What IS can do for Environmental Sustainability

A Report from the CAiSE´11 Panel on Green and Sustainable IS

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1. Introduction

Concern about the environmental impact of human activities is ever increasing and several efforts have been initiated globally to reduce energy consumption and to increase energy efficiency. At a European level, a number of initiatives exist under the "Energy 2020" label which identifies the energy priorities for the period up to 2020. In December 2008 the European Council and Parliament adopted the Climate and Energy Package that reinforces Europe's commitment to:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- Source 20% of EU energy from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

Focusing on Information Technology, the European Commission DG on Information Society and Media has started several projects that focus on the two main issues that are related to energy and ICT:

- *Energy reduction enabled by ICT*: this includes energy efficient buildings, smart energy grids, optimized manufacturing, telecommuting and teleconferencing, and reduced paper consumption.
- *Energy consumption of ICT solutions*: ICT itself is a consumer of energy, in PCs, data centres, networks, and other computer-based devices. It is estimated that energy consumption of ICT will equal 15% of total consumption by 2020 (source EU Commission DG SocInfo, Unit H4).

The panel on Green and Sustainable Information Systems at the 21st International Conference on Information Systems Engineering (CAiSE'11), held in London in June 2011, was intended to discuss issues in Environmental Sustainability and Information Systems within the Information Systems Engineering research community. Information systems, which have become pervasive and hence impact on most aspects of human activity, can help to reduce the negative impact of human activities on the environment in two main areas.

On the one hand, information systems can play an important role in raising awareness of and controlling energy efficiency in a variety of areas, such as smart cities and smart buildings, traffic control, and utility management. Therefore, we can talk of designing *Information systems for sustainability*.

On the other hand, information systems themselves use computing resources and related facilities in data centres and offices and therefore have an impact on the environment. When these resources are handled with care, we may talk of *Sustainable Information Systems*. Several authors, starting with Murugesan (2008), have discussed the impact on the environment of all the phases in the ICT life cycle, from design to production of IT equipment, to usage and finally to disposal.

Whilst great emphasis has been placed on the production and assessment of energy efficient hardware, consideration of energy efficiency in the context of information systems and their design has only recently emerged as an issue. The panel has provided a forum to examine the different types of green and sustainable information systems and the participants have discussed emerging research topics and possible future research developments and goals. Recent work by Watson et al. (2010) has proposed some general approaches to energy management. Using the term *Energy Informatics*, the authors emphasize the importance of information in reducing energy consumption. In particular, they analyze energy and flows and the need for providing adequate monitoring and control both for users and providers of systems. Such a general approach is relevant to many of the themes analyzed by the panel which has focussed on information management for energy efficiency.

The areas of research in ICT and the impact on the environment considered by the panel have been the following:

- *Information Systems as consumers of power*: In this domain the impact on the environment of IT infrastructure such as office equipment, data centres and service centres is considered. Research in this field is labelled in various ways, such as Green IT, Green IS and Sustainable computing. In the following, we denote this area as *Green IS*.
- *Information Systems to support awareness and control of energy efficiency*, for example in buildings, cities, water, electricity grids and so on. In this case the research is mainly in the specific application area, but IS research can contribute towards understanding and developing the Green Domain, defining the relevant concepts and the relations between them, managing monitoring data, providing services and service infrastructure and focusing on Quality of Service (QoS). This research area is labelled Green IS or IS for Green. We will adopt *IS for Green* for the sake of clarity.

All the authors of this report have served on the panel that was led by Barbara Pernici. The following questions were posed to the panelists:

- what is the contribution that the information systems community (and here, we refer primarily to those who engineer information systems) can make to addressing the above themes? The main underlying concepts are based on conceptual modelling, the definition of requirements with several stakeholders and process modelling.
- what are the possible directions for future research and what experience and results have you gained within the field?

This report summarises the panelists' views, focusing on specific aspects related to information systems engineering and, in particular, on the following main themes:

Green IS

- Service centres design;
- Service centres and networks.

IS for Green

- Developing Capabilities for Sustainable ICT;
- Establishing Green Processes in Organizations;
- A “Smart World” perspective;
- An ethical perspective.

The paper discusses the topic of sustainability and information systems engineering, focusing on the themes listed above. In Section 2, we discuss the contributions of the IS research community to Green IS and IS for Green. Then, in Section 3 we analyze research directions and results. Finally, in Section 4 we summarize future research and place it within the context of related work.

2. Contributions of the IS community

2.1 Green IS

The growing development of online services results in an increased number of large service centres, often interconnected to each other to provide a better performing and more reliable service. Advanced information systems can improve the energy efficiency of such an infrastructure in several ways.

2.1.1 Service centres design

The main focus of service centres design is the IT infrastructure and its lifecycle. One of the first aspects of the design process is the management of equipment and, in particular, the acquisition of energy efficient systems. Initiatives such as the SPEC Power[1] support the evaluation of the impact on the environment of IT equipment. In this area, the main

[1] http://www.spec.org/power/

contribution of information systems lies within the management of information to support decisions relating to the most energy-efficient infrastructures.

Recent studies have also underlined the fact that the same application can be more or less energy efficient based on the middleware infrastructure on which it is executed; for instance, Capra et al. (2012) analyze CRM and browsers running on different platforms and how their energy consumption varies. Such analyses can be a starting point to support system configuration, considering not only performance but also the energy consumed by applications.

On the other hand, considerable attention is paid to improving energy efficiency in data centres with the goal of reducing the PUE (Power Usage Efficiency), defined as the ratio of total energy consumption within the data centre to IT power consumption. In this case the emphasis is only on the facility infrastructure and how to manage the service centre building using IT support to control the facility. However, some recent research is approaching energy efficiency from the point of view of managing the computing resources. This research focusses on a more efficient use of computing resources, for instance, using consolidation and virtualization approaches and dynamic management of resources such as servers, storage and the task allocation of servers. The research considers not only performance but also energy efficiency and the possibility of power capping.

2.1.2 Service centres and networks

In many studies concerning Green IT the importance of networks tends to be neglected, while much research focuses on servers and data centres (Berl, 2009).

Networks currently consume more energy than data centres and this tendency is expected to increase towards the year 2020. Indeed all alternatives regarding the manner in which we organize human activity that requires information processing will heavily impact energy consumption in the networks themselves. Thus any choice we make about simple options such as:

- whether to distribute or concentrate the computational and data storage and retrieval activities;
- whether to do collaborative work on a shared database or in a distributed manner with separate copies;
- whether to travel to the office or work from home,

will all have an effect on how much energy is actually consumed within the networks. This includes networks that are needed within data centres and organisations, as well as the networks that interconnect us worldwide, allow us to reach each other by voice or email, and which allow us to access and store data and services.

Major network service providers, such as BT, have annual electricity bills in excess of one billion dollars or the equivalent, so that a single large communications provider has an electricity consumption that is comparable to 500 medium to large scale computer and data centres. Of course these networks are not just composed of links and link drivers, but also contain intermediate nodes that store packets and data, carry out routing functions and then forward packets. The networks may also contain various forms of intermediate servers that manage the network. Furthermore we also have to consider the significant energy impact of the wireless systems that serve our mobile computing and communication needs. Note however that whilst the wireless systems cover essentially the last "few meters to a few kilometers", data transfers and communication services are increasingly based on the Internet Protocol and are carried over the providers' wired backbone packet networks. In addition, as we move towards the Smart Grid to improve our energy profile and respond to the opportunities offered by renewable energy sources, telecommunication networks will dominate the need to sense the energy provision and its consumption in appliances, homes and vehicles, and will meet the need to convey this information to decision nodes, and distribute the decisions or recommendations back to homes and appliances.

2.2 IS for Green

In this section the panelists analyze how information systems can support energy efficiency or the reduction of energy consumption and identify the general approaches to research in this area.

2.2.1 Developing Capabilities for Sustainable ICT

As organizations embrace sustainability agendas they will need to develop relevant capabilities to deliver on the promise. IT departments that want to be key players within their organization’s sustainability strategy will need to develop significant Sustainable ICT (SICT) capability. However, a SICT capability goes beyond technology to encompass other factors such as alignment with corporate sustainability strategy, project planning, developing expertise, culture, and governance. Using Green IT and Green IS, SICT can develop solutions that offer benefits both internally and across the enterprise by:

- aligning all ICT processes and practices with the core principles of sustainability, which are to reduce, reuse, and recycle; and
- finding innovative ways to use ICT in business processes to deliver sustainability benefits across the enterprise and beyond.

Unfortunately, organizations often do not exploit ICT’s full potential in their efforts to achieve sustainability. Business and IT leaders frequently cannot find satisfactory answers to questions such as

- Does the organization recognize ICT as a significant contributor to its overall sustainability strategy?
- How is ICT contributing to the organization’s sustainability goals?
- What more could ICT do to contribute to those goals?
- Are there clear measurable goals and objectives for SICT?

IT departments face additional challenges specific to new ICT methods and tools, industry metrics, and standards bodies as well as a general lack of relevant information such as power consumption quantifications.

The challenge for IT departments is further complicated by the fact that sustainability is an enterprise-wide issue that spans the full value chain. The business is facing its own challenges in developing clear strategies and priorities to address a burning problem in such a dynamic and uncertain environment and might lack the maturity to fully include SICT in its efforts. This puts the onus on the ICT organization to deliver SICT benefits across the organization.

2.2.2 Establishing Green Processes in Organizations

In order to leverage the potential of Information Systems to “green” organisations, not only technology but processes in particular need to be taken into account. Hence, in this section we argue for the role of “process” in Green IS and discuss how far knowledge from the field of Business Process Management (BPM), respectively (Hammer 2010; vom Brocke et al. 2011) can be leveraged. We build on previous contributions in the field, mainly presented by Seidel et al. (2011), Loos et al. (2012) and vom Brocke et al (2012).

In general, BPM concerns the continuous improvement and the fundamental innovation of business processes to increase an organisation’s efficiency and effectiveness (DeToro and McCabe, 1997; Smith and Fingar, 2004). BPM makes use of information technology, but ultimately intends to design socio-technical work-systems (Bostrom et al. 1977), and hence includes business- and people-related issues of design. With this, BPM has become established as a comprehensive management approach (Rosemann and vom Brocke, 2010) that helps enterprises to operate and achieve their business goals, may these be related to logistics, manufacturing, financial services, healthcare, education or other areas. Naturally, the execution of a process consumes energy, the energy tied to any activity of the process and the energy necessary to run the BPM system itself. This refers not only to the energy of technical resources but, to a large extent, also the energy of human resources. In addition, not only energy consumption should be considered but also any other kind of effect the process execution may have on the (systems) environment. Water consumption, emissions and social effects of organizational processes are further examples to be listed here. There is thus both a need and an opportunity to optimize and manage processes according to sustainability objectives.

Business process optimization has been investigated widely, e.g. Dayal (2004), but not specifically tailored to energy savings and their environmental impact in general. To date, these approaches have essentially been looking into value dimensions such as time, cost, quality and flexibility, also referred to as the ‘devil’s quadrangle’ (Reijers and Mansar, 2005) of business process management. In fact, energy is hard to account for. It is hard to know what the real environmental footprint of any execution of a process is like. In addition, energy and emissions may trade off with other (e.g. conventional) performance dimensions, making optimization harder. With respect to energy efficiency, the challenge (and opportunity) for information system research and engineering is to build energy aware and energy optimizing business process systems. In the field of energy informatics, for example, sensor networks have been proposed that enable a better alignment of supply and demand of energy in socio-technical work systems (Watson et al., 2010). Further work has been conducted, e.g., by Lufei (2007), Ardagna et al. (2008) and Leitao et al. (2010). Smart energy aware processes go beyond being compliant with recent ISO 14000 standards which address various aspects of environmental management. An interesting example of a commercial information system that aims at energy saving in the logistics sector is the Dynafleet: the Volvo truck management information system which collects real-time data in order to optimize fleet logistics and specifically to reduce the energy footprint.

With the notion of Green BPM, it has been argued that “Green IT” as such may remain too limited in order to fully explore the role of IS (see Figure 1). Considering the remarkable dissemination of IT artefacts in all areas of business and society, the energy consumption of these artefacts plays a major role indeed. In addition, however, there is great potential in innovating the use of IT in business as one of the characteristic elements of the IS discipline, that has been framed as the study of “(1) how IT artefacts are conceived, constructed, and implemented, (2) how IT artefacts are used, supported and how they evolve, and (3) how IT artefacts impact (and are impacted by) the contexts in which they are embedded” (Benbasat and Zmud, 2003, p. 186). Business innovations and transformations can actually make an immediate contribution to energy efficiency using the given technology (Loos et al., 2011). Studying mechanisms of innovating and transforming business processes towards more environmentally sustainability work practices, thus, seems to be a promising field of IS research (vom Brocke et al., 2012).

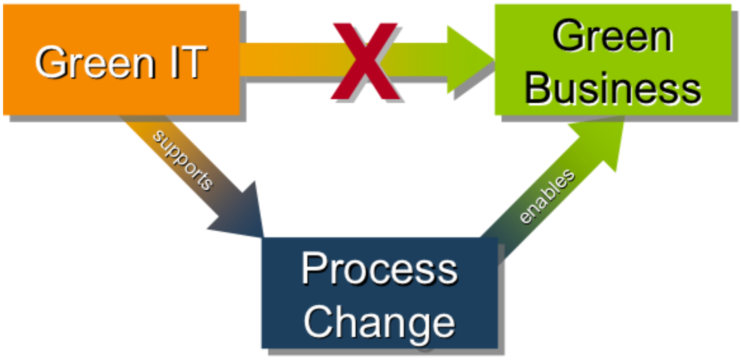

Fig. 1: The Role of Process in Green IS (Seidel, vom Brocke, Recker 2011)

2.2.3 A “Smart World” perspective

We consider a system to be *green* when it consumes minimal amounts of energy compared to systems with the same goal or when the system helps saving energy for an existing process. To simplify, let us consider electricity as the main sort of energy. In fact, electricity is the basic ingredient which makes modern computers, and in turn information systems work, but also it is something our everyday life is constantly related to. This may be energy that we use in our homes to operate appliances, to see in the dark, to charge batteries embedded in personal devices such as phones, shavers and laptops, or energy that makes the subway run or that powers one of the thousands of servers at Google that replies to one of our Web queries. In fact, energy is one of the few utilities that forms the critical infrastructure of any country and that we nowadays take for granted. Information systems are tied to energy in two ways: they need it to operate and they can help save it, thus building greener systems and performing greener processes. Let us focus on the latter aspect and consider how information system engineering can help save energy and make our world *smarter*.

First of all, we can be smarter about how the energy is produced and distributed. We have inherited a energy distribution grid which was designed as a hierarchical–monopolistic infrastructure with large generation facilities which is becoming more and more inefficient. Secondly, we can be smarter in the way we run processes, whatever these are. The first necessary step is to make the process activities 'aware' of the energy they require to execute. Then we can make choices with respect to the design and execution of the process itself in order to reduce that amount of energy consumed. Thirdly, we can build smarter physical environments that we use daily. This goes beyond the simple execution of processes and requires active environments that proactively engage in activities to save energy. A prominent case is office buildings which are responsible for most of the energy consumption in highly industrialized countries.

A smarter energy grid

In the second half of the XIX century, Samuel Insull, the trusted right-hand man and successor of Thomas Edison stated:

"every home, every factory and every transportation line will obtain its energy from one common source, for the simple reason that that will be the cheapest way to produce and distribute it."

This made sense for the time and laid the roots of the power grid as we know it. It is a hierarchical infrastructure having high-voltage backbones and low-voltage capillary infrastructure reaching the end user. The main issue being always keeping in balance demand and supply. Such an infrastructure is very inefficient because transport is lossy and because keeping the load in balance, translates into using costly and polluting energy sources (e.g. oil burning) for bootstrapping generators just in time (some studies put the level of inefficiency of the UK power grid higher than 50%). How can one improve on this?

There are reasons for being optimistic. Simply investing in the infrastructure will not improve the efficiency considerably and will be too costly, but the emergence of renewable sources both at the large scale and the small scale may do the trick. In his journalistic overview 'Power to the People', Vaitheeswaran (2005) indicates the state of the art of microgeneration facilities and illustrates future scenarios where energy generation happens locally, with high use of renewables and even storage mobility.

Smarter energy aware spaces

In modern countries, buildings account for between 40 and 50% of energy consumption. This is a huge value that deserves to be scrutinized. Are we using the energy wisely? Take a simple example, that of the illumination of an office room. Ideally, one would want the light to be just enough to support the activity of the user and any other illumination to be powered off if not useful. Current solutions involve either having the user directly control the light with a switch, or having a passive infra-red sensor that, based on movement detection, leaves the light on for a given time interval. But this is far from being ideal. Human users are forgetful and may leave the lights on when unnecessary. Motion sensors are imprecise and do not adapt to the actual user activity. (Just being in the office, typing at a computer at night will cause the light to switch off!.) Therefore, we need the space to be aware of its use and therefore 'smartly' regulate itself. Actually, one may also need rooms to negotiate with the neighbouring spaces to optimize energy consumption. (On a hot summer day, there is no point in raising the air conditioning if in the next office all windows are open).

2.2.4 An ethical perspective

The harmful effects of the production of new and the disposal of obsolete information and communications technologies on both human health and the environment have been well documented (Grossman, 2006, Kostigen, 2008, Hugo, 2011). Organisations such as the Basel Action Network (BAN) have campaigned for many years against the tide of harmful e-waste (Basel Action Network, 2011), much of which is illegally exported from developed to developing nations where it is processed by low paid workers without adequate health and safety protection. The problems of ICT production and e-waste disposal are further exacerbated by our insatiable appetite for new gadgets. According to research cited by BAN, 'there are upwards of 300 million computers and one billion cell phones produced every year. All of these electronics become obsolete or unwanted, often within two to three years of purchase.' The mountain of e-waste shows no signs of shrinking, in fact, quite the opposite. According to BAN, the 'global mountain of waste is expected to continue growing 8% per year, indefinitely.'

Whilst the problems associated with ICT production and e-waste disposal are well known and reasonably well understood, the impact of global ICT operations on the world's climate has only relatively recently attracted the attention of researchers and industry professionals. Recent research (O'Neill, 2010) suggests that global ICT operations are currently responsible for a total of 2% of all man-made CO_2 emissions and are expected to rise to 4% over the next 10 years. Whilst 2% might not be regarded as a significant contribution to global CO_2 emissions, it is roughly equivalent to that of the aviation industry. Is it therefore only a matter of time before environmental groups, which have vigorously campaigned against the aviation industry, start campaigning against companies whose massive data centres consume huge amounts of electricity and emit millions of tons of CO_2 every year? It might appear somewhat fanciful at this moment in time to imagine environmental campaigners chaining themselves to the fences surrounding Google's data centres. However, there is clear evidence that environmental groups, such as Greenpeace, are increasingly aware of and intent on publicising the negative impact of ICT operations on the climate and environment. In a recent report (Cook and Van Horn, 2011), Greenpeace were very critical of Google, Microsoft, Apple and others for their over-reliance on dirty sources of energy, such as coal, and their failure to prioritise energy efficient data centre design over the acquisition of cheap sources of energy.

3. Future directions

3.1 Green IS

3.1.1 Service centres design

Future research in service centres design is focused in two main areas.

The first is based on providing advanced monitoring and assessment of service centres. Monitoring can support both adaptive approaches to the management of the service centre and assessment to support evaluations based on maturity models, such as the one proposed by the Greed Grid Consortium[2].

In the FP7 EU project GAMES: Green Active Management of Energy in IT Service centres[3], service centre energy efficiency is improved by monitoring the services at all levels, with a holistic approach involving both services at application level and software and infrastructure services. The energy consumption of components at all levels is monitored and an adaptive approach to the usage of resources is proposed. Adaptation can be at the level of single components, and at a more general level considering the global performance of the service centre and taking global level adaptation actions (Bertoncini et al., 2011). Based on monitored values, it is also possible to provide a general assessment of the service centre using Green Performance Indicators (Kipp et al., 2012). On the basis of this assessment, it is also possible to study holistic approaches to design a more efficient service centre and to dismiss or redesign inefficient services.

In fact, the second research direction points towards the design of energy efficient service centres. It seeks to establish context-aware energy efficiency goals and service configurations that can be adapted on the basis of the current context of execution and load with an energy-efficiency goal.

In the design of efficient service centres, it is important to take into consideration both the characteristics of the services and applications being executed on the software and hardware infrastructure. In particular, the requirements for quality of service and Service Level Agreements can become a basis for designing service centres which are focusing not only on performance but also on energy efficiency. Within Green IS, adaptive approaches can support the design of service centres which are capable of adapting to different contexts of execution.

One of the critical aspects is the ability to design an appropriate level of monitoring and of coordinating adaptivity actions that can have an impact at different levels, from applications to middleware to infrastructure. Another research direction is the ability to be able to assess the impact of each action on the functioning of the system and on other indicators. Such dependencies are non linear and have to be evaluated on different time scales.

3.1.2 Service centres and networks

So far there has been considerable work on energy savings for wireless networks. One reason for this is the military driver for much research in ICT especially in the United States; the concern about the physical weight of the batteries that must be carried by individual soldiers has now been present for a couple of decades, and there has also been concern about the battery life-time of unattended ground sensors. Another reason is of course that in the civilian domain we are concerned with the battery life-time of mobile devices. On the

2 http://www.thegreengrid.org/en/Global/Content/white-papers/DataCenterMaturityModel
[3] http://www.green-datacenters.eu/

other hand, there have only been preliminary studies of energy savings that can be expected by turning off or putting to sleep the network equipment, or managing it more efficiently (Chabarek, 2008, Nedeveschi, 2008, Chiaraviglio, 2009).

Studies have not yet addressed the continuous stop-free needs of the highly reliable packet networks that society must rely on for all of its economic, social and security needs. Therefore it is essential that we have realistic predictions for energy needs of networks as a function of the network density and degree of penetration, their required traffic capacity, and the expected levels of availability, dependability and quality of service. In addition, accurate measurements regarding the power usage of network equipment are not yet available to the research community. Such evaluations would be particularly useful if we can also predict the expected energy efficiency of future ICT components and technologies including opto-electronics equipment, processors and memory systems (Gelenbe, 2010a, Gelenbe, 2011b).

Research and engineering development in this area can examine many topics, but perhaps the most important three are:

- How can one characterize the realistic energy trade-offs between centralized (or semi-centralized) and shared ICT, against distributed or parallel ICT solutions with respect to the interplay between energy consumption in networks and in processing units and centres?
- What are the current and future energy consumption profiles of networking equipment and systems as a function of the load they carry and also in idle or dormant state?
- For large scale and global networks what are the realistic percentage energy savings that can be expected via network planning as well as real-time network management, in the presence of stringent availability-dependability and realistic quality of service constraints?

3.2 IS for Green

3.2.1 Developing Capabilities for Sustainable ICT

Melville (2010) has outlined the research challenges associated with Green Information Systems under six themes:

a) Context: How do the distinctive characteristics of the environmental sustainability context, such as values and altruism, affect intention to use and usage of information systems for environmental sustainability?
b) Design: What design approaches are effective for developing information systems that influence human actions about the natural environment?
c) Causality: What is the association between information systems and organizational and sustainability performance?
d) New Business Models (e.g. Cloud Computing): What is the association between IS and Cloud Computing from an efficiency and environmental perspective?
e) Systems Approaches: How can systems approaches shed light on organizational and environmental outcomes that result from the use of IS for environmental sustainability?

f) Models/Metrics: Multi-Level models and metrics that encompass enterprise-wide sustainability initiatives.

There are also significant challenges for IT R&D functions within organizations. Sustainability is an important business issue, affecting new products and services, compliance, cost reduction opportunities, the organization's reputation, and revenue generation. Many organizations think it requires a significant transformational change program, yet the ultimate goal is to embed sustainability into business-as-usual activities.

Organizations face many challenges in developing and driving their overall sustainability strategies and programs:

- the complexity of the subject and its rapid evolution,
- the lack of agreed-upon and consistent standards,
- changing stakeholder expectations,
- the lack of subject-matter expertise,
- the need for new metrics and measures, and
- evolving and increasing regulations and legislation around the world.

There is a need to improve the sustainable IT behaviours, practices and processes within organizations to deliver greater value from Sustainable IT. To address the issue, a consortium of leading organizations from industry, the nonprofits sector, and academia decided to develop a framework for systematically assessing and improving SICT capabilities. The core of this framework is a maturity model for Sustainable ICT which provides a management system with associated improvement roadmaps that guide senior IT and business management in selecting strategies to continuously improve, develop, and manage the sustainable IT capability (Donnellan et al., 2010).

Maturity models are tools that have been used to improve many capabilities within organizations, from Business Process Management (BPM) (Roseman and de Bruin, 2005) to Software Engineering (Paulk et al., 1993). Typically, these models consist of a set of levels that describe how well the behaviours, practices, and processes of an organization can reliably produce required outcomes. They can have multiple uses within an organization, from helping them find a place to start, providing a foundation to build a common language and shared vision, to helping organization prioritize actions and define roadmaps. If a community of organizations defines the model it can capture the collective knowledge of the community's prior experiences. A maturity model could also be used as an assessment tool and benchmark for comparison assessments of the capabilities of different organizations.

The Innovation Value Institute (IVI; http://ivi.nuim.ie) consortium used an open-innovation model of collaboration, engaging academia and industry in scholarly work to create the SICT-Capability Maturity Framework (SICT-CMF). The development of the SICT-CMF was undertaken using a design process with defined review stages and development activities based on the Design Science Research (DSR) guidelines advocated by Hevner et al. (2004). During the design process, researchers participate together with practitioners within research teams to capture the views of key domain experts (Curley 2004).

The framework defines a five-level maturity curve for identifying and developing SICT capabilities:

Initial: SICT is ad hoc; there's little understanding of the subject and few or no related policies. Accountabilities for SICT aren't defined, and SICT isn't considered in the systems life cycle.

Basic: There's a limited SICT strategy with associated execution plans. It's largely reactive and lacks consistency. There's an increasing awareness of the subject, but accountability isn't clearly established. Some policies might exist but are adopted inconsistently.

Intermediate: A SICT strategy exists with associated plans and priorities. The organization has developed capabilities and skills and encourages individuals to contribute to sustainability programs. The organization includes SICT across the full systems life cycle, and it tracks targets and metrics on an individual project basis.

Advanced: Sustainability is a core component of the IT and business planning life cycles. IT and business jointly drive programs and progress. The organization recognizes SICT as a significant contributor to its sustainability strategy. It aligns business and SICT metrics to achieve success across the enterprise. It also designs policies to enable the achievement of best practices.

Optimizing: The organization employs SICT practices across the extended enterprise to include customers, suppliers, and partners. The industry recognizes the organization as a sustainability leader and uses its SICT practices to drive industry standards. The organization recognizes SICT as a key factor in driving sustainability as a competitive differentiator.

This maturity curve serves two important purposes. First, it is the basis of an assessment process that helps to determine the current maturity level. Second, it provides a view of the growth path by identifying the next set of capabilities an organization should develop to drive greater business value from SICT. A contrast of low- and high-levels of Sustainable ICT are offered in Figure 2.

Low Maturity	**High Maturity**
Un-coordinated, isolated projects	Coordinated SICT Activities
Low SICT Skills	High SICT Expertise
Key Personnel	Organisational Wide Coverage
Reactive	Proactive
Vague Metrics	Meaningful Metrics
Internally Focused	Extended Organisation
Low Resourcing	Efficient Resourcing
Naïve	Comprehensive Understanding
Static	Innovative

Fig. 2: Comparison of Low and High Maturity

The maturity curve can remain open for as long as the participating organizations chooses. Typically, a range of business and IT individuals who are involved in or accountable for SICT complete the survey.

3.2.2 Establishing Green Processes in Organizations

Recent studies have presented a number of research agendas for Green IS (e.g., Watson et al. 2010, Elliot 2011 and Melville 2010). In this section we would like to leverage the power of process management for Green IS (vom Brocke et al., 2012). Research directions can be derived using well-established BPM frameworks and discussing contributions needed in order to extend such frameworks towards a sustainability-aware BPM. One example is the "Green Process Management Lifecycle" presented by Seidel et al. building on the Process Management Lifecycle presented by Hammer (2010). In this section, we would like to use another framework which is built on BPM maturity model research (de Bruin, 2007) and that differentiates between six core elements of business process management (Rosemann and vom Brocke, 2010).

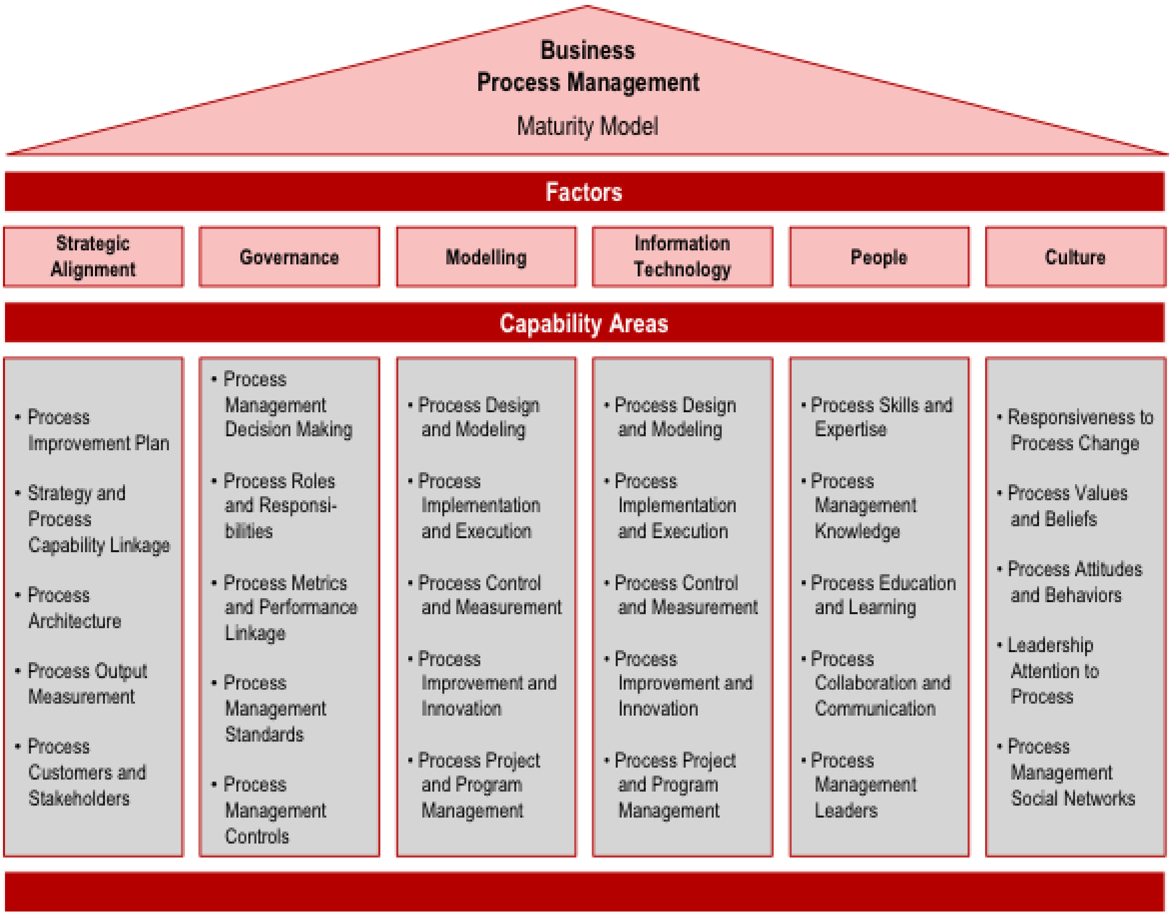

Fig. 3: The Six Core Elements of BPM (Rosemann and vom Brocke 2010).

The six core elements illustrate capability areas that are empirically grounded by means of a global Delphi Study conducted by de Bruin and Rosemann (2007). The results show that, in addition to more technical capabilities in the field of methods and IT, also business related capabilities, such as strategic alignment and governance, as well as human-related capabilities, such as people and culture need to be considered for successful BPM. Applying this model, the following essential research directions can be identified for Green BPM (vom Brocke et al., 2012):

- **Strategic Alignment:** How to operationalize sustainability? What are the relevant value dimensions and should they be measured?
- **Governance:** How to organise sustainability? What roles are needed and what procedures can be applied in specific organisational contexts?
- **Methods:** How to identify the sustainability impact of processes. What extensions to modelling languages are needed?
- **IT**: How to find technology supporting process change? What is sustainability enabling technology and what are best practice use cases?
- **People**: How to educate people to adopt sustainability practices? What is the Curriculum of Sustainability Training?
- **Culture**: How to identify, operationalise, and communicate values relevant for sustainable processes. How to transform people's attitudes?

We believe that both contributions to theory and innovative solutions will be needed to leverage BPM for sustainability management. Building on the BPM body of knowledge, research needs to focus on the specific challenges imposed by the phenomena of greenness or sustainability in a wider sense. We need to guide research to focus on sustainability-specific matter and truly advance BPM research. But what actually is "sustainability" and how can it be operationalised in more detail? This leads to another major challenge:

IS research needs to establish a good understanding of the phenomenon of sustainability, which most likely requires interdisciplinary research. Depending on the particular field of interest disciplines such as engineering, life sciences and architecture are highly relevant to partner up. Architecture, for example has a long lasting tradition of applying the principles of sustainable design. The design of sensor networks, mentioned above, is an example where, in particular, electrical engineering and information systems come together. Since, in BPM social technical systems are concerned (Bostrom et al.,1977) findings from sociology and psychology respectively also need to be considered.

Sustainability is a major challenge of our modern society and solutions will require out of the box thinking. Also for the information systems discipline this means to increasingly think in terms of solutions rather than in disciplines. It will be promising to explore the contributions IS can make to such solutions supporting environmental sustainability. Considering the vital role of information in all areas of our modern world, this development can embody a great opportunity for the IS discipline since it can prove its usefulness. The notion of process and the knowledge of process management can prove particularly helpful, since processes are the nucleus of socio-technical work systems and BPM has proven particularly successful at integrating the perspective of various disciplines. The emerging field of Green BPM sets out to leverage these potentials in IS research (vom Brocke et al.2012).

3.2.3 A "Smart World" perspective

Introducing smartness into our energy production, distribution and consumption patterns will generate some of the most interesting challenges for the scientific community in the next year. The scenario of decentralized energy trading will inevitably affect the physical infrastructure (Pagani and Aiello, 2011). Here are three examples. First, the burden of keeping the network in balance moves from the central authority to the delocalized end-users. In Hoogkerk in the Netherlands, an agent-based system called the PowerMatcher (Kok et al., 2005) is being tested to keep the network in balance with decentralized control. Second, if generation is not regulated, a market will emerge for trading energy at the local level. If I'm on holiday, why not auction the energy that my solar panels produce to the best offering neighbour (see Capodieci et al., 2011 for an initial model and simulation)? Third, the grid will be smarter. Already, with the introduction of the smart meters in many countries, we assist with bidirectional communication on the grid and the availability of increasing volumes of grid data. The smartness will spread around the whole distribution and production grid, requiring real-time scalable information systems to support the infrastructure. Actually, the communication regarding energy will go beyond the smart meter and enter the homes. Appliances will communicate with the grid in order to provide a perfect balancing system.

At the energy consumer level, we will also see interesting problems arising. Consider the usage of energy in office or residential buildings. In fact, smart building infrastructures will need to collect huge amounts of sensor data to provide centralized control together with decentralized user freedom to change settings. Patterns of users' activities must be detected and turned into control strategies. Trivial solutions such as switching off anything which consumes energy are, of course, not valid, as the user satisfaction level should not be hindered by the controlling information systems. In fact, if anything, it must increase.

There are many initiatives that go in this direction. Think simply about the IBM Smarter Planet framework. Here, two personal experiences in the context of EU FP7 projects are reported. With the GreenerBuildings project, currently underway, we aim at building an information system to control office spaces that is aware of user activities based on simple pervasive sensing, and controls the lighting and heating systems in order to save energy but with the requirement that the user experience is unaffected. The user, in principle, needs not to be concerned with the control of the space, though he may overrule a decision of the system at any moment. In the Smart Homes for All project, we offer the user the possibility to express his desires, which may be very complex, then the information system translates them into a set of actions that realize them (Kaldeli et al., 2010). This can happen, taking into account the energy consumption as a parameter to minimize. In both projects, smartness is thus achieved by acquiring large amounts of sensor data, translating this into user context information and applying Artificial Intelligence techniques to control the spaces.

In summary, energy is transforming its role in our society. It is moving from being a utility towards becoming a commodity. As such, information systems will help in managing it effectively and efficiently, while themselves being aware and hopefully frugal in its use.

3.2.4 An ethical perspective

As the information systems community's awareness and understanding of the impact of the ICT industry on the environment increases so does our need to identify how we can help solve the problems associated with this impact. We should realistically expect that our activities will be subject to increasing scrutiny. It is imperative therefore that we seek ways to reduce the impact of ICT operations on the environment. But how should we set about this? ICT manufacturers are striving to reduce the use of harmful substances in the production of new equipment and to manufacture more energy efficient equipment. Meanwhile, organisations are employing a range of initiatives designed to reduce the impact of ICT operations on the environment. Some initiatives, such as green printing, are aimed at changing employees' behaviour whilst others involve the application of 'green' technologies, such as power management and virtualization within the data centre.

As IS/IT professionals, we should also be mindful of our ability to influence the behaviour of organisations as a whole, rather than simply the IT Department within it. IT is uniquely positioned to help organisations reduce their overall environmental impact even if this reduction can only be achieved by 'silicon trading', an overall reduction at the expense of an increased ICT footprint. The Smart 2020 Report, commissioned by the Climate Group (2008) and written by international management consultants, McKinsey and Company, provides some interesting statistics in relation to silicon trading. The report predicts an almost 100% increase in the ICT sector's footprint by 2020 but estimates that the effective use of ICT within organisations could cut CO_2 emissions by up to five times this amount. The report then goes on to identify four areas in which ICT could make very significant impacts; smart motors and industrial automation, smart logistics, smart buildings and smart grid technologies. In all four cases, it is the ability of ICT to measure and optimise energy consumption which appears to offer the greatest benefits.

One of the greatest challenges facing the IS community is determining where best to direct its limited resources. If the Smart 2020 report is correct, then it would make most sense to prioritise the development of systems to manage energy consumption within the four key areas identified by the report. Prioritising the development of such systems would, at least in theory, help to maximise the IS community's contribution to tackling climate change. However, in prioritising such systems, the IS community should not loose sight of the existence of other opportunities to make a difference. Wherever processes exist that can be fully or even partially automated, opportunities exist for increasing efficiency and

Increased efficiency = reduced energy consumption = lower CO_2 emissions

So how should the IS community maximise its contribution towards tackling climate change and reducing the impact of ICT on the environment? The answer is perhaps more obvious than we think. The IS community needs to continue doing what it has always tried to do - developing efficient and effective information systems - and the only restriction on this process is the community's own imagination.

4. Synthesis and Lessons Learned

The theme of energy and sustainability are becoming increasingly important to people and therefore for ICT which plays such a major role in the organizations that support our society and our lives. The challenge facing the IS community now is the need to analyze the impact of IS and as a result, consider the trade-off between energy use and support for sustainability.

The growing attention on green ICT is also testified by international events in the field. For instance, within the Association for Information Systems (AIS), the Special Interest Group, SIGGreen, aims to foster research, education and practice in ways to design, build and use information systems so that we can reduce the harmful environmental impact of all human endeavours. Currently SIGGreen is focusing on the impact on the environment of associations themselves.

Molla et al. (2011) discuss IT and sustainability, considering *“three layers: IT and communications technologies (e.g., physical servers and network devices); shared services (e.g., enterprise-wide databases and electronic data interchange); and business applications that utilize the shared infrastructure (e.g., sales analysis, purchasing)”* with the goal of defining G-readiness as the readiness of organizations to tackle Green IT initiatives. The concept of the maturity model has been extended to green IT, for instance, in the Green Grid Consortium.

The panel on Green and Sustainable Information Systems at the 21st International Conference on Information Systems Engineering (CAiSE’11) has raised a number of important issues and identified open challenges. The following table summarizes them from the point of view of each panelist, that is, from experts with very different IS backgrounds.

Perspective	Why important	What directions	Challenges
Process	Processes are “what organisations do”. Making processes more sustainable will ultimately lead to making organisations more sustainable. This addresses organisations of various kinds. Their process innovations can make an immediate contribution by using existing technology in a specific manner.	Extend existing BPM research towards the management of more sustainable business processes. Exemplary directions are illustrated according to the six core elements of BPM: strategic alignment, governance, methods, IT, people, and culture.	Research needs to be specific towards the phenomenon of sustainability.
Capabilites	IS Organizations will have to develop a systematic approach to Sustainable ICT. Only by adopting a systematic approach, will it be possible to	This systematic approach can be based on a maturity model approach. The IVI has developed a maturity model for Sustainable ICT that	A challenge is to initiate and maintain progress and momentum across the broad spectrum of both technical and non-technical initiatives that constitute Green IS (and not just Green IT) – as

	drive continuous improvement across a range of technical and non-technical initiatives.	has been verified in a number of companies.	outlined by Melville (2010).
Smartness	IS can help build Smart Systems that are Energy Aware and Energy Saving	Smart Grid Smart Processes Smart Buildings	How to make the Grid Smart by considering it as an Information Infrastructure, Energy awareness in IS, Artificial intelligence for proactive energy saving
Ethics	We have a responsibility to reduce the impact of what we do, as much as any other industry. We are also uniquely positioned to influence the behaviour and impact of organisations as a whole.	We should look at ways to green IT but also leverage IT as a green enabler (so called 'silicon trading').	How can we, as IS professionals, make the most effective contribution to the environmental agenda? By the development of enabling systems or systems to green IT?
Green IS	Service centres and network interconnections are becoming an ever increasing power consumer.	Approaches based on monitoring and on an intelligent and energy efficient usage of resources.	The ability to define an adequate level of monitoring to be able to enforce adaptivity mechanisms. Evaluation of the impact of adaptation decisions on the global system

Figure 4 – Synthesis from the panel report

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