MODULE J

INFORMATION AND COMMUNICATION TECHNOLOGY

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1 Introduction. ICT as a source of innovation – devices and systems .

Information and Communications Technology (ICT) is widely credited with bringing about significant improvements in the resource efficiency of industrial economies over the last few decades, though this is very hard to determine with any accuracy. What is clear is that any contribution to the environmental efficiency of the economy has essentially been as a 'by-product' of the main focus on the application of ICT – improving *economic efficiency* (through transforming management systems, transaction processes and so on).

ICT is included as a specific technological area in this Guide because of its potential to contribute to the development of more innovative designs for new products, services and systems. The idea is to utilise the technology, intentionally, as a way of realising new sustainable solutions.

Of course ICT is already a critical ingredient in most design work today. Design processes rely on ICT and software tools for calculation, visualization, documentation and so on. Most production processes have been improved by the incorporation of ICT and many goods and services depend on information systems to operate. New product-service systems are very likely to involve a substantial incorporation of information and communication systems.

When we talk about ICT we tend to think in terms of 'hardware' devices (computers, mobile phones, video-cameras, sensors, and so on) or in terms of software and networks, (the web, internet, browsers, email and so on). Any contribution to the development of new eco-designed products and services that comes from thinking about ICT *will* involve the application and use of hardware devices along with software and communications networks. Like any other area of technology, some new innovations will originate from a desire to exploit new possibilities which originate from new software or hardware devices. This ***'technology inspired approach'*** is described below. Innovation of this kind involves the exploration of questions such as '*what can we do with this device that we could not do before it existed*'. Such innovation can be environmentally focused if the 'what can we do' focuses on reducing the consumption of resources (or the production of waste) - for example by thinking *'what could you do to reduce physical travel by using an information technology device or communications system?'*

But, there is another way in which ICT can be a starting point or a facilitator for design or innovation which does not focus on the hardware or software but on the 'systems potential' of the technology. All those ICT devices and software and networks are technologies for acting on information, to transform its value or utility. The devices are just tools to work on the real substance of economic value – information. The ***'information systems approach'*** starts from a focus in information flows and the potential to 're-shape' them to deliver different outcomes (substitution of material flows, new user behaviour, new functionality and so on.)

In this approach the hardware or software is selected to deliver outcomes which are first defined.

This section of D4S is also more focused on *ways of thinking about the potential of ICT* – in terms of eco-design and eco-innovation - than about particular hardware or software devices. The 'ways of thinking about ICT' have been drawn from research and case studies.

2 TECHNOLOGY INSPIRED APPROACHES – EXPLOITING NEW POTENTIALS OF ICT DEVICES.

'Seeing' new possibilities opened up by new technological devices is a less systematic, more 'inspirational' way in which (eco)innovation can take place. It is very hard to provide any guide to assist that process. ICT devices change rapidly; new devices enter the market, the capacity of most existing devices changes rapidly (think how fast the capacity of a personal computer is out-dated by new models).

There are many reliable sources of prediction about the appearance of new devices. Since the producers of such equipment want to see their success in the market, they generally support many magazines and web-sites 'showing' new concepts well before they are available for consumers. Scanning such magazines and web-sites on a regular basis is therefore about the only systematic starting point for inspiration. Of course there are also regular, international, trade exhibitions (such as CeBit – www.cebit.de) which can also be valuable sources of new 'technology–inspired' thinking. It is often difficult in retrospect to know whether a particular new innovation began as an inspiration for the new use of a device (or whether the device was found to support a new innovative system (see next section). Clearly the existence of mobile information and communication devices (mobile phones , Personal Digital Assistants, note-book computers etc) has inspired many new services. Sensors and monitoring devices also open up new possibilities to be exploited.

The internet as an open communications system has transformed business-to-business and business-to-consumer relationships and is probably the most obvious example of new innovative solutions abased on the exploitation of a new technical capacity.

BOX

The rate of change of the technical capacity of devices.

One attribute of most ICT devices can be predicted with some confidence. Whatever the key capacity or attribute of a device - its memory size, its communication speed, its processing power – it will double roughly every 18 months for a given level of investment/cost. There is a related and similar (but inverse) effect in relation to the energy consumption of some devices (and possibly even their physical size) which will decrease significantly every 18mths to 2 yrs. For either the technology inspired approach or the information systems approach, this regular improvement can be anticipated in any design/innovation development. Some innovative solutions will require 'pushing' the boundaries of technology in terms of the capacity; with these rough laws in mind system performance can be related to ICT capabilities and cost at a future time.

