

9

Sustainable Information Systems and Green Metrics

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Key Points

- Introduces green and sustainable informatics and metrics as a tool to monitor and drive sustainable behaviour.
- Describes the multilevel nature of green metrics with examples at the regional, organizational, functional, product/service, and individual levels.
- Provides an overview of the metrics and standards for greenhouse gas reporting, life cycle impact analysis, energy efficiency within data centres and assessing the maturity of sustainable information and communication technology (SCIT) within organizations.
- Illustrates applications of the Natural Step Framework to develop a sustainable strategy for local government, with relevant KPIs.

9.1 Introduction

It is estimated that information and communication technology (ICT) is responsible for at least 2% of global greenhouse gas (GHG) emissions (Webb, 2008). The first wave of green Information Technology (green IT), *greening of IT*, aims to reduce 2% of global emissions from IT by reducing the footprint of ICT by actions such as improving the energy efficiency of hardware (processors and disk drives), and waste from obsolete hardware. The second wave of green IT, *greening by IT*, also called Green IT 2.0 or Sustainable IT (Murugesan and Laplante, 2011), is shifting the focus towards reducing the remaining 98% by focussing on the innovative use of IT and Information Systems (IS) in business processes to deliver positive sustainability benefits beyond the direct

footprint of IT, such as monitoring a firm's emissions and waste to manage them more efficiently. The potential of *IT for greening* to reduce GHG emissions has been estimated at approximately 7.8 Gt CO₂ of savings in 2020, representing a 15% emission cut in 2020 and £600 billion (US\$946.5 billion) of cost savings (Webb, 2008). The use of IT for greening will play a key role in the delivery of benefits that can alleviate an estimated five times the GHG footprint of IT itself (Enkvist, Nauc  r, and Rosander, 2007).

Relevant and accurate data, information, metrics and key performance indicators (KPIs) are critical to supporting sustainable practices, and the need to manage this information has led to the emergence of green information systems (GIS) as a field in itself. There is substantial potential for green IS to bring together business processes, resource planning, direct and in-direct activities and extended supply chains to effect positive changes across the entire activities of governments, organizations and individuals. Green IS is the engine driving both the strategic and operational management of sustainability. Organizations pursuing a sustainability agenda will need to consider their green IS (Watson, Boudreau, and Chen, 2010) to be as critical as their other operational IS such as finance or production.

Whilst distinction between green IS and green IT exists (Boudreau, Chen, and Huber, 2008), in this chapter we will consider the broad need for *sustainable information* to support both *green for IT* and *IT for green*. As sustainable information is needed at both the macro and micro levels, it will require a multilevel approach that provides information and metrics that can drive high-level strategic corporate and regional sustainability plans as well as low-level actions like improving the energy efficiency of an office worker.

The chapter starts with an overview of the need for multilevel sustainable information, and introduces the wider context of sustainability frameworks, principles and tools. It then examines the information requirements and methods utilized at multiple levels including regional (regional sustainability plan), organization (GHG emission reporting), business function (data centre energy efficiency), individual (commute tracking), and product and service (life cycle assessment (LCA)). It also examines how the sustainability capability of an organization can be examined to determine its effectiveness and highlight areas for further research.

9.2 Multilevel Sustainable Information

Sustainability requires information on the use, flows and destinies of energy, water and materials including waste, along with monetary information on environment-related costs, earnings and savings. This type of information is critical if we are to understand the causal relationships between the various actions that can be taken and their impact on sustainable performance. However, the problem is broad in scope and the necessary information may not be available, or may be difficult to collect. Improving sustainability performance, especially through changing the way an organization or activity operates, requires a number of practical steps which will include the need for a systematic approach for information gathering and analysis.

In order to tackle the problem, it is important to break it down into smaller, manageable pieces by adding boundaries and scopes to activities to make them more manageable. A 'boundary' or 'scope' can be drawn narrowly for a specific activity (e.g. to consider only the emissions that arise directly from that activity) or broadly (including emissions indirectly associated with the activity).

We will look at the problem of sustainability from the perspective of a multilevel information problem, where individual levels are used to provide a scope and boundary for activities (see Table 9.1).

Information can flow between levels as necessary, allowing the granularity of the problem to be set as needed. This allows the sustainable information to be tackled at high or low levels of detail. In order to avoid a myopic view of the benefits of sustainable

Table 9.1 Multilevel sustainable information

Level	Stakeholders	Information requirements	Information regarding
Regional/City	Public administration, policymakers, politicians, corporations, citizens, and regulators	Regional sustainability plans, movement and transport, biodiversity and environmental impacts, health and well being, resource management, waste disposal	Regional energy consumption Energy consumption by sector GHG emissions per capita GHG intensity of energy consumption
Organizational	Executive team, shareholders, citizens, regulators, suppliers and consumers	Corporate sustainable reports, sustainability plans, sustainable business objectives, business function performance, and so on	Total energy consumption Total electricity consumption Percentage of renewable energy sources
Functional	Function management team, organization management and employees	Function sustainability performance, functions sustainability objectives and so on	Facility electricity consumption Internal electricity consumption DC electricity consumption
Individual	Citizens and employees	Direct and indirect cost of actions of the individual, private travel, energy use, work commute and impacts of products and services consumed	Business travel Employee commuting Employee IT energy use
Product or service	Product producers and consumers	Analysis of the sustainability impacts of the product or service, manufacturing cost, usage cost, disposal cost and so on	Server electricity consumption Laptop electricity consumption

information and to understand its real impacts, we must first understand and examine the bigger picture of sustainability.

9.3 Sustainability Hierarchy Models

Sustainability is a complex and broad subject. In order to make sense of the various frameworks and tools, Hitchcock and Willard (2008) created a hierarchy of sustainability models that is illustrated in Figure 9.1.

- **Natural laws:** The laws imposed upon us by Mother Nature such as the Law of Conservation of Mass and Energy, Law of Entropy and Laws of Thermodynamics.
- **Frameworks:** High-level conceptual rules for sustainability that conform to natural laws.
- **Principles:** General and sector-specific guidelines that detail sustainable practices and actions.
- **Tools:** Methodologies, standards and strategies for implementation.

As natural laws are well described by their respective disciples, for the remainder of this section we will focus on the bottom three levels of the hierarchy, starting with frameworks for sustainability.

9.3.1 Sustainability Frameworks

In order to improve the understanding and communication of sustainability issues and to provide high-level definitions of sustainability, a number of frameworks have been proposed. Natural Capitalism, The Natural Step, Ecological Footprint and the triple bottom line (TBL) are popular frameworks and are described in this section. These frameworks are used to reach a shared mental model of sustainability, providing concrete definitions and scoping for concepts and terms (Hitchcock and Willard, 2008). The frameworks can be used to develop high-level visions and planning for sustainability activities.

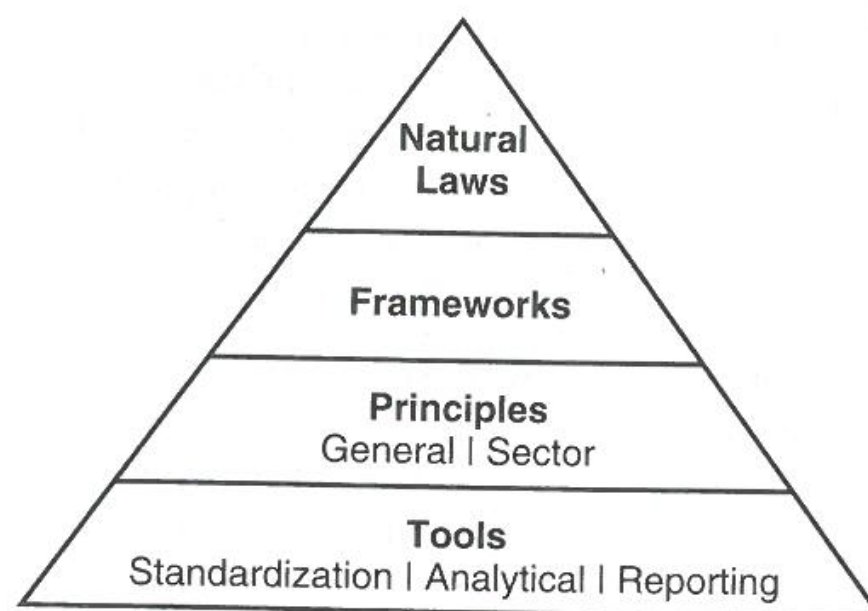


Figure 9.1 Hierarchy of sustainability models (adapted from Hitchcock and Willard, 2008).

