

Energy Consumption Monitors: Building Occupant Understanding and Behavior

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ABSTRACT: Architects can help reduce CO₂ emissions from buildings by helping occupants understand their energy usage, and providing motivation for behavioral changes. One of the most promising technologies being developed are energy monitors, which have shown the potential to reduce energy usage by providing building occupants the opportunity to understand and alter energy consumption. This paper analyzes existing studies of energy monitors, in particular the theories behind their design and the methods employed in testing these theories. Analysis of the studies raises some basic questions such as: what behavioral models are used in the design of the monitors, what information do these monitors provide, and do users really understand the information provided to them? Findings suggest that many aspects of energy monitor design and information communication can have an impact on energy consumption, but that this impact has limits. They also suggest that this potential is not yet fully understood, and that there are many aspects of energy consumption and behavioral motivations that could be explored in future studies.

KEYWORDS: energy monitors, energy behaviors, energy consumption, user interface, buildings

INTRODUCTION

Imagine that you go home, walk in the door, and turn on your lights. How much power are you using? How much is it costing you? What fuel source is the electricity being generated from? Building occupants are responsible for energy consumed in buildings, but often lack basic information about their consumption. It can be complicated to associate activities of energy consumption with effects of use or amount used without understandable and accessible information (Burgess and Nye 2008). This lack of transparency results in a situation of *double-invisibility* where occupants cannot tell quantities of energy being used in the home, and later cannot connect information to previous actions (Burgess and Nye 2008). Without this information, it is difficult for occupants to be motivated or make intelligent changes in behavior.

If we could remove buildings from the energy load of the United States, we would eliminate the largest consumer of energy and producer of carbon dioxide (CO₂) emissions in the country. Buildings in the United States consumed 41% of *primary energy* in the country and 7% of total primary energy worldwide in 2010 (D&R International, Ltd. 2012). In the past several years there has been a large push for architects to help curb CO₂ emissions from buildings through design. The 2030 Challenge has asked for buildings to become *carbon-neutral* [producing no CO₂ emissions] by the year 2030 (Architecture 2030 2012). The idea that the building design and systems are the sole determinant of energy usage is not accurate though. While the efficiency of design and technology impact energy consumption, they are the mediums of consumption and occupant need and behavior are the generators and determinants of consumption. Peschiera, Taylor, and Siegel (2010, 1329) point out, "there is tremendous potential for reducing greenhouse gas emissions by motivating energy efficient behavior." In seeking to reduce CO₂ emissions from buildings architects must consider the potential of building occupant behavior as well as that of building design. Giving occupants understandable information about their energy consumption is a first step in helping them understand this problem, and their ability to change it.

Architects have traditionally sought to address the problem of CO₂ emissions through the use of efficient building design and technological improvements in building materials and systems. The organization Architecture 2030 suggests reducing emissions through design, *integrating technologies*, and using *renewable energy sources* (Architecture 2030 2012). The green building rating system Leadership in Energy and Environmental Design (LEED) suggests options such as *optimizing energy performance, measurement and verification*, and *on-site renewable energy sources* (USGBC 2012). While these improvements in buildings can certainly abate emissions, they are one-sided solutions that don't address the significance of occupant energy behavior in buildings. The problem of CO₂ emissions from buildings is the complex result

of many contributing factors, and will require a solution that addresses both physical and behavioral variables.

1.0 The Problem

Energy monitoring has been studied as a method to help occupants understand their energy usage and in turn reduce their consumption. Jain, Taylor, and Peschiera (2012) established in their review of previous studies that both simple and complex monitors demonstrated energy savings ranging between 5% and 55%. Many studies have asserted that these monitors have the ability to help occupants reduce their energy consumption, but found this reduction often to be limited and temporary (Chen et al. 2012; Hargreaves, Nye, and Burgess 2012; Hargreaves, Nye, and Burgess 2010; Peschiera, Taylor, and Siegel 2010). These studies suggest that energy monitoring has the potential to help reduce energy consumption through behavior, but have not been able to define or sustain that potential. Understanding why this has happened will help shape future studies examining how this information can be used to influence building occupant behavior.

Fields such as business, psychology, design, and engineering have used a large variety of design, theoretical, and methodological approaches in studying energy monitors (Table 1). This has resulted in vast information, but information that is varied, complicated to compare from one study to another, and sometimes contradictory. Additionally, it is often difficult to separate theory from design, as one is used as a medium to test another, and studies thus begin measuring one unknown with another. For example, Jain, Taylor, and Peschiera (2012) noted in their review of studies that some of the fluctuation in savings could be caused by the unique characteristics between *interfaces*. This acknowledges the difference that variation in design of the graphic user interfaces (GUIs) could have on the study results. Researchers need to know what information is valid and why it is valid to inform future studies.