3 INFORMATION SYSTEMS APPROACH.

Exploiting the systems potential of ICT starts with information flows. This is presented as two step process.

NOTE: In practice whilst starting with 'step one' (defining the information flows for you system) is the most logical, a quick review of step two (categorisation and examples of ICT system potentials) can actually help clarify existing information flows as well as suggest innovative alternatives. The best process is probably to move iteratively back and forth between steps one and two until a suitable solution is found.

3.1 STEP ONE: DEFINE THE INFORMATION FLOWS.

For your project, using a version of a system list or system map (see module B), identify and mark the information flows that are required for the system (or product) to operate. Begin with the existing system/product. Mark in all the information flows, noting:

>*What they do* (what information is being transferred)

>*What form* the information takes and *how it travels* (remember it might be physical or digital in the existing system)

>What *devices and resources* are used to support information flows.

>What *outcomes* result from the information flows.

Then, consider the intended outcome (or the aim or brief) for a new (innovative) system or product and: define what information could make the intended performance of the new concept most efficient and effective (economically and environmentally). (It is best to do this without regard to whether that information appears to be easily available or not.)

If you already have an initial idea for a new concept, the on its system map mark in the information flows as above.

The design/innovation aim for the next step is then to:

Configure an information and communications technology system that will support the efficient and effective operation of the system/product. NOTE: this will entail identifying and choosing (or, in some cases where there is sufficient investment available, specifying the characteristics for) a set of ICT devices and/or software to handle the information and communications processes to achieve the desired outcomes.

3.2. STEP TWO: IDENTIFY ANY ICT 'SYSTEM POTENTIALS' THAT COULD BE RELEVANT TO YOUR CONCEPT.

The information that follows is intended to provide both a guide and an inspiration for developing new ICT based system/product solutions.

The first part of this section provides a framework of six different (but often overlapping) ways of thinking about the potential for ICT to 'transform' systems and products. These have been developed from a large study of actual system/product changes. These six approaches should be considered as possible design directions for developing new sustainable systems and products. They suggest 'ways of thinking' about eco-design and eco-innovation.

The second part focuses on 'smart systems and imbedded eco-intelligence' and includes a set of approaches to the development of 'smart' ICT based systems.

3.2.1 SIX TRANSFORMATIVE POTENTIALS OF ICT

1> Aware-sense - smart senses for system status.

ICT provides new opportunities for the development of (real-time) sensing systems for monitoring ecological conditions. Satellite systems can monitor changes at the earths surface; new sensors can monitor many environmental factors and communicate information wirelessly; very small sensors (often called 'smart-dust' – see BOX below) are being developed which can be spread over a terrain and operate like a 'sense net' requiring little or no maintenance.

Sensors can deliver real-time information on conditions via networks including the internet.

Sensors do not have to be based on digital data streams; they could be, for example, smart materials which change colour in different environmental conditions (e.g. responding to air quality).

2 > Intelligent feedback.

(Re)connecting key elements of the environmental system broken by the scale of physical conditions. "Feedback" means the provision of information on the outcomes, or the environmental impacts of actions, behaviour, decisions, functions.

This feedback can be at the product/ component level: sensors providing real-time data to optimally change product operation (see next section).

Feedback can be at product/user interface ('selecting this option will consume so much resources').

Feedback can be at the macro scale: information on household or neighbourhood resource consumption; or a another scale still - information on the current environmental conditions of a community of city (air quality, water consumption, waste production levels, UV/sunlight levels, etc)

3> Tele-presence and virtual extension.

Through the use of visual and audio information ICT provides opportunities for 'virtual transportation' to another environment, replacing material transportation for whatever purpose.

This can replace personal travel 'to' somewhere, such as for meetings, conferences (e.g video or tele-conferencing) or with web-cameras etc, this could also be 'visiting' some place, such as a home (to check security) or a café (to check who is there), or a nature (for a virtual holiday or bird-watching) and so on.

Virtual extension can change the apparent spatial configurations beyond physical boundaries - extending the experienced dimensions of a home or office (satisfying spatial needs and connectivity) without increasing the real one.

4> Virtualising /Visualising potential realities.

ICT (computing hardware and software) has provided enormous opportunities to create simulations and models of new systems, products and environments. These models can help in the design of systems but also in their (efficient) operation (another form of 'feedback').

With the development of new display systems (including 3D) 'simulation' can involve new immersive virtual environments to explore new systems potentials. This could be called 'transformative simulation', providing users with the experience of 'living-in' some future conditions or of current conditions of a space that cannot be safely or conveniently visited.

5> From 'atoms' to 'bits' - reversing the hardware / software balance.

One overriding aim of eco-innovation is to reduce material flows and to 'dematerialise consumption'. ICT systems can be used to shift the value or utility of products from atoms to bits, from physical material to information. This is one important strand of intelligent systems/products where what is valued is the intelligence rather than the material resources (see next section).

Sustainable products, systems and services can rely heavily on software rather than hardware. Product life can be extending without prohibiting upgrading and functional innovation if they are viewed as a system of 'eternal hardware' combined with 'mutable software': eternally yours but ever changing, through up-grading only the 'operating system'. (Some washing machines, cars and sewing machines, which depend on software to deliver operational efficiency and effectiveness, are already able to benefit from up-grading their 'operating system').

6> Eco-logistics - eco-efficient resource tracking.

Major shifts in industrial production - remanufacturing, just-in-time delivery, efficient (shorter) transport networks - depend on the power of new logistics systems, with information flows to track vehicles, define transport routes, monitor the conditions of goods in transport etc. This delivers economic benefit from reduced inventory and higher transport utilization factors, with potentially large increases in resource efficiency.

With closed cycle production systems with product take back at end of life, logistics systems will probably come to include product transponders or identity chips to track products/components through their life.

BOX

Motes and *Smart Dus*t are different names given to miniaturised sensors, able to communicate wirelessly, sending data on specific conditions. These are small enough that a large number can be spread out as a net covering an area or volume to be monitored. Sensors can monitor temperature, pressure, moisture, vibration, magnetic fields, in fact any form of data collection that can be easily miniaturised. Motes are already smaller than half a match box and rapidly reducing in size, with new prototypes about the size a grain of rice. These devices, running a tiny software operating-system, handle communications through radio links to other motes, operating as a network, transferring data along the net. The mote-net is smart enough to reconfigure after the loss of a device or with the introduction of additional devices. To reduce power, devices sleep for most of the time, waking periodically to take a reading, sending data only when there is a change of conditions. New devices use so little power that they will soon run from micro-miniature batteries and may eventually not need batteries at all, being able to 'scavenge' energy from light and heat and even vibration. Recent demonstrations have shown that such a net can track the movement of a vehicle and relay that information fast enough to guide a following robot vehicle.

BOX

Distributed Computing.

Millions of PC users are volunteering the idle or unused processing power of their home or office computers to help analyse data and perform computer simulations for research that is seen as socially and environmentally valuable. Conservative estimates put the processing power available in this way at over 10 billion megahertz and with over 10 thousand terabytes of memory and storage. Software for distributing such tasks between idle computers has moved from the initial system for SETI@home (the search for extra-terrestrial intelligence that has over 4.5 million users) based on a new platform called Boinc from the University of California. Data analysis and simulation now extends to climate change (climateprediction.net) to analysing DNA sequences and folding proteins for issues with Alzheimer's and Parkinson's diseases) – (folding @home).

BOX

RFID Tags - digital product identification systems.

Product identification systems have grown in sophistication based around improvements to the standard printed/optical 'bar codes'. The traditional 'one dimensional' bar codes could store around 100 bits of information; more recent two dimensional printed codes can increase information density to around 1000 bits. All these codes need to be read with a line-of-sight optical (laser) reader. Radio frequency (RFID) tags use an electronic reader that does not require line-of-sight. Most of these small flat devices measure about 3-5 cm across. Cost per tag is currently around 25cents, but industry estimates that this will fall to 5 cents, when quantities reach 5-10 billion. Tags are mostly 'passive devices' having no battery and only responding to signals from a reading scanner. They respond to a reader by returning their identification code. Current systems use a 64 bit code although there are schemes for 96 bit codes, with data on manufacturer, product and serial number. These have a range of about a metre (although less if they are covered by metal). Some battery backed tags (in use for toll-roads for example) have ten times that range. KSW-Microtec, a German company, has invented a washable RFID tag designed to be sewn into clothing and clothing companies such as Benetton have floated plans to use these tags in all their clothing for inventory processes. Some countries are considering embedding RFID tags into banknotes. Pira in the UK has established an on-line database comprising a directory of over 9000 RFID products and manufacturers world wide and regularly up-dated news about new applications. [http://www.pira.co.uk/]

BOX

Embedded intelligence.

