Journal of the Association for Information Systems

JAIS

Research Article

Designing and Using Carbon Management Systems to Promote Ecologically Responsible Behaviors

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Abstract

With the hope of mitigating the harmful impacts of climate change, many organizations are taking actions to reduce their carbon footprints. Carbon-reducing initiatives in organizations are varied: they range from green product innovations to encouraging behavioral changes by customers and employees. Green IS can play an important role in environmental sustainability by supporting a number of these strategies. Drawing on theories of persuasive systems design, this paper explores how one category of Green IS, carbon management systems (CMS), can be designed and used in order to persuade employees to perform ecologically responsible behaviors. The results from three organizational case studies suggest that CMS can be effective at changing employees' environmental behaviors, demonstrate the extent to which persuasive system design principles (including an emergent category of Integration) are reflected in CMS, and highlight the importance of understanding the persuasion context. The findings of the study are used to inform the development of four propositions, which can serve as a foundation for further research in the Green IS domain.

Keywords: *Green IS, Persuasive Systems, Sustainability, Carbon Footprint, Case Study.*

* Fred Niederman was the accepting senior editor. This article was submitted on 12th April 2011 and went through three revisions.

Volume 14, Issue 7, pp. 339-378, July 2013

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1. Introduction

In 2004, HSBC, one of the world's largest banks, announced its intention to become carbon neutral. Since then, organizations of all types and sizes around the world have made similar pledges to reduce their carbon emissions in the hope of slowing the pace and lessening the harmful impacts of climate change (BSR, 2007). Indicative of the rise in corporate carbon management efforts, the Carbon Disclosure Project[1] (2012) sent out carbon emission questionnaires in 2011 to more than 8000 companies operating in 60 different countries. With increased pressure to reduce their carbon footprints, many companies are beginning to implement a range of strategies, which requires that they mobilize the entirety of their resources (Lee & Rhee, 2007). Operationally, these strategies range from improving energy efficiency, developing green products, and instituting innovative approaches to reducing greenhouse gas (GHG) emissions in business processes and voluntarily providing environmental performance reports (Wittneben and Kiyar, 2009). In addition, many organizations are making efforts to change stakeholders' attitudes and behaviors by integrating sustainability considerations into their decision making, fostering sustainable practices in the supply chain, and encouraging individual customers and employees to change their behaviors (Muster, 2011; Wittneben & Kiyar, 2009).

As with other organizational resources, information systems (IS) can play a significant role in promoting environmental sustainability. Recognition of IS's potential contribution (both negative and positive) has led to a new field of practice and research in Green IS, which focuses on information systems and technologies that are used to support environmental sustainability (Dedrick, 2010; Jenkin, Webster, & McShane, 2011b). Although different streams of research exist under the Green IS umbrella, one of the central questions uniting work in this area is how information can lead to better organizational and individual decisions to preserve the natural environment (e.g., Watson & Boudreau, 2011). Carbon management systems (CMS), defined as software that provides information and tools used to calculate, monitor, and reduce carbon footprints, represent a new category of Green IS that is starting to gain a foothold in practice. Many different CMS have been developed and are available for organizations and individuals. At an organizational level, a CMS supports practices related to managing and reporting carbon emissions across a wide range of business practices and, when implemented for individual use, can foster more environmentally responsible behaviors by employees. Because organizations see value in using CMS to support a variety of carbon-reducing initiatives, the market for carbon management software solutions and services is growing, and is predicted to reach $5.7 billion in annual spending by 2017 (Navigant Consulting, 2011).

Although the bulk of spending on CMS relates to organization-level software and services, some organizations are implementing individual-level CMS to help engage their employees (e.g., Bradshaw, 2007; Dimension Data, 2012; RPA, 2011). These efforts are motivated by the belief that individuals' attitudes and behaviors are important to overall corporate environmental performance (Boiral, 2007; Daily, Bishop, & Govindarajulu, 2009; Jenkin et al., 2011b), a position that is also taken here. When companies adopt CMS with the intention of motivating employees to voluntarily reduce their carbon footprints, the CMS becomes an instrument of persuasion (or, in other words, it becomes a persuasive system). Building on seminal work related to computers as persuasive technologies (Fogg, 1999; Fogg, 2003), persuasive systems are defined as "computerized software or information systems designed to reinforce, change or shape attitudes or behaviors or both without using coercion or deception" (Oinas-Kukkonen & Harjumaa, 2008, p. 202). As in other areas of IS, research on persuasive systems has drawn extensively on theories in social psychology to help explain how these inanimate systems can be effective in the very human act of persuasion. As companies take a more active role in changing employees' attitudes and behaviors with respect to environmental sustainability, persuasive systems theory provides a useful lens for understanding Green IS at work.

Motivated by the observation that organizations are beginning to take real steps toward managing and reducing their carbon footprints, this study explores how organizations design and use CMS in

[1] The Carbon Disclosure Project is a not-for-profit organization that maintains the largest collection of self-reported climate change data.

order to persuade employees to engage in ecologically responsible behaviors. This paper reports on the results of three case studies of organizations that have implemented individual-level (personal) CMS for use by their employees. In order to gain a more holistic view of the design and use of CMS, I gathered data through qualitative interviews with employees in these organizations and five CMS vendors. Consistent with the view of CMS as persuasive systems, I used the persuasive system design (PSD) framework (Oinas-Kukkonen & Harjumaa, 2009) to guide the collection and analysis of the data. I employed a mixed-method approach that involved qualitative analysis and the quantification of qualitative data through frequency counting (Saldana, 2009). The findings provide insights into the relationship between CMS and employees' environmental attitudes and behaviors, and highlight the extent to which principles of persuasive system design are reflected in CMS.

This paper makes several contributions to the IS literature. Most importantly, this work expands the body of knowledge about Green IS by identifying CMS as a new type of IS and exploring how these systems can help to support efforts to promote environmental sustainability. In doing so, this study also enhances our understanding of persuasive systems and extends the PSD framework through the discovery of eight new principles and a distinct category of principles that emphasizes the value of integrating the CMS with organizational goals, complementary sustainability programs, and other corporate resources and systems. This study's findings also provide insights into the connections between individuals, organizations, and IS in the context of preserving the natural environment. The results are used to inform the development of four propositions that serve as an initial theoretical frame regarding the use of Green IS to promote environmental sustainability.

The remainder of this paper is organized as follows. In Section 2, I situate research on CMS in the context of Green IS, discuss the literature on persuasive systems, and articulate the research questions. In Section 3, I describe the research methodology. In Section 4, I present and discuss the research findings. In Section 5, building on the findings, I theorize on persuasive systems design in the context of environmental sustainability, and develop four propositions. In Section 6, I conclude by discussing the study's contributions, limitations, and future research possibilities.

2. CMS as a New Category of Green IS

Just as the importance of addressing environmental concerns has risen in the management literature (e.g., Andersson & Bateman, 2000; Hart, 1995; Marcus & Fremeth, 2009), so too has environmental sustainability emerged as a key topic in the IS literature. Beyond initial analyses regarding the negative ecological impacts of information technologies, there is growing recognition that IS represents a potentially powerful positive force for dealing with climate change because IS has the ability to shape beliefs about the natural environment, is deeply embedded in organizations, and can transform business practices at all levels and across all functions (Elliot, 2011; Jenkin et al., 2011b; Melville, 2010; Watson, Boudreau, & Chen, 2010). Green IS brings together work from a range of different IS sub-fields and unites them through the common interest in protecting the planet for future generations.

Although many environmental problems respond to the same fixes that IS generally provides, such as increased efficiency and reduced consumption and waste (Velte, Velte, & Elsenpeter, 2008), there is increasing evidence that Green IS differs from traditional IS in a variety of ways (Melville, 2010). Environmental problems have special characteristics that demand new types of technologies (Barrett, 2009) and management capabilities (Fernandez, Junquera, & Ordiz, 2006). Recognizing these differences, a number of research agendas and frameworks, drawing on a variety of theoretical perspectives, have been proposed for Green IS research (e.g., Dedrick, 2010; Elliot, 2011; Jenkin et al., 2011b; Watson et al., 2010). For the purpose of situating CMS in this body of research, this paper uses a concise view of the extant research on Green IS by categorizing it along two dimensions: impact (direct vs. indirect) and level of analysis (organization vs. individual), which Table 1 shows.

Table 1. Categorization and Examples of Green IS Research

		Level	
		Organizational	Individual
Impact	Direct	Green data centers	Energy efficient PCs
	Indirect	Energy informatics **Organizational CMS**	Sustainable HCI **Personal CMS**

Research involving the direct impact of Green IS (often referred to as Green IT) is driven largely by the observation that 3 percent of global carbon emissions are directly attributable to IT, and that this percentage is expected to continue to grow (The Climate Group, 2008). Therefore, scholarship in this area focuses on opportunities to reduce the direct negative effects of using IT and IS (i.e., through implementing green data centers (Daim, Justice, Krampits, & Letts, 2009; Kurp, 2008). Beyond these first-order effects, research in Green IS also considers the second-order, or indirect effects of IS (Dedrick, 2010). This stream of work is motivated by data suggesting that IS can be used to support and enable reductions in carbon emissions by as much as 15 percent (The Climate Group, 2008). Along these lines, Watson et al. (2010) assert that energy informatics can enable organizations to make more environmentally conscious decisions, which leads to improved energy efficiency, and ultimately to lower carbon emissions and carbon-neutral footprints.

The second dimension by which Green IS research can be categorized is the level of analysis, primarily whether it is at an organizational or individual level[2]. To date, Green IS research has been primarily set at the organizational level (Jenkin et al., 2011b); in other words, it has focused on how businesses can reduce their environmental impacts by using IS. This research considers enterprise resources and systems, such as green data centers (e.g., Daim et al., 2009), energy informatics (e.g., Watson & Boudreau, 2011; Watson et al., 2010) or green supply chains (e.g., Sarkis, Zhu, & Lai, 2011). Besides the organizational-level research, there is a growing body of Green IS work at the individual level, which is reflected in research related to, for example, sustainable HCI (e.g., DiSalvo, Sengers, & Brynjarsdottir, 2010) and the use of mobile technologies to support ethical consumption (e.g., Watts & Wyner, 2011).

A new category of Green IS that invokes the indirect influence of IS on environmental sustainability is a Carbon Management System (CMS). A carbon management system supports the measurement and management of carbon footprints, which are defined as the quantity of GHG emissions (expressed in terms of carbon dioxide equivalent) released "into the atmosphere by an individual, organization, process, product, or event from within a specified boundary" (Pandey, Agrawal, & Pandey, 2011, p. 138). Like many evolving information systems, a CMS may exist as an informal collection of tools, such as specially designed spreadsheets, Internet pages, and emails, or as a formally developed, integrated, and packaged software application. There has been significant commercialization of CMS in the last decade (Pandey et al., 2011), and formal CMS are developed and offered by a range of organizations including universities, governmental agencies, not-for-profit environmental groups, and commercial vendors (Bottrill, 2007) for use by both organizations and individuals (e.g., www.carbonfootprint.com, www.zerofootprint.net). In this regard, CMS can be likened to other software types, such as tax preparation software, that are also developed for organizational and individual use. The basic purpose and functions of the systems are the same across user types, but the content, procedures, and interfaces may vary.

With the growing emphasis on carbon neutrality, the demands of and expectations for CMS are rising. At an organizational level, a CMS measures the impacts of operational activities, such as facility energy consumption and business travel, and supports management decision making and the prioritization of carbon-reducing initiatives. Additionally, carbon footprint calculations provided by CMS

[2] Although Green IS research may adopt other levels of analysis, it is limited here to organizational and individual as these reflect the two predominant perspectives.

may have implications for legal or regulatory compliance, financial costs associated with carbon trading and offsetting [3], and perceptions regarding an organization's level of corporate social responsibility (Pandey et al., 2011). At the individual level, personal CMS focus on individual actions with the objectives of creating awareness about the impact of specific behaviors on one's carbon footprint (Bottrill, 2007). They also focus on motivating users to make ecologically responsible choices, such as purchasing green products, buying carbon offsets, or changing personal travel behaviors. A large number of personal CMS are publicly available on the Internet (for an example, see www.epa.gov/climatechange/emissions/ind_calculator.html) and many have been enhanced beyond basic carbon footprint calculators to include options for setting goals, recommending actions, monitoring carbon emissions, purchasing carbon offsets, and social networking.