9.3.1.1 Natural Capitalism

The concept of Natural Capitalism, an extension of the economic concept of capital to the natural environment (Hawken, Lovins, and Lovins, 1999), is to look at the environment as a system that yields a valuable flow of goods and services (e.g. fish, trees and other such things). Natural capitalism requires the following shifts in business practices: Radically increase productivity in the use of natural resources; shift to biologically inspired production models and materials; move to a 'service-and-flow' business model; and reinvest in natural capital.

9.3.1.2 The Natural Step

The objective of The Natural Step (Nattrass and Altomare, 1999) is to help reduce the potential causes of environmental problems. This framework defines four system conditions, derived from the Laws of Thermodynamics, for a sustainable society. In a sustainable society, nature's functions and diversity must not be systematically subjected to (1) increasing concentrations of substances extracted from the Earth's crust, (2) increasing concentrations of substances produced by society and (3) degradation by physical means. Furthermore, (4) resources must be used fairly and efficiently to meet the basic needs of people worldwide (Table 9.2).

9.3.1.3 Ecological Footprint

The ecological footprint (Rees, 1992; Wackernagel and Rees, 1996) is the measure of environmental impact of particular actions on the Earth's natural resources and ecosystem functionality. It compares human demand with the Earth's ecological capacity to regenerate. The assessment can be used at the individual, city or regional level to estimate how much of the Earth (or how many planet Earths) it would take to support humanity if everybody lived a given lifestyle.

Table 9.2 The natural step framework: system conditions and sustainability principles

System conditions	Sustainability principles
Concentrations of substances extracted from the Earth's crust	Eliminate our contribution to the progressive build-up of substances extracted from the Earth's crust (e.g. heavy metals and fossil fuels)
Concentrations of substances produced by society	Eliminate our contribution to the progressive build-up of chemicals and compounds produced by society (e.g. dioxins, polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT))
Degradation by physical means	Eliminate our contribution to the progressive physical degradation and destruction of nature and natural processes (e.g. over-harvesting forests and paving over critical wildlife habitat)
In that society, people not subject to conditions that systemically undermine their capacity to meet their needs	Eliminate our contribution to conditions that undermine people's capacity to meet their basic human needs (e.g. unsafe working conditions and not enough pay to live on)

9.3.1.4 Triple Bottom Line (TBL)

The TBL framework (Elkington, 1998) allows an organization to focus on not only its economic bottom line, but also its environmental and social 'bottom lines'. TBL expands the scope of responsibility for an organization from shareholders and owners to also include stakeholders – anyone who is influenced, either directly or indirectly, by the actions of the organization.

Other sustainability frameworks include cradle to cradle (McDonough and Braungart, 2002), biomimicry (Benyus, 1997), social return on investment (Scholten and Olsen, 2006) and the sustainability helix.

9.3.2 Sustainability Principles

Below the high-level frameworks are a broad range of principles that provide guidance on the sustainability practices needed to achieve the objectives set out in higher level frameworks. Principles are typically created via a group or community process with the aim to produce a number of aspirational statements to provide guidance (often common sense) on sustainability.

General principles for sustainability are broad guidelines that can be applied within any domain or sector. Two well-known general principles, mentioned in this section, are the 3 Rs and Earth Charter. Sector-specific principles complement general principles with guidance to help translate what sustainability means within the context of a sector such as government, international business or higher level education.

9.3.2.1 Reduce, Reuse and Recycle (3R's)

Reduce, *Reuse* and *Recycle* are three waste management strategies that are used collectively within a waste hierarchy known as the 3 Rs. The 3 Rs classify the strategies according to the desired order of use: It is better to reduce than reuse, and better to reuse than recycle. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

9.3.2.2 Earth Charter

The Earth Charter is an international declaration on the principles needed to build a just, sustainable and peaceful global society. The Earth Charter proposes that environmental protection, human rights, equitable human development and peace are interdependent and indivisible.

9.3.3 Tools for Sustainability

At the bottom of the hierarchy are the sustainability tools that provide guidance and best practices. Sustainability tools come in many forms, from methodologies used to help determine the environmental impact of a steel water bottle, to certifying the design and construction of a building. Sustainability tools can be general purpose, such as the GHG Protocol for emissions reporting, or specific to a sector, like the Leadership in Energy

and Environmental Design (LEED) for green building certification. A detailed list of sustainability tools is given in this chapter's Appendix. These tools provide sustainability information needed to make sustainable decisions and drive sustainable behaviour. Many of these tools can be classified as *IT for green* or as an opportunity for IT to 'green' processes or activities outside of IT.

9.4 Product Level Information

Understanding the impacts of a product or service requires an analysis of all potential impacts associated with a product, process or service for its entire life cycle. This is achieved using a technique known as life cycle assessment.

9.4.1 Life-Cycle Assessment

Life-cycle assessment (LCA), also known as life cycle analysis, is a technique to systematically identify resource flows and environmental impacts associated with all the stages of product and service provision. LCA provides a quantitative cradle-to-grave analysis of the products or services' global environmental costs (i.e. from raw materials through materials processing, manufacture, distribution, use, repair and maintenance and disposal or recycling). The demand for LCA data and tools has accelerated with the growing global demand to assess and reduce GHG emissions from different manufacturing and service sectors (Horne, Grant, and Verghese, 2009).

LCA can be used as a tool to study the impacts of a single product to determine the stages of its life cycle with most impact (Levi Strauss & Co., 2009). LCA can also be used as decision support when determining the environmental impact of two comparable products or services (Goleman and Norris, 2009).

9.4.2 The Four Stages of LCA

For a LCA, both ISO 14040 (ISO, 2006a) and 14044 (ISO, 2006b) standards follow four distinct phases process, which are briefly described here.

1. **Goal and scope definition:** It is important to ask the right question to ensure whether the LCA is successful. The first step in this process is the framing of the key questions for the assessment. Typical steps include defining the goal(s) of the study, determining what type of information is needed to inform decision makers, defining functional units (environmental impact, energy efficiency, life span, cost per use, etc.), defining the system boundaries and studying perspective, allocation principles, environmental impact assessment categories and level of detail.
2. **Inventory analysis:** The second phase involves data collection and modelling of the product and service system with process flow models and inventories of resource use and process emissions. The data must be related to the functional unit defined in the goal and scope definition and include all data related to environmental (e.g. CO₂) and technical (e.g. intermediate chemicals) quantities for all relevant unit processes within the study boundaries that compose the product system. Examples of inputs and outputs include materials, energy, chemicals, air emissions, water emissions, solid

waste, radiation and land use. The results of a life cycle inventory provide verified information about all inputs and outputs in the form of elementary flow to and from the environment from all the unit processes involved in the study.

3. **Impact assessment:** The third phase evaluates the contribution to selected impact assessment categories, such as 'climate change', 'energy usage' and 'resource depletion'. Impact potential of the inventory is calculated and characterized according to the categories. Results can then be normalized across categories (same unit) and weighted according to the relative importance of the category; both of these actions are voluntary according to the ISO standard.
4. **Interpretation:** The final phase involves interpretation of the results to determine the level of confidence and communicate them in a fair, complete and accurate manner. This is accomplished by identifying the data elements that contribute significantly to each impact category, evaluating the sensitivity of these significant data elements, assessing the completeness and consistency of the study and drawing conclusions and recommendations based on a clear understanding of how the LCA was conducted and the results were developed (Skone, 2000).

9.4.3 *CRT Monitors versus LCD Monitors: Life Cycle Assessment*

A comprehensive environmental LCA of the traditional cathode ray tube (CRT) and newer liquid crystal display (LCD) monitors was conducted through the EPA's Design for the Environment (DfE) programme. The objective of the study (Socolof, Overly, and Geibig, 2005) was to evaluate the environmental and human health life cycle impacts of functionally equivalent 17 in. CRT and 15 in. LCD monitors. The study assessed the energy consumption, resources input and pollution produced over the lifetime of the equipment. The cradle-to-grave analysis was divided into three stages: (i) cradle to gate (manufacturing), (ii) use and (iii) end of life (disposing or reusing). Each stage was assessed for the energy consumed, materials used in manufacturing and associated waste. Components manufactured in different locations, where energy sources can differ due to the way local energy is produced, such as coal versus nuclear, were taken into account.

A sample of the results from a life cycle environmental assessment is presented in Table 9.3. In summary, the LCA concluded that LCD monitors are about 10 times better for resource usage and energy use, and five times better for landfill use. However, LCDs are only 15% better for global warming because the LCD manufacturing process uses sulphur hexafluoride, a significant GHG.

9.5 Individual Level Information

In a similar manner to other levels, understanding impacts at the level of an individual requires a holistic view of activities. Primary sources of emissions for an individual will include the life cycle of products and services they purchase and use, the construction (LCA of material and construction) and operation of their residence (energy use, water use and waste disposal and recycling) and private travel (especially emissions from long-haul flights).

The ability for individuals to understand the impacts of their activities is critical. Online carbon calculators are a popular mechanism to calculate impact; however, these may

Table 9.3 Life cycle analyses of CRT and LCD monitors

	17 in. CRT	15 in. LCD
Total input material	21.6 kg	5.73 kg
Steel	5.16 kg	2.53 kg
Plastics	3 lb.	1.78 kg
Glass	0.0 kg	0.59 kg
Lead-oxide glass	9.76 kg (0.45 lb. of lead)	0.0 kg
PCBs	0.85 kg	0.37 kg
Wires	0.45 kg	0.23 kg
Aluminium	0.27 kg	0.13 kg
Energy (in manufacturing)	20.8 GJ	2.84 GJ
Power drawn	126 W	17 W
Energy (use – five years at full power)	2.2 GJ	850 MJ

have significant limitation including static calculation, a lack of personalization and limited capacity for historical analysis. However, tools are improving for individuals. For instance, home energy usage is an area that has seen the early adoption of real-time monitoring systems with the on-going development of smart meters and the Smart Grids. Studies have shown that energy conservation improves if residents receive real-time feedback on their energy usage; one study in Ontario showed the average household reduced its electricity usage by 6.5% (Mountain, 2006). Another interesting development is the utilization of smart phones as a low-cost means to determine the impacts associated with commuting.

A significant contribution to CO₂ emissions levels is the daily commute by an individual. In response to addressing this challenge, a group of Volvo employees wanted to develop an IT solution that would motivate people to reduce the emission cost of their daily commute by measuring the time, efficiency and environmental impact of their commuting. By using a small application on mobile phones, Volvo turned the device into a CO₂ pedometer to calculate the environmental impact of each commute, whilst helping them to make the right daily choices of transport modes towards efficiency and sustainability. In a 2009 pilot, Volvo employees were able to reduce their CO₂ footprint by 30% in just one month's time.

This app was transformed into a global service and launched as Commute Greener!, which is able to help companies, cities and individuals around the world understand how to commute in a greener way (Commute Greener, 2010). The system aggregates the commute data of individuals to build commute patterns that are useful for decision making at higher levels, for understanding the commute pattern within a city or for providing information for a company. This information can be used to optimize public transport, company shuttles and carpooling. Efforts such as Commute Greener and Smart Grids show how tracking information at the individual level can benefit the individual directly, and also be aggregated at a higher level of analysis to benefit a region or community.

9.6 Functional Level Information

An organization typically comprises multiple functions or operating divisions and departments including marketing, finance, operations, human resources and research and development. Sustainability issues at the functional level are related to business processes and the value chain; they involve the development and coordination of resources through which the overall organization's objectives and goals can be executed efficiently and effectively.

A close relationship exists between organization level and functional level metrics, and it is important that metrics at both levels be aligned. Typically, metrics at the functional-level will be more granular to provide specific detail on the operations of the function. Functional level metrics can then be aggregated into an organization level metric.

Monitoring energy usage for an IT function can involve metrics around building energy usage (lights and heat), staff computer energy usage and in particular energy used within data centres. In Section 9.6.1, we examine energy usage within the data centre and the role of metrics.

9.6.1 Data Centre Energy Efficiency

The power needs of data centres may range from a few kilowatts for a rack of servers in a closet, to several tens of megawatts for large facilities. Power usage in a data centre goes beyond the direct power needs of servers to include networking, cooling, lighting and facilities management. The US Environmental Protection Agency (EPA) estimates that servers and data centres are responsible for up to 1.5% of the total US electricity consumption (EPA, 2007) or roughly 0.5% of US GHG emissions for 2007. The same report also highlights that significant power consumed by data centres is not used on computation; for every 100 W supplied, only 11.2 W were used for computation. With electricity costs the dominant operating expense of a data centre, it is vital to maximize the centre's operational efficiency to reduce both the environmental and economic costs (Belday *et al.*, 2008). In this section, we focus on metrics that help to understand a data centre's energy efficiency.

9.6.2 Data Centre Power Metrics

Developed by the Green Grid, power usage effectiveness (PUE) is a measure of how efficiently a data centre uses its power. PUE measures how much power the computing equipment consumes in contrast to cooling and other overheads uses. PUE is defined as follows:

$$PUE = \text{Total Facility Power} / \text{IT Equipment Power}$$

The reciprocal of PUE is data centre infrastructure efficiency (DCiE) and is defined as follows:

$$DCiE = 1/PUE = \text{IT Equipment Power} / \text{Total Facility Power} \times 100\%$$

IT equipment power includes the load associated with all of the IT equipment, such as compute, storage and network equipment, along with supplemental equipment used to monitor or otherwise control the data centre including Keyboard Video Mouse (KVM) switches, monitors, workstations and laptops. *Total facility power* includes everything

that supports the IT equipment load such as power delivery (uninterruptible power supply (UPS), generators, batteries, etc.), a cooling system (chillers, computer room air conditioning units (CRACs), direct expansion air handler (DX) units, pumps and cooling towers), compute, network, storage nodes and other loads such as data centre lighting.

9.6.3 Emerging Data Centre Metrics

When assessing the financial health of a business, one should not look at one metric in isolation. The same is true for assessing the efficiency of a data centre. Whilst PUE and DCiE have proven to be effective industry tools for measuring infrastructure energy efficiency, there is a need to measure the operational effectiveness of the data centre. To this end, a number of metrics are under development to measure dimensions including resource utilization and environmental impact. Each of these metrics provides data centre operators more visibility into where opportunities for further efficiency improvements exist.

- **Carbon usage effectiveness (CUE):** Measures data centre-specific carbon emissions, which are emerging as an extremely important factor in the design, location and operation of a data centre. CUE, combined with PUE, can assess the relative sustainability of a data centre to determine if any energy efficiency and/or sustainable energy improvements need to be made. Note: CUE does not cover the emissions associated with the data centre or the building itself. CUE is defined as:

$$CUE = CO_2 \text{ emitted (kgCO}_2 \text{ eq)/unit of energy (kWh)} \\ \times (\text{Total Data Centre Energy/IT Equipment Energy})$$

- **Energy reuse effectiveness (ERE):** Many data centres are now recovering waste energy from their operations and reusing it outside of the data centre such as heating office space or homes. Since PUE does not consider these alternate uses for waste energy, the ERE metric is used.

$$ERE = (\text{Total Facility Power} - \text{Power Reuse})/\text{IT Equipment Power}$$

- **Data centre energy productivity (DCeP):** DCeP quantifies useful work compared to the energy it requires. It can be calculated for an individual IT device or a cluster of computing equipment. DCeP is a sophisticated metric where useful work and energy are compared relative to a user-defined time limit.

$$DCeP = \text{Useful Work Produced/Total Data Centre Energy Consumed over time}$$

- **Data centre computer efficiency (DCcE):** DCcE – and its underlying submetric, server compute efficiency (ScE), enables data centre operators to determine the efficiency of their compute resources, which allows them to identify areas of inefficiency. The metric can reveal unused compute resource within a data centre making it easier for data centre operators to discover unused servers (both physical and virtual) and then decommission or redeploy them.
- **Environmental consumer chargeback:** Carbon dioxide and environmental damage are gaining acceptance as viable chargeable commodities. Using environmental chargeback models (Curry et al., 2012b) data center operators can “chargeback” the environmental

impacts (i.e. CO₂ emissions), in addition to the financial costs, of their services to the consuming end-users. Environmental chargebacks can have a positive effect on environmental impacts by linking consumers to the indirect impacts of their service usage, allowing them to understand the impact of their actions.

Energy consumption metrics do not tell the full story of the impacts of data centres on the environment. In order to understand the full environmental burden of a data centre a full life cycle assessment of the data centre facilities and IT equipment is needed. These additional costs should not be under-estimated. Take, for example, Microsoft's data centre in Quincy, Washington that consumes 48 MW (enough power for 40 000 homes) of power. In addition to the concrete and steel used in the construction of the building, the data centre uses 4.8 km of chillers piping, 965 km of electrical wire, 92 900 m² of drywall and 1.5 metric tons of batteries for backup power. Each of these components has its own impact that must be analysed in detail. This level of analysis is discussed later in the chapter.

9.7 Organizational Level Information

Whilst specific measures may differ, sustainability is important to organizations from all sectors – from service-based organizations to manufacturing organizations, from national government to local authorities and city councils. Sustainability strategy and direction are determined at the organization level based on macro concerns; identifying the overall sustainability goals of the organization, determining the types of businesses and activities in which the organization should be involved and defining organizational responsibilities.

Organizations need to determine their goals and objectives for sustainability. Typically, organizational sustainability goals involve one or more of the following:

- Develop significant capabilities and a reputation for sustainability leadership.
- Keep pace with industry or stakeholder expectations.
- Meet minimum compliance requirements and reap readily available benefits.

Agreeing on one's desired business posture on sustainability will have a significant impact on business and thus on necessary goals and priorities. It is important to be clear about the organization's business objectives and the role of sustainability in enabling those objectives.

Performance metrics and KPIs are used to measure environmental, social and economic impacts, and to ensure the delivery of strategic (and sustainability-related) objectives. Further, they help to ensure the alignment of organizational activities and performance to sustainable strategy. Sustainability performance measures and KPIs help organizations to establish progress against sustainability goals and to ensure that they cover their environmental, social and economic impacts. A sample of widely used TBL KPIs typically found in organization level sustainability reports, also known as integrated reporting (Eccles and Krzus, 2010), is provided in Table 9.4.

9.7.1 Reporting Greenhouse Gas Emissions

The GHG Protocol is the most widely used international accounting tool for government and business leaders to understand, quantify and manage the emissions of all six major

Table 9.4 A summary of widely used KPIs in sustainability reports

Economic indicators	Environmental indicators	Social indicators
Revenues	Investments in	Raises awareness and upholds
Operating costs	environmental protection	organization's values, code of
Operating margin	Greenhouse gas emissions	conduct and principles
Operating profit	Spills	Total workforce by employment
Employee wages	Water use	type, contract and region
Employee benefits	Waste (hazardous and	Hours worked
Payments to providers	nonhazardous)	Employee turnover
of capital	Employee commuting	Minorities in management
Payments to	Environmental and polluting	Benefits for full-time and
government in	finances	part-time employees
taxes	Total energy consumption	Employee education and training
Research and	Renewable energy	expenditure
development	consumption	Percentage of employees receiving
Sustainable	Facility energy consumption	regular performance and career
innovations	Internal energy consumption	reviews
Customer satisfaction	Data centre energy	Flexible working arrangements
Product safety and	consumption	Employee satisfaction
quality	Business travel (flights)	Remuneration and bonuses related
Capital and	Fleet fuel consumption	to sustainable development
exploration	Paper consumption	Injuries and accidents
expenditure	Noncompliance with	Child labour
Sales and marketing	regulations and voluntary	Community contribution
General and	codes	Losses of customer data
administration	Sites with a (certified)	
	environmental	
	management system	

GHGs: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆). Many of these gases have a 'global warming potential' that is many times greater than that of CO₂. The GHG emissions generated directly and indirectly by an organization can be classified into three 'scopes', based on the source of the emissions. The scope of emissions is illustrated in Figure 9.2. The GHG Protocol is based on five principles (relevance, completeness, consistency, transparency and accuracy) and lays out a sequence of steps that organizations should follow to account for and report their emissions of GHG. These include the following:

1. Defining the geographical boundaries within which the organization operates.
2. Setting organizational boundaries.
3. Identifying reporting entities at the corporate and facility levels.
4. Deciding emission scopes (1, 2 and/or 3) and which GHGs are to be reported.
5. As appropriate, adopting estimating protocols specific to their sector(s) of industry.
6. Establishing a base year and setting targets for future years.

Common Sources of Greenhouse Gas Emissions

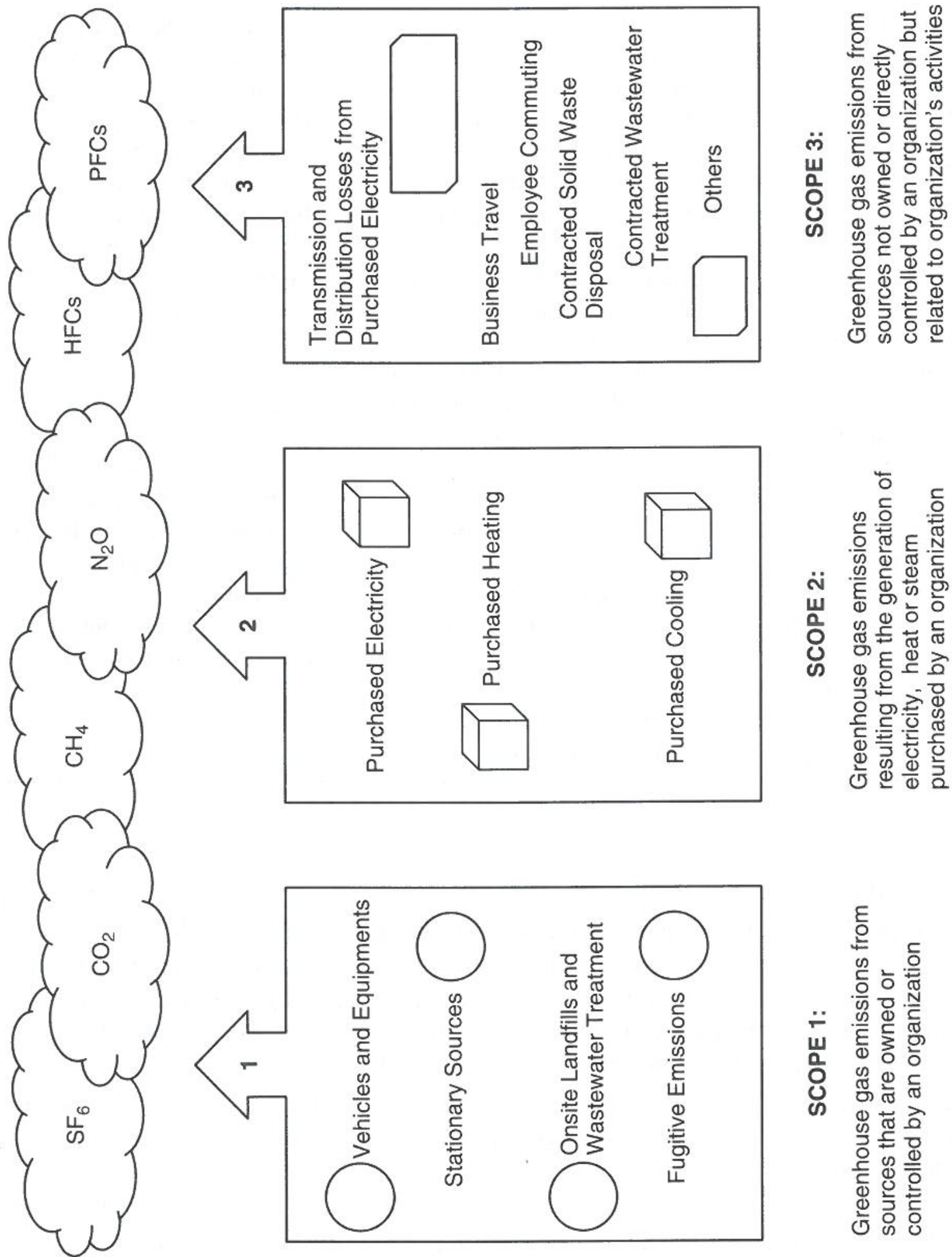


Figure 9.2 Scopes of greenhouse gas emissions.

9.8 Regional/City Level Information

It is critical that we understand the impacts that regions have on people and the environment. Understanding the relationship between economic, environmental, and social factors is essential for the authorities within a region to manage their approach to sustainability. In 2008, for the first time in human history, over half the world's population live in cities in addition, cities are responsible for generating more than 80% of global GDP yet they occupy just 2% of the world's land surface. The challenge of developing sustainable city regions is likely to become more complex as populations continue to migrate to urban centres.

Strong leadership and governance plays a key role in enhancing a regions sustainability through plans and policies that enhancing resource efficiency and embrace new technologies to improve levels of sustainability through careful management and planning. To ensure that the region is moving towards sustainability the baseline and trend information across all aspects of the region must be made using indicators to track the progress of key aspects of the region such as energy use, total employment rate or level of mental well-being, and to use this information to effect positive change. These indicators should be contextualized with a set of region statistics against which the indicators can be measured or analysed (i.e. population, population density, age dependency ratios, geographical size, national and regional gross domestic produce and gross national product, consumer price indices, life expectancy, etc.).

To contextualise a regions performance in an international context it is possible to benchmark against peer regions, for city regions a number of benchmarks are available. The European Green City Index is a collaboration between Siemens and the Economist intelligence unit developed. The 2009 index compared 30 European Cities with one another along 30 different criteria, both qualitative and quantitative. The Index considers eight themes; CO₂ emissions, energy, buildings, transport, water, waste & land use, air and environmental governance. The Carbon Disclosure Project has a wealth of experience in monitoring the GHG emissions from companies; they are extending the project to the city scale. Carbon Disclosure Project for Cities initiative allows cities to disclose their emissions data and benchmark their performance against other cities.

9.8.1 Developing a City Sustainability Plan: A Case Study

We examine how Dublin City Council went about developing its sustainability plan.

In January 2009, Dublin City Council began preparation of its new *Dublin City Development Plan 2011–2017*, as required under Ireland's Statutory Planning Process. The Dublin City Council used the Natural Step Framework, summarized in Table 9.2, to define a generic 'golden standard' planning process to help the local authority better leverage its internal resources and refine governance systems to achieve long-lasting cultural change from within to accelerate the city's progression towards sustainability.

Dublin City Council operationalized the framework through an implementation schema (Ny *et al.*, 2006, 2008) composed of five specific levels: systems level, purpose level, strategic level, actions level and tools level. The City Council developed a governance model based on these levels as detailed in Table 9.5.

Table 9.5 Sustainability governance plan of Dublin City Council

Level	Practical application of framework
Joined-up systems	Six themes identified to build alliances
Vision	Vision of a sustainable Dublin
Strategy	Development plan policies
Actions	Implementation of development plan Development management Guiding principles Sustainable standards Objectives
Tools	Monitoring body and indicators

Source: Dublin City Council (2010).

This integrated approach is useful as it helps ‘avoid the tendency in planning to focus only on a subset of issues or areas ignoring broader, connected issues leading to a need to expand the system boundaries’ (Waldron *et al.*, 2008). The integrated action plan arising out of this approach is given in Table 9.6.

Examples of indicators used to support the Dublin City Council sustainability plan are provided in Table 9.7. However, as illustrated by Table 9.6, this information is spread across many initiatives and functions within the council, and with partners. Sustainable information management is a significant challenge for the council.

9.9 Measuring the Maturity of Sustainable ICT

IT organizations need to develop a sustainable information and communication technology (SICT) capability to deliver sustainability benefits both internally and across the enterprise. However, due to the new and evolving nature of the field, few guidelines and guidance on best practices are available. In order to assist organizations understand the maturity of their SICT capability, a number of tools for measuring SICT maturity have been developed including the G-readiness framework (Molla *et al.*, 2008; O’Flynn, 2010) which provides a benchmark score against SICT best practices, or the Gartner Green IT Score Card which measures corporate social responsibility (CSR) compliance. In the remainder of this section, we examine the SICT–Capability Maturity Framework (SICT-CMF) from the Innovation Value Institute (IVI). The SICT-CMF Maturity provides a comprehensive assessment to determine current maturity level and a set of practices to increase SICT capability; performing an assessment allows an organization to identify capability gaps and identified opportunities to improve SICT performance.

9.9.1 A Capability Maturity Framework for SICT

The SICT–CMF gives organizations a vital tool to manage their sustainability capability (Curry *et al.*, 2012; Donnellan, Sheridan, and Curry, 2011). The framework provides

Table 9.6 Integrated sustainability plan of the Dublin City Council

Action	Water	Waste	Transport	Biodiversity and parks	Sustainable society	Procurement	Energy
Action at work scheme		X					
Active leakage reduction	X						
Allotments strategy				X			
Bike-to-work scheme			X		X	X	
Biodiversity action plan				X			
Cycling training programme			X		X		
Region water conservation	X						
Energy action plan							X
Energy smart community							X
Framework for Sustainable Dublin (FSD)					X		
Green procurement guide						X	
Hydro power	X						X
Kilbarrack Flagship Project	X	X	X	X	X	X	X
Litter management plan		X		X			
Mary's Lane project		X	X				X
Minus 3% project							X
Mobility management			X				
Parks and landscape strategy				X			
Energy action plan							X
Sustainable drainage systems (SuDS)	X			X			
Switch off campaign							X
Water tap tips	X						
Transport eco-awareness			X				X
Water conservation policy	X						X
Water mains rehabilitation project	X						
Workplace travel plan			X		X		

Source: Dublin City Council (2010).

Table 9.7 Indicators used in the Dublin City Council's sustainability plan

Theme	Indicators	Example
Transport	Vehicle fleet fuel usage for reporting period. Broken down into fuel type (e.g. diesel, petrol or biofuel). Equivalent CO ₂ emitted.	Between 8 November and 9 October, Dublin City Council used about: 3.3 million L of diesel 61 500 L of petrol 4 800 L of biofuel This is equivalent to 8105 tonnes of CO ₂ per annum.
Waste recycling	Total waste from offices for reporting period. Broken down into percentage of waste recycled.	For 2009 Dublin City Council offices disposed of about 32 000 bags of waste in landfill and 40 300 bags of waste were sent for recycling. This equates to a recycling rate of 56% for waste generated in Dublin City Council offices.
Water use	Volume of water consumed in offices for reporting period.	The volume of water used in civic offices was 20 432 m ³ between 8 September and 9 August. From 9 September to 10 August, the volume used was 18 197 m ³ . This is a reduction of 11%.
Biodiversity and parks (zoned land)	Amount of land zoned in the development plan for amenity and open space lands, green network, waterways protection, recycling facilities and so on	The total amount of Z9 (amenity and open-space lands and green network), Z11 (waterways protection) and Z12 (institutional land including recycling facilities, etc.) lands zoned in the Dublin city development plan in 2008 was 2882 ha.
Energy use	Total electricity and gas usage in council offices for reporting period	Total electricity and gas usage in council buildings between 1 January and 31 December 2009 was: Electrical usage: 49 533 019 kW h Gas usage: 96 919 704 kW h

Source: Dublin City Council (2010).

a comprehensive value-based model for organizing, evaluating, planning and managing SICT capabilities. Using the framework, organizations can assess the maturity of their SICT capability and systematically improve capabilities in a measurable way to meet their sustainability objectives (Curry *et al.*, 2012a). The SICT-CMF offers a comprehensive

value-based model for organizing, evaluating, planning and managing SICT capabilities, and it fits within the IVI's IT-CMF (Curley, 2004, 2007).

The SICT-CMF assessment methodology determines how SICT capabilities are contributing to the business organization's overall sustainability goals and objectives. This gap analysis between what the business wants and what SICT is actually achieving positions the SICT-CMF as a management tool for aligning SICT capabilities with business sustainability objectives.

The framework focusses on the execution of four key actions for increasing SICT's business value:

- Define the scope and goal of SICT.
- Understand the current SICT capability maturity level.
- Systematically develop and manage the SICT capability building blocks.
- Assess and manage SICT progress over time.

9.9.2 *Defining the Scope and Goal*

Firstly, the organization must define the scope of its SICT effort. As a prerequisite, the organization should identify how it views sustainability and its own aspirations. Typically, organizational goals involve one or more of the following:

- Develop significant capabilities and a reputation for environmental leadership.
- Keep pace with industry or stakeholder expectations.
- Meet minimum compliance requirements and reap readily available benefits.

Secondly, the organization must define the goals of its SICT effort. It is important to be clear on the organization's business objectives and the role of SICT in enabling those objectives. Having a transparent agreement between business and IT stakeholders can tangibly help achieve those objectives. Significant benefits can be gained even by simply understanding the relationship between business and SICT goals.

9.9.3 *Capability Maturity Levels*

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

1. **Initial:** SICT is ad hoc; there is little understanding of the subject and few or no related policies. Accountabilities for SICT are not defined, and SICT is not considered in the system's life cycle.
2. **Basic:** There is a limited SICT strategy with associated execution plans. It is largely reactive and lacks consistency. There is an increasing awareness of the subject, but accountability is not clearly established. Some policies might exist but are adopted inconsistently.

3. **Intermediate:** A SICT strategy exists with associated plans and priorities. The organization has developed capabilities and skills and encourages individuals to contribute to sustainability programmes. The organization includes SICT across the full system's life cycle, and it tracks targets and metrics on an individual project basis.
4. **Advanced:** Sustainability is a core component of the IT and business-planning life cycles. IT and business jointly drive programmes 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.
5. **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. Firstly, it is the basis of an assessment process that helps to determine the current maturity level. Secondly, 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.

9.9.4 SICT Capability Building Blocks

Whilst it is useful to understand the broad path to increasing maturity, it is more important to assess an organization's specific capabilities related to SICT. The SICT framework consists of nine capability building blocks (see Table 9.8) across the following four categories:

- *Strategy and planning*, which includes the specific objectives of SICT and its alignment with the organization's overall sustainability strategy, objectives and goals
- *Process management*, which includes the sourcing, operation and disposal of ICT systems, as well as the provision of systems based on sustainability objectives and the reporting of performance
- *People and culture*, which defines a common language to improve communication throughout the enterprise and establishes activities to help embed sustainability principles across IT and the wider enterprise
- *Governance*, which develops common and consistent policies and requires accountability and compliance with relevant regulation and legislation.

The first step to systematically develop and manage the nine capabilities within this framework is to assess the organization's status in relation to each one.

The assessment begins with a survey of IT and business leaders to understand their individual assessments of the maturity and importance of these capabilities. A series of interviews with key stakeholders augments the survey to understand key business priorities and SICT drivers, successes achieved and initiatives taken or planned. In addition

Table 9.8 Capability building blocks of SICT

Category	Capability building block	Description
Strategy and planning	Alignment	Define and execute the ICT sustainability strategy to influence and align to business sustainability objectives.
	Objectives	Define and agree on sustainability objectives for ICT.
Process management	Operations and life cycle	Source (purchase), operate and dispose of ICT systems to deliver sustainability objectives.
	ICT-enabled business processes	Create provisions for ICT systems that enable improved sustainability outcomes across the extended enterprise.
	Performance and reporting	Report and demonstrate progress against ICT-specific and ICT-enabled sustainability objectives, within the ICT business and across the extended enterprise.
People and culture	Adoption	Embed sustainability principles across ICT and the extended enterprise.
	Language	Define, communicate and use common sustainability language and vocabulary across ICT and other business units, including the extended enterprise, to leverage a common understanding.
Governance	External compliance	Evangelize sustainability successes and contribute to industry best practices.
	Corporate policies	Enable and demonstrate compliance with ICT and business sustainability legislation and regulation. Require accountability for sustainability roles and decision making across ICT and the enterprise.

to helping organizations understand their current maturity level, the initial assessment provides insight into the value placed on each capability, which will undoubtedly vary according to each organization's strategy and objectives. The assessment also provides valuable insight into the similarities and differences in how key stakeholders view both the importance and maturity of individual capabilities as well as the overall vision for success.

Plotting current levels of maturity and strategic importance lets an organization quickly identify gaps in capabilities. This is the foundation for developing a meaningful action plan. Figure 9.3 shows the results of an organization's assessment of the importance of capabilities versus its own assessment of its current maturity in those capabilities.

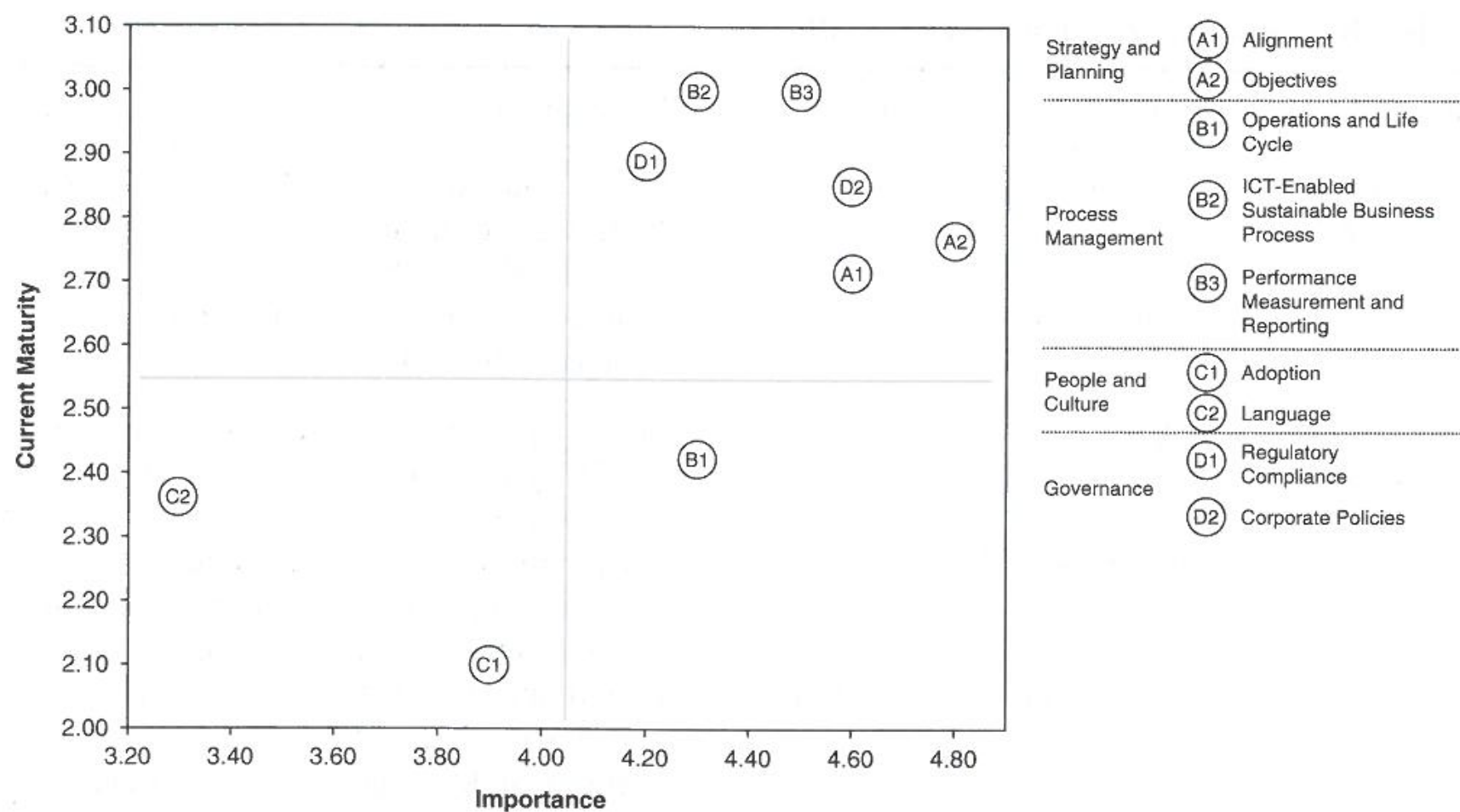


Figure 9.3 Maturity level versus importance plotted for each capability building block.

Figure 9.4 shows the consolidated survey results, resulting in an overall maturity level for each capability building block. This organization is close to level-3 maturity overall but is less mature in some individual capabilities. It views alignment and objectives under the strategy and planning category as the most important capability building blocks, but it has not achieved level-3 maturity in these areas. It also views operations and life cycle as important capabilities, but its maturity level for that building block is even lower (level 2).

9.9.5 Assessing and Managing SICT Progress

With the initial assessment complete, organizations will have a clear view of current capability and key areas for action and improvement. However, to further develop SICT capability, the organization should assess and manage SICT progress over time by using the assessment results to achieve the following goals:

- Develop a roadmap and action plan.
- Add a yearly follow-up assessment to the overall IT management process to measure over time both progress and the value delivered from adopting SICT.

Agreeing on stakeholder ownership for each priority area is critical to developing both short-term and long-term action plans for improvement. The assessment results can be used to prioritize the opportunities for quick wins – that is, those capabilities that have smaller gaps between current and desired maturity and those that are recognized as more important but might have a bigger gap to bridge.

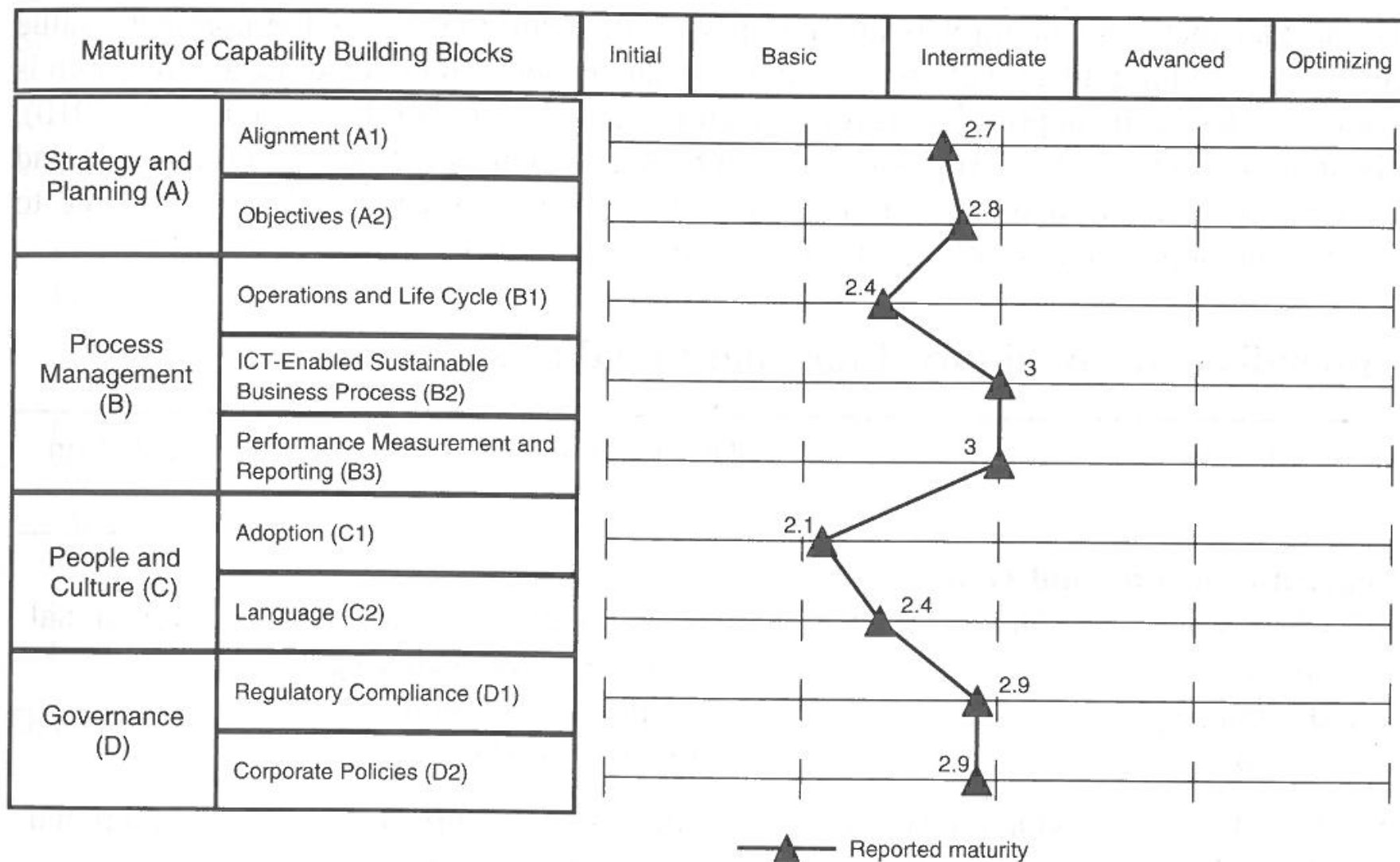


Figure 9.4 Aggregated results for the current maturity level from the assessment.

9.10 Conclusions

The next wave of green IT will tackle broad sustainability issues outside of IT. Sustainable IT has significant potential to contribute to sustainability and to enhance existing sustainability practices. Sustainability information is needed at both the macro and micro levels; it will require a multilevel approach that provides information and metrics that can drive high-level strategic corporate and regional sustainability plans, as well as low-level actions such as improving the energy efficiency of an office worker.

Many organizations think sustainability requires a significant transformational change, yet the ultimate goal is to embed sustainability into business-as-usual activities. In aiming to improve sustainability, organizations are facing both business and technical challenges that are complicated by the inherent breadth of information (Curry *et al.*, 2011), which spans the full value chain through an enterprise.

Whilst organizations are fighting a data deluge within their information systems (Cukier, 2010), there is a significant lack of data on sustainability concerns. A 2010 survey of more than 600 chief information officers and senior IT managers highlighted that few organizations are performing well at measuring the effectiveness of their sustainability efforts (O'Flynn, 2010). The paucity of sustainable information within organizations is a significant challenge and one that needs to be addressed if sustainable IT efforts are to deliver on their potential.

With the relative immaturity of practices within organizations, effective use of metrics is an emerging area (O'Flynn, 2010). The development of effective metrics is complicated

by the fact that sustainability is an enterprise-wide issue that spans the complete value chain. Determining the granularity for effective data is not well understood, and research is needed to define the appropriate level of usefulness (Watson, Boudreau, and Chen, 2010). The appropriateness of information will also be highly dependent on the stakeholders and the task or decision at hand (Hasan *et al.*, 2011). Green IS will need to be flexible to provide the appropriate level of information for the given situation.