Only 2 percent of the approximately 8 billion microprocessors produced in 2000 ended up in computers. The rest went into production machinery, home appliances and white-goods, toys, cars and other transport systems, mobile phones and PDA's , audio and video equipment etc. All these microprocessors are increasingly becoming interconnected with each other and with the internet forming new pervasive networks. Estimates are that there could be as many as 10,000 telemetric devices per person by 2010. Within a decade more things will be using the internet than people. [Rejeski 2002 (a)]

BOX

Trash That Thinks

At the end of 2001 the City of Barcelona in Spain put microprocessors and RFID tags in their public city litter bins at a cost of 20 million pesetas. The memory chips in these bins are designed to store data on how full the containers are and when they were last emptied. The system is intended to reduce problems of overflowing bins and inefficiency in collection logistics based on fixed routes and schedules. With the new system, sanitation employees, with the aid of a portable computer, will be able to record and retrieve data including the last three times a particular bin was emptied, how full it was each time and even when it was last maintained and painted. The data, along with specially-developed software, will help plan the most efficient routes and schedules for trash collection. To begin with, the system is being installed on 600 containers in Barcelona's Old Town, after which it is scheduled to be expanded to all 18,000 of the city's public waste bins.

Trash collection systems currently have little flexibility to vary schedules or routes, even though patterns of waste disposal may vary significantly over time. The Barcelona experiment is expected to dramatically improve the effectiveness and the efficiency of collection, reducing the total distance travelled at the same time as increasing the service to high-intensity-use areas. As sensing systems with radio communications capabilities become cheaper and smaller these monitoring systems could send in data on the level of trash in each bin and efficient routes for collection could be calculated each day. [IDG News 2001. www.idg.com]

3.2.2 Intelligent systems and embedded eco-intelligence.

Eco-innovation can derive from the contribution of ICT to the improved function and environmental performance of products or services resulting from the incorporation of ICT systems and intrelligence.

Many ordinary mass-produced products now imitate the sophisticated performance once possible only in advanced systems, using sensors and controls to ensure that functionality is delivered efficiently and only when needed. This has also delivered resource efficiencies through more efficient operation. The potential for such improvements is significant. A new set of eight approaches to eco-innovation through embedded eco-intelligence in shown in the following table. Examples from existing products, new concept developments, research into product-service systems and other future-concept speculations are shown.

Design/ innovation approach for product or product-service	Examples
1.Eco-intelligent function The use of embedded sensors to optimise (and automate) product function and deliver resource efficient operation.	Using sensors to check water quality in washing machines to reduce unnecessary rinsing and to check load to ensure optimal water level (prevent over-filling). 'Wake-up' sensors response to the presence or the command of operator to resume full power from stand-by mode (computers; photocopiers). Power management systems matching power use to need (portable devices now use less than 25% of energy of average desktop computer of same computing power) . Can be combined with GPS systems to deliver intelligence related to location.
2. Operational feedback to user Communication to the user about operational choices. (Important where user behaviour effects efficiency.) Note: this can be considered as a 'service' added to a product (see PSS module # 11).	Dishwasher displaying predicted water consumption and energy consumption, for selected operation. 'Image' of photo-copy page on screen, before paper used (to reduce waste paper from copy errors). Cars display of short-term average fuel consumption. Home consumption (water, energy) daily usage meters (in trials by UK power companies); monthly reports on bills; comparative consumption with relevant average.
3. ***Digital product life-signs/ digital diagnostics*** On-line, or batch, information for maintenance, and for return of components for refurbishment (closed cycle systems). Sensors systems that monitor key functional conditions during life of product, to aid in assessment of 'useable' life of components. Shared knowledge systems for technicians involved in maintenance.	Intelligent monitoring of equipment during operation, checking wear of components, operating temperature range, diagnostic comparison with expected performance ('digital signatures' and 'digital service' Xerox and Canon). Car maintenance systems diagnostics for service. Sensors for monitoring and recording 'product life' during operation (total hours of use, range of working temperatures). Such data and other internal diagnostics, could be downloaded at time of disassembly of product, to provide information about refurbishment of components.
4. The digitally networked product *(using feedback to service supplier)* Considering the product and its resource supply as one system that can be optimised for overall efficiency.	Domestic appliances that can be powered up or down, switched on by electricity suppliers to balance load of supply; Eg: Merloni, Italy, prototype refrigerators, dishwashers, washing machines, provide reduced energy costs to consumers for using 'low load energy'- turned on or off from signals sent by energy supplier.). Electrolux pay by wash system tested in Sweden; customers billed by electricity provider. Building services (heating cooling) run on-line by service provider (commercial buildings serviced by Texas A&M; California trial of homes and offices; Enron), can allow temperature to climb in summer (or reduce in winter) by agreed amount with customer in return for cost savings.
5. Digital upgradability *(software operating systems for electromechanical devices)* Extending functionality, efficiency and useable life of 'hardware' through changing only the software that controls its functionality. (see also PSS Module #11).	Dishwashers (e.g. Miele) upgradeable operating system allowing for improvements in washing cycles, new washing chemicals, better power management. Sewing machines, that can be upgraded to take account of new fabric, threads and stitches. Cars timing and fuel consumption systems can be up-graded for different fuels, different pollution controls. Computers upgrading function through new operating systems.

