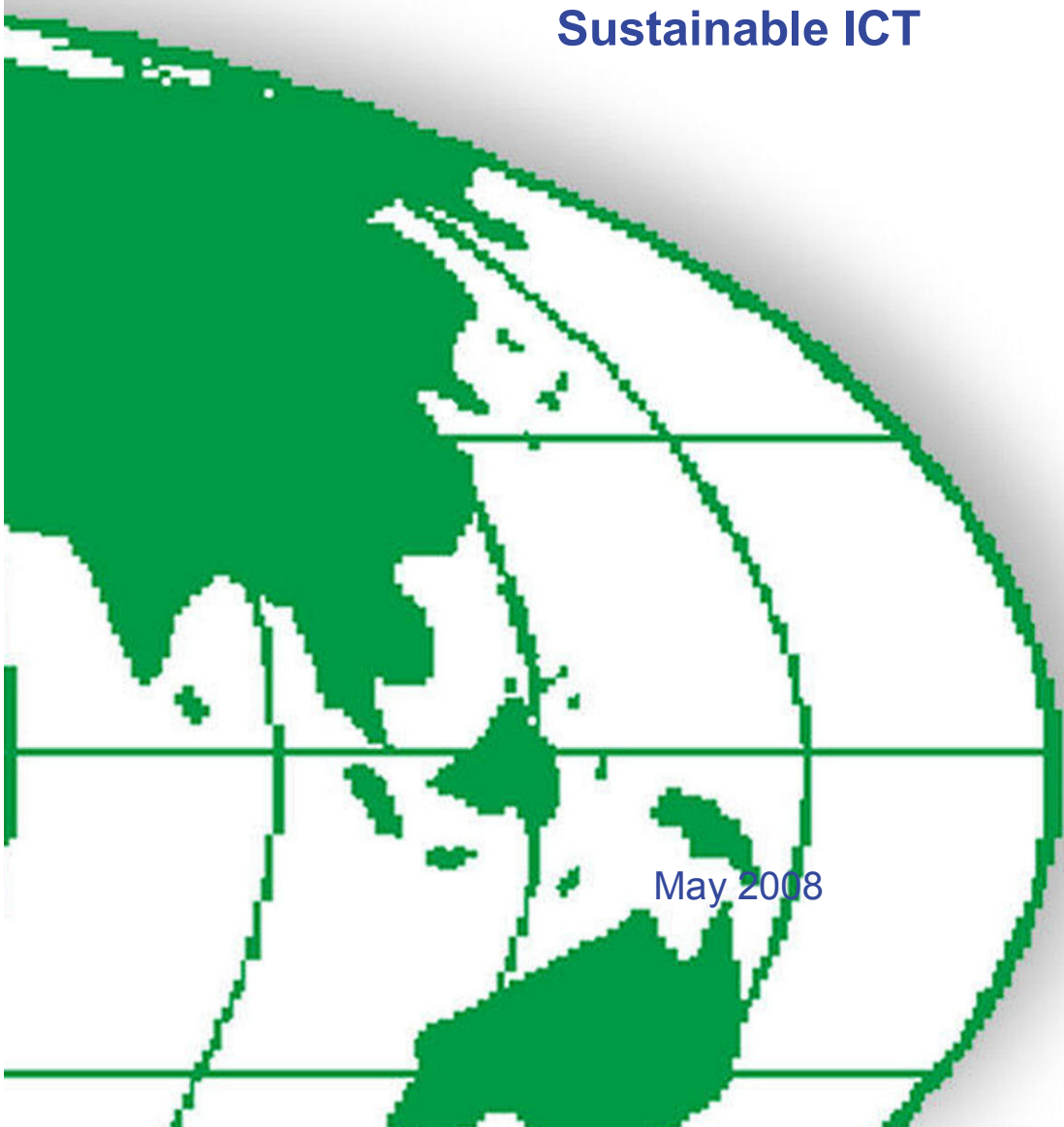
ICT Innovatie Platform
Duurzame ICT

Sustainable Visionary Innovation

ICT Innovation Platform Sustainable ICT



May 2008

ICTInnovationplatform
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1. Preface

Over the past two decades, information and communications technology (ICT) has become the glue that holds our economy and our society together. Without the use of ICT, no government could function, no factory could operate, no goods nor passengers could be transported, no stock market could operate, no salary check would be paid, and so on and so on. On top of that, ICT has given us countless new ways of working, communicating and accessing information, thereby revealing the potential to create a larger degree of welfare for a larger number of people than ever before.