Appendix: Sustainability Tools and Standards

Standard name	Level	Description	Jurisdiction
General reporting and GHG			
GHG Protocol: accounting and reporting standard	Organization	Internationally recognized procedure for preparing verifiable emission reports (2004)	International
ISO 14064-1, 2 and 3: GHG accounting and verification	Organization or project	Modelled on the GHG Protocol; used to quantify, report and verify GHG emissions	International
The Climate Registry (TCR): General Reporting Protocol	Organization	Guidelines and calculation tools for voluntary emissions reporting programmes	North America
BSI PAS 2050: specification for the assessment of life cycle GHG emissions of goods and services	Product or service	Detailed technical specifications for the carbon footprint of goods and services (2008)	International
BSI PAS 2060: specification for the demonstration of carbon neutrality	Organization	Details quantification, reduction and offsetting of GHG emissions to achieve and demonstrate carbon neutrality (2010)	International

Standard name	Level	Description	Jurisdiction
UK Department for Environment, Food and Rural Affairs (DEFRA) Guidance: How to Measure and Report Your GHG Emissions	Organization	Procedure for organizations to measure and reduce GHG emissions (2009)	United Kingdom
GHG Protocol: Product and Supply Chain Standards	Product	—	International
ISO 14067-1 and 2	Product or service	Standard to quantify and communicate the GHG emissions of goods and services; builds on life cycle assessments (ISO 14040/44) and environmental labelling and declarations (ISO 14025)	International
Climate Disclosure Standards Board (CDSB)	Organization	Standard guidelines for corporate reporting of emissions	International
Global Reporting Initiative (GRI) Guidelines	Organization	Version G3 launched in 2006, standard guidelines for sustainability reporting	International
Life cycle costing	Product or service	A process to determine the sum of all the costs associated with an asset including acquisition, operation, maintenance and disposal costs	Standards by countries

(continued overleaf)

Standard name	Level	Description	Jurisdiction
Government			
Smart growth	General principles	Urban planning and transportation theory that concentrates growth in urban centres	International
New urbanism	General principles	Urban design movement that promotes walkable neighbourhoods of housing and jobs	International
Industrial ecology	General principles	The study of material and energy flows through industrial systems and their effects on the environment	International
Manufacturing			
Waste from Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS)	Product	EU law in 2003, setting collection, recycling and recovery targets of electrical goods	Europe
REACH	Product	EU regulation in 2006, addressing the production and use of chemical substances and their potential impacts on human health and environment	Europe
EUP	Product	EU directive in 2005, addressing the security of its energy supply and its potential impacts on human health and environment	Europe

Standard name	Level	Description	Jurisdiction
LCA, ISO 14040	Product or service	A process to evaluate the effects that a product has on the environment throughout its entire life cycle	International
Design for environment	Product or service	US EPA Programme in 1992, working to prevent pollution and its risk on human health through design approaches that reduce environmental impacts of a product	United States
Cradle to cradle	Product or service	Biometric approach to the design of systems that models human industry in a way that materials are viewed as nutrients circulating in healthy and safe metabolism	International
EPEAT	Product	Global registry for greener electronics, covering the most products from the broadest range of manufacturers, ranking products as gold, silver or bronze based on a set of environmental performance criteria	International
Green seal	Product or service	Third-party, nonprofit, standards development body since 1989	United States
Hannover Principles	Buildings or objects	Copyrighted in 1992, a set of statements about designing buildings and objects with forethoughts about their environmental and sustainable impacts	International

(continued overleaf)

Standard name	Level	Description	Jurisdiction
Product stewardship and electron paramagnetic resonance (EPR)	Product or service	An approach whereby everyone who is involved in the product life cycle takes the responsibility to reduce the environmental impacts, for example through moving the costs to producers and consumers instead of taxpayers	International
Precautionary principle	General principle	An approach whereby if a policy or an action is suspected to be harmful with no scientific evidence, the ones who take the action have to prove that it is not harmful	International
Building			
LEED	Building	Incepted in 1998 by USGBC, a green building certification system, providing third-party verification that a building or community was designed and built using strategies intended to improve environmental performance	North America
BREEAM	Building	Incepted in 1990 by UK BRE, a green building certification system	United Kingdom
Natural resources			
Food alliance	Organization	Started in 1993, defines and promotes sustainability certification standards in agriculture and food industry	North America

Standard name	Level	Description	Jurisdiction
Marine Stewardship Council	Organization	Founded in 1997, defines and promotes sustainability certification standards in fishery and seafood industry	International
Forest Stewardship Council and Sustainable Forestry Initiative	Organization	Defines and promotes sustainability certification standards for the responsible management of the world's forests	International
Green Globe	General principles	Based upon the Agenda 21 plan of the Rio Earth Summit of 1992; provides a set of principles for local, state, national and international action on sustainable development in travel and tourism industry	International
STEP	Organization	Comprehensive, global sustainable tourism certification programme	International

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Review Questions

1. Explain the hierarchy of sustainability models. What is the role of sustainability frameworks, principles, and tools?
2. What are multi-level models needed?
3. What are the key metrics for data centre energy efficiency?

4. What is LCA? Explain the four stages of LCA.
5. Discuss the maturity of SICT capabilities.

Discussion Questions

1. How sustainable is your organization, education institute or personal lifestyle?
2. What activities have the largest impacts on sustainability? How could they be measured?
3. What would a life cycle assessment of your day's activities involve? Consider both direct and indirect impacts.
4. What metrics could be used to track the activity? How could an information system help you reduce your impacts?

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Further Reading and Useful Web Sites

(All sites accessed April 2012.)

General

- Global Footprint Network: <http://www.footprintnetwork.org/en/index.php/GFN/>

Reporting

- GHG Protocol: <http://www.ghgprotocol.org/>
- EPA Climate Leaders: <http://www.epa.gov/climateleaders/>
- Global Reporting Initiative: <http://www.globalreporting.org>
- Carbon Disclosure Project: <http://www.cdproject.net>
- The UN Conference on Trade and Development (UNCTAD) *Manual for the Preparers and Users of Eco-Efficiency Indicators*: http://www.unctad.org/en/docs/iteipc20037_en.pdf
- UK Department for Environment Food and Rural Affairs – *Environmental Key Performance Indicators: Reporting Guidelines for UK Business*: <http://www.defra.gov.uk/publications/2011/03/25/environmental-kpi-guidelines-pb11321>
- UNCTAD guidance on corporate responsibility indicators in annual reports: http://www.unctad.org/en/docs/iteteb20076_en.pdf

IT and Data Centre Energy Efficiency

- The Green Grid: <http://www.thegreengrid.org/>
- The Uptime Institute: <http://www.uptimeinstitute.org/>
- Climate Savers Computing: <http://www.climatesaverscomputing.org/>
- EU Code of Conduct for Data Centres: http://re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative_data_centers.htm
- Energy Star: <http://www.energystar.gov/>
- Chapter 5 of this book, 'Green Data Centres'

Product and Service Life Cycle Assessment

- The Sustainability Consortium: <http://www.sustainabilityconsortium.org/>
- Walmart Sustainability Index: <http://walmartstores.com/Sustainability/9292.aspx>
- Jeffrey Ball, 'Green Goal of "Carbon Neutrality" Hits Limit', *Wall Street Journal*, December 30, 2008: <http://online.wsj.com/article/SB123059880241541259.html>
- Levi Strauss & Co. – Life Cycle of a Jean: <http://www.levistrauss.com/sustainability/product/life-cycle-jean>
- EPA Desktop Computer Displays a Life Cycle Assessment: <http://www.epa.gov/dfe/pubs/comp-dic/lca/>

Tools and Carbon Calculators**Reporting**

- GHG Calculation Tools: <http://www.ghgprotocol.org/calculation-tools>
- SAP Sustainability Report: <http://www.sapsustainabilityreport.com/>
- eXtensible Business Reporting Language (XBRL): <http://www.xbrl.org>

Product and Service Life Cycle Assessment

- Earthster: <http://www.earthster.org/>
- OpenLCA: <http://www.openlca.org/>