# Development of a Prototype Knowledge Discovery Portal for Energy Informatics

**Gabriel J. Costello[1], Ray Clarke[1], Brian Donnellan[2], John Lohan[1]**

[1]Galway-Mayo Institute of Technology, Ireland

{gabrielj.costello, ray.clarke, john.lohan} @gmit.ie

[2]National University of Ireland, Maynooth

brian.donnellan@nuim.ie

**Abstract** This paper describes the development of a prototype knowledge discovery portal (KDP) for energy informatics. The research domain is Ireland which is increasingly challenged to achieve energy efficiency targets and to implement renewable energy systems (RES). The reasons for undertaken this research is to provide a mechanism to disseminate information on energy efficiency and renewable energy technologies to a number of sectors: community, educational, industrial and research. The prototype KDP was developed using design-science methodology. The work integrates information both in the horizontal and vertical axes. In the horizontal plane it provides information to community users, educational bodies and industrial companies. In the vertical plane it allows deeper access depending on the requirements of the user: from technological overviews to detailed data from the energy system (solar collectors, heat pump and wind turbine). Future work will involve further development of the portal and extending the KDP for energy to other technologies and sectors.

## Introduction

The issue of environmentally sustainable development and the area of "Green IS" has recently begun to appear on the information systems research agenda (Watson et al., 2010; Boudreau M. et al., 2008; Chen et al., 2008; Webster, 2009). The aim of this paper is to contribute to this debate by describing the development of a prototype knowledge discovery portal (KDP) for energy informatics. The research domain is Ireland which is increasingly challenged to implement energy efficiency targets and renewable energy systems (RES) to decrease dependency on imported fossil fuels. The success of the Irish economy in the 1990s resulted in an increase in energy demand with an associated rise in greenhouse gas emissions. Recently an energy white paper has been published on delivering a sustainable energy future for Ireland (DCMNR, 2007). Priority has been given to energy management practices in industry, the services sector and the public sector (Forfas, 2010). Also an Irish government report has outlined the vision of how the development of the green economy can create employment and exploit export opportunities (DETI, 2009). The longer term goal of developing this portal is to provide a mechanism to disseminate information on energy efficiency and renewable energy technologies to a number of sectors: community, educational, industrial and research.

The paper will be presented as follows. Firstly the background and drivers of the development of a KDP is outlined. Then a literature review is presented. The research approach will then be outlined followed by an overview of the knowledge discovery portal (KDP) for energy. Finally a discussion of the significance of the KDP will be presented together with conclusions and plans for future work.

## Background

The research is based in a third level educational institution in Ireland that has a total enrolment of approximately nine thousand students. The mission statement and vision of the Institution is to "develop life-long learning opportunities through our teaching and research, by supporting regional development consistent with national higher education policy". The Knowledge Discovery Portal for Energy (KDP-Energy) concept supports all these broad Institute goals. It was identified by the Institution's Centre for the Integration of Sustainable Energy Technologies (CiSET) in 2007 as an efficient means of disseminating information to a wide range of stakeholders including the wider external community, undergraduate students, internal/external researchers and industry. In recent years a department within the Institution has undertaken a number of initiatives to build a state-of-the-art teaching and research infrastructure which consists of an undergraduate Energy Training Laboratory, Campus Energy Monitoring Programme and the development of Postgraduate Research Facilities through CiSET.

Each of these initiatives is heavily instrumented so that energy system performance or energy consumption can be continually monitored. The prototype KDP presently includes one solar thermal collector. Figure 1 presents a vision of the hardware energy infrastructure on which the KDP software application will be built. The circled area shows the sections for which the prototype was developed.

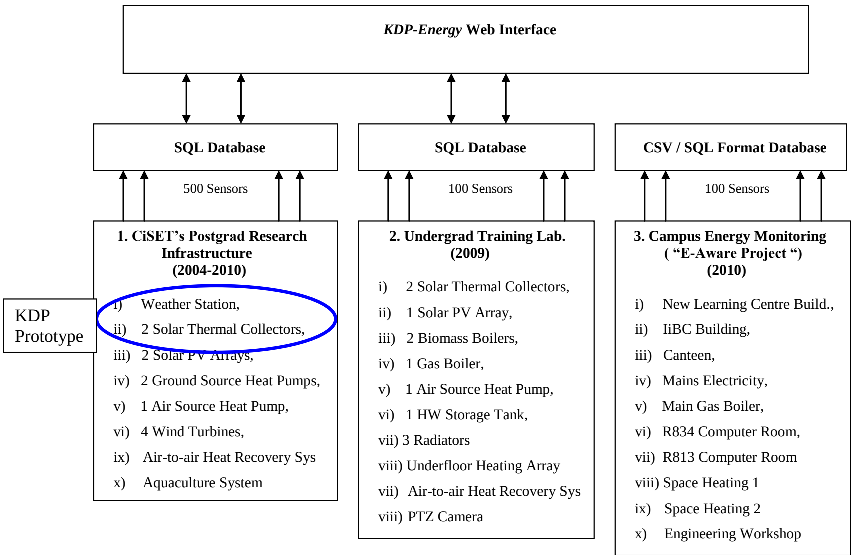


**Fig. .** 1: Top level schematic of the energy efficiency and sustainable energy initiatives

A brief literature review of the emerging area of energy informatics is presented in the next section.

## Literature Review

For every extra kilowatt hour (kWh) of electricity used by ICT equipment, the US economy increased overall energy savings by a factor of around 10. That was the conclusion of research by the American Council for an Energy Efficient Economy (ACEEE), which claims that the current focus on soaring IT energy use has distracted from the net energy savings IT systems deliver for other sectors of the economy. The report, *Information and Communication Technologies: The Power of Productivity*, (Laitner & Ehrhardt -Martinez, 2008) argued that IT's role in the design of new products and services and its ability to replace many energy intensive processes has led to a net improvement in energy use. It proposed that the ICT systems were subject to an "energy paradox" whereby "more attention tends to be paid to the energy consuming characteristics of ICT than to the broader, economy wide, energy saving capacity that emerges through their widespread and systematic application."

Despite the fact that Green IT (Sobotta *et al.*, 2009) now holds a significant position on the strategic agenda of many large corporations and government agencies, relatively little has been published in the IS academic literature about either the theoretical or practical aspects of managing and measuring this nascent phenomenon. Academics are starting to look at Green IT from three viewpoints:

(i) the Innovation Perspective where IS researchers (Webster, 2009) have drawn attention to the potential of IT Innovation (in this case Green IT Innovation) to contribute to company competitiveness.

(ii) Competitive Strategy Perspective where researchers such as Michael Porter explore the concept of "innovation offsets" – where companies can "not only lower the net costs of meeting environmental regulations, but can lead to absolute advantages" over competitors (Porter & Van Der Linde, 1996). Banking on growing consumer demand for green products and services, some retailers have developed "sub-brands" with a green angle. Increasingly, manufacturers across industries will use green products and green corporate behavior as a way to appeal to this growing segment of customers.

(iii) Corporate Social Responsibility

Appelman and Krishnan (2010) argue that while ICT energy efficiency objectives are important, they need to be supplemented by eco- efficiency programs to maximise the impact. Furthermore, in a point that is very relevant for this paper, they conclude that better building design, management and automation could save 15% of buildings emissions. They calculate that globally, smart buildings technologies would enable 1.68 $GtCO_2e$ of emissions savings, worth Euro216 billion ($340.8 billion). An important distinction to be made here is the key difference between "green IT" and "green IS" (Boudreau M. *et al.*, 2008):

- An information technology (IT) transmits, processes, or stores information.
- An information system (IS) is an integrated and cooperating set of software using information technologies to support individual, group, organizational, or societal goals.

The development of this KDP for energy, we argue, meets the definition of a "green IS" as it uses ICT to support the "individual, group, organizational" and "societal goals" as outlined above.

Some authors (Robèrt *et al.*, 2002) advocate a systems approach to sustainability and they map essential elements for developing sustainability. This includes the documentation of how each of the elements relate to the application of sustainability tools pioneered by the authors. Another interesting addition to the sustainability debate is the cost reduction and increased efficiencies associated with the move to "cloud" computing. In a recent report commissioned by Microsoft it was found that carbon emissions were reduced by 30% when cloud computing applications were used compared with on-premise installed business applications (Accenture, 2010). Vezzoli & Manzini (2008) contend that ICT has the capacity to support environmental sustainability by gathering together "individuals concerned about the same topic, to collect the critical mass required to do something, and act accordingly" (p. 35).