TABLE 1 ___ EMBEDDED INTELLIGENCE AND ECO-INNOVATION STRATEGIES FOR PRODUCTS AND PRODUCT-SERVICES.

6. ***Digital product DNA*** *(embedded information about material content, producer/batch details, disassembly processes).* Important data for refurbishment/ recycling and remanufacturing. Date to be incorporated in product at design/production, to aid end of life strategies (see 'smart trash' below).	Data on materials encoded into embedded chips interrogated for product declarations, and for more automated disassembly, to ensure recovery of valuable or harmful substances. Next level of automation for closed cycle systems . Systems for tracking products through live- production, transport (for logistics) as well as. end-of-life recovery and reuse.
7. ***Increasing the software-hardware ratio*** *(the information to material ratio)* *Achieving effective* dematerialisation through increasing the relative value of information compared to value of resource/materials content. *Virtual Products* limiting case of above (new services). (see also table 2.3 - 7)	Mobile phones; PDA's etc. Music and entertainment: MP3 files; digital images; Replacing phone books by CD's and online systems (NTT Japan).
8. ***Digitally enhanced product-service systems*** . (see table 2.3 6) Systems for: ensuring efficient product-use sharing of products, providing the use of a product (e.g. Leasing)	Intelligence in commercial car sharing systems, to aid sense of 'individuality' and ease of use using cards to open and start vehicles; 'tuning' car systems to user (seat positions; dashboard functions; radio station pre-sets; music files; GPS systems to locate/track vehicle location). 'Isharestuff.com' internet portal for sharing goods.

TABLE 1 ___ EMBEDDED INTELLIGENCE AND ECO-INNOVATION STRATEGIES FOR PRODUCTS AND PRODUCT-SERVICES.

RESOURCES AND FURTHER READING

Information is provided on additional available resources and on sources used and/or referenced in each of the chapters. Information includes internet sites and publications and is not exhaustive.

UNEP DTIE

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UNEP has a history of working with companies to identify and promote best practices – among them- the development of more sustainable products and services. Examples include a collection of best practice product service systems examples, the Efficient Entrepreneur Calendar (which outlines a simple step-by-step approach that companies can use to understand how their activities affect the environment); awards schemes, support to reporting initiatives such as the Global Compact and the Global Reporting Initiative, and the promotion of dialogue fora for companies to exchange experience. UNEP also works in specific sectors such as mobility, telecommunications, advertising, retail and sustainable construction to facilitate change through business-to-business channels. UNEP is also active in promoting life cycle thinking and innovation strategies through its Life Cycle Initiative. The Initiative's activities aim to develop and disseminate practical tools for evaluating the opportunities, risks, and trade-offs associated with products and services over their entire life cycle to achieve sustainable development. UNEP is also supporting the recently launched United Kingdom supported International Task Force on Sustainable Products, which is a result of the Implementation Plan of the World Summit of Sustainable Development. On the right is a selection of relevant UNEP web-sites and publications.

Web-sites

www.unep.fr
www.unep.fr/pc/sustain/
www.talkthewalk.net
www.unep.fr/en/branches/partnerships.htm
(see comments on the left)

Publications

Products and services

Brezet, J. C. and C. G. v. Hemel (1997). Ecodesign: A promising approach to sustainable production and consumption. UNEP, Paris.

UNEP (in collaboration with the Interdepartmental Research Centre Innovation for the Environmental Sustainability (C.I.R.I.S)) (2002). Product Service Systems and Sustainability: Opportunities for Sustainable Solutions. UNEP, Paris.

UNEP (in collaboration with Delft University of Technology (expected 2006)).Design for Sustainability: A Global Guide. UNEP, Paris.