Rising energy consumption of ICT

Unfortunately, there are also downsides. The energy consumption of ICT systems is rising at a frightening rate, thus putting an increasing pressure on already rapidly diminishing natural energy sources. Today the consumption of electricity by ICT amounts to some 156 GW, which is 8% of the global electricity consumption, of which only the Internet usage (data centres, network equipment, personal computers) already consumes some 4%.[1] It's widely expected that the share of ICT in the worldwide electricity consumption will continue to grow in the foreseeable future. According to various estimates, the share of ICT in the worldwide consumption of electricity may grow to anywhere between 11% and 20% in 2020.[2]

ICT also puts a burden on the environment in various other ways; by creating toxic waste through the use of hazardous materials; by polluting air, water and soil during the production of components and systems, and by the increased CO_2 emission caused by the aforementioned consumption of energy.

Also for the benefit of future generations

If we want to safeguard that future generations will also be able to enjoy the benefits of ICT, all of today's stakeholders urgently need to address the negative issues mentioned above– not only by developing sustainable ICT solutions, but also by employing ICT to further enhance the sustainability of our society as a whole. Obviously, as ICT professionals we can only work on a part of the puzzle to make the world a more sustainable place. However, the relevance of this part is growing rapidly, because of the even more increasing amount of embedded ICT we use in our daily life. Hence we have to take our responsibility, and initiate research and innovation in the areas mentioned above. The Dutch ICT Innovation Platform Sustainable ICT (IIP Sustainable ICT)[3] has been founded to accomplish these aims by stimulating research into and creating awareness for sustainable ICT.

From white paper to strategic research agenda

This 'Sustainable Visionary Innovation' white paper outlines the most important challenges in the area of sustainable ICT, as well as the activities that the IIP Duurzame ICT plans to overcome them. This paper is meant as a living document that is subject to regular updates. Eventually, it will evolve to the formal strategic research agenda of the IIP Duurzame ICT. New versions will be made available (if desirable within a secured walled garden) at the website[4] of the IIP Duurzame ICT.

[1] M. Pickavet et al., "Energy footprint of ICT", Broadband Europe conference, Antwerp, Dec. 3-6, 2007
[2] http://www.isi.fraunhofer.de/e/eng/publikation/online/iuk/iuk-e.htm
[3] Hereafter IIP Duurzame ICT. The Dutch name of the IIP Sustainable ICT is ICT Innovatie Platform Duurzame ICT or IIP Duurzame ICT.
[4] see www.iipduurzameict.nl

About this publication

The Sustainable Visionary Innovation white paper was produced by the IIP Duurzame ICT steering committee. Consulted organizations are universities and HBO, industry, non-profit organizations, SMEs, research companies and platforms:

Mr. Roel Croes, GreenICT foundation
Prof. ir. Ton Koonen, Eindhoven University of Technology
Prof. dr.ir. Ignas Niemegeers, Delft University of Technology
Prof. dr. ir. Gerard Smit, University of Twente
Ing. Fred Snijders, Philips
Drs. Mark van der Wolf, Lewis PR

The steering committee likes to thank the following persons for their contribution:

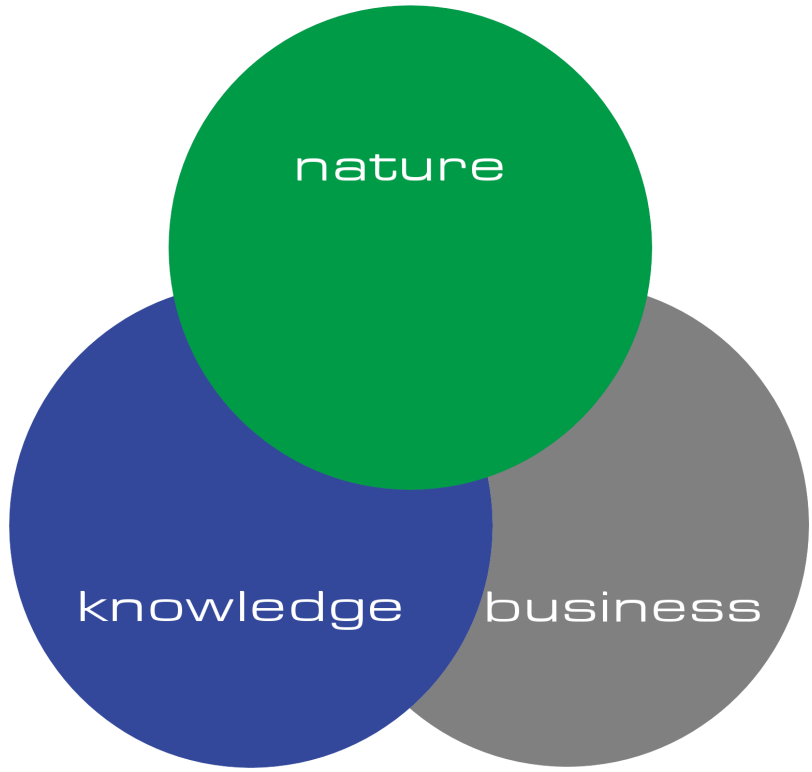
Prof. Harm Dorren, Eindhoven University of Technology
Ass. Prof. Ramin Hekmat, Delft University of Technology
Ass. Prof. Gerard Janssen, Delft University of Technology
Ass. Prof. André Kokkeler, University of Twente
Ir. Dirk-Jan Peet, Delft university of Technology.