## Research Approach – Design Science

This section will provide an overview of the research approach employed in this study. The seminal paper by Hevner *et al.* (2004) provides "a concise conceptual framework and clear guidelines for understanding, executing and evaluating [design science] research" (p. 75). They go on to state that design science is fundamentally a problem-solving paradigm that seeks to "create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, implementation, management and use of information systems can be effectively and efficiently accomplished" (p. 76). Furthermore they trace the roots of design science to Simon's well-regarded publication in the 1960s of *The Sciences of the Artificial*. Markus *et al.* (2002) outline their use of design science to address the challenge of developing executive information systems (EICs). An important concept in design science is that of an IT artefact which is summarised in table 1 below.

**Table 1.** A taxonomy of IT artefacts -from Hevner et al.(2004 p 77)

| ***Artefact*** | ***Description*** |
|---|---|
| constructs | vocabulary and symbols |
| models | abstractions and representations |
| methods | algorithms and practices |
| Instantiations | implemented and prototype systems |

Hevner *et al.* describe the primary goal of their paper is "to inform the community of IS researchers and practitioners of how to conduct, evaluate, and present design science research" (p. 77). According to Walls *et al.* (1992) design is both a process (or set of activities) and a product (artefact) while Markus et al (2002) explain that a build-and-evaluate loop is usually iterated a number of times in the development of an artefact. We used the seven guidelines proposed by Hevner *et al.* for this study: Design as an Artefact, Problem Relevance, Design Evaluation, Research Contributions, Research Rigor, Design as a Search Process and Communication of Research.

Recent research on the implementation of DSR has found that while the guidelines of Hevner *et al.* are largely endorsed, caution needs to be exercised when applying them (Venable, 2010). We will evaluate the research in terms of the design-guidelines in the discussion section of the paper. However we must first provide an overview of the artefact developed in this study.

## KDP Prototype

This section describes the current status of the KDP prototype which has been developed for the area of energy informatics. The homepage is shown in figure 2 and it has been designed to deliver relevant information on energy systems and efficiency to the following four user groups:

i) **Wider Community:** including both general interest audience (through 'general interest' content on the Home Page) and proactive communities who are undertaking different community based energy awareness projects within their communities (e.g. E-Aware Project); SEZ Project at Tuam; and the Sustainable Islands Project on Innis Oir ) through content on the Community Pages.

ii) **Education:** students undertaking formal education, with the priority being third/fourth level; second level and primary level (in that order). This information will be made available through the Education Pages.

iii) **Research:** Activities of the Centre for the Integration of Sustainable Energy Technologies (C*i*SET) and its collaborators will be reflected on the Research Pages.

iv) **Industry:** Deliver material that supports related industry groups such as Solar Industry; Wind Power Industry, BER Assessors, Building/Construction Industry on the Industry Pages.

The KDP homepage is presented in figure 2 below.

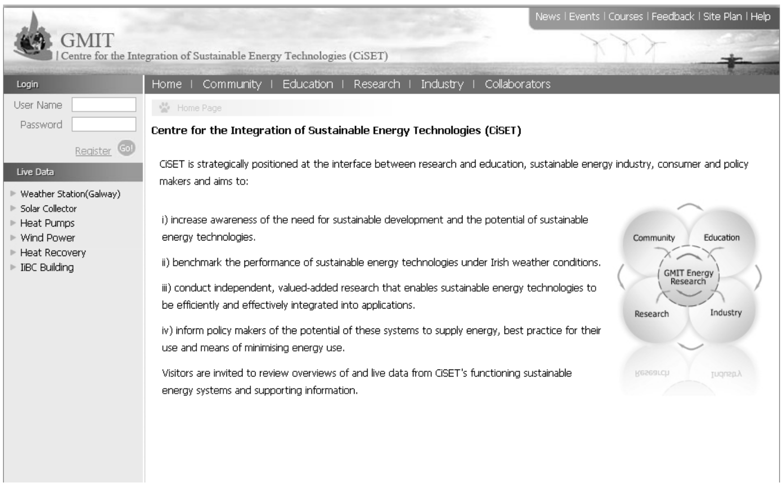


**Fig 2:** Homepage of the prototype KDP for Energy.

## *E-Learning Methodology*

An e-learning environment has been developed for two technologies, a solar thermal collector representing one element of the infrastructure together with a weather station representing another element.

Figure 3 presents the IS interface for the solar thermal collector. This sequence was specifically designed to support e-learning.

A five step e-Learning methodology was employed during the research:

- **Step 1** – System Overview.
  Concept: Displays the key features of the system.

- **Step 2** – Principle of Operation.
  Concept: Defines the principle by which a system operates and the sequence of events or conditions under which it operates.

- **Step 3** – Institution's Systems.
  Concept: Introduces the user to the specification of the system.

- **Step 4** – LIVE Data..
  Concept: Presents both Live and Historical (in case of weather station) performance data.

- **Step 5** – Further Information.
  Concept: Presents URL for other related and useful sites (inside and outside of the Institution)For both systems, live data can be retrieved from the relational database (Step 4) (if viewed from within the firewall) and displayed on a flash enhanced system schematic. While it is possible to retrieve historical weather data, such an interface has yet to be developed for the solar thermal collectors.

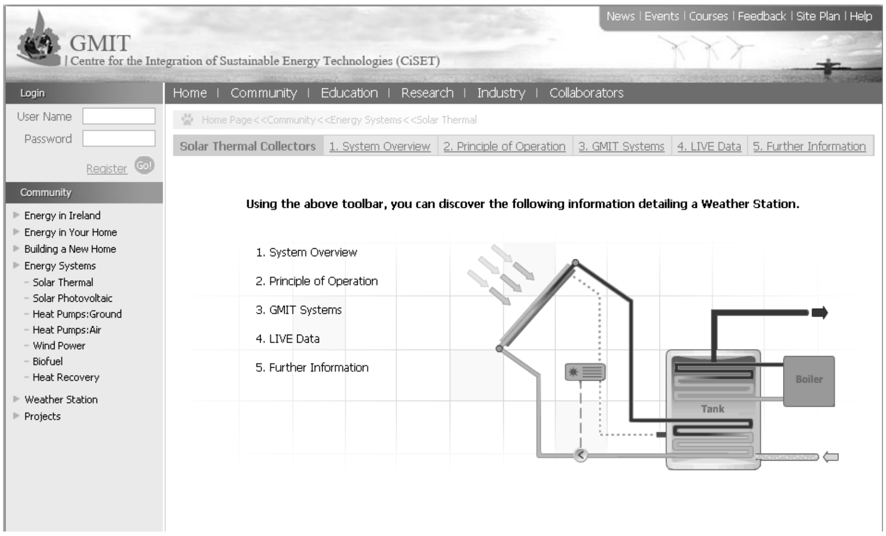


**Fig 3:** Index page of the educational component for on-line solar system

## *Graphical User Interface and Programming Languages*

Emphasis is placed on the use of simple, yet attractive, consistent and engaging graphics, which are supplemented by small portions of relevant information that pop-up when the user move a mouse over certain active zones. The intention is to engage the user with a combination of interactive graphics and take them on an educational journey of 'discovery' (Steps 1-3) that culminates in an opportunity to view real (LIVE) system data (Step 4). Links to other useful or relevant sites are also presented under Further Information (Step 5).

This journey should be of equal interest to specialists in the energy field and non-specialists alike, whether student or casual visitor, researcher or industrialist.

This demo web-portal has been developed using the following software: Microsoft Visual Studio 2005, Microsoft SQL Server 2000, Flash CS3, Dreamweaver, Photoshop and Flex 3.0, and programmed using ASP.NET(C#), T-SQL, Actionscript 3.0 as well as HTML/CSS/Javascript and XML web services.

## Discussion

The concept of establishing a Knowledge Discovery Portal (KDPs) is a key and distinctive element to enable the Institution to fulfil the Research Strategy articulated in the Strategic Plan (2010-2014) to 'integrate research, teaching and regional development'. KDPs aim to encourage the transfer and sharing of knowledge and research outcomes to all learners and end users so as to maximise the returns to education, the economy and society. They will foster the vision of promoting knowledge discovery and innovation which will allow the Institution deliver new learning opportunities for the knowledge society. This dovetails perfectly with the Institution's teaching and learning remit and facilitates the integration of research, teaching and regional development.

The knowledge discovery portal will place research, including the personnel, project or initiative, motivation, methodology and findings on a more accessible platform within the wider community. This should help to increase awareness of the knowledge creation process as well as maximise the economic and societal impact derived from ongoing research by promoting the exchange of ideas between the education (including primary and secondary level) and the research community, policy makers, private enterprise, and societal stakeholders. The success of this initiative depends heavily on the ability of researchers and the Institute to build-in a new level of access, communication and dissemination about research so that new knowledge and methodologies can be disseminated effectively.

Accessibility will be provided by ensuring both physical access to visit research facilities, meet researchers and view animations, demonstrations, laboratories and posters as well as remote access through interactive web-based models, information sites and virtual laboratories.

Effective knowledge discovery platforms would help to excite younger generations about possible research careers, promote on-going research and aid the development of the knowledge society regionally, nationally and internationally, stimulate interaction with external stakeholders to generate new research ideas, while also helping to attract further funding to help sustain future research initiatives."

This concept embraces the traditional modes of disseminating research findings such as publication and presentation, but also builds a new level as accessibility to the research environment whether technology enabled via the internet or physically via demonstration or site visits. We will now examine the work using the guidelines proposed by Hevner *et al.* which were alluded to previously.

*Guideline 1: Design as an Artefact*: Hevner *et al.* propose that the result of design-science research must produce an IT artefact that addresses an important problem. The prototype KDP is an artefact, albeit an early version of a longer term project, that meet this criterion.

*Guideline 2: Problem Relevance:* The issue of sustainability and energy sources are a pressing problem for not alone business and industry but society. The KDP is an attempt to use information systems to contribute not only to the debate but to assist those who wish to implement solutions to this global problem

*Guideline 3: Design Evaluation:* Hevner *et al.* point out (p. 85) that the technical infrastructure is incrementally built and the present KDB artefact is a step on the complete research journey. They provide five design evaluation methods for the designed artefacts (p. 86). We believe that our study meets two of these evaluation methods. It meets method 1 –*observational*- as this is part of a case study of the artefact in an organisational environment. Also it meets method 5 –*descriptive*- as detailed scenarios have been implemented to test the KDP in a simulated environment.

*Guideline 4: Research Contributions:* We believe that the KDP is a novel contribution to an emerging area in the provision of live data from renewable energy systems and from energy management systems.

*Guideline 5: Research Rigor:* The authors have striven to meet both rigor and relevance in the development of the artefact which have used established information systems development techniques.

*Guideline 6: Design as a Search Process:* A search process that was employed to benchmark the KDP against initiatives in this area by other educational institutions.

*Guideline 7: Communication of Research:* The KDP has been extensively demonstrated to energy professionals, IT developers and member of the public interested in this area. This paper is the first attempt to bring the work to the attention of the IS community.

We argue that this paper makes a contribution to both research and practice. Some similar initiatives have been introduced in the educational area (Harvard, 2010 ). However this work integrates information both in the horizontal and vertical axes. In the horizontal plane it provides information to community users, educational bodies and industrial companies. In the vertical plane it allows deeper access depending on the requirements of the user: from technological overviews to detailed data from the energy sensors. The work is limited in that it is the first phase of a more detailed project, articulated in figure1 that will require more extensive evaluation.

## *Conclusions*

This paper makes a contribution to the emerging debate in the information systems discipline concerning sustainability. It outlines the initial prototype development of an energy informatics portal that will integrate both RES (renewable energy sources) and RUE (rational use of energy) data. The approach taken to the paper was based on design-science methodology. It is constructed from a real-life case that is based in the educational sector but had the objective of reaching out to both industrial and community sectors.

Future work will involve further developing the KDP based on four goals:

1. Evaluate the aesthetic design of the current portal to enhance appeal and navigation (Task 1)
2. Refine the existing web-portal architecture to increase performance and functionality (Task 2)
3. Develop engaging GUIs for each of the 4 remaining energy systems (Task 3)
4. Profile the Campus' E-Aware energy monitoring project (Task 4)

Also there is room, we argue, to use this study to contribute to the philosophical debates on energy and sustainability. For example the work of Jacques Maritain on the concept of the "common good" could provide a fruitful basis for this discussion (Maritain, 2002). The development of the KDP provides an exemplar of how ISD can be used for eco-sustainability from the knowledge creation, dissemination and discovery perspectives. Watson *et al.* (2010, p24) call for action by IS scholars in incorporating eco-sustainability as an "underlying foundation in their teaching.". We hope that the paper helps to stimulate debate on how the ISD discipline can contribute to the important sustainability agenda by generating, disseminating and using energy for both economic and social advantage.

## References


Accenture (2010) Cloud Computing and Sustainability:The Environmental Benefits of Moving to the Cloud. In Green IT Expo 9th November *2010*, QEII Conference Centre London.

Appelman, J. H. and Krishnan, S. S. (2010) EFFICIENT AND EFFECTIVE - Toward a Strategy that Works 'Forever. In *INNOV 2010 - International Multi-Conference on Innovative Developments in ICT*, Athens, Greece 29th-31st July 2010.

Boudreau M., Chen A. and Huber M. (2008) Green IS: Building Sustainable Business Practices In *Information Systems: a Global Text Project* http://globaltext.terry.uga.edu/. (Watson, R., Ed).

Chen, A. J. W., Boudreau, M. C. and Watson, R. T. (2008) Information systems and ecological sustainability. *Journal of Systems and Information Technology* 10 (3), 186-201.

DCMNR (2007) Delivering a Sustainable Energy Future for Ireland 'The Energy Policy Framework 2007-2020'. *Government White Paper. Dublin.*

DETI (2009) Developing the Green Economy in Ireland. Department of Enterprise, Trade and Innovation

Forfas (2010) Adaptation to Climate Change: Issues for Business www.forfas.ie.

Harvard (2010 ) Harvard University Building Dashboard http://buildingdashboard.com/clients/harvard/cowperthwaite/ accessed November 2010.

Hevner, A. R., March, S. T., Park, J. and Ram, S. (2004) Design Science in Information Systems Research. *MIS Quarterly* 28 (1), 75-105.

Laitner, J. and Ehrhardt -Martinez, K. (2008) Information and Communication Technologies: The Power of Productivity: How ICT Sectors are Driving Gains in Energy Productivity", Report No. E081, American Council for Energy Efficient Economy, February 2008. .

Maritain, J. (2002) *The Person and The Common Good (translated by John J. Fitzgerald).* University of Notre Dame Press; New Impression edition (October 31, 1973)

Markus, M. L., Majchrzak, A. and Gasser, L. (2002) A Design Theory for Systems that Support Emergent Knowledge Processes. *MIS Quarterly* 26 (3), 179-213.

Porter, M. and Van Der Linde, C. (1996) Towards a New Conception of The Environment-Competitiveness Relationship. *Journal of Economic Perspectives* 9 (4), 97-118.

Robèrt, K.-H., Schmidt-Bleek, B., de Larderel J. Aloisi , Basile, G., Jansen, J. L., Kuehrg, R., Thomase P. Price , Suzukig, M., Hawkeni, P. and Wackernagelj, M. (2002) Strategic sustainable development — selection, design and synergies of applied tools *Journal of Cleaner Production* 10 (3), 197-214

Sobotta, A. T., Sobotta, I. N. and Gøtze, J. (2009) *Greening IT : How Greener IT Can Form a Solid Base For a Low-Carbon Society.* Creative Commons Attribution Non-Commercial Share Alike http://creativecommons.org/licenses/by-nc-sa/3.0/legalcode.

Venable, J. R. (2010) Design Science Research Post Hevner et al.: Criteria, Standards, Guidelines, and Expectations. In *Global Perspectives on Design Science Research, 5th International Conference, DESRIST 2010, St. Gallen, Switzerland, June 4-5, 2010.* (Winter, R. and Zhao, J. L. and Aier, S., Eds), pp 109-123, Proceedings. Lecture Notes in Computer Science 6105 Springer

Vezzoli, C. and Manzini, E. (2008) *Design for environmental sustainability.* Springer, Berlin ; London.

Walls, J. G., Widmeyer, G. and Sawy, O. E. (1992) Building Information System Design Theory for Vigilant EIS *Information Systems Research* 3 (1), 36-59.

Watson, R. T., Boudreau, M.-C. and Chen, A. J. (2010) Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community. *MIS Quarterly* 34 (1), 23-38.

Webster, J. (2009) A Call for Action in Tackling Environmental Sustainability Through Green Information Technologies and Systems, . In *Panel Discussion at ECIS 2009 Conference, Tuesday 8th June, 2009*.