Although CMS are principally designed for either organizational or individual use, there are cross-over CMS applications in which personal (individual-level) CMS are sponsored by organizations. This may occur, for instance, where organizations make a CMS (or components of a CMS) available to customers in order to drive more-sustainable buying behaviors. This practice is common with airline companies that allow customers to calculate the carbon footprint of a flight and then neutralize it by buying carbon offsets. Some organizations are also recognizing the potential of using personal CMS in their organizations to change employees' personal behaviors (RPA, 2011). This study investigates three such examples. There are several points of distinction between a cross-over CMS application and a traditional organizational or individual-level IS. A personal CMS is designed for individuals but sponsored, implemented, and used in a given organizational context. Employees are not required to use the system to complete job functions. When using the CMS, employees act as private individuals and may change personal behaviors. Some behavioral changes may impact the organization directly, but many others do not. Although the organization might hope to improve its environmental performance as a result of CMS, the way in which the system achieves these results is different than traditional organizational IS. Thus, viewing these cross-over applications as traditional organizational or personal IS may prevent the discovery of new insights that could enhance our understanding of IS.

By exploring the role of personal CMS in promoting ecologically responsible behaviors in employees, this study represents a niche in the Green IS research domain. Nevertheless, the work is important because it helps to explicate the role of IS in advancing environmental sustainability. For organizations, employees' actions, such as turning off lights or computers, reducing paper consumption, and commuting can directly impact the achievement of organizations' carbon reduction objectives (Muster, 2011). In addition, employee engagement has been identified as crucial for improved corporate environmental performance (Boiral, 2007; Daily et al., 2009; Govindarajulu & Daily, 2004). From a societal perspective, this research is also important because personal CMS initiatives supported by organizations may contribute to broader societal awareness of environmental concerns and lead to more environmentally responsible behaviors in a wide range of non-work related routines and activities.

2.1. Existing Research on Individual-level CMS

Despite the increasing number of CMS available for personal use in recent years (Padgett, Steinmann, Clarke, & Vandenbergh, 2008), there remains a lack of academic research on CMS in the IS field. For the most part, research on personal CMS has examined web-based calculators that are publicly available, focusing on the design characteristics that may influence their effectiveness (e.g., Kenny & Gray, 2009; Padgett et al., 2008). Research has found large variations in the accuracy of the output calculations of publicly available carbon calculators caused by factors such as the underlying emission data, scope of the calculator, quality of the input values, and calculation methods (Andrews, 2009; Bottrill, 2007; Miyoshi & Mason, 2009; Padgett et al., 2008). These variations in designs often lead to inconsistent and contradictory calculations, which make them difficult for people to use effectively (Kenny & Gray, 2009). However, evidence suggesting that CMS positively impact individual environmental behaviors exists (Froehlich et al., 2009; Tight, Vocat, Bristow, Pridmore, & May, 2007). For instance, Tight et al. (2007) found that a 20 percent reduction in carbon emissions from land-based travel could be achieved by households when a CMS was used to summarize travel behavior

[3] A carbon offset is "a unit of carbon dioxide equivalent that is reduced, avoided, or sequestered to compensate for emissions occurring elsewhere" (Goodward & Kelly, 2010, p. 1).

and provide estimates of the carbon footprint resulting from changes in these behaviors. Nevertheless, many carbon calculators are not as effective as they could be due to weaknesses in usability, poor communication and presentation of carbon footprint calculations, limited social networking capabilities, absence of automated data inputs, and a lack of standard and transparent calculation methodologies (Bottrill, 2007; Froehlich et al., 2009; Padgett et al., 2008). Building on the extant literature in this area, on-going CMS research would benefit from the application of new theories (Smart, Armstrong, & Vanclay, 2007; Watts & Wyner, 2011) that provide alternative perspectives on the link between these systems and individual behaviors. Thus, this study draws on the persuasive systems design theories to explore the design and use of CMS in organizations to promote ecologically responsible behaviors by their employees.

2.2. Persuasive Technologies and Systems

With advances in interactive computer technologies, such as the Internet, mobile devices, and video games, academic interest in the role of computers in persuasion has grown. That human interaction with computers leads to changes in individuals' attitudes and behaviors is not new: what differentiates persuasive technologies is their intentionality (Fogg, 1999). Persuasive technologies are designed with the deliberate intention of creating a change in people's attitudes and behaviors with respect to a particular problem domain (Fogg, 1999; 2003). Although, persuasive technologies may take many forms, the most prevalent type is the persuasive information system (King & Tester, 1999), which is designed to effect voluntary changes in attitudes and/or behaviors without the use of deception (Oinas-Kukkonen & Harjumaa, 2008, p. 202).

In these systems, the persuasion can be applied either directly by the technology (computer-human persuasion), or indirectly, whereby people persuade others through the computer systems (computer-mediated persuasion) (Oinas-Kukkonen & Harjumaa, 2009). As either direct or indirect agents of persuasion, persuasive systems function in one of three ways: as tools, as media, and as social actors (Fogg, 1999; Fogg, 2003). As tools, persuasive systems increase their users' capabilities and support decision making by providing analytics or access to new information or resources (Fogg, 2003). This type of persuasion is most closely aligned with the traditional perspective on computers and how they support human activities. When persuasive systems function as media, they provide experiences (vicarious or simulated) that allow users to explore cause and effect relationships (Fogg, 2003). These interactive experiences, such as the ability to practice a desired behavior, can help to motivate individuals to adopt the intended attitudes or behaviors. Finally, as social actors, persuasive systems, assuming animate roles relevant to the users (such as coach or competitor), create relationships with users. By engaging with users in social interactions, these systems can encourage and support the desired behaviors (Fogg, 2003).

Subsequent to Fogg's (2003) seminal work on persuasive technologies, Oinas-Kukkonen and Harjumaa (2009) summarize the underlying reference theories, predominantly in social pyschology, that explain how characteristics of a persuasive system might represent and emulate human persuasion techniques. In creating the persuasive systems design (PSD) model, design principles from earlier work (e.g., Fogg, 2003) were adopted, dropped, refined, or augmented, and a higher order categorization was developed to provide greater cohesion of the framework. The end result was twenty-eight distinct design principles organized in four categories: primary task support, dialogue support, social support, and system credibility (Oinas-Kukkonen & Harjumaa, 2009). The first three of these four categories draw to a large extent on the three means by which persuasive systems function (e.g., tools, media, social actors), while the latter category recognizes that a system must be credible in order to be persuasive. Task support relates to features of the system that assist the user in the performance of desired behavior. Dialogue support refers to interactive functions of the system, such as feedback mechanisms, which will help users achieve their goals. Social support includes features that take advantage of social influences to encourage users toward the desired behaviors. System credibility includes elements of the system that make it more credible. Table 2 summarizes the four categories and associated design principles.

Table 2. Persuasive Systems Design Principles (Adapted from Oinas-Kukkonen & Harjumaa, 2009)

Category	Design principle	Description
Primary task support		Features of the system that assist the user in the performance of desired behavior
	Reduction	System reduces effort required of users to perform desired behavior
	Tunneling	System guides users in attitude change process
	Tailoring	System provides information tailored to users
	Personalization	Content and services are personalized for users
	Self-monitoring	Users can monitor and track their performance
	Simulation	System allows users to see connections between cause and effect
	Rehearsal	Users can use the system to practice the desired behavior
Dialogue support		Interactive functions of the system with the expectation that system feedback will help users achieve their goals
	Praise	System provides praise to users based on performance
	Rewards	Virtual rewards are provided to users for performing desired behaviors
	Reminders	Users receive reminders regarding desired behaviors
	Suggestion	System provides suggestions for behavior changes
	Similarity	System imitates users in some way
	Liking	Look and feel of system is appealing to users
	Social role	System adopts a social role
System credibility support		Elements of the system that make it more credible and thus persuasive
	Trustworthiness	Information is accurate, unbiased
	Expertise	Information provided by system reflects expertise and competence
	Surface credibility	System has competent look and feel
	Real-world feel	Information on organization and people responsible for the system is transparent
	Authority	System refers to people in authority
	Third-party endorsements	System provides endorsements from respected sources
	Verifiability	System provides means for verifying accuracy of content
Social support		Features that take advantage of social influences to encourage users toward the desired behavior
	Social learning	Users can observe and learn from other users
	Social comparison	Users can compare their performance with others
	Normative influence	Users can form groups with others who have similar goals
	Social facilitation	Users can see that others are doing
	Cooperation	Users can cooperate through the system
	Competition	Users can compete with others
	Recognition	Public recognition is provided for users who perform desired behavior

A second notable contribution of the PSD framework is that it highlights the importance of the persuasion contexts in the design, implementation, and use of these types of systems. There are three aspects relevant to understanding the persuasion context: the intent, the event, and the strategy (Oinas-Kukkonen & Harjumaa, 2009). When assessing the intent, there are two

considerations: who is behind the persuasion (e.g., the system creator, provider or user) and the nature of the desired change, whether attitudinal or behavioral. With respect to the persuasion event, specific characteristics of the problem domain (e.g., environmental sustainability) such as the use, user, and technology are addressed. The third component, strategy, refers to the message and its channel of delivery. Once the persuasion context is understood, it is possible, using the design principles as a guide, to determine the actual design and implementation of system features. Therefore, investigating the application of persuasive systems *in situ* is necessary to gain a fuller understanding of how they work.

Persuasive systems can be used to change attitudes and behaviors in a wide range of domains. Environmental concerns in particular have been identified as a natural fit for the application of persuasive systems because 1) protection of the environment is generally desirable (King & Tester, 1999), which makes individuals more receptive to persuasion approaches; 2) the growth of information and communications technologies and mobile devices provides the opportunity to reach large numbers of people (Tscheligi & Reiberger, 2007); and 3) traditional methods of encouraging positive environmental behaviors have had only limited success (Abrahamse, Steg, Vlek, & Rothengatter, 2005). Recognizing this natural connection, researchers have begun to apply persuasive systems design principles and theories to work in different areas of Green IS (e.g., Dourish, 2010; York, Watson, Boudreau, & Chen, 2009). Although other theoretical perspectives may also be relevant, persuasive systems design seems particularly appropriate for investigating the design and use of personal CMS in organizational settings. Organizations sponsor and deploy personal CMS to encourage employees to engage in ecologically responsible behaviors. However, as described above, employees have discretion about whether to use the CMS because it is not required as part of a particular business process or activity. Thus, these characteristics are well aligned with the definition of persuasive information systems.

2.3. Research Questions

As summarized in Section 2.2., much work has gone into developing theory pertaining to persuasive system design. The PSD model provides not only a taxonomy of design principles, but also a Type II theory for explaining (Gregor, 2006) the construction of persuasive systems. The principles included in the PSD model are based on reference theories that help to explain why and how a certain principle contributes to the persuasiveness of a system. For instance, expectancy theory (Vroom, 1964) is used to help explain why the design principle of task reduction will make a system more persuasive: because people behave in ways to maximize their expected benefits, features of the system that lower the cost of performing a targeted behavior (reduction) contribute to the persuasiveness of the particular system (Fogg, 2003). The PSD model also reflects characteristics of a theory for design (Type V) (Gregor, 2006) by including normative design statements such as the "system should provide virtual rewards for users in order to give credit for performing the target behavior" (Oinas-Kukkonen & Harjumaa, 2009, p. 493) and visual examples for how the design principles could be implemented within the system.

While this paper recognizes the theoretical strengths of the PSD model, it does not test the PSD model's arguments. Rather, it extends theory building on the use of Green IS in organizations. To do this, this study examines two weaknesses in the PSD model. First, although the PSD framework emphasizes the need to analyze the persuasion context, it does not make explicit links between the persuasion context and individual design principles and categories. Second, the PSD framework is a generic theory that does not specifically address elements unique to environmental sustainability. The study of Green IS would be enhanced by the development of theoretical statements that elucidate the connections between systems design, organizational context, and protection of the natural environment. This research takes a first step in that direction by exploring how the design and use of personal CMS can help organizations promote ecologically responsible behaviors by their employees. Specifically, the study investigates three questions:

1. Do personal CMS in organizations help to promote ecologically responsible behaviors by employees?

2. Which, if any, of the persuasive system design principles are most relevant to personal CMS deployed within organizations?

3. How does the persuasion context of environmental sustainability influence the design of personal CMS used in organizations?

3. Research Methods

In order to investigate the above research questions, I employed a positivist case study approach (Dube & Pare, 2003; Pare, 2004). Case studies are preferred when the research focuses on contemporary phenomena occurring in real-life settings over which the researcher has little control (Yin, 2008). In addition, case studies are useful for not only describing phenomena, but also generating new theoretical insights (Eisenhardt, 1989). Positivist case studies assume the existence of defined constructs and relationships in a given phenomenon and that the researcher can objectively identify and analyze them (Dube & Pare, 2003).

3.1. Selection of Cases and Participant Recruitment

I recruited participant organizations primarily via my own professional network in conjunction with information publicly available on the Internet. I used three criteria to select the case studies; that is, the organizations needed to have 1) had an on-going or recent CMS initiative, 2) espoused a proactive environmental strategy, and 3) identified one or more individual employees responsible for managing the CMS initiative. I approached three user organizations, and all agreed to participate in the study. The organizations were a community-based not-for-profit environmental organization ("NFP"), a public utility company ("PUC"), and an equipment rental company serving the film industry ("ERC"). While these organizations were similar on the above selection criteria, there were differences in other areas. The organizations were from different industries and varied in ownership type, size, and the geographical reach of their operations, which Table 3 shows. The three organizations also had different forms of CMS. NFP had adopted a formal, web-based, third-party developed CMS that employees, volunteers, and, principally, members of the local community used. In contrast, PUC and ERC had informal CMS that incorporated third-party carbon calculators, email communications, and intranet sites that were targeted principally at employees.

Table 3. Profile of Case Study Organizations

	NFP	PUC	ERC
Description	Community-based environmental not-for-profit organization	Canadian public utility	Equipment rental provider to film and television industry
Environmental strategy	Organizational mission is to promote sustainability	Over-riding goal for environmental leadership, subject to regulatory requirements	Proactive goal of becoming carbon neutral
Type of CMS	Formal CMS deployed on internet	Informal CMS: in-house developed, spreadsheets, intranet, email, & other IS tools	Informal CMS: carbon footprint generated by vendor, intranet, email, & other IS tools
CMS vendor	Vendor 3	None, in-house	Vendor 5
Application	Community-wide implementation of personal CMS	Employee conservation and commuting	Employee recycling and conservation
CMS focus	Social welfare, broad-based	Grass-roots, employee driven, supported by organization	Top-down, management driven
Duration of CMS initiative (at time of study)	~ 1 year	5 months	~ 2 years
Number of employees	17 permanent paid staff, plus part-time volunteers	~6000	~125
Operational location(s)	Operates in a single Canadian municipal region	Operates in a single Canadian province	Operates across multiple Canadian provincial and municipal jurisdictions

To supplement information received from the case studies, I also recruited CMS vendors to participate in the study. Through their involvement in multiple CMS initiatives, vendors provide a unique perspective that helps to mitigate key informant bias and provides a broader understanding of the phenomenon under investigation (Dibbern, Winkler, & Heinzl, 2008). Additionally, the degree of match between user and designer perspectives has implications for the success of a system (DeSanctis, Snyder, & Poole, 1994). I contacted eight CMS vendors with a request to participate and five agreed. Of these, two had existing vendor-client relationships with the case study organizations.

Once I secured the user and vendor organizations, I worked with the primary contact in each to identify specific participants and to set up interviews. I chose participants based on their involvement in organizing the CMS initiatives (not simply as users) and their availability. In total, I recruited ten individual participants from the user organizations: two from NPF, three from PUC, and five from ERC. On the vendor side, I interviewed ten individuals. Of the ten, eight of the vendor participants were associated with formal CMS offerings, and six represented a single CMS vendor (Vendor 3). Vendor participants were split between product research and development (five), and sales/business development/executive (five) positions. Table 4 summarizes the individual participant profiles.

Unlike quantitative methods where sample sizes are determined in consideration of statistical power, the number of cases in qualitative studies is largely a matter of judgement on the part of the researcher (Pare, 2004; Yin, 2008) and should be based on gathering sufficient information to fulfill the purposes of the research. Although the inclusion of additional case studies or individual participants may have provided incremental value to the findings, it is the author's judgement that a level of theoretical saturation (Eisenhardt, 1989) was reached; the three cases provide rich insights that highlight patterns both in and across cases, with a convergence of common themes arising from the data.

Table 4. Participant Profile

	Vendors	Clients	Total
Number of participants	10	10	20
Number of organizations	5	3	8
Executive level	3	1	4
Director / Manager	4	5	9
Staff level	3	4	7
Female/Male	3/7	2/8	5/15
# of interviews	10	8	18
In person/Telephone	6/4	7/1	13/5
Total interview minutes	422	431	853
Pages of transcripts/notes*	104	114	218

Notes: * single-spaced, 11pt font, approx. 480 words per page

3.2. Data Collection

I used semi-structured interviews as the primary method of data collection. From the base interview protocol (see Appendix A), I tailored questions to take into account the participant's role and organizational context (Dibbern et al., 2008). I conducted a total of 18 interviews between March and August 2009 that range from 16 to 70 minutes in length and have an average duration of 47 minutes per interview. I conducted thirteen interviews in person, normally at the participant's place of work, and five by telephone. Except in one case where three participants participated in a single telephone interview, I conducted all interviews with a single participant. I recorded all face-to-face interviews and

these recordings were professional transcribed. I took notes for the telephone interviews. I conducted a total of 853 minutes of formal interviews, which results in 218 pages of single-spaced transcripts and notes, which Table 4 shows.

In addition to interviews, I collected and used archival data to corroborate information collected during the interviews (Yin, 2008). These additional sources included relevant information from publicly available websites and confidential company information, such as results of the CMS initiatives, carbon footprint calculations, and internal communications. For client organizations, confidential company information was dated from 2007 to 2009, spanning the periods during which the CMS initiatives were being planned and implemented. With respect to information on publicly available websites, I accessed these data during the same period as the interviews. In the case of NFP, I also collected copies of eight feedback forms completed by users during the rollout of the CMS and included these in my analyses.

3.3. Data Analysis Procedure

For data analysis, this study employed several methodological approaches suggested by Miles and Huberman (1994) and Saldana (2009). Specifically, I used a mixed-method approach (Saldana, 2009) in which I qualitatively evaluated the data (both interview and text-based archival data) using descriptive coding (Saldana, 2009). Then, I quantified the coding with respect to the persuasive design principles by means of counting (Miles & Huberman, 1994). I coded and analyzed the data with the qualitative analysis software NVivo.

I employed two approaches to coding the data. The first approach focused on the specific persuasive design principles. I created an initial set of codes using the design principles of the PSD model (Oinas-Kukkonen & Harjumaa, 2009). Beginning with twenty-eight initial codes, I reviewed and then coded the data to the most relevant design principle. To facilitate later analysis using counting, I coded each distinct comment separately. For instance, if a participant spoke about how the CMS provided suggestions for reducing their carbon footprint three times in the course of an interview, there would be three separate coding references (i.e., one for each occurrence). I coded and treated equally comments by participants referring to specific features (that reflected the design principles) or the design principles more generally in the analysis. In this way, the coding frequencies discussed in Section 4 show how often a particular design principle (whether directly or as instantiated by a feature) is mentioned in the data. This coding treatment assumes that the most frequently mentioned design principles were most salient to the participants, and that principles with higher salience were more important to the persuasiveness of the CMS (e.g., participants felt they encouraged ecologically responsible behaviors). Features that were not important were either not mentioned or were discussed in a negative way. Therefore, the coding also involved negative confirmation (Miles & Huberman, 1994). If participants expressed a negative perception of the design principle, such as not liking a particular feature, this was coded and then verified during the qualitative analysis process. Finally, consistent with the perspective of IS as an "integrated and cooperating set of people, processes, software and information technologies to support individual, organizational, or societal goals" (Watson & Boudreau, 2011, Loc 227), this study took a broad view of the CMS. That is, although coding of the design principles focused primarily on the software, it also considered organizational processes, people, and technologies that collectively support the goal of reducing employees' personal carbon footprints.

Throughout coding, I reviewed and augmented the initial set of codes to reflect emerging design principles. Where descriptions of the CMS's features or characteristics were not consistent with the principles as outlined in the PSD model, I created new codes. In total, I added eight additional codes (for a total of 36), including four in a new category that I defined as integration support (see Section 4). Subsequent to my initial coding, a graduate student randomly selected and coded eight (44%) of the interview transcripts not involved in the research. The inter-rater agreement for these transcripts was 77 percent.

In parallel with the first approach to coding, the second approach invoked an emergent theme-based approach. Here, I reviewed the data for other elements relevant to the PSD framework. Specifically, I captured themes related to the outcomes of CMS (e.g., ecologically responsible attitudes and behaviors) and the persuasion context. I used the findings from this phase of coding to help explain results obtained in the frequency coding, and to develop new theoretical insights. The results of the study are discussed in Section 4.

4. Results and Discussion

To explore how CMS are used in organizations to promote ecologically responsible behaviors by employees, the first research question asks whether any behavioral changes actually occurred in the three organizations. Although difficult to quantify, the qualitative data suggests some level of causal connection between the CMS and employees' behaviors. Many employees expressed thoughts similar to Rita[4] from NFP, who noted that she had been "trying to work better or work harder" to reduce her carbon footprint since beginning to use the CMS. For Rachel at Vendor 3, the changes were both specific and general: "I eat less meat. It does make me think when I buy stuff". In only one interview did a participant express a negative reaction as a result of his involvement in developing the CMS:

> *I think it's not so much using the tools that has changed my behavior, it's just in doing all the research for the tools, I have become certainly more jaded about personal responsibility and how much of an effect you can actually have* (Owen, Vendor 3).

Participants also reported improvements in organizations' environmental performance. For instance, when discussing waste, Thomas at ERC talked about changes that were happening in the organization as a result of the CMS, and commented about feeling "good about the steps that we've taken internally to reduce [from] what we've been doing in the past". At PUC, individual changes led to significant collective benefits: in conjunction with the CMS initiative, 12 percent of the employees targeted by the CMS made positive changes to their commuting behaviors, which resulted in a 5 percent reduction in carbon emissions.

Turning now to the second research question, an analysis of the coding frequencies of the PSD principles showed that 492 total references were coded to the expanded list of 36 persuasive system design principles (refer to Table 5). Of these, 228 (46%) were from vendors and 264 (54%) were from clients. For the original 28 principles, there were 374 coded references accounting for 76 percent of the total.

Table 5. Coded References by Design Principles

	ERC	NFP	PUC	Total clients	Total vendors	Total	Total as % of category	Total as % of grand total
Credibility								
Verifiability	1	1	2	4	20	**24**	31.2	4.9
Surface	0	9	0	9	6	**15**	19.5	3.0
Expertise	1	1	0	2	10	**12**	15.6	2.4
Authority	2	0	3	5	2	**7**	9.1	1.4
Third-party	0	1	0	1	6	**7**	9.1	1.4
Real-world	0	1	0	1	6	**7**	9.1	1.4
Trust	0	1	0	1	4	**5**	6.5	1.0
Category total	**4**	**14**	**5**	**23**	**54**	**77**	100.0	**15.7**
% of category total	**5.2**	**18.2**	**6.5**	**29.9**	**70.1**	**100.0**		

[4] All participant names are pseudonyms.

Table 5. Coded References by Design Principles (cont.)

	ERC	NFP	PUC	Total clients	Total vendors	Total	Total as % of category	Total as % of grand total
Dialogue								
Liking	0	5	0	5	13	**18**	25.0	3.7
Rewards	0	4	6	10	4	**14**	19.4	2.8
Social networking*	0	4	1	5	8	**13**	18.1	2.6
Suggestion	0	5	2	7	4	**11**	15.3	2.2
Reminders	3	0	3	6	0	**6**	8.3	1.2
Similarity	0	0	1	1	4	**5**	6.9	1.0
Praise	0	2	0	2	1	**3**	4.2	0.6
Social role	0	1	0	1	1	**2**	2.8	0.4
Category total	**3**	**21**	**13**	**37**	**35**	**72**	100.0	**14.6**
% of category total	**4.2**	**29.2**	**18.1**	**51.4**	**48.6**	**100.0**		
Social support								
Facilitation	2	8	3	13	6	**19**	25.0	3.9
Comparison	3	5	1	9	9	**18**	23.7	3.7
Social-learning	4	0	2	6	2	**8**	10.5	1.6
Norms	2	2	1	5	3	**8**	10.5	1.6
Recognition	1	0	6	7	1	**8**	10.5	1.6
Cooperation	6	0	0	6	0	**6**	7.9	1.2
Guilt*	5	0	0	5	0	**5**	6.6	1.0
Competition	0	0	0	0	4	**4**	5.3	0.8
Category total	**23**	**15**	**13**	**51**	**25**	**76**	100.0	**15.4**
% of category total	**30.3**	**19.7**	**17.1**	**67.1**	**32.9**	**100.0**		
Task support								
Tailoring	1	13	8	22	29	**51**	28.0	10.4
Reduction	5	13	5	23	27	**50**	27.5	10.2
Self-monitoring	4	4	6	14	14	**28**	15.4	5.7
Simulation	2	4	4	10	8	**18**	9.9	3.7
Personalization	0	2	3	5	11	**16**	8.8	3.3
Tunneling	2	2	0	4	4	**8**	4.4	1.6
Commitment*	1	2	0	3	3	**6**	3.3	1.2
Personal learning*	0	2	1	3	2	**5**	2.7	1.0
Rehearsal	0	0	0	0	0	**0**	0.0	0.0
Category total	**15**	**42**	**27**	**84**	**98**	**182**	100.0	**37.0**
% of category total	**8.2**	**23.1**	**14.8**	**46.2**	**53.8**	**100.0**		
Integration*								
Complementary programs*	14	3	22	39	6	**45**	52.9	9.1
Goal Consistency*	4	0	12	16	1	**17**	20.0	3.5
Technological*	0	5	0	5	8	**13**	15.3	2.6
Intra-organizational*	2	2	5	9	1	**10**	11.8	2.0
Category total	**20**	**10**	**39**	**69**	**16**	**85**	100.0	**17.3**
% of category total	**23.5**	**11.8**	**45.9**	**81.2**	**18.8**	**100.0**		
Grand total	**65**	**102**	**97**	**264**	**228**	**492**		
% of grand total	**13.2**	**20.7**	**19.7**	**53.7**	**46.3**	**100.0**		
Notes: *New design principle/category								

Due to space constraints, not all of the design principles can be discussed in the body of the paper; however, additional illustrative quotations are included in Appendix B.

4.1. Comparison by Design Category

At a category level, principles related to task support were cited most frequently, which accounts for 182 (37%) of the total references coded. For the three remaining categories, the number of coded references was approximately 15 percent of the total: 77 references coded for credibility support (15.7%), 76 for social support (15.4%), and 72 for dialogue support (14.6%). As described in Section 4.6., a new category called integration support emerged, which contained four design principles. Integration support, referring to a CMS's ability to link with other systems across organizations and contexts, had a total of 85 references (17% of the total). Next, the results for each design category are described in turn.

4.1.1 Task Support

In the task support category, participants most frequently identified the principles of tailoring and reduction (that is, reduction of effort). According to PSD, the tailoring design principle specifies that the system should provide information that is relevant to its user groups. In the data, references to tailoring occurred 51 times as participants spoke of the need to make the CMS more relevant by customizing it to the organization or their geographical location. Since the value of a carbon footprint can vary by geography, consideration of local conditions and constraints are seen as important to the success of CMS initiatives:

> *I was involved in making everything local. Some of the questions didn't fit with us. I took out a water question because our water isn't metered, and questions about subway and streetcars, we don't have those. So those aren't important* (Rita, NFP).

Participants primarily used features related to the principle of reduction to reduce the effort and complexity of calculating the impact of their behaviors. In interviews, participants talked about the difficulty of determining one's carbon footprint and viewed the CMS as essential to simplifying this task. For example, one vendor remarked:

> *It* [carbon footprint] *would be pretty hard if not impossible to measure; all of the rules and regulations that just go into calculating are mind boggling. I work with a group that does it and there is no way that I could figure it out any time soon* (Josh, Vendor 3).

In the task support category, I identified two new design principles: commitment and personal learning. Commitment relates to a CMS's ability to enable users to make specific commitments to change. For instance, when individuals make clear pledges with the CMS, this can help to reinforce their commitment to making changes. A NFP focus group participant noted the benefit of pledges: "Pledges are clear and specific, which makes it easier to accomplish".

The second emergent design principle, personal learning, is the system's ability to support the accumulation of individual knowledge about the subject of the persuasion (e.g., carbon footprints in the case of CMS). The importance of personal learning seems to relate to the complexity of carbon footprint calculations and understanding the effects of personal actions. Unless individuals have basic skills and knowledge with respect to environmental sustainability, it is difficult for them to make ecologically responsible choices (Moisander, 2007). As one participant noted, "The barrier is really knowledge. It's a difficult thing to do, so it's one thing we're trying to address" (Mark, PUC).

4.1.2 System Credibility Support

There were 77 references coded for principles related to system credibility, with vendor comments accounting for 70 percent of this total. In this category, the principle of verifiability appeared to the greatest concern for vendors. The combination of users who are not comfortable with carbon footprint calculations and the availability of different CMS on the market using different data elevated the need for vendors to provide transparency and verifiability of the calculations and content provided:

> *One of the challenges is making people comfortable with the final results of the calculations; that is, incorporating an element of transparency into the calculation that we do and providing that information* (Owen, Vendor 3).

4.1.3. Social Support

There were 76 instances for which design principles related to social support were noted. In contrast to system credibility, design principles related to social support were more frequently mentioned by client participants who accounted for 67 percent of the category total. In the social support category, the principles of facilitation and comparison were most frequently mentioned, with 19 and 18 references, respectively. This result is not surprising because knowing what others are doing and being able to compare your performance against others tend to go hand-in-hand. Participants viewed both principles as positive attributes of the CMS that helped to build momentum for change:

> *It's good to see that things are actually going on to try to help the planet – I think a lot of people's lack of participation reflects a lack of faith in any real purpose in trying because they hear our effects on earth are just so strong, but the events really show that a lot of people are trying to change things, and in many different ways! (*Feedback form, NFP)

I identified one new design principle in this category: guilt. Feelings of guilt can arise when a person either experiences or anticipates that their own standards of behavior have or will be violated (Hibbert et al., 2007). These feelings may arise voluntarily or be activated through "guilt appeals", which have been the subject of much debate in the marketing literature (Hibbert, Smith, Davies, & Ireland, 2007). Although invoking guilt may, arguably, be considered coercive rather than persuasive, for one organization, ERC, guilt was repeatedly identified as part of the persuasion strategy. As Trevor observed: "It's a little bit of 'everybody wants to recycle because it's good for the environment', and it's a little bit of 'the guilt thing' as well".

4.1.4. Dialogue Support

Seventy-two references were coded for the dialogue support category, which includes interactive features of the system that help users meet their goals. The design principle of liking, the extent to which the look and feel of the CMS appeals to users, was identified the most often with 18 references. As one vendor participant explained: "If somebody clicks on a website and it is interesting, then they stay there. And they click through to other things. If it's boring or there is too much information, then they exit" (Richard, Vendor 5).

The design principle of rewards was the second-most frequently mentioned principle in this design category (14 references). At PUC, a rewards program using the CMS was set up to provide incentives for people to conserve:

> *They* [staff in one office location] *started their own incentive program to help promote conservation. For instance if you're seen turning off your monitor you get* [a credit] *and you collect these and at the end of their initiative you purchase conservation relief items on a storefront* (Mark, PUC).

The third most frequently mentioned principle related to dialogue support was the new principle of social networking with 13 coded references. Unlike the principle of social role in which the CMS actually adopts an animate social role (such as coach or competitor), social networking refers to the system's ability to connect individuals to the CMS. Although participants talked about the importance of social networking, it was one area in which participants were not satisfied with existing CMS. Eight of the thirteen references related to social networking contained mixed or negative views of how features associated with this design principle were implemented. As James explained:

> [The CMS] *is very, very rudimentary when it comes to social networking. Anyone who's used to the level of social networking that exists right now, with Facebook and Twitter and things like that, are going to be sorely disappointed in the abilities to network* (James, NFP).

4.1.5. Integration Support

In total, 85 references were coded to the new category of integration, with 69 (81%) coming from clients. The integration support category speaks to the system's need to go beyond the technical confines of the software, and views the CMS in a broader definition of IS in organizations. In other words, the CMS can be more persuasive if it provides linkages with other systems and elements in the organizational context. This is consistent with the sustainability literature, which has found that connectedness, such as the ability of leaders to understand the wider political landscape and make connections with new and different types of external parties, is a key organizational lever for achieving high environmental performance (Lacy, Arnott, & Lowitt, 2009). In this category, there are four new design principles: complementary programs, goal consistency, technological integration, and intra-organizational cooperation.

4.1.5.1. Complementary Programs

There were 45 coded references related to complementary programs, which refers to the CMS's ability to link with a variety of resources and programs provided by the organization to support ecologically responsible behaviors by employees. Participants noted that people often understand the need to change and have intentions of doing so, but are prevented by physical and other barriers. Removing barriers to actions have been identified as being critical for individuals to improve their environmental performance (McKenzie-Mohr & Smith, 1999). With respect to CMS, features associated with the principle of complementary programs helped to reduce these barriers by providing the resources necessary to support employees' behavioral changes. Participants at both NFP and PUC indicated that various social marketing techniques were used in support of their CMS initiatives. In addition, participants in the two for-profit organizations, PUC and ERC, commented on their organization's willingness to support the CMS initiatives in tangible (and financial) ways to reduce barriers, such as providing subsidized public transit passes, upgrading to energy efficient hardware and software, providing monitoring devices, making recycling stations more convenient, or installing showers to encourage bicycle commuting.

In these examples, the underlying theme is that organizations must do more than simply "talk the talk"; they must also "walk the walk" and they do that by taking corporate actions to support their employees. When employees perceive stronger indications of organizational and supervisory encouragement, they are more likely to engage in ecoinitiatives (Ramus & Steger, 2000). Consequently, when organizations implement CMS with the hope of encouraging ecologically responsible behaviors by their employees, they must also consider the design principle of complementary programs.

4.1.5.2. Goal Consistency

The second most-frequently identified design principle in the integration category, with 17 references, was goal consistency. This design principle refers to the ability of the CMS to support the alignment of environmental goals and behaviors in the organization. In particular, participants from the two for-profit case studies, PUC and ERC, spoke repeatedly about ensuring consistency between corporate sustainability objectives and the CMS initiatives. CMS were also viewed as a mechanism for ensuring cohesion across the organization. In ERC, using the CMS helped them to align goals across geographically dispersed offices so that all employees were working toward reducing carbon emissions: "Pretty much at the very beginning, the goal was trying to get all of the [locations] on the same page. The ultimate goal is getting everybody emissions free" (Trevor, ERC).

The alignment of goals between organizations and their employees is not a new issue for IS researchers. However, the topic seems to be especially salient for CMS. This may be, in part, the result greenwashing, which occurs when organizations make exaggerated or unfounded claims about the environmental performance their products and services or methods for providing them. The prevalence of greenwashing has made consumers sceptical of claims made by organizations (Moisander, 2007). Even in cases when organizations express their desire to improve their environmental performance, many still have real challenges doing so. For instance, Jenkin, McShane, and Webster's (2011a) study of Green IS found significant gaps between organizations' espoused (stated) objectives, actual motivations, and performance. When employees perceive these conflicts,

the persuasiveness of the CMS may be diminished because employees feel that the organization is placing an expectation on them to which the organization itself does not hold itself accountable. Therefore, alignment of both stated and implied goals across the organization and with the CMS is a persuasive system design principle that should be taken into account.

4.1.5.3. Technological Integration

Participants mentioned the design principle of technological integration 13 times. In the IS literature, technological integration has been defined as a "electronic integration among an organization's various IT components (i.e., data, systems, applications, telecommunications) in order to form and use a common IT architecture" (Pollalis, 2003, p. 478). Thus, in relation to CMS, technological integration refers to the ability of the CMS to connect with corporate IT components and other internal and environmental resources. In addition to improving the effectiveness of operations by integrating disparate existing and new systems (Lee, Trauth, & Farwell, 1995), research suggests that an integrated IS infrastructure has a high strategic value to organizations (Byrd, Lewis, & Bradley, 2006). In practice, technological integration may take the form of automated data flows between enterprise systems, or seamless interactions and linkages between different applications (Pollalis, 2003).

In this study, several features reflecting the principle of technological integration were identified. For example, NFP users were concerned about having to create a separate login ID and password for the CMS. Implementing single sign-on capabilities between the company network and the CMS could have the effect of reducing or removing this barrier. Further, implementing CMS functionality through mobile devices such as cellular phones, as suggested by a participant at PUC, could enhance the ability of the CMS to provide immediate feedback or contextual reminders to employees (Froehlich et al., 2009; Watts & Wyner, 2011). Links to other relevant environmental websites or corporate resources (both internal and external) were also perceived to be value-added: "The news and events links were also awesome. It's really good to have relevant news links at your access, and events that are (possibly) local" (Feedback form, NFP).

4.1.5.4. Intra-organizational Coordination

Intra-organizational coordination, the fourth emergent principle of integration support, was noted in ten instances. This principle refers to the ability of the CMS to extend beyond the sponsor organization to coordinate carbon management initiatives with other organizations, such as employee unions or supply chain partners. Although there was no evidence that features supporting intra-organizational coordination have been implemented thus far, participants in all three client organizations raised the topic as a potential enhancement. For example, at PUC, coordination with unions was seen as an opportunity that could be leveraged to enhance support for environmental programs: "The unions have been really supportive of what we're doing and they're always wanting to help. In the near future we will hopefully engage the unions and have them include us in their communications to all the union members" (Mark, PUC).

The emergence of this design principle is in line with previous research that has found demonstrable spill-over effects in the context of environmental concerns (Cambra-Fiero, Polo-Redondo, & Wilson, 2008). People do not belong exclusively to a single organization or group: how an individual acts in one situation impacts their behaviors in other situations. A CMS user may be an employee, a union member, live in a city or rural community, be part of a household, have children in school, and participate in voluntary organizations. Spill-over effects occur when attitudes and behaviors in one area affect actions in other areas (Muster, 2011). For example, Trevor at ERC spoke about how the availability of recycling both at home and work make the behaviors more engrained or second-nature: "When it's more available to you, it seems like second nature to do the recycling; where, when it's not, it's hard for some people to get their heads around the sorting and the recycling" (Trevor, ERC).

Spill-over effects may relate to the individual's self-identity, or how one sees oneself. The more that people see themselves as environmentally responsible generally, the more likely they are to take actions that are consistent with this self-identity (McKenzie-Mohr & Smith, 1999). Research has found direct links between self-identity and green consumerism (Sparks & Shepherd, 1992), and suggests

that individuals are more likely to engage in a social change initiative when it fits into a coherent and holistic view of their lives (Mankoff, Matthews, Fussell, & Johnson, 2007).

As a result of self-identity and spill-over effects with respect to ecologically responsible behaviors, a CMS deployed in one organization may be more persuasive if it is similar or complementary to CMS initiatives in other organizations. Further, it has been suggested that, to really take hold, initiatives to promote sustainable consumption must be introduced in people's everyday settings (Muster, 2011), whether that be at work, home, or elsewhere. Therefore, as more communities, associations, and business organizations implement CMS for their multiple stakeholders (employees, members, customers), the degree to which there is coordination between these systems could have significant implications for the persuasiveness of the CMS.

In summary, the analyses of the persuasive design principles by category reveal a number of findings. First, design principles in the category of task support were mentioned most often, and accounted for over a third of the total references coded. When it comes to adopting ecologically responsible behaviors, participants recognized the importance of features in the system that reduced their effort and provided additional capabilities. Such a finding may not be surprising given the predominant view of computers as "tools". However, it does suggest that "doing the right thing" for the environment is not a trivial task and may call on new skills and knowledge. Second, eight new persuasive design principles were identified, bringing the total to 36, and a new category of design principles called integration emerged from the data. Third, there was substantial variation, both in and across categories, in the frequency counts for the various design principles. It may be that the high salience of certain design principles may be related to the problem domain of environmental sustainability, or the use of a cross-over application of Green IS. These findings highlight the value of investigating persuasive systems in different contexts and from multiple perspectives.

4.2. Cross-Case Comparisons of Clients and Vendors

This study's research design, which includes three organizational case studies and data from vendors, provides a valuable opportunity to explore different perspectives and gain deeper insights on the design and use of CMS. I conducted two sets of comparisons: client-vendor and client-client.

4.2.1. Client-Vendor Comparisons

As discussed in Section 4.1.1, both clients and vendors spoke frequently of the design principles related to task support, particularly reduction and tailoring. However, as Table 5 shows, there were notable variations in three other design categories: system credibility, social support, and integration.

4.2.1.1. System Credibility Support

For vendors, design principles associated with credibility of the CMS were highly salient. This category had the second highest number of vendor mentions (after task support) and vendors accounted for 54 of the 77 (70%) of the references coded in this category. In particular, vendors referred to verifiability and expertise five times more often than the client participants. With carbon footprint calculators, there is significant underlying data and calculations required in order to determine an accurate value. Many organizations implementing CMS do not have expertise in complex carbon footprint calculations and thus rely on the CMS vendor to provide it: "Sometimes we are dealing with companies that really don't have this kind of in house knowledge and they just kind of assume that we are the experts on it and we're trusted to do research on this" (Owen, Vendor 3).

This lack of company knowledge and reliance on vendors may help to explain vendors' attention to principles related to system credibility. In light of research that has raised issues with the accuracy of carbon emission calculations (Kenny & Gray, 2009; Padgett et al., 2008), the credibility of the CMS may become a competitive issue for vendors, motivating them to focus on this aspect of the system. To support the design principle of verifiability, the PSD framework suggests that the system should incorporate features that make it easy to check the accuracy of the content (Oinas-Kukkonen & Harjumaa, 2009). Providing the underlying references and sources is one mechanism for doing this:

> *We put the reference, the source. If you go into the little question mark, so there is a short help and a long help, and in the long help we try to put all the things that we got our sources from* (Rachel, Vendor 3).

Although accuracy of the CMS is important to organizations and individual users, principles related to system credibility may be less salient for these participants because employees may naturally expect that the organization has vetted the quality of the CMS.

4.2.1.2. Social Support

While vendors were focused on the principles of system credibility, clients placed a greater emphasis on the principle of social support. Client comments in this category accounted for 51 coded references in contrast to 25 for vendors. Despite this imbalance at the category level, the design principle of comparisons was mentioned by vendor and client participants with similar frequency. All participants felt it was important that the CMS enable individuals to compare themselves to others. However, other than the principle of comparison, vendors did not discuss other principles related to social support to the same extent as clients. Clients spoke frequently about the principle of facilitation (13 coded references); that is, using the system to help identify others who are engaging in similar behaviors, but, like social marketing, identified limitations in the extent to which this principle was implemented in the CMS. This may be explained in part by the novelty of carbon management practices in organizations.

A final area of social support where clients and vendors had different views of the CMS was with respect to the principles of competition and cooperation: clients spoke primarily of cooperation, while vendors exclusively mentioned competition. These divergent views are illustrated in the following contrasting comments:

> *We're all kind of a little bit of a resource for each other* (Thomas, ERC).

> *So you add in competition theory and it's not just guilt, it's I want to be better, and when you start to do things like leader boards and rankings and how are you with people and groups and all that online gaming theory, it works well* (Josh, Vendor 3).

To understand clients' focus on the principles associated with social support, it is necessary to recognize that climate change is largely a social problem. What individuals see other people doing has an impact on their own actions (Goldstein, Griskevicius, & Cialdini, 2007), and substantial progress toward environmental sustainability can only be made when a critical mass of individuals adopt ecologically responsible behaviours. The design principles associated with social support enable the CMS to function as a social actor (rather than merely providing tools for individuals to use) and draw upon more emotional and indirect (computer-mediated) forms of persuasion.

4.2.1.3. Integration

The third category where there was a large discrepancy between vendors and clients was integration support. In this category, 81 percent (69 of 85) coded references came from clients. This difference is largely attributable to clients' frequent mentions of complementary programs. As described above, the design principle of complementary programs refers to linkages between the CMS and other sustainability-related initiatives. Although these initiatives may be physically distinct from the CMS, they can be integrated through the provision of information, one-click links, or by automatically feeding certain information (such as printing metrics) into employees' carbon calculations. For the most part, these vomplementary programs are beyond the purview of CMS vendors; however, employees see them as an important part of the broader CMS and environmental initiatives.

4.2.2. Client-Client Comparisons

In addition to differences between vendors and clients, there were also some notable variations between clients. As Table 3 indicates, the three organizations included in this study differed on a number of dimensions: size, ownership type, industry, and CMS type (e.g., formal vs. informal). These dimensions may help to explain the variations seen across different categories and design principles.

4.2.2.1. Credibility Support

Among the three cases, NFP was the only one with a formal CMS. They contracted with Vendor 3 to provide a comprehensive CMS offering. On the other hand, ERC and PUC had informal CMS that relied on existing company infrastructure, such as email and intranets, which were supplemented with different CMS functionality, such as carbon calculators from external vendors. As Table 5 shows, it appears the greatest differences between formal and informal CMS clients were in the design category of system credibility. In this category, PUC and ERC collectively represent only 12 percent of the total references coded. Additionally, participants from both organizations did not mention the design principles of surface credibility, third-party endorsements, trustworthiness, feedback, and real world feel. In contrast, participants at NFP spoke of these principles (although not to the same extent as vendors), with a particular emphasis on surface credibility.

One potential explanation for the differences between formal and informal CMS relates to the predominant type of persuasion associated with the CMS. In the case of a formal CMS, there is a higher level of direct, computer-human persuasion. Thus, credibility of the system, particularly on an initial inspection (i.e., surface credibility), is an important requirement for users of formal CMS solutions. Alternatively, from the perspective of users of an informal CMS, there may be a lower emphasis on system credibility because those organizations are leveraging existing technologies and systems in which there is already a high degree of confidence. Adding CMS functionality into an existing internal infrastructure is almost taken-for-granted and perhaps less scrutinized. In addition, informal systems seem to have a higher level of indirect, computer-mediated persuasion. As a result, credibility support for the CMS comes more from internal sources (associated with the design principle of authority) reflected through the CMS. As Thomas at ERC explained:

> *The general manager emails everybody and says, "Some people walk the walk and some people talk the talk", and there's a picture of him pushing his push mower, mowing his lawn just covered in sweat, and you know, that's pretty cool* (Thomas, ERC).

4.2.2.2. Dialogue Support

A second category for which there were notable differences between the three organizational cases was dialogue support. Unlike the other cases, ERC had only three coded references and referred exclusively to reminders. Participants at the other two organizations identified several different design principles in this category, although PUC had a lower number of coded references compared to both NFP and vendors (13 vs. 21 and 35 respectively). The lower emphasis on the principles associated with dialogue support by ERC and PUC may be explained by the greater level of computer-mediated persuasion in informal CMS, moderated by the size of the organization. As compared to PUC, ERC is a small organization (with 125 employees). The smaller size may enable more personal contact in the organization regarding carbon management initiatives and require less emphasis to be placed on computer-human dialogue in the CMS.

In sum, the cross-case comparisons help to draw out new insights regarding the design and use of CMS. The findings of the client-vendor comparisons hint toward the effects of different sources of persuasion intentions (e.g., designers and providers). Because system quality can be negatively impacted by mismatches of designer and user expectations (DeSanctis et al., 1994), it is important to identify potential tensions and understand how they may play out in the context of CMS. Furthermore, the comparisons between client organizations reinforce the importance of considering organizational contextual factors when implementing and deploying CMS.

4.3. A Core-Periphery Perspective on Design Principles

The analysis of design principles by category revealed significant variations with respect to the importance of design categories and individual principles. Through the cross-case analyses, several factors were identified that help to explain significant variations between vendors and clients and across organizations. However, these findings are set in a categorical view of the design principles. Although the PDS model provides a useful structure for conceptualizing the design principles, it may be edifying to consider the principles independent of their categories.

In order to explore relationships among the individual persuasive design principles, I decoupled the principles from their respective categories and plotted the coded references for each on a radar chart. As Figure 1 illustrates, organizing the principles in this manner provides a visual mapping of the design principles. The shaded area in the center of the circle captures design principles that had more than 30 coded references, representing what could be considered the core design principles of the CMS. Only three of the design principles—tailoring, reduction, and complementary programs—fell into this group. The shaded ring on the outside of the circle captures those principles that were discussed less than ten times by participants. Half of the principles (18 of 36) are located in this group, which could be considered to be at the periphery of the CMS. The remaining thirteen principles, having coding frequencies between 10 and 30, lie in the white area between the core and the periphery. Table 6 summarizes these groupings.

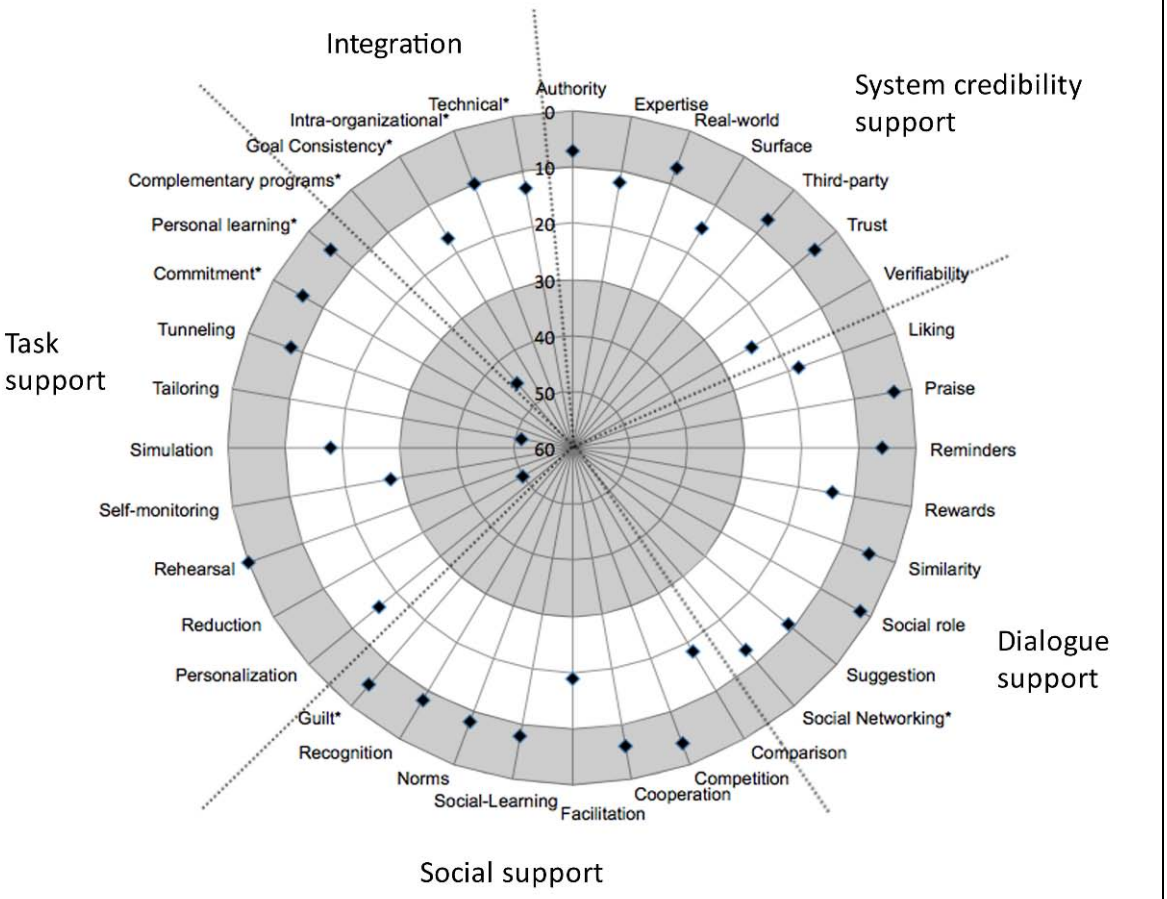

Figure 1. Core-Periphery Perspective of Design Principles for CMS

The existence of this frequency pattern, which crosses different design categories, suggests that there may be a hierarchy among the persuasive design principles in relation to personal CMS use in organizations. Put another way, the three core design principles may represent a first-order requirement to reduce the cognitive effort to understand the concept of carbon footprints, tailor the CMS to its particular use context, and lower the physical barriers to taking action. On the other hand, persuasive design principles in the periphery, such commitments or rehearsals, may appeal to different types of users and help to enhance the persuasiveness of a CMS in certain contexts.

Table 6. Groupings of Design Principles by Count of Coded References

Core (> 30 coded references)	**Intermediate** (10-30 coded references)	**Periphery** (<10 coded references)
Complementary programs* Reduction Tailoring	Comparison Expertise Facilitation Goal Consistency* Intra-organizational* Liking Personalization Rewards Self-monitoring Simulation Social Networking* Suggestion Surface Credibility Technical* Verifiability	Authority Commitment* Competition Cooperation Guilt* Norms Personal learning* Praise Real-world Recognition Rehearsal Reminders Similarity Social role Social-Learning Third-party Trust Tunneling

Notes: *New design principle

4.4. Overall Summary of Results

This study sought to answer three research questions. With respect to the first question (i.e., Does personal CMS deployed in organizations help to promote ecologically responsible behaviors by employees?), the answer seems to be yes. Overall, participants who used the CMS reported positive changes in their attitudes and behaviors with respect to environmental sustainability. The second question asked which, if any, of the persuasive system design principles are most relevant to personal CMS deployed in organizations. Here, the answer appears to be that many different principles, including eight emergent principles, come together to make a CMS persuasive. However, the results also suggest that there is a hierarchy of persuasive design principles. The core-periphery analysis revealed a small set of design principles that are more frequently salient to the persuasiveness of the CMS. With respect to the third question, the results point to several areas where the persuasion context of environmental sustainability may influence the design of personal CMS used in organizations. For instance, the analyses showed that vendors typically focus on a different set of design principles than their clients/users. Although this difference may not be surprising, it highlights potential tensions and synergies that can occur between the different actors and must be taken into account during CMS design and use. Finally, the study shows that contextual factors in organizations may lead to an emphasis on different persuasive design principles. These results support the argument that persuasive systems must be studied in context in order to fully understand the implications for their design, use and ultimate outcomes.

5. Toward a Theory of Persuasive Systems for Environmental Sustainability

For those interested in the study of Green IS, the results of this study are encouraging. Theoretically, the PSD framework has provided a useful lens for exploring the design and use of CMS in organizations. However, this study did not test persuasive system design theories; rather, it engaged in theory-building concerning the use of Green IS to promote environmental sustainability. To this end, the paper now presents four propositions, based on the findings of this study, that can serve as a starting point for further theorizing, testing, and refining in subsequent Green IS research.

5.1. Combining a Variety of Persuasive Design Principles

Designed with the intention of encouraging individuals to voluntarily change their behaviors and attitudes, a CMS is a multi-dimensional information system. System features designed and developed with attention to the PSD principles enable CMS to be persuasive by enhancing the credibility of the information and interactions of the system (system credibility), which makes reducing carbon footprints easier (task support), provides feedback to users on their progress (dialogue), leverages social influence (social support), and facilitates links across different contexts (integration). Although each of these dimensions is important in its own right, the results suggest that persuasiveness is enhanced when a variety of design principles are combined in the CMS.

When trying to promote environmental behaviors, many different tactics and techniques are required to sustain changes. For instance, early environmental campaigns, relying almost exclusively on the provision of information, helped to create awareness, but were relatively ineffective at changing attitudes and behaviors (Dobson, 2007). Economic-based approaches such as financial incentives or penalties have also been used; however, the positive effects tend to be short-lived and disappear when the incentives or penalties are removed (Abrahamse et al., 2005; Dobson, 2007). In social marketing, interventions, such as making commitments (Katzev & Wang, 1994), prompts (Austin, Hatfield, Grindle, & Bailey, 1993) and message framing (Bator & Cialdini, 2000), have also demonstrated effectiveness in certain contexts. Although these different approaches aid in promoting ecologically responsible behaviors, research suggests that they are more successful when used in combination (Abrahamse et al., 2005).

When the results of this study are considered in the context of the sustainability and social marketing literatures, it appears that CMS are successful at changing employees' attitudes and behaviors because they include features that reflect multiple categories of the design principles. Even though the design category of task support was referred to most often (Table 5), comments by the participants indicate that features associated with the other design principles were also instrumental in enhancing the CMS's persuasiveness. This synergy between design principles ties back to idea that persuasive systems function in three different ways: as tools, media, and social actors (Fogg, 1999; Fogg, 2003). Although each mechanism is necessary, one alone may not be sufficient. For instance, simply providing a tool (e.g., task reduction) may not lead significant changes in behaviors if not accompanied by other design principles that simulate social interactions (e.g., suggestions). Therefore, the first proposition is stated as follows:

> **Proposition 1**: *Carbon management systems will be more effective at promoting ecologically responsible behaviors when they embody multiple categories of the persuasive system design principles.*

5.2. Reducing the Complexity of Environmental Sustainability

When designing and implementing persuasive systems, organizations must be attentive to the unique characteristics of the persuasion context (Oinas-Kukkonen & Harjumaa, 2009). Perhaps the most fundamental element of the persuasion context is the problem domain; that is, what "problem" the persuasive system intends to solve. Persuasive systems can be applied to a variety of problems such as smoking, personal health, or environmental sustainability. Differences in the causes, scope, and interventions applicable to different problem domains may influence the relative strength (persuasiveness) of individual design principles. In this study, three principles emerged as central to the CMS based on the core-periphery analysis. The problem domain of environmental sustainability undoubtedly elevates the importance of all three; however, it seems that the impact is stronger for the principle of task reduction. Therefore, I propose that the highly complex nature of climate change necessitates that a greater emphasis be placed on task reduction in order to enhance the persuasiveness of a CMS.

Evidence from both the literature (e.g., Pandey et al., 2011) and the results of this study indicate that the concept of a carbon footprint is confusing. Understanding what a carbon footprint means and then taking actions to reduce it is not a trivial task. Reducing one's carbon footprint is not like breaking an

addiction, losing weight, or even other environmental issues such as reducing waste. In those situations, there is a clear distinction between the original behaviors (e.g., smoking) and the intended behaviors (e.g., not smoking) and associated outcomes (e.g., personal health benefits). When considering carbon emissions, the connections between individual actions and climate change are not straightforward. Many computations based on complex hierarchies of assumptions are needed to, first, calculate a carbon footprint and, second, determine how it would be affected by a given change in behavior. Furthermore, in many cases, there is no single right answer as the environmental impact depends on other upstream and downstream activities that may not be known or controlled by the individual. For instance, Will at Vendor 3 explained how comparing the environmental impacts of driving versus taking the train should include full lifecycle considerations (including the environmental cost of the vehicle and infrastructure) in order to get a "true" assessment. However, what is true at one point in time, for one individual, in a given location is not necessarily true in all contexts. Thus, for average users, a carbon footprint can easily become a mythical number without a tangible connection to their lives.

Because unravelling the composition and impacts of carbon footprints is highly complicated, it is not surprising that the principle of task reduction was top-of-mind for both vendors and users of CMS. The principle of reduction emphasizes the importance of reducing cognitive effort and making it easier and less costly for people to know what the right, or "best", choice is in a given circumstance. Therefore, I theorize that, in the context of environmental sustainability, persuasive systems should emphasize the principle of task reduction. This leads to the second proposition:

> **Proposition 2**: *When carbon management systems emphasize the persuasive design principle of task reduction, individuals will be more likely to engage in ecologically responsible behaviors.*

5.3. Tailoring Change to the Organizational Context

A second core design principle identified in this study was tailoring. As part of the task support category, this principle (like reduction) contributes to system persuasiveness by reducing the effort associated with the desired behavioral changes. However, instead of acting to simplify the concept of carbon footprints, tailoring increases the persuasiveness of a system by making it more relevant to the specific use context. For example, a feature consistent with the tailoring design principle might be a webpage that provides information specifically related to the user's geographical location (e.g., indicating the closest location and hours of operation for recycling centers). Although the ability to tailor a CMS is valuable across many use contexts, the results of the core-periphery analysis imply that the principle of tailoring is especially important when CMS are deployed in organizations. Thus, it follows that that placing a higher emphasis on the design principle of tailoring will enhance CMS persuasiveness and lead to ecologically responsible behaviors by employees.

As discussed in Section 2.2, it is the intentionality of persuasive systems that sets them apart from other types of systems. This intentionality can arise from three different sources: the creators of the system (e.g., vendors), the providers of the system (e.g., organizations), and the users of the system (e.g., employees) (Fogg, 1999; Oinas-Kukkonen & Harjumaa, 2009). Ultimately, vendors, organizations, and employees of a CMS share a similar intent to reduce carbon footprints. However, the roles that these actors play in the persuasion context and the relationships between them may dictate that different emphases be placed on the design principles. Persuasive system design theory suggests that, when persuasion intentions arise predominately from vendors, the design of the system should be more attentive to the voluntary nature of changes usage and provide transparency (e.g., verifiability) in order to reveal the bias and reinforce perceptions of objectivity (Oinas-Kukkonen & Harjumaa, 2009). When organizations represent the predominant source of persuasion, the CMS should incorporate principles that allow for customization to the specific use contexts (e.g., tailoring) (Oinas-Kukkonen & Harjumaa, 2009), in effect, to be consistent with the organizational setting in which the system is being used. Finally, with strong persuasion intentions at the user level, design principles associated with capturing the attention of the individual (which provide high usability and interest; e.g., liking) help to keep users engaged with the CMS, which allows it to have a more persuasive effect (Oinas-Kukkonen & Harjumaa, 2009).

With respect to the cross-over type of CMS investigated in this study, the results point to a natural interplay between the three sources of persuasion. However, organizational persuasion intentions appear to be the most prominent. In this case, design principles that allow for customization to the specific use context (e.g., organizational setting) are expected to have greater impacts on the persuasiveness of the system (Oinas-Kukkonen & Harjumaa, 2009). With formal CMS applications, organizations may not be able to influence the overall system design; however, they choose which CMS to deploy and can often configure them to fit in their organizational contexts. With informal CMS, organizations have a greater degree of control over the system's design and implementation because they leverage organizational resources and are more active in designing and developing the CMS.

When a CMS is highly tailored to the organizational use context, its persuasiveness is enhanced in two ways. First, more relevant information makes it easier for employees to take the desired actions. Second, because tailoring should suggest to employees that their organization supports environmental initiatives, employees may interpret the CMS as a strong indication of the organization's environmental commitment. When this is the case, past research demonstrates that employees are more likely to engage in positive environmental behaviors (Daily et al., 2009; Ramus & Steger, 2000). Therefore, the third proposition suggests that:

Proposition 3: *When carbon management systems emphasize the persuasive design principle of tailoring, employees will be more likely to engage in ecologically responsible behaviors.*

5.4. Enabling Change through Complementary Programs

I identified the emergent principle of complementary programs as the third core persuasive design principle for CMS. As part of the integration category, this principle highlights the need for the CMS to connect with other resources and programs provided by the organization in order to encourage ecologically responsible behaviors by employees. This study's results suggest that people need added incentive in order to change their behaviors and that features consistent with the principle of complementary programs provide the necessary boost.

People often understand the need to change and have intentions of doing so, but are prevented by many potential barriers (Koger, 2009; McKenzie-Mohr & Smith, 1999). This gap between intentions and actions is evident in green consumerism. Research has found that individuals' personal ecological consumption practices may not match their intentions for several reasons, including the fact that they may not have the opportunity or ability to take ecologically responsible actions (Moisander, 2007). For instance, in order to improve the carbon footprint of the electricity sector, many utilities are implementing a number of strategies aimed at reducing electricity usage. However, there is significant inertia in consumers' decision-making with respect to electricity usage and other barriers, such as time and cost constraints, make it difficult for consumers to make substantial changes (Ek & Soderholm, 2010).

Recognizing the difficulty of changing behaviors, social marketing has become more prominent in the domain of environmental sustainability (Smith & O'Sullivan, 2012). Social marketing involves the application of various marketing and other techniques in order to change behaviors for the social good. Among the various techniques used, removing barriers to actions has been proposed as critical to improving environmental performance by individuals (McKenzie-Mohr & Smith, 1999). In this study, both NFP and PUC indicated that various social marketing approaches were used in support of their CMS initiatives. In addition, participants in the two for-profit organizations, PUC and ERC, commented on their organization's willingness to support the CMS initiatives in tangible ways to reduce barriers, such as providing subsidized public transit passes, upgrading to energy efficient hardware and software, providing monitoring devices, or making recycling stations more convenient. Thus, I propose that, if this complementary program support were designed in the CMS itself (such as including features that link to other organizational resources or programs), the CMS would help to reduce barriers that stand in the way of individuals making good environmental choices. Therefore, the fourth proposition is stated as follows:

Proposition 4: *When carbon management systems emphasize the persuasive design principle of complementary programs, employees will be more likely to engage in ecologically responsible behaviors.*

6. Conclusion

As the urgency to address climate change increases, organizations are beginning to adopt proactive environmental strategies. Green IS can play a pivotal role in supporting these strategies and bringing them to fruition. Using three organizational case studies, this study explored how an emergent category of Green IS can be designed and used to promote ecologically responsible behaviors. The paper now concludes with a discussion of the contributions this work makes to the field, limitations of the study, and future directions for research.

6.1. Contributions

As an early example of empirical and theory-building Green IS research, this work makes several contributions to the IS literature. First, this paper introduces and describes a new category of Green IS: carbon management systems. Although Green IS may take many forms (Mingay, Tratz-Ryan, & Stokes, 2010) and target different environmental problems, much of the extant research considers Green IS at an aggregate level (e.g., Chowdhury, 2012; Melville, 2010). In order to fully understand the variations and nuances of the relationships between information systems and environmental sustainability, it is necessary to unpack the black box of Green IS. Therefore, rather than taking a broad view of the subject, this study focused on an emergent category of Green IS. Specifically, the study examined the situation of cross-over IS, where personal-CMS were used in organizational settings, and, in the process, uncovered a number of new patterns with respect to the interactions between people, technologies, and the natural environment.

Second, this paper adds to and extends our knowledge of persuasive systems. By exploring how different design principles are reflected in CMS, the study provides a qualitative assessment of the persuasive system design model. Additionally, the study identified eight new design principles and one new high-level category called integration support. Future research will be essential to refining and validating these results. Additional principles may be found and some may be challenged. However, the main implication of these emergent principles is the need for research to go beyond the confines of the software and take an in-depth look at persuasive systems in specific and diverse problem domains.

A third contribution of this work is that it reinforces the importance of examining IS at multiple levels. Understanding complex information systems requires looking at both detailed features and more holistic characteristics (DeSanctis et al., 1994). In this study, CMS were considered at several different levels: the individual design principles, the five higher level categories of design principles, and the persuasion context. By layering the analysis across these parts, a more complete picture of CMS was achieved, providing new insights and research avenues.

The fourth main contribution of this paper is the initial theorizing it provides with respect to the use of Green IS to promote ecologically responsible behaviors. In developing these propositions, the paper brings together multiple theoretical perspectives. In addition to persuasive systems design theory, the paper draws on literatures in sustainability, green consumerism, and social marketing in order to present a more cohesive and multidisciplinary view (Elliot, 2011) of persuasive systems for environmental sustainability. These propositions are in need of further refinement, but it is hoped that they may serve as a guide both for academia and practice.

Finally, from a practical perspective, this research provides benefits for both software vendors and organizations seeking to elevate their contributions to environmental sustainability. The results highlight the core and intermediary principles of persuasive system design that contribute to motivating ecologically responsible behaviors. These findings can provide direction to vendors who build these systems and the organizations that implement them. Similarly, this research presents a new opportunity for user organizations related to the use of Green IS to support their environmental

strategies, and outlines a number of important considerations for designing initiatives targeted at motivating individuals to engage in positive environmental behaviors.

6.2. Limitations

As with any research, there are a number of limitations of this work that must be acknowledged. Despite the mixed-methods approach and specifically the use of frequency counting, this study is predominately qualitative. Thus, the ability to generalize the results is limited (Myers, 2009). For instance, an open question remains whether the results would be the same for CMS deployed by organizations in different industries or geographical locations. This limitation is partially addressed by the multiple case study approach (Eisenhardt & Graebner, 2007), which included three fairly different organizations. However, all organizations espoused a strong commitment to environmental sustainability, a characteristic that was purposefully specified as part of the selection criteria. The effect of this choice may be an overstatement of the level of changes in employees' behaviors attributable to the CMS. It is possible that employees in these organizations were already disposed to green choices or that they were influenced in part by other factors in the organization. Thus, the results of this study should be viewed as preliminary and interpreted in the appropriate context.

Another limitation of this research was the inability to investigate employees' responses to CMS at a more granular level. Although participants represented a range of demographic characteristics (e.g., gender, age) and job positions, there was an insufficient sample to compare results across different sub-segments of the population. Based on level of environmental concern, GfK Group (www.gfk.com) has identified five green consumer segments, ranging from the true blue greens who are environmental leaders and activists, to the basic browns who have no interest in environmental issues (Thompson, Anderson, Hansen, & Kahle, 2010). Given different personal motivations, individuals may respond more positively to different persuasion techniques (Oinas-Kukkonen & Harjumaa, 2009). For instance, those who are highly motivated (true blue greens) may be both interested in and capable of dealing with direct messages, such as suggestions made by the CMS, while those at the other send of the spectrum might respond more favourably to indirect persuasion messages. In the latter case, features that reflect the design principles of social networking and facilitation might be more persuasive. The presence of different green intentions at the individual level adds another layer of complexity to the design and study of Green IS.

A third limitation of this study relates to equivocality of the dependent variable. For this study, the assessment of ecologically responsible behaviors was based on subjective self-reports by participants and it was not possible to objectively confirm whether these changes actually occurred. Thus, it is possible that changes reported by participants were favorably biased toward pro-environmental responses. Even if individuals' actions could be objectively measured, there is still significant ambiguity about whether they would constitute ecologically responsible behaviors because such a determination is highly contextual. For example, in the simple case of "turning off the lights" (an ecologically responsible behavior), the impact of such an action on an individual's carbon footprint might be vastly different if the electricity for the light is coal-generated (high carbon footprint) or hydro-generated (low carbon footprint). As a result, there remains some degree of fuzziness associated with the dependent variable.

6.3. Future Research

In order to address these limitations and to build on the results of this study, research could progress in several diverse directions. Four areas in particular hold promise for IS scholars: definition and operationalization of the dependent variable, theory testing and refinement, application of concepts to other applications of Green IS, and further investigation of cross-over and boundary-spanning CMS.

The issue of environmental sustainability is one of the most difficult and complex challenges that humans have faced, and there are few simple solutions to the problem. Achieving sustainability will require the efforts of many individuals, organizations, and governments working together (Watson, Corbett, Boudreau, & Webster, 2012). It is important, therefore, for individuals to engage in activities that are ecologically responsible, and for researchers to develop theories to explain and predict how

and when this will happen. However, the definition and operationalization of this dependent variable remains a significant impediment. What exactly is meant by ecologically responsible behaviors and how can it be measured accurately and reliably? As new and greener technologies and products, such as electric vehicles or organic clothing, come to the market, trying to define and measure ecologically responsible behaviors will continue to be a challenge for both practitioners and researchers. Other fields, such as green consumerism, have begun to tackle these questions (e.g., Hopkins & Roche, 2009; Moisander, 2007), which may provide useful insights and directions. Thus, IS researchers are encouraged to collaborate with scholars from other areas and take an inter-disciplinary approach to explicating this essential concept and construct.

In the IS field, Green IS research is still in its infancy. Through the investigation of three case studies, this paper demonstrates that opportunities exist for the use of Green IS in organizations. The propositions represent initial theoretical statements regarding the relationships between system design principles, organizational context and individuals' behaviors vis-a-vis the environment. However, there are rich opportunities for further theory-building and testing. As a starting point, subsequent research could test the connection between the frequency of particular design principles and their importance for users and designers of CMS. For this study, the analysis assumed a logical connection between salience and importance, which could be explicitly validated with other research methodologies such as experiments or surveys. In addition, qualitative studies could explore CMS in different organizational contexts or across various green consumer sub-segments. The results may point to other persuasive design principles or combinations thereof that influence individuals' behaviors. Such research may also attempt to elucidate the impact of trade-offs between design principles. For instance, when a CMS emphasizes the principle of task reduction, simplifying assumptions may be made in the carbon footprint calculation with the effect of reducing accuracy and comprising the design principles of system credibility. Quantitative research methods, including laboratory and field experiments, could be used to test the proposed relationships and assess potential boundary conditions. Finally, turning theory into action, more participatory methods, such as action research, could examine the real-time impacts of specific CMS interventions in organizations (Lau, 1999; Myers, 2009). Collectively, these efforts would serve to augment the conceptual foundations of CMS specifically, and Green IS more broadly.

A third stream of research suggested by this work relates to the application of these findings to other technologies and categories of Green IS. This study complements previous work in sustainable HCI (e.g., DiSalvo et al., 2010; Dourish, 2010) and could help to shape future work. CMS target a wide range of attitudes and behaviors that affect the amount of carbon dioxide emissions attributable to an individual. However, other technologies and types of IS may target a more specific subset of ecologically responsible behaviors. Social media, for example, is increasingly being used to promote environmental initiatives (Mankoff et al., 2007) and home area networks are proposed in the electricity sector as a means to influence household consumption patterns (McDonald, 2008). These applications share similar characteristics to CMS in terms of intending to evoke voluntary behavioral changes. Thus, this study could help to inform research into these other applications, which could in turn uncover new and interesting insights in this domain.

Fourth, the emergence of the new category of integration support and the related persuasive design principles suggests that further research into cross-over applications of CMS that span individual and organizational perspectives is warranted. This research could take various forms. One logical progression would be to investigate the relationship between CMS, employees' environmental behaviors, and the overall effects on the organization's carbon footprint or environmental performance. Another intriguing avenue could be to explore the potential for integrating CMS with organizational CMS and environmental management systems. Research objectives could include delineating the unique design challenges and opportunities associated with such an integration; and articulating how needs of different stakeholders are protected and promoted within a multipurpose CMS-environmental management system. Finally, in the longer term, research should examine the implications of CMS that apply across an individual's multiple personal domains: work, home, community, volunteer organizations, and others. Admittedly, this type of global sustainability system is still more conceptual than real, but, as more communities and organizations begin to make

commitments to environmental sustainability, new opportunities for extending Green IS beyond traditional boundaries will arise. Therefore, exploratory research on this topic could address practical concerns while at the same time building scholarship pertaining to a new category of IS.

Climate change is a long-term, increasingly critical global issue; one that requires action from multiple levels, government, organizations, and individuals. It also requires that all available resources, including both technology and people, be leveraged. Through the practical and strategic use of Green IS, organizations can engage these resources, adopt more proactive environmental strategies and, in so doing, assume a meaningful leadership role in addressing this crucial global challenge.

Acknowledgements

I would like to thank Fred Niederman, the four anonymous reviewers, and participants of the Queen's School of Business MIS seminar series for their helpful comments on earlier versions of this paper. I would also like to thank Jane Webster for her constant support and guidance, and Alec Cram for his assistance with the research. Financial support for this research was received from The Monieson Centre at Queen's University and the Social Sciences and Humanities Research Council of Canada.

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Appendices

Appendix A. Sample Interview Protocol

This protocol is based on a vendor participant. Questions for client/user participants were tailored to adjust for their organizational roles.

Background

- Why did you join this company?
- How long have you worked for the company?
- How would you describe your role?
- What is your background or training?
- When it comes to environmental sustainability, some companies talk the talk and some of them actually walk the talk. How would you describe your company?

Design

- Please describe in more detail how the CMS was developed / [for clients: implemented within your organization]?
- What sources did you use with respect to design criteria? How were specific features chosen?
- What do you think about the idea of a "carbon footprint"? Do you think it makes sense? Is it easy to explain to customers/colleagues? Are there other/ better indicators?

User Feedback

- In one or two sentences, how would you describe the main objective of the CMS?
- Before developing the CMS did you do any market research? Did you do any pilot testing or user acceptance?
- What kind of feedback do you get from companies and their employees [for clients: from your colleagues]?
- What do companies/you do to encourage employees to use it? Can you give some examples where it has been really successful?

Specific Features

- What do you think is the best feature of the system? Can you show me? How did this come about?
- What constraints did you have to deal with in building [for clients: implementing] the system?
- If you had more resources (time, budget, developers), what features would you want to add and why?

Personal Impact

- Do you use CMS yourself? How often and for what?
- Does your company use it to manage its carbon footprint?
- From a user perspective, what do you like / dislike?
- Has it changed your behaviors at work or at home?
- Outside of the system, what things would make it easier for you to reduce your carbon footprint?

General Impact

- Technology is often considered as a potential change agent – changing how people work or perhaps view the world. Do you think CMS fits into this category? If so, how do you think it would change things?
- Do you think that using it has changed people's behaviors? Can you think of examples?
- Do you think all companies should have one?

Appendix B. Illustrative Quotations

Table B-1. Task Support

Vendors	Clients
Task Reduction	
"I think you can go from a ripple to a tsunami of details but neither one will matter until people clearly see the consequences. How does it affect you?" (Richard, Vendor 5)	"Well, for some people it is difficult to associate the tonnes of carbon dioxide. What does it mean to you?" (Sam, PUC)
Tailoring	
"They also sometimes ask us if they give us specific numbers for certain questions.... They gave us specific water treatment and pumping emission factors so we can incorporate that to make it more accurate for the client." (Rachel, Vendor 3)	"I was involved in making everything local. ... Some of the questions didn't fit with us. I took out a water question because our water isn't metered, and questions about subway and streetcars, we don't have those. So those aren't important." (Rita, NFP)
Personalization	
"You only get certain tips if you answer certain questions. For example, if I don't drive a car then I won't get all the driving tips." (Rachel, Vendor 3)	"Liked the option to tailor questions to self and eliminate irrelevant questions" (Focus group feedback, NFP)
Self-monitoring	
"So for me to want to use something like that I would want to be able to say okay well this is what my emissions where at this point in time and this is what they are now, am I making progress, am I getting worse? Without that kind of over time feedback it's kind of well you do it once, well that was neat, it sort of loses the… you're not bringing people back." (Owen, Vendor 3)	"The idea was to spend this year and tune ourselves up, find out where the problem areas were... to see what could be done, and then take another snapshot later in this year, see how this year had developed." (Thomas, ERC)
Simulation	
"For me to want to use a tool like this, there would have to be far more to it. I would want to have some scenario-type stuff because I would want to be able to go what if, what if, what if." (Owen, Vendor 3)	"We've actually talked about... trying to actually do some comparisons, like.. "if you recycle this much, it does that, and this and that", and it was amazing how much just little things could affect it so much." (Trevor, ERC)
Commitment	
"Using the pledges thing will definitely be something very important." (Megan, Vendor 3)	"I like the Pledge section as well because you can put different things on the pledge" (Rita, NFP)
Personal Learning	
"I would rather sit with someone and go through their hydro bills and their waste sent to land fill and go through all that kind of stuff. And say, okay this is what this means." (Richard, Vendor 5)	"The barrier is really knowledge, I think it's a difficult thing to do, so it's one thing we're trying to address" (Mark, PUC)

Table B-2. Dialogue Support	
Vendors	**Clients**
Praise	
	"Perhaps you can ask people what they are doing to reduce their footprint as they go along so they get some positive re-enforcement as they go." (Focus group feedback, NFP)
Rewards	
"I mean, a calculator is only as useful as the initiatives that are put around it. If I just put a calculator on the web...[and say] take advantage of it if you wish, it's not going to get a lot of traction. But, if you put it out and say if you fill it out you could win a Prius, you know, you would find a lot more people filling it in." (Will, Vendor 3)	"They [staff in one office location] started their own incentive program to help promote conservation. For instance if you're seen turning off your monitor you get [a credit] and you collect these and at the end of their initiative you purchase conservation relief items on a storefront." (Mark, PUC)
Reminders	
	During the campaign email reminders were sent out 2-3 times per month. In addition, the company takes advantage of company and departmental communications. (Sam, PUC)
Suggestions	
"We also have a tips section which I think is quite beneficial. So that lets them know what they can do to reduce their footprint." (Rachel, Vendor 3)	"We have tips on how to print efficiently in the various office programs like Microsoft Word, Excel, there's little tips and tricks that people can do to make sure that they don't print unnecessarily or they can maximize their spacing when they're printing, things like that to reduce the paper." (Mark, PUC)
Similarity	
"So how do you embed the message? How do you do it? Electronic Arts, Need for Speed is a good example. Kids are absolutely enthralled sitting there with their X-Box, Gameboy or whatever thing they've got, big cars, big engines, speed. So.. What do you do – Need for Speed hybrid?" (Richard, Vendor 5)	
Liking	
"If somebody clicks on a website and it is interesting, then they stay there. And they click through to other things. If it's boring or there is too much information, then they exit." (Richard, Vendor 5)	"Attractive site, clearly stated questions and easy to use" (Focus group feedback, NFP)
Social Role	
Social Networking	
"The whole social networking bit in [our CMS] hasn't been really worked out. It hasn't been fully implemented or worked out so I personally haven't used them" (Megan, Vendor 3)	"I feel like in terms of networking online we've progressed from a forum kind of way to more interactive with people. And I feel like that would be really neat, if our calculator had that." (Rita, NFP)

Table B-3. System Credibility Support	
Vendors	**Clients**
Expertise	
"Sometimes we are dealing with companies that really don't have this kind of in house knowledge and they just kind of assume that we are the experts on it and we're trusted to do research on this." (Owen, Vendor 3)	"We have a fairly strong knowledge of sources and operations...[and], we do have very strong links to getting that kind of data when needed" (James, NFP)
Surface Credibility	
"It is something that people can't convey, they just look at it go 'oh, this is better', well, why is it better?" (Josh, Vendor 3)	"The calculator covered, from what I can tell, most areas that would contribute to carbon outputs very well." (Focus group feedback, NFP)
Real-world Feel	
"So the big asset of our company, for Vendor 3, isn't the products, it's the questions. It's the research and we are... that was a bit of an epiphany when I realized it." (Logan, Vendor 3)	"I like the "help us improve" (Focus group feedback, NFP)
Authority	
"You're seeing that in certain places like the UK for example, where I'd say almost everybody is using the UK DEFRA guidance documents to calculate. In Australia they are all using government documents to calculate." (Owen, Vendor 3)	"The general manager in Halifax, he says, he emails everybody and says, "Some people walk the walk and some people talk the talk", and there's a picture of him pushing his push mower, mowing his lawn just covered in sweat, and you know that's pretty cool." (Thomas, ERC)
Third-party endorsements	
"[CMS] offers "Gold Standard offsets" which are the most expensive and cost up to a factor of 2.5 times other non certified offsets." (Nick, Vendor 2)	"We had some high profile people coming in and doing this advertising campaign in the newspaper where these tips would show up, randomly in the newspaper." (James, NFP)
Verifiability	
"One of the challenges is making people comfortable with the final results of the calculations; that is, incorporating an element of transparency into the calculation that we do and providing that information." (Owen, Vendor 3)	"So we need to look at our spread sheets... my team has really made a concerted effort to have a very documented spread sheet monitoring [government] emission factors, really making sure that we have a system of QA/QC in place." (Victoria, PUC)

Table B-4. Social Support	
Vendors	**Clients**
Social Learning	
"Just the idea that you could compare to other people, you could share your results with other people easily, that's something that more and more I have seen in other competing calculators, everybody is kind of building that in." (Owen, Vendor 3)	"Some of the [locations] were more advanced in what they had been doing over the past little while than other places, but the Green Team was mostly to try to get everybody on the same page, and try to get some places brought up and, you know, try to get everybody to a point where we can try to get rid of our carbon footprint." (Trevor, PUC)
Comparison	
So, comparing it to other people, they get a sense of how good or bad they are. The Canadian average is 12 or something, they think oh, I guess I'm not that bad. But if you are living in Sweden, then it's 2, then you think oh, geez, same basic latitude on the planet but completely different footprints. So that comparison is important." (Josh, Vendor 3)	"I really liked comparing my footprint to other cities/countries, really interesting to see the differences." (Focus group feedback, NFP)
Normative Influence	
	"And I think the peer pressure thing helps a bit too, because you'll get the odd person who is more into it than the other and kind of… they're policing each other a little bit." (Thomas, ERC)
Facilitation	
	"It's good to see that things are actually going on to try to help the planet – I think a lot of people's lack of participation reflects a lack of faith in any real purpose in trying because they hear our effects on earth are just so strong, but the events really show that a lot of people are trying to change things, and in many different ways! (Feedback form, NFP)
Cooperation	
	"We're all kind of a little bit of a resource for each other." (Thomas, ERC)
Competition	
"So you add in competition theory and it's not just guilt, its I want to be better, and when you start to do things like leader boards and rankings and how are you with people and group and all that online gaming theory it works well." (Josh, Vendor 3)	
Recognition	
	"Now, the fellow that organized that has since been nominated by his peers for the conservation leadership awards and so it is being recognized and that is being shared across the organization, so… that is a way of building momentum for actions like that." (Victoria)
Guilt	
	"It's a little bit of 'everybody wants to recycle because it's good for the environment', and it's a little bit of 'the guilt thing' as well." (Trevor, ERC)

Table B-5. Integration Support	
Vendors	**Clients**
Complementary Programs	
“Sometimes it does take the big guy to make the decision to say ‘no printers’. We don’t reimburse [any] more for ink cartridges. You network to the printer in our office.” (Richard, Vendor 5)	“There's a carpool webpage and actually it's not even done by us, it's somebody else that... it's actually for only a few sites, and we're hoping to have that for every site where they have a carpool list of people that are seeking people coming from certain areas.” (Mark, PUC)
Goal Consistency	
“The other major benefit to companies is that company's employees today are more, very measurably interested in the environment and so often they have questions. So if you hire someone out of school today you will often get the question, 'what are you doing for the environment?' And so a company that does something for the environment looks better than one that doesn't.” (Will, Vendor 3)	“Pretty much at the very beginning, the goal was trying to get all of the [locations] on the same page. The ultimate goal is getting everybody emissions free.” (Trevor, ERC)
Technological Integration	
“That’s one of the reasons why they are porting the reporting tool over to [CMS] because then you can create a system where you can have an employee engagement tool that feeds directly into a company assessment tool. So if you had a tool that allowed the employees to answer all their commuting information that could feed directly into your corporate accounting there is an interesting synergy between the two products that if you ever got them tied together properly they could feed into there quite well.” (Owen, Vendor 3)	“The only thing that might be viewed as a barrier to some for calculating their carbon footprint is the fact that they have to log-in and become a member. My one friend believed this is a barrier to participation, another one of my friends disagreed and I am sort of sitting on the fence about it.” (Focus group feedback, NFP)
Intra-organizational Coordination	
	“The unions have been really supportive of what we're doing and they're always wanting to help. In the near future we will hopefully engage the unions and have them include us in their communications to all the union members.” (Mark, PUC)

About the Author

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