Table 1: Theories and models used in energy monitor studies

<i>Theory/Model</i>	<i>Explanation</i>
Information-Deficit Model	The idea that providing more information about energy consumption will create understanding and that users will automatically make behavioral changes given this knowledge and thus reduce their consumption (Hargreaves, Nye, and Burgess 2010).
Social-Norms Theory	Postulates that users will not want to stray from what is considered the <i>descriptive norm</i> , or the definition of what is usually done (Schultz et al. 2007).
Focus Theory of Normative Conduct	Differentiates between <i>descriptive</i> or <i>injunctive</i> nature of norms, injunctive being what is usually approved or disapproved (Kallgren, Reno, and Cialdini 2000).
Social Network Theory	In threshold models the possibility that someone will assume a behavior can be related to the number of contacts within a social network who have the same behavior (Peschiera and Taylor 2012).
Feedback Intervention Theory	"FIT has five basic arguments: (a) Behavior is regulated by comparison of feedback to goals or standards, (b) goals or standards are organized hierarchically, (c) attention is limited and therefore only <i>feedback-standard gaps</i> that receive attention actively participate in behavioral regulation, (d) attention is normally directed to a moderate level of the hierarchy, and (e) FIs change the locus of attention and therefore affect behavior" (Kluger and DeNisi 1996, 259).
Computers As Persuasive Technology (CAPTology)	"CAPT-ology aims to alter the mindsets, attitudes, and behaviors of users via machine–user interaction, program design, and research and analysis in conjunction with other means, excluding coercion" (Chen et al. 2012, 107).

Beyond research design issues, there are several aspects of occupant understanding and motivation that remain to be explored or explained. Some of the most basic building blocks to understanding and behavior change, such as a comprehension of energy information, are not present in building occupants. In studying preferences for electricity feedback Karjalainen (2011) found that consumers couldn't differentiate between watts or kilowatt-hours (kWh) and didn't know how carbon dioxide emissions were related to electricity use. Bonino, Corno, and De Russis (2012, 385) also found that "...householders hardly understand energy usage in kWh..." In contrast, most people who own a car can describe how much they pay for a gallon of gas, how far a full tank of gas can take them, and how many mpg their car gets. One could theorize that information which building occupants don't really understand might not be very effective in motivating them to change behaviors, and this lack of understanding could affect study results.

2.0 Theories and Methods in Monitor Design and Research

The task of studying energy monitors is multi disciplinary pulling together knowledge from computer science, psychology, social sciences, and economic sciences, etc. For example Chen et al. (2012) used *persuasive technology theory*, which is based in computer science, whereas Peschiera and Taylor (2012) used *social network theory* out of social behavioral sciences. As much as technology cannot be isolated from behavior in this topic, neither can the theories be isolated from the design of elements used to test them. Arguably several theories are already inherited based on design choices and purpose of the monitor itself (Table 2). For example, any monitor that uses a normative feature is already testing the theory of social norms. This complicates the opportunity to validate one theory superior to another.

Table 2: Information Options and related theories/models

<i>Information Option</i>	<i>Explanation</i>	<i>Theories/Models Drawn On</i>
Historical	Information about past energy consumption.	• Information Deficit Model
Disaggregated	Energy consumption is broken down by appliance load.	• Information Deficit Model
Normative: Descriptive	Information about other users consumption, what the <i>social norm</i> or <i>descriptive norm</i> is.	• Social-Norms Theory
Normative: Injunctive	Information about what levels of consumption are approved or disapproved, what the <i>injunctive norm</i> is.	• Social Norms Theory • Focus Theory of Normative Conduct
Goals	The ability to set a goal.	• Feedback Intervention Theory
Rewards/Penalties	Rewards or penalties are offered based on consumption patterns.	• Feedback Intervention Theory • Social Norms Theory

In methodological approach, previous energy monitor research can be divided into two categories: those studies which seek a solution in the monitor, and those which seek a solution in occupant understanding of energy, and understanding of the occupant energy behaviors. For example Jain, Taylor, and Peschiera (2012) sought to measure the relationship of user interaction with features to energy consumption. Meanwhile Hargreaves, Nye, and Burgess (2013) sought to fill a knowledge gap by using qualitative methods over a longer time period to review the impacts of energy monitors on energy use. These studies covered a spectrum from monitor feature design to energy behavior, but often only focused on one end of this spectrum. Studies that measured monitor features did not explain why features failed or succeeded, and studies that examined occupants and context didn't measure the monitors in actual use. Both sides of this spectrum need to work congruently in order to address the problem of emissions.

2.1 Design as an Agent to Reduce Consumption

Studies that have focused on the monitor as an agent for reduced consumption have drawn on various design models, behavioral models and theories through the medium of information options and representations. Wood and Newborough (2007, 495) asserted that the largest savings from the most users would come from a monitor interface with an "optimal design arrangement". Examining the studies of Chen et al. (2012), Jain, Taylor, and Peschiera (2012), Peschiera and Taylor (2012), and Peschiera, Taylor, and Siegel (2010) this seems to have been interpreted as meaning that finding the correct theory representing the optimal monitor design would result in the greatest savings. For instance, Jain, Taylor, and Peschiera (2012) wanted to test how different design components would affect interaction and energy consumption. Chen et al. (2012) wanted to test whether their monitor could portray information in a way that would be persuasive by creating an emotional response. Using monitors with only one design option to test theories inadvertently tests not only the theory, but the design of features as well, making it sometimes impossible to distinguish if the theory behind a feature or the design of the feature contributed to its success or failure. Furthermore designs that might be affective for one user may not necessarily be affective for another, and in seeking to accommodate all users this must be considered.

Historically the information deficit model has been the standard 'go-to model' in attempts to motivate behavior changes which impact the environment, with the idea that a lack of knowledge is what prevents people from making decisions that don't harm the environment. However, education and encouragement have not been effective in changing behaviors (McKenzie-Mohr 2000). Furthermore consumer studies have found that people often behave or make energy choices based on needs which they deem more important than saving energy or money (Wallenborn, Orsini, and Vanhaverbeke 2011). This information points towards the failure of the information deficit model as a standalone solution to changing energy behaviors, although examination of a behavioral model for persuasive design developed by Fogg (2009) points toward the

necessity of this information as simply one aspect in increasing the likelihood of behavioral changes, along with motivation and triggers. While only Chen et al. (2012) explicitly acknowledged their testing of *CAPTology*, or persuasive design, it could be argued that each of these studies is using persuasive design methods as each are designing feedback monitors on machines with the ultimate goal of changing behavior.

Both social norm theory and focus theory of normative conduct were used in many studies through providing normative information, which proved to have more success than just individual historical information. Providing information about the energy consumption of other occupants used social norm theory, and focus theory of normative conduct was used in providing information that also held judgment, portraying energy consumption as positive or negative in the eyes of society. Social norm theory was employed in Chen et al. (2012), Jain, Taylor, and Peschiera (2012), Peschiera and Taylor (2012), and Peschiera, Taylor, and Siegel (2010) through the use of normative information. Chen et al. (2012) also used focus theory of normative conduct to some degree as their information framing portrayed increased energy consumption as harmful or negative. Peschiera and Taylor (2012) tested social network theory as they compared what impact the relevance of network member consumption had on individual consumption. These theories and their employment in the studies demonstrated potential in contributing to behavioral changes.

While ultimately each of these experimental studies tested a behavioral model, it was conveyed through a treatment that utilized information options and representations as a medium. Information options used in studies included historical, injunctive, disaggregated, rewards/penalties, and incentives/goals (Chen et al. 2012; Jain, Taylor, and Peschiera 2012; Peschiera and Taylor 2012; Peschiera, Taylor, and Siegel 2010). Each of these data options offer a different way to interpret information and to some degree tests a model or theory about how different information can impact behavior. Additionally information framing was used as information representation options used in these studies included kilowatt/hours (kWh), simple comparison, or animals (Chen et al. 2012; Jain, Taylor, and Peschiera 2012; Peschiera and Taylor 2012; Peschiera, Taylor, and Siegel 2010). Chen et al. (2012) sought to frame information in a way that would have a positive or negative emotional impact on users by representing energy consumption through an increased or decreased diversity of animal life forms. This example of information framing demonstrates the potential power of information to become more than just numbers, to go beyond the information deficit model, and to tap into the influence of emotion and the role it plays in behavior.

A problem encountered in studies which seek to quantify the effectiveness of these theories or features is that if a monitor's design affects the ability of users to understand and interpret the information, then one could assert that variation in designs could result in variation in findings even from studies that test the same aspects of a monitor. In designing these monitor studies not only used various behavioral theory and design methods, but also drew heavily on literature review to define which features and methods of information framing might be relevant. This seems to have raised some questions about how design may have affected the results of their research. For example Jain, Taylor, and Peschiera (2012) used a *disaggregated* information option, which Karjalainen's (2011) study had indicated users wanted, but their findings didn't support. Jain, Taylor, and Peschiera (2012) goes on to point out that in general:

Furthermore, results for components that were not supported must be taken as inconclusive because usage data could have been impacted by the idiosyncratic design of these components in the eco-feedback interface studied. (15)

If it is true that results from unsuccessful components could be the result of design, could not also the successful results be from design impact? The findings of these studies should be considered in light of this information. The design of a monitor can affect the users ability to understand and interpret information, and this in turn could affect his or her ability or desire to utilize the monitor or change behavioral patterns.

These studies used measurement to collect data and statistical analysis to interpret that data and determine whether their treatments had been successful or not. In the case of Chen et al. (2012) a questionnaire was also used to gain user feedback. Primarily quantitative studies used measurement of electricity to assess savings and Jain, Taylor, and Peschiera (2012) also used click stream data to measure interaction. Studies then looked for a statistically significant correlation in data. Peschiera and Taylor (2012), Jain, Taylor, and Peschiera (2012), and Peschiera, Taylor, and Siegel (2010) all had a control group to compare data against, and both Chen et al. (2012) and Jain, Taylor, and Peschiera (2012) used an energy consumption baseline from a pre-study period. While these methods did yield statistically significant correlations of energy consumption reduction, they are not able to provide causal evidence or explain if occupants understood the information that was presented to them.

Study results showed that users who interacted more with the monitor and those who could view personalized normative information reduced their energy consumption, but this reduction was temporary, with the exception of Peschiera and Taylor (2012). In studying interaction Jain, Taylor, and Peschiera (2012)

found that users who had increased their consumption over the study period had logged into the monitor only half as often as those who had reduced consumption. Chen et al. (2012) and Peschiera, Taylor, and Siegel (2010) both observed initial savings, but these were not sustained for the duration of the study. In the case of Chen et al. (2012) a falloff period happened mid-study where occupants returned to before study levels of usage with one study group, and the other group experienced an increased spike in usage the last week as well. Whereas Peschiera, Taylor, and Siegel (2010) found that:

In every instance that a group showed significant improvement after receipt of an electricity consumption profile, three days later behavior would essentially relapse to pre-study utilization levels. (1336)

Peschiera and Taylor (2012) found that personalized network normative information was more effective in reducing energy consumption than impersonalized information. Peschiera and Taylor (2012) also point out that this verified the findings of Peschiera, Taylor, and Siegel (2010) over three weeks rather than three days. This time period could have followed the trajectory of Chen et al. (2012) though, and a longer study period is needed to verify that *user fatigue* will not occur. These findings show that while there is potential in certain monitor design information options and representations to help occupants reduce consumption, that potential unaided is not enough to produce sustained reductions.

The results of these studies have opened many areas of potential research, from learning about user understanding to addressing the problem of consistency in savings. Chen et al. (2012) suggested investigating user fatigue, and Peschiera, Taylor, and Siegel (2010) called for a better understanding of how external factors affected this condition. Peschiera, Taylor, and Siegel (2010) also suggested that future studies might instigate and examine the impacts of monitors on social interaction and discussion. All of these suggestions point towards a better understanding of users, their interaction with these devices, and their context of use. The dependency of these studies on unmeasured factors beyond the display, and in most cases not well explained in depth, may be responsible for experienced *user fatigue* or monitor feature failures. As pointed out by Chen et al. (2012, 111) the spaces being tested are not “condition-controlled experimental environments” but rather are normal working school spaces with the behavioral influences of those contexts. In seeking to communicate information to occupants and influence behaviors more research needs to be conducted that takes into account the external factors of a non *condition-controlled experimental environments*. We need to understand energy consumption behaviors, as they exist in the context of building space usage.

2.2 Occupants As an Agent to Reduce Consumption

Studies that have sought a solution in user understanding and behavior have sought to design information for user understanding, assessing what users think, and how they behave. The studies of Bonino, Corno, and De Russis (2012) and Karjalainen (2011) both have monitor designs that were created, but the point of these studies is not to measure the efficiency of these designs, but to assess if users can understand the information communicated. Karjalainen (2011) studied which type of information display people wanted to see and understood. Hargreaves, Nye, and Burgess (2013) focused on gathering user feedback from those living with a commercial monitor for a year, specifically on what types of social dynamics developed around and from interaction with the monitor. These studies do not offer the same statistical evidence as those which sought a solution in monitor design, but instead offer empirical data about user understanding and behaviors. In seeking to communicate information to users and influence behaviors, it is logical that this cannot be done without a prior proper understanding of the users current state of understanding and behavior.

In the studies that focused on user understanding of information, user-centered design methods were adopted to guide the monitor design and to some degree persuasive behavioral models were used, though this is not explicitly stated. Karjalainen (2011) used *human-computer interaction guidelines* for developing prototypes of energy consumption with both graphical and numerical data. Bonino, Corno, and De Russis (2012) employed user-centered design in their survey that assesses user understanding and approval of an energy monitor shown in use. In a review of previous studies Bonino, Corno, and De Russis (2012, 385) notes that they found “Psychological implications of energy displays and interaction paradigms may also influence the effectiveness of IHD’s [In-home Displays]...” This approach is intended to gain understanding of what occupants understand and need from energy monitors. Since purpose of these monitors as a persuasive technology is to give users the motivation, abilities, and triggers to make behavioral changes, gaining an understanding of how those needs translate into monitor features from the users perspective is an important aspect of the design process.

The study done by Hargreaves, Nye, and Burgess (2013) explores this idea more in depth through its use of grounded theory of long term (12 months) user experience of monitors in a home environment to fill an existing research gap. Hargreaves, Nye, and Burgess (2013) also points out that many studies treat the context of use as a *black box* which obscures context conditions which might affect energy usage. This

heuristic approach allows the black box to be lifted and the context of the experience of using an energy monitor to be revealed in a long-term setting. This type of research could be a powerful tool in combination with energy data and post occupancy evaluations to start explaining energy behaviors.

The user-based design studies used information options and representation, as the experimental studies had, as a medium of communication. Karjalainen (2011) utilized different combinations of historical, normative, disaggregation, or incentive options in the representation of charts, pictorials, tables, numbers and text using units of kWh, watts, monetary costs, or environmental damage (CO₂). This wide range of options resulted in eight distinct interface prototypes. Bonino, Corno, and De Russis (2012) chose to create a prototype that was demonstrated in action through video simulation. The prototype catered to two types of information options, historical and goals. This was represented through a colored floor plan reflecting energy usage in each room's contribution to consumption, it was also shown numerically in kW and kWhs (Bonino, Corno, and De Russis 2012). While these studies used some of the same information options as the experimental studies, what they began to assess was not actual energy consumption, but occupant understanding of the displays.

What questionnaire and interview data from these two studies started to show was that there are several information options and units that people do not completely understand, but can sometimes use contextual clues to begin understanding. Karjalainen (2011) found that:

The problems with understanding the prototypes mainly involved two issues: (1) many people are not familiar with scientific units and do not understand the difference between W and kWh and (2) many people do not understand how carbon dioxide emissions are related to electricity consumption. (464)

While this finding was from a very small sample size located in Finland, it was still used by Jain, Taylor and Peschiera (2012) to inform their decision to use a disaggregated feature, but they didn't find this feature to be statistically successful. The results of Karjalainen (2011) also matched those of Bonino, Corno, and De Russis (2012) finding that users liked the direct feedback of kWh, but didn't completely understand kWh. Despite this issue, users will still be able to understand energy consumption based on color feedback and relate the units to use (Bonino, Corno, and De Russis 2012). These findings indicate that occupants could potentially relate units such as kWh with associated usage graphics, but that they do not completely understand these units.

Findings from the grounded theory approach used by Hargreaves, Nye, and Burgess (2013) were consistent with both these studies and the experimental studies. It was found that user fatigue occurred due to, amongst other reasons, the monitors continually portraying the same information (Hargreaves, Nye, and Burgess 2012) This is consistent with the findings of Jain, Taylor, and Peschiera (2012) and Chen et al. (2012), and offers the added insight of why this happened with occupant behavior. While they do not say occupants explicitly understand the units of display on these monitors, kWh in this case, they do explain that the monitors allowed users to understand their normal energy usage level, and to make informed adjustments if it went over. (Hargreaves, Nye, and Burgess 2012) This information is important because it reinforces some of the findings from the experimental and simulation test in a more typical real life context, and begins to explain why with user insight.

In addition to these findings Hargreaves, Nye, and Burgess (2013) also shed light on the experience of living with energy monitors from the occupant's point of view, revealing that monitors actually have the potential to create new energy social interactions.

In addition to these effects on levels of awareness and types of behavior, a key theme running throughout several of the follow-up interviews, much more strongly than in the initial set of interviews, was the ways in which the monitors had given rise to new forms of social interaction around energy use both within and beyond the household. Most commonly, interviewees stressed that the monitors had made it easier for them to communicate the impacts of energy use – either on their bills or on their carbon emissions – to other, less interested household members. (Hargreaves, Nye, and Burgess 2012, 131)

These findings also bring up a condition of energy usage not mentioned in other studies: energy consumption is the result of a household of individuals, all with different interests and behaviors. If one of the first steps in changing energy behavior is to give occupants the ability to understand their usage, then these monitors were successful in this aspect. The study also revealed that there are contextual constraints to savings. People were willing to make some changes initially, such as switching lamps, but didn't have as much flexibility in larger appliances, and were not willing to give up certain comforts such as television (Hargreaves, Nye, and Burgess 2012) In considering how occupants might change their energy usage behaviors these limits would be important to consider, as well as the complex social situations in which energy consumption occurs.

The strengths of these studies are their ability to start explaining why certain occupant understanding, behaviors, or interactions with monitors might occur. Their weakness is that none of these measure the

actual reduction of energy consumption or lack thereof. Karjalainen (2011) suggests that in the future the prototypes tested be put to use. This was done with Jain, Taylor, and Peschiera (2012), but the findings weren't consistent with Karjalainen (2011). This indicates that a comprehensive study that begins with user assessment, implementation of a design, and followed up on user point of view in combination with energy data might be very beneficial in better understanding the effect of energy monitors on user understanding, behaviors, and interactions.

3.0 Discussion

While these studies show overlap, they appear to be divided between seeking a design solution and a user solution. The complexity of the problem of energy consumption though is such that one or the other will not yield a solution; design and user must engage each other to provide the most effective feedback and motivational means. Additionally the built environment must be considered in greater depth, and perhaps information about this should be factored into these monitors as well. In helping occupants understand their energy usage we must define what their understanding of energy information is. In helping them change their energy usage behaviors we must know what those existing behaviors are, and how environment and context affect them.

While there are many aspects of these studies that may not necessarily directly translate to future studies, what can be gleaned from reviewing them is a need for understanding of the occupant perspective. The behavioral models employed in the experimental studies address some aspects of users, but there aren't studies that test all models or combinations against each other, and it is possible to say that a model could have been compromised by ineffective design or information choices. The studies which focus on user understanding explain the user's point of view on some aspects of these monitors, such as information options and units, but don't begin to form a model of behavior that might inform design decisions that could translate in to an effective system of user and monitor. Since the changes made have to be behavioral, finding behavioral models that fit the variety of occupant types is of key importance.

In studying energy monitors, the context of behaviors should not be separated out as a detached element. Buildings and building systems are the mediums of energy consumption, and research studying energy consumption should take note of the impact that these context could have on results. Additionally the context of social interactions within space could be a major contributor to energy behaviors and social norms. Future studies might investigate energy cultures within a larger variety of context and the role that monitors could play in these environments, beyond simply being a monitor, but becoming part of the social or injunctive norm of energy consumption.

Studies that examine the consumer aspect of energy monitors have found similar results to these studies in terms of adoption of monitors and reactions, but also postulate about the ways that monitors might diffuse themselves into existing technologies. Wallenborn, Orsini, and Vanhaverbeke (2011) predicts:

A probably future of these monitors is to be integrated into existing devices such as PC or mobile phones (152). Indeed this has already started happening with a variety of applications available for smart phones and computer systems. As these types of monitors continue to develop research about what theories and features create the most successful technologies for user behavior will be useful to architects seeking to lower CO2 emissions as well as other disciplines involved in the development of these products.

CONCLUSION

In seeking an *optimal design* for energy monitors, one must consider, as Hargreaves, Nye, and Burgess (2013) points out, that there is not one solution for all users. The optimal design will differ for different countries, cultures, social contexts, and user desires. The best design will be one that adapts to each users needs and should not be based on an empirical comparison of features, but rather based on the most efficient behavioral and design models. This has yet to be researched in a comparable manner across studies, and it might be the case that a new model needs to be developed. Architects can begin to take part in this process by studying occupant behavior and energy cultures in buildings, and identify how persuasive technologies can start to become part of the architectural environment to address energy consumption behaviors.

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