2. Mission & scope

2.1 Motivation

Multi-disciplinary Approach

A multi-disciplinary development, deployment and exploitation of sustainable ICT is crucial for the positioning of the Netherlands as leading country in the worldwide debate on urgently needed improvements of national and global environmental conditions. The huge impact of ICT on all sectors of society, including personal life, asks for a focused and well-orchestrated approach. Safeguarding our prosperity in the digital age asks for an active role in the development of the architecture of sustainable ICT devices, infrastructures and processes.



2.2 Mission

Stimulating ICT sustainability

The mission of the IIP Duurzame ICT **is to stimulate sustainability in and through information and communications technology by facilitating research and creating awareness.** The IIP firmly believes sustainability in ICT should be designed in right from the start, instead of being a mere afterthought in the design process. It aims to mobilize the Dutch ICT community to set out the research and innovation agenda with sustainability in mind. Only then will it be possible to keep benefiting from ICT in our daily life during the years to come. The platform provides concrete objectives for key areas of the social and economic activities in the Netherlands that should be realizable within the next 10 years.

2.3 Approach

Strategic activities

Research agenda

Creating attention

Creating Awareness

The IIP Duurzame ICT plans to work towards its mission by means of the following activities:

- The joint development of a theme-based Strategic Research Agenda, based on a number of general themes;
- Creating attention for commercially interesting scientific research in the field of sustainable ICT;
- Creating consumer/society awareness for results (already) achieved in the field of sustainable ICT in general;
- Creating consumer/society awareness for results (already) achieved by the IIP.

Fundamentals

Scientifically challenging Commercially responsible

Communicatively Clear

Striving these activities and goals the IIP Duurzame ICT takes three fundamentals into account:

- Scientifically challenging. The IIP Duurzame ICT initiates and stimulates innovative and state-of-the-art research.
- Commercially responsible. If society wide success is desirable, the research results should lead to commercially interesting applications and derivative business.
- Communicatively clear. Crystal clear and effective communication is essential to create the necessary support in society.

2.4 Themes and definitions

Sustainability and ICT are both very broad concepts that are used in many different contexts. Hence, the concept of sustainable ICT is equally broad. Left undefined, it may refer to anything ranging from designing energy-efficient computer chips to employing teleworking technology in order to reduce CO_2 emission, depending on the definition used.

During its formative stage, the platform has considered various ways to narrow down this scope. However, during discussions with various stakeholders it quickly became clear that the need for more sustainable ICT is felt in every corner and layer of the industry. Therefore, the IIP Duurzame ICT has opted not to restrict itself to any particular technology or application, but address the issue in its entirety.

That being said, there are two important ways to classify sustainability-related innovations:

Who or what is affected by the innovation?

- **Who or what is affected by the innovation?** an innovation in sustainable ICT may either apply to sustainability within ICT systems, or to sustainability generated through the use of ICT systems.

What is the sustainability benefit of the innovation?

- **What is the sustainability benefit of the innovation?** This can typically be measured in either lower energy consumption or a more effective use of materials. In addition, there is the human factor to consider: sustainability in ICT may also be furthered by motivating people to work and live in a more environmentally friendly way.

When put alongside different axes, these two categorizations can be combined into a comprehensive listing of sustainability-related issues. Table 1 shows a number of examples.

sustainability	within ICT	through ICT
energy	- reducing data centre energy and cooling requirements - low power networking equipment - energy-efficient data transport and distribution - efficient CPUs - optimization of data processing algorithms	- ICT for intelligently deploying alternative energy sources such as solar power, wind power, hydropower, etc.
materials	- cradle-to-cradle / recycling - environmentally friendly production facilities - BIOPOF project - (Bio)degradability	- ICT for preventing climate change (e.g by CO_2 emission reduction through teleworking, optimized route planning and dematerialization)
usage	- switching computers off if not used e.g. during the night - sustainability as a purchasing criterium	- embedded ICT systems that help people live in a more sustainable way, e.g. by automatically switching off lights at night

Table 1

Definitions

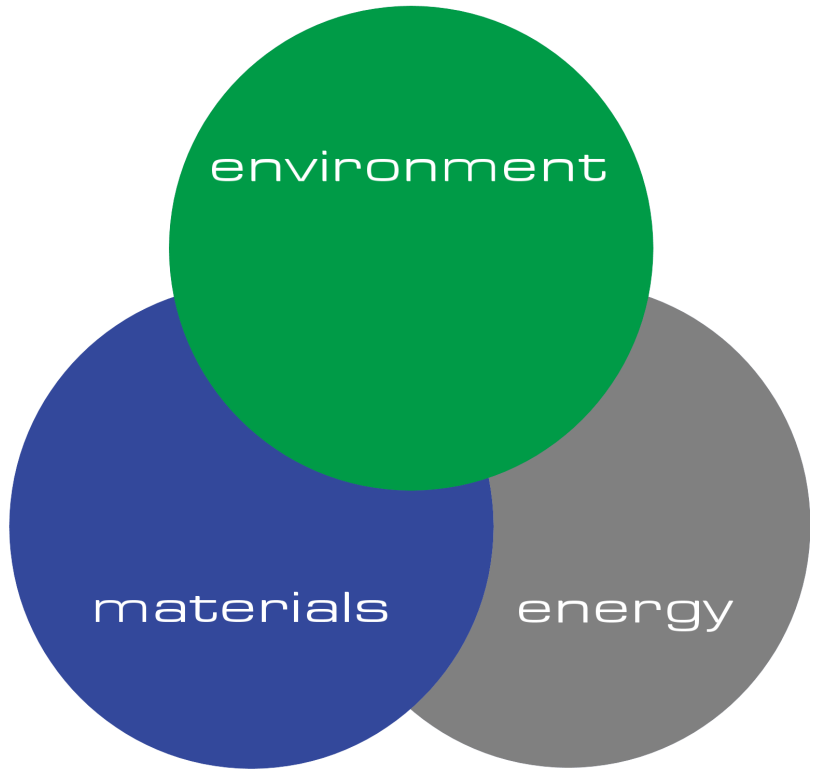
Sustainability in this context is defined as the concept of meeting the needs of the present without compromising the ability of future generations to meet their needs.[5] ICT is defined as any computer-based resource, networked, embedded or stand-alone, hardware or software.

[5] According to the so-called Brundtland Report of the World Commission on Environment and Development (WCED) chaired by Gro Brundtland. It is implied that satisfaction of the future needs is as important as the satisfaction of present needs.

3. General themes

General themes

In the field of Sustainable ICT are two major general themes. In the following sections, we will zoom in on the potential sustainability benefits for materials and energy, respectively. Since usage[6] is a derivative of these two themes, it will not be described separately.



3.1. Materials

Scope materials

The general theme of materials covers a wide range of topics. Besides relatively straightforward applications such as cabling made from bio-based materials, one can think of sustainability standards for components of ICT equipment, placed at the consumer premises and in the field, which concern a lot of (combinations of) materials and their organic feedstock as well as their biodegradability and recycling.

Energy effects

Materials also have energy effects. Because of the continuous growth of wireless communication, among other things, shielding or amplifying characteristics of materials will become more and more important. Because of the large number of applications wired environments could benefit from well-considered solutions as well. From that point of view highly conductive bio-based materials, or better: bio-based materials with the most optimum conductive characteristics, might be of special interest.

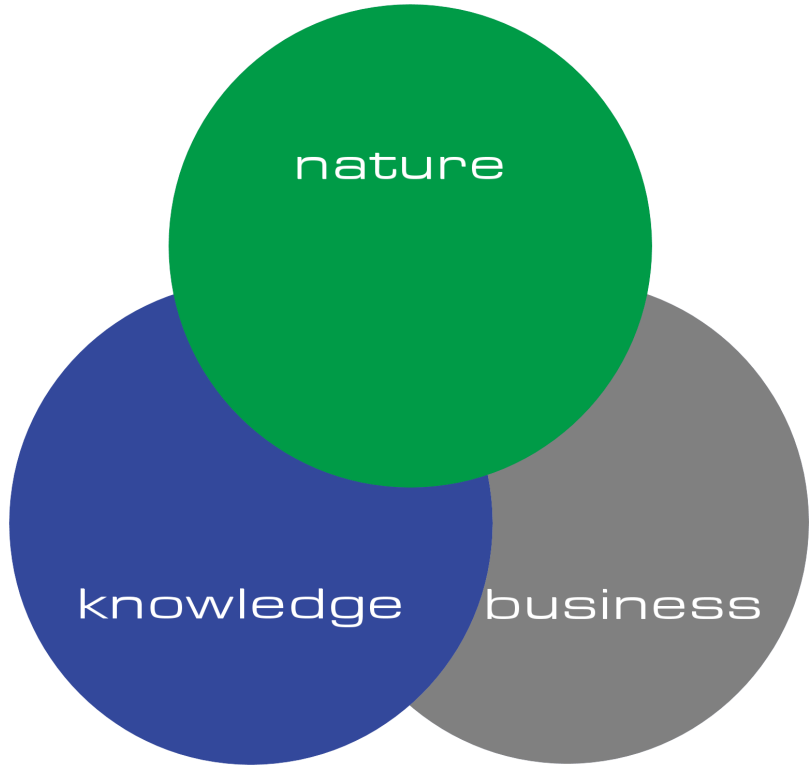
Bio-based materials

Bio-based materials are becoming more and more commercially

[6] as mentioned in table 1 as a third theme

Rising prices of currently used raw materials

interesting. Rising oil and copper prices will only increase this attractiveness in the nearby future. A lot of ICT hardware is made of (or at least partly consists of) oil and/or copper based components.
In general plastics are currently produced from petrochemical feedstock. As a result of decreasing fossil resources, price increases of petrochemical feedstocks and polymers based upon them may be expected. The economic attractiveness of industrial production of bio-based alternatives will only increase in the nearby future.



Decreasing fossil resources

As a result of decreasing fossil resources, price increases of petrochemical and metal raw materials may be expected. Energy-lean made (bio-based) materials will become proper alternatives, and in particular materials which can be gained from waste in recycling processes. As an example, promising studies have been started to create high-purity polymer materials for optical fibre communication cables from biological waste materials (the BiOPOF initiative).

Another example is the use of environmentally-friendly processor chips. For instance, the widely used Gallium arsenide based integrated circuits (high speed, expensive raw material and high energy consumption) might be replaced by more environmentally friendly silicon-based integrated circuits.

The use of waste

When using bio-based materials we have to be aware of the increased pressure on the world-wide agricultural area. Using large fertile fields for the production of e.g. bio-based fuels might lead to food-scarcity. From that point of view we have to use bio-based materials very efficiently and if possible, the use of waste material deserves preference.

Cradle to Cradle

Indeed, why shouldn't the Cradle to Cradle philosophy[7] enter the ICT domain?

Software

Materials can also be virtual feedstock. ICT is made of hardware and software. Hardware is more or less self-evident. The sustainability-role of software may be less evident. But without doubt software impacts all applications. Software may make all kinds of processes run more efficiently, by doing tasks in the right order, in their right combination, and at the right moment. Starting from here software will also impact the environment part of these applications.

Software itself could be more sustainable. Mobile versions of popular software are well-known. Besides the urge to perform at mobile devices as smartphones, they also have the general advantages to operate relatively fast and require less power. This might be an avant-garde eye-opener regarding software development in general.

Software can also be used to intelligently control the environment. The themes one can think of are e.g. energy management both as general utilities and as a (dedicated) part of one application. Software explicitly designed with sustainability in mind will become more and more interesting.

For instance, ICT services and tools may incorporate parameters for controlling emissions and energy consumption. Examples include, but are not restricted to: simulation tools able to assess the full life-cycle energy associated with new products before their realisation; Enterprise Management Systems able to implement energy savings and emissions trading across industry boundaries.

3.2 Energy

Economic growth is increasing the demand for energy. To maintain its prosperity and competitiveness on global markets, the Netherlands has to focus on energy efficiency in most sectors of industry. Society at large is increasingly aware and sensitive to climate change impact and to the importance of a safe, clean and healthy environment to sustain quality of life. ICT plays an increasing role in reducing the energy intensity of the economy, thus helping to decouple growth from energy consumption and creating new opportunities. Innovative ICT-based energy saving tools and techniques will help the products and services to become more competitive and will lead to the emergency of a new category of jobs and energy efficiency services.

ICT-based energy saving tools and techniques

Low power consuming production

Because of decreasing fossil resources, price increases of petrochemical and metal raw materials can be expected. Low power consuming production of materials and bio-based materials will become proper alternatives.

Energy efficiency

Rising energy prices will only increase this in the nearby future. For truly energy-efficient systems a holistic approach is needed, which means that all levels of systems (hardware, systems software and applications) need to be addressed simultaneously.

[7] 'Cradle to Cradle: Remaking the Way We Make Things' by William McDonough & Michael Braungart, North Point Press, 2002. Man can be "wasteful" if the products he produces go completely back into nature or are completely reborn as new products.

Research could include issues such as dynamically reconfigurable ICT architectures for electricity management, technologies and tools for ICT systems survivability and security when elements fail in the electricity network, and specific platforms integrating (near) real-time information from wireless sensor networks and external information systems such as weather forecasts.

Intelligent software

Intelligent software designed with sustainability in mind will also become increasingly important, for instance with regard to (renewable) energy management both as general utilities and as a (dedicated) part of one application. Other examples include simulation tools able to assess the full life-cycle energy associated with new products before their realization and Enterprise Management Systems able to implement energy savings.

4. Research and innovation

Research and innovation themes

The two general themes as described above are to be addressed in a number of more detailed research and innovation themes. These themes are:

- ICT and energy (energy reduction within ICT systems, using ICT for energy reduction)
- Sustainable network technology (sustainable optical communications, sustainable wireless communications)
- ICT policy for sustainability
- Communicating the need for and achievements reached in sustainable ICT

4.1 ICT and Energy

ICT and Energy covers the fields of both energy reduction within ICT systems and using ICT for the reduction of energy

4.1a Energy reduction within ICT systems

energy-efficient architectures

Energy consumption is one of the main concerns of today's chip designers and system integrators. Regarding energy-efficiency, the first type of devices people usually think of are portable devices as these devices rely on batteries and therefore the functionality is strictly limited by the energy consumption. However, for high performance computing there is also an increasing need for energy-efficient architectures to reduce the cost for cooling and packaging. Already today the performance of these systems is limited by energy dissipation and electricity supply.
In addition to that there are also environmental concerns that urge for more efficient architectures, in particular for systems that run 24/7 (24 hours per day, 7 days per week) such as wireless base stations, server parks, data centres and search engines (e.g. Google has an estimated server park of one million servers that run 24/7). There are several ways to reduce the energy consumption of ICT systems.

Holistic view

- It is a common misconception that the energy problems can only be solved at the hardware level. For true energy-efficient systems a holistic approach is needed which means that all levels of systems (hardware, systems software, and applications) need to be addressed simultaneously. Within the traditional strictly layered approach; an optimization at one level often leads to inefficiencies at other levels making the overall system inefficient. Therefore, for efficiency a cross-layer approach is needed. For example: the design of energy-reduction features of the hardware platform needs to be coordinated with the system software (compilers and operating systems), and the system software needs to be synchronized with the design of the specific application domains. Eventually, for an overall efficient system there should be a good fit between the application requirements, development and systems software, and the hardware capabilities.

Efficient processing platforms

- Today most modern general purpose processors are optimised for speed rather than for low energy consumption. In typical general purpose processors a lot of energy is wasted in

instruction decoding, speculative execution and memory hierarchy. In ASICs (Application Specify Integrated Circuits) and reconfigurable platforms this overhead is significantly lower, but unfortunately their programmability is limited. Research is needed to reduce the energy consumption of processors. Energy-efficient multi-core architectures will need to be developed. Next to savings in hardware also in software (compilation as well as operating systems and applications) important energy savings can be obtained.
In this IIP we plan to perform pre-competitive research on energy-efficient systems (hardware as well as software), efficient compiler technologies, mapping and scheduling technologies and run-time technologies.

Locality

- References to memory typically display a high degree of temporal and spatial locality. Temporal locality of reference refers to the observation that referenced data is often referenced again in the near future. Spatial locality of reference refers to the observation that once a particular location is referenced, a nearby location is often referenced in the near future. Accessing a small and local memory is much more energy-efficient than accessing a big and distant memory. Transporting a 32-bit value over a 1 mm on-chip distance in a 45 nm technology will require more than 50 times the energy of a 32-bit operation in the same technology, whereas a 32-bit off-chip memory access consumes more than a 1000 times the energy of a 32-bit operation. Transporting data over a wireless interface is even more expensive energy-wise. A multi-core architecture, with local memory, intrinsically encourages the use of locality. Due to this locality the communications within a core are more frequent than between cores. Exploiting the locality extensively improves the energy-efficiency substantially.

Adaptivity

- When the system can adapt (at run-time) to the environment, significant savings in energy costs can be obtained. For example, if a computer system can rapidly switch to a low-power standby or hibernate mode (like in most laptops), when it is temporarily not needed, significant savings can be obtained. Current desktop PCs are capable of doing this already, but today most users have not found this feature in their operating systems yet. One step further would be to switch off certain parts of the system that are currently not needed. For example: when a user at some point in time only uses his PC to listen to MP3 music, significant parts of the PC could be switched off. This type of adaptivity fits quite well with future multi-core architectures.

Research topics

Some challenges are:

R & D challenges

- How to program future parallel architectures with hundreds of programmable cores, in an energy efficient and cost-effective way;
- How to support the cross-layer paradigm for these parallel architectures;
- How to exploit the adaptivity of applications on a microscopic level for a multi-core architecture;
- How to promote energy awareness of PC users. Forrester Research predicted that there will be around 1.3 billion

computers worldwide by the year 2010.[8] So there is much potential to save energy there.

4.1b Using ICT for energy reduction

ICT systems to control electricity consuming and generating appliances

Although much of the worldwide increase in electricity consumption is credited to ICT[9], the same ICT technology can also be used for reducing the worldwide energy consumption. Efficient ICT systems can, for example, be used to control the consumption, production and storage of both electricity and heat in offices and homes. Next ICT systems can be used to control large electricity consuming appliances in an optimal way. In the coming decade we will see a strong trend towards distributed electricity generation, like solar cells, micro-CHP appliances, mini gas turbines and micro-windmills. It is expected that within a few years a large percentage of the electricity will be generated in or near the place of consumption. For example a micro-CHP appliance is a system that consumes natural gas and produces heat and electricity. The heat is used for the heat demand in the home such as central heating, showering, hot water taps etc. and the electricity is used for electrical appliances. Micro generation systems generate electricity at the kilowatt level which will allow the units to be installed in an individual home or office building and connected directly with the building heating and electrical systems. This entails a very high efficiency (up to 90%) in usage of primary energy. The so called 'micro-generation' concept has the additional benefit of reduced distribution and transmission losses, delivering significant advantages in terms of overall efficiency relative to centrally-generated power.

Reduction of CO_2

Moreover, distributed generation offers an attractive financial option for the consumer by reducing energy bills, and nationally in the reduction of primary energy consumption and therefore carbon dioxide (CO_2) emissions.

Any electricity that cannot be consumed in the home can be exported to the electricity distribution network. For the house-owner it is advantageous to consume the locally generated electricity in the home as much as possible. Therefore ICT systems can be applied to coordinate the micro-generation with the electricity demand in the home. Such ICT systems may for example determine to switch on a generator when electricity is needed for large consumers like a dishwasher.
One of the problems is that not all decentralised generation systems have predictable electricity generation patterns. For example solar cells are dependent on the time of the day and the amount of sunlight. Wind energy is only available when there is wind and micro-CHP systems only produce electricity when there is a heat demand. As a consequence, decentralised systems sometimes produce electricity when there is no need for it locally.

An important ICT contribution will be to inform the house occupants or building owner on their energy behaviour to make them more energy aware.

[8] Forrester Research: Sizing The Emerging-Nation PC Market (www.forrester.com)
[9] S.H. Clevers, R. Verweij. ICT stroomt door. Inventariserend onderzoek naar het elektriciteitsverbruik van de ICT-sector & ICT-apparatuur. Den Haag 25-10-2007. (http://www.ez.nl/content.jsp?objectid=155077&rid=155076)

R & D challenges

Research topics

Some challenges are:

- to develop models for forecasting the electricity consumption and production of a house or neighbourhood;
- to develop scheduling and optimisation techniques that can manage the variability of the inputs;
- to develop an efficient and low-cost (in-house) ICT infrastructure that can help control the consumption and production of a cluster in real-time (in particular, there is a large potential to increase energy efficiency through so-called “Demand Side Management” (especially the residential and small commercial domain) through systematic and pervasive use of ICT);
- to develop an efficient communication protocol to enable interoperability between electricity producing (e.g. micro-CHP appliance), consuming (e.g. dishwasher) and control units;
- to develop ICT solutions to facilitate and promote the energy awareness of consumers.

4.2 Sustainable network technology

Until now ICT network technology related research projects were focused on optimum communication (from an ICT technological point of view) and user friendliness. The IIP Duurzame ICT emphasizes at sustainability. This approach is new. Of course the points mentioned above will not be neglected.

4.2a Sustainable optical communications

Sustainable alternatives for Copper

The use of optical networking technology has many interesting advantages. Traditionally, information transport has been done via copper wires, such as the huge base of twisted-pair copper cables in the telephony network, and coaxial cables in the cable television networks. Replacing these copper wires by optical fibre offers many advantages regarding sustainability:

- Copper is rapidly becoming an expensive natural resource, as the worldwide resources have shrunk noticeably. In some countries (such as Argentina), telecommunication copper cables are illegally taken out of the network, melted, and the copper is sold at high prices again. Silica fibre, however, is made of purified silica obtained from sand, of which virtually endless quantities exist. For polymer fibre similar observations hold; moreover, its ingredients can be extracted from natural biological waste, thus also contributing to the recycling processes of natural resources.

- In copper cables, the transmission losses increase with the square of the signal frequency. Hence in particular for broadband communication the losses become very high, and hence many power-consuming intermediate amplifiers and regenerators are needed in the field. These devices need to be adequately protected, requiring expensive housings. Furthermore, they need to be powered remotely, which entails extra power losses. And the housings often need to be climatised, requiring even more power for keeping them within the required temperature range. In contrast,

the losses of optical fibre are very much lower, and independent of the data signal frequency. At higher data rates, the dispersion penalties get larger, necessitating somewhat higher transmission powers, but they are several orders of magnitude lower than in copper cables. Hence intermediate amplifiers and regenerators are only needed in very long (such as nation-wide) optical fibre links. Thus the data transport via optical fibre saves considerably on powering, and does not need expensive to install and maintain intermediate devices. Polymer fibres at present still are considerably more lossy than silica fibres; however, their development is still in an early stage, and a lot of progress is foreseen to be made in the near future (for comparison, the first silica fibres in the late sixties had losses of some 20 dB/km, whereas after lots of industrial process refinements they are now below 0.2 dB/km).

Electromagnetic non-interference

- Optical fibre is not susceptible to electromagnetic interference. Hence it does not need special shielding against disturbing external electrical fields coming e.g. from lightning, or other electrical cables. Hence optical fibre cables do not require specific extra materials for this shielding.

- Optical fibre is considerably thinner than high-bandwidth copper cables. Hence it needs less space, and can be installed in smaller ducts (or much more of them can be installed in existing ducts). This can save considerably on installation efforts, and equally on the costs of the duct materials.

So the wide deployment of optical communication technologies can bring in an important share in improving the sustainability of ICT.

Examples of sustainability improvements by using optical network technology are:

Optical access network infrastructures

- In today's access networks, homes are connected by twisted-pair copper lines for telephony, and coaxial cables for CATV. The twisted-pair lines are point-to-point architectures, requiring a separate copper pair per home. Optical fibre-to-the-home networks can be laid out as a shared infrastructure, in which a (long) feeder fibre is shared by many homes, and from a passive optical signal splitting point only short individual fibres are needed to connect each home. Moreover, the same fibre infrastructure can carry the CATV signals, as well as the internet data signals. Thus fibre-to-the-home networks require significantly less cables, can offer more services, and are future-proof as their capacity is so large that any foreseeable service can be transported. Hence they entail a significantly more efficient and longer-lasting use of scarce natural resources.

Optical access network equipment

- Today's copper-based broadband access solutions require equipment to be installed in outdoor cabinets. These cabinets need to be installed, need to be of sturdy materials, and need to be powered and maintained. Examples are the VDSL modems and CATV roadside cabinets. Optical access networks are a fully passive infrastructure, which can be buried in ducts in the ground, not needing expensive cabinets nor remote powering. Moreover, the terminal equipment is installