will often produce fewer results with this group [38].

Precontemplation	• "Plant the seed" to acknowledge problematic unsustainable behaviors
Contemplation	• "Tip the balance" in favor of change
Preparation	• Develop a *plan* that is acceptable, accessible and effective.
Action	• Positively reinforce sustainable action • Develop intrinsic motivations
Maintenance	• Maintain durable behavior change

Table 2. Motivational goals for each stage of change

Recommendation #1: Provide personalized feedback that acknowledges *both* the benefits and consequences of the individual's *non-sustainable* energy behavior. Present these benefits and consequences in relation to what the individual values, in a neutral, non-biased way.

Rationale: Technologies must acknowledge both the pros and cons of the individual's current non-sustainable energy behaviors before they can expect precontemplators to "decrease resistance" [38] and become open to considering the "not so good" things" [38]. This is especially important when motivating energy action as *non-sustainable* energy behaviors offer many benefits, such as comfort, luxury, convenience, social status, and sometimes cost. These benefits appeal to Rokeach's values of "a comfortable life" and "social recognition".

Example, centered on Mary's computer and monitor use

SUMMARY FOR THIS WEEK
Total energy used: 43.68 kWh (ON for 168 hours, 37% while not present)
Pros: Your sporadic usage and immediate computer access fit well with your busy work schedule and driving kids to activities this week.
Cons: *1)* Cost = $4.47 (At this rate, monthly cost will be $17.88, equal to 54% of Logan's monthly soccer league fee), *2)* Your computer while ON was more susceptible to viruses, *3)* CO_2 emissions = 109.2 kg (At this rate, monthly CO_2 emissions will be 436.8 kg), requiring 64 full-grown pine trees to offset in one year.

Recommendation #2: Refer to social norms regarding sustainable energy behaviors by aligning the use of descriptive and injunctive normative messages.

***Rationale*:** *Social norms* are "the 'rules' or expectations for appropriate behavior in a particular social situation" [29]. The idea is motivate the individual to think: "if many people value it, maybe I should as well". *Descriptive norms* are "perceptions of behaviors that are typically performed" (e.g. "85% of your neighborhood recycles"). These appeal to Maslow's value of "love/belongingness". *Injunctive norms* are "perceptions of behaviors that are typically approved or disapproved" (e.g. a thumbs-down sign with the text: "Protect the environment – don't litter!). These appeal to Rokeach's value of being "obedient". Normative messages that *align* normative and injunctive messages tend to

have higher rates of success [11] – i.e. highlighting *popular* pro-environmental behaviors that are socially *approved*.

Example: A thumbs-up sign with the following text:

> Join the rally for efficient computer usage! This month, your community reduced consumption by 29%, saving 271 kWh, $ 27.75 and 677.5 kg CO2 emissions, just from simple changes in computer power management!

Recommendation #3: Provide personalized feedback of a variety of small energy actions that, if performed, would have positive impacts on the environment.

Rationale: Two barriers to motivation include: "not feeling competent" [15] and "not believing it will yield a desired outcome" [45]. Providing information of energy actions that can make a positive impact addresses the barrier of "not feeling competent" and appeals to Rokeach's value of being "capable". Presenting a variety of action *choices* appeals to Rokeach's value of "freedom", and increases one's sense of personal control [44] and intrinsic motivation [32]. Providing projections of the positive impacts of potential energy actions addresses the barrier of "not believing it will yield a desired outcome".

Example: To provide information in moderation, one energy tip could be provided each day.

> **TODAY'S ENERGY TIP** – ***Efficient monitor usage***
> Tired eyes? Turn down your monitor brightness and increase the contrast. You'll reduce your monitor consumption by almost 50%, doing a big favor for your eyes *and* the environment! Click here to find out how.

STAGE 2 - CONTEMPLATION

Goal #1: "Tip the balance" in favor of change [38]

Rationale: Contemplators have acknowledged the problem, are open to information, but are not yet ready to take action [38]. Ambivalence is the key issue that must be resolved, as evaluations of the pros and cons of the current behavior are more or less equal [38].

Recommendation #1: Provide personalized feedback on the pros of *sustainable* energy behavior, and the cons of *non-sustainable* energy behavior. The pros should emphasize an improvement to the individual's quality of life (in relation to what they value). The cons should be presented in terms of loss (in relation to what they value) rather than gain.

Rationale: This recommendation aims to reduce feelings of ambivalence by providing a more one-sided perspective. The individual should perceive the 'pros' of sustainable behavior as *enhancing* their quality of life. This is important as people resist making changes that they perceive as reducing their quality of life, in particular, those that stress self-sacrifice for the welfare of the common good [33]. The 'cons' should focus on the costs of *non*-sustainable behaviors, from a perspective of *loss* rather than gain [50]. This maximizes the impact of information as people are more willing to take actions to avoid or minimize a loss, than do the same action for gain [50]. The focus on values emphasizes *personally relevant* information or feedback, which can be extremely persuasive at this stage [38].

Example:

> ***SUMMARY FOR THIS WEEK***
> **Total energy used:** 43.68 kWh (ON for 168 hours, 68% of energy wasted)
> ***Loss* from inefficient usage:** 1) $29.70 – almost 1 month of Sarah's piano lessons, 2) Increased susceptibility to contracting computer viruses when the computer is ON, 3) 109.2 kg CO_2 emissions – requires 16 full-grown pine trees to offset the environmental pollution in one year.
> ***Benefits* of efficient usage:** 1) Decreasing monitor brightness and increasing the contrast reduces eye strain, and may support increased work productivity, 2) Sleeping or turning off the computer reduces the amount of received computer radiation, 3) Sleeping the computer reduces energy consumption by 97%, while still allowing you to access your open applications and Internet tabs in just a few seconds.

Recommendation #2: Remind individuals of their pro-environmental attitude, inform them of the *discrepancy* between their attitude and the corresponding behavior, and encourage a change towards more sustainable behavior.

Rationale: Contemplators hold pro-environmental attitudes but do not behave according to those attitudes. This recommendation uses this discrepancy through *cognitive dissonance* - "an uncomfortable state" that occurs when a person holds an attitude and a behavior that are "psychologically inconsistent" [19]. When this happens, people try to reduce this uncomfortable feeling, either by changing their attitude or their behavior [19]. Cognitive dissonance appeals to Rokeach's values of "inner harmony" and being "honest", and often leads to enduring changes in attitude or behavior [47]. As people change attitude more easily than behavior [46], an emphasis on encouraging sustainable *behavior* change is important.

Example:

> **Your energy inefficiencies:** Yesterday, ***67%*** of your computer power consumption was used while you were away from your desk. We know how much you care about efficient computer power management! You can do better tomorrow! ☺

Recommendation #3: Provide encouragement for small energy actions (whether or not the individual's original intention was sustainable energy usage) to encourage larger energy actions in the future.

Rationale: This recommendation uses cognitive dissonance through *"Foot-in-the-Door"* processes [50]. The idea is, if people can be encouraged to perform a small energy action on their own accord, they can be encouraged to perform larger energy actions in the future [46]. This occurs because of *cognitive dissonance* - individuals will change their internal attitudes to justify or rationalize their already performed external actions [19].

Example: Yesterday, Mary was working on Sarah's surprise birthday invitations when Sarah came home. Mary turned off her monitors to keep the invitation a secret in case she glanced over. While Mary's original intention was not energy savings, a message the next day could say:

> **Thanks for turning off your monitors!** You saved 2.21 kWh, $0.23, and 5.53 kg in CO_2 last night! Great job! ☺ To be even more efficient, consider sleeping your computer when finished for the workday. It only takes a few seconds, reduces consumption by 97%, and gives you (almost) immediate access to your work whenever you want!

Recommendation #4: Link the feedback technology to a sustainable energy usage community website, and encourage the individual to browse and read information of the experiences of sustainable energy users in the community.

Rationale: Contemplators are open to information, but are not ready to commit to action [38]. Providing an opportunity to read about the experiences of sustainable individuals in their community is a *vivid* and *personalized* way to appeal to *social norms* regarding energy usage, without pushing any type of commitment.

Example:

> Visit the Edsen Community Sustainable Lifestyles Website - Read about the experiences of real people in your community who've made **small** energy changes with **BIG** environment impacts!

STAGE 3 – PREPARATION

Goal #1: Support individuals in developing a *plan* that is acceptable, accessible and effective [38]. These plans can relate to "one-off actions" (e.g. purchasing an energy-efficient fridge) or "day-to-day" actions (e.g. taking shorter showers) [46].

Rationale: A *goal* is defined as "an internal representation of a desired outcome" [3]. Individuals in the preparation stage may have abstract goals but do not necessarily know the best way to achieve them.

Recommendation #1: Support individuals to self-set specific and quantitative goals (preferably at medium to high levels of difficulty.

Rationale: *Goal-setting* and *goal commitment* influences the success of goal achievement. *Specific*, *difficult* and *self-set* goals lead to higher performance and commitment than do-best, easy or assigned goals [49]. Specific goals make clear when the goal has been achieved [49]. Difficult goals provide a greater sense of achievement, though there is a lower probability of success [49]. Achieving difficult goals appeals to Rokeach's value of being "capable", and Maslow's value of "esteem". Goal difficulty can start at the easy level, as success builds on success, and with each small change the individual builds self-efficacy about making bigger changes [38].

Example:

> I commit to a medium difficulty level goal to reduce my CPU usage by 20%, starting April. 1, 2010 and ending April 30, 2010. My current usage: 15.12 kWh. My goal for April: 3.02 kWh.

Recommendation #2: Support individuals to develop multiple methods to achieve these goals, and encourage them to apply their personal expertise and knowledge to these plans.

Rationale: *Implementation intentions* are the "plans that specify the when, where and how to lead to goal attainment" [26]. Goal intentions that are furnished with implementation intentions are more easily attained than mere goal intentions [27]. Flexibility in goal attainment is good, providing the option to switch to other routes [26]. Implementation intentions appeal to Rokeach's values of being "logical" or "imaginative". Applying one's personal expertise to a situation is called *adaptive muddling* [33]. When this happens, people perceive a role for themselves, and may feel an obligation or responsibility to help the change succeed [21]. This has two benefits. First, it may increase the individual's level of goal commitment, targeting Rokeach's values of being "responsible", "helpful" or having "wisdom". Second, adaptive muddling may encourage self-reflection of one's energy behaviors, which may invoke the *intrinsic* emotions of curiosity and interest.

Example: Technologies can automatically generate potential implementation intentions while also encouraging adaptive muddling:

> **To reach this goal, I will:**
> √ Set automatic power settings to turn my monitor off after 30 minutes of inactivity
> √ Sleep my computer when finished for the workday
> __ Decrease my monitor brightness setting by 15%
> **Be creative!** *What other ways can you reach this goal?* _____

Recommendation #3: Within the sustainable energy usage community website, provide individuals with the option to be connected to energy "mentors" - people in the action or maintenance stages of sustainable energy behavior change.

Rationale: This recommendation employs *social diffusion* - the observation that people are more likely to follow the modeled behavior or example of others who have successfully adopted energy actions [50]. Being connected to an energy mentor also implies a level of commitment, which may be acceptable for individuals who are preparing to act in the near future.

Example: Feedback technologies could provide Mary with brief descriptions and profiles of energy mentors, highlighting those with similar energy needs or interests. Technologies could also provide text chat, photo exchange or other ways in which Mary and her "mentor" could communicate and share their experiences.

STAGE 4 – ACTION

Goal #1: Positively reinforce sustainable energy actions

Rationale: Positive reinforcement (PR) is the most effective technique for motivating the *increased* occurrence of a desired behavior [29]. Techniques such as punishment or negative reinforcement stop the undesired behavior, but do not replace anything in its place [29].

***Recommendation #1*:** Provide positive performance feedback in relation to progress made towards energy goals set in the preparation stage. Deliver PR *immediately* after the preferred behavior occurs, and in *multiple* ways.

Rationale: Positive performance feedback tends to increase intrinsic motivation, whereas negative performance feedback tends to decrease intrinsic motivation [14]. Providing positive feedback on goal progress may lead to the intrinsic satisfaction of competence, which appeals to Rokeach's value of being "capable". Delivering PR immediately and in multiple ways enhances the effectiveness of PR [29].

Example: Technologies could provide PR immediately after Mary performs energy actions, for example, using

sound, rewarding changes in graphics, social recognition of her actions, and so on. Feedback on goal progress could also be provided, with messages such as:

> You've made excellent progress towards your goal today! ☺ Keep up the great work, and you'll reach your goal in only 2 days!

Goal #2*:* Develop intrinsic motivations for sustainable energy behavior.

Rationale: Constructive behavior change arises when the person connects it something of *intrinsic* value [38].

Recommendation #1: Allow for interactive exploration, customization and annotation within the feedback interface.

Rationale**:** Interactive exploration and annotation may invoke self-reflection of one's energy behaviors, and in turn, the *intrinsic* satisfactions of curiosity and interest. Customization provides choice, appeals to Rokeach's value of "freedom", and increases *intrinsic* motivation [32].

Example: Technologies could allow Mary to explore with "what if" questions of her energy usage, for instance, by interactively manipulating existing energy information to see the potential positive or negative effects. Interface customization and annotation allows Mary to *personalize* the interface, which is a more effective motivator than general and non-personalized information [50].

STAGE 5 – MAINTENANCE

Goal #1*:* Maintain *durable* sustainable energy behavior

Rationale: In maintenance, the individual works to consolidate the gains attained during the action stage and struggles to prevent relapse [38]. Often change is not established even after 6 months or so of action [41]. At some point, behaviors will become sustained over time and integrated into their lifestyle so that the individual can exit the cycle of change [38]. While it is not possible for every decision to be "maximally green", the goal in this stage may be to be "just a little more conscious and aware" [48].

Recommendation #1: Support energy actions to become energy *habits* using opportune prompts reminding individuals to take specific energy actions. As the habit becomes well-instantiated, these prompts can gradually disappear.

Rationale: *Habits* are "associations between goals and actions that allow the instigation of *automatic* behavior on activation of these goals by the environment" [1]**.** In other words, when a behavior has been performed many times in the past, future behavior becomes increasingly under control of an automaticized process [20]. The instantiation of habits may be especially important in this stage, as it may help to reduce the occurrences of relapse and recycling.

Example: Feedback technologies could make use of automatic sensing technologies and computer usage rhythms to provide reminder prompts (for example, using text, sound, and/or graphics) based on the individual's proposed goal implementations. An example using text could be:

> Going grocery shopping? Don't forget to turn off your monitors!

Recommendation #2: Provide the choice for individuals in the maintenance stage to become "energy mentors" to individuals in the preparation stage.

Rationale: This recommendation employs *cognitive dissonance* - "individuals who have attempted to persuade someone else will internally rationalize their behavior, and therefore are particularly prone to increase their commitment" [50]. The social component also adds a dynamic factor to the technology, and may inspire new and unpredictable ways in which the individual's motivation may be sustained. This method appeals to Rokeach's values of "social recognition" and "wisdom", and in turn, may invoke the intrinsic satisfactions of competence and enjoyment.

Example: A post on the "Edsen Community Sustainable Lifestyles Website" could say:

> **Dear Mary, our sustainability guru** ☺: Would you like to become an *Energy Mentor*? Click here to find out how you can share your knowledge and expertise with less experienced energy users in the community!

If Mary showed interest, she could be asked to submit a profile of herself, her interests and experiences, and would be contacted when someone has chosen her for a mentor.

Recommendation #3: Encourage individuals to *self-reinforce* and *self-reflect* on their energy experiences through daily journal-keeping. The aim is to invoke deeper thought regarding their energy behaviors and encourage more advanced energy actions.

Rationale: Journal-keeping is a form of expressive practice and promotes reflection on one's experience [9]. *Reflection* of one's energy behaviors and viewing one's progress over time may invoke the intrinsic satisfactions of interest, competence and enjoyment. *Self-reinforcement* (in the form of pride or a sense of accomplishment) may invoke the intrinsic emotion of competence, and lead to higher perceptions of self- efficacy. This is important as "in order for individuals to experience long-term success, they require adequate *self-efficacy* and *intrinsic* attributions of the behavior" [38].

Example: Feedback interfaces could provide flexible ways in which Mary could journal-keep within the interface. For example, Mary could take snapshots of notable milestones in her goal progress, and annotate visualizations by circling or highlighting areas of interest and writing her thoughts. If desired, the technology could also automatically record energy summaries for each day or week in the journal.

Recommendation #4: Maintain the cyclical loop of intrinsic motivation: interest, curiosity, optimal challenge, competence feedback and enjoyment.

Rationale: Intrinsic motivation is a cyclical, two-step process [42]. First, stimuli such as novelty, complexity and change [7] attract attention, *curiosity* and *interest* [42]. This invites exploration, investigation, and manipulation of the stimulus [42]. Second, *competence* performances on *challenging* tasks are enjoyed, where increased *enjoyment* increases one's willingness to continue the activity and to confront similar challenges in the future [12].

The importance of intrinsic motivation is supported by the work of Woodruff et al. (2008), who studied the motivations and values of "extremely green individuals" [48]. First, participants pursued their "environmental goals", "creatively solved problems" and "modest mental challenges", where they derived satisfaction from the "cleverness and resourcefulness" of their solutions and gained a strong sense of "empowerment and confidence" [48]. From these findings, we argue that participants maintained their behavior due to *intrinsic* satisfactions of performing energy behaviors. Specifically, pursuing "goals", "problems" and "challenges" indicate the intrinsic satisfactions of *curiosity* and *interest* leading to *exploration,* taking on *challenges* and *competence performances*. Participants also gained "empowerment and confidence", indicating the intrinsic emotion of *enjoyment.* These reflect Rokeach's values of being "intellectual", "imaginative" and "capable".

Example: Technologies could continually provide Mary with novel, complex and changing information to maintain her curiosity and interest. Technologies could also provide and encourage Mary to take on new challenges and responsibilities in regards to sustainable behavior. Social components (e.g. social networks) could also be used in the system, incorporating a dynamic factor which may sustain motivation and behavior in ways technology cannot.

DISCUSSION

We now discuss our framework (and its employment of the TTM and MI) to energy feedback technology design.

First, the TTM assumes behavior change occurs in discrete states [34]. However, studies show that "rather than simply being in one stage or another, clients show patterns of differential involvement in each of the stages" [37]. In this case, "the concept of stages loses its meaning" [34]. For example, in our scenario, Mary could be in the action stage of sustainable *computer* usage, and in the contemplation stage of *composting*. In addition, rather than a progression through stages, change can come about swiftly, often as a result of life events or external pressures [34]. While we recognize the value of these critiques, we make use of the TTM 's stages of change for its heuristic value, recognizing it is as a simplified model of "*ideal* change" [34], rather than how behavior processes necessarily occur in real life. We hope the value of our framework lies in its contribution of a new and potentially useful way of thinking about motivating sustainable energy behaviors, while inspiring new ideas and approaches to this problem.

Second, the TTM is a general model of behavior change [34] with applications in a variety of addictive and health-risk behaviors [38]. To our knowledge, no other work has applied TTM to energy behaviors. While we believe we have shown that TTM provides a useful starting point, further exploration is needed as to whether the TTM is a suitable model to apply to this problem.

Third, we argued that the *success* of feedback technologies employing this framework lies in its effectiveness in motivating a move towards the *next stage* of change. Based on this, feedback technologies must 1) be able to correctly assess the stage the individual is in, and 2) evaluate whether a move to the next stage has occurred. This puts forth difficult challenges in terms of the validity of stage assessment and staging algorithms. This needs further exploration.

Fourth, our framework aims to motivate sustainable energy behavior primarily from the psychological perspective. However, energy consumption is seldom an end in itself, but rather a by-product of a variety of diverse actions [23] (e.g. cooking, socializing, doing laundry). Consequently, it is also important to consider how social, cultural, contextual, and situational factors can be incorporated into the proposed framework.

Fifth, Pierce et al. (2008) explore questions regarding the life cycle and end-goal of feedback technologies. Should technologies 1) "evolve over time" to keep pace with user's "deepening commitment and understanding", or 2) "act as a training device that is no longer needed after certain behavioral or intellectual changes have been made"? [40]. We argue that if technologies are adaptive, a dynamic component should be present (e.g. social networks), as technologies cannot be expected to keep up with complex human motivations. If technologies act as training devices, designers should consider sustainable interaction design principles proposed in [8].

Finally, as in most persuasive energy feedback systems, our framework assumes that it is necessary to motivate sustainable energy behavior change in the individual. We recognize this is only a partial solution - holistic approaches are also required, such as energy-efficient technology, government policies and so on. However, we believe the issue of motivation is still crucial in these domains, and future work should also look at applying motivational theory to motivate government or business policy makers to affect higher-level changes that can potentially make a bigger impact.

CONCLUSION AND FUTURE WORK

We made three contributions: 1) A framing of motivational psychology literature as key notions important to designers of technology that aims to motivate sustainable energy behavior change, 2) A critique of selected feedback technologies from a motivational perspective, 3) A motivational psychology framework that addresses individual motivations at different stages of behavioral change.

Future work includes 1) the on-going development and refinement of the framework, 2) an implementation of visualizations based on this framework, 3) a longitudinal study of whether visualizations based on the framework actually motivated behavior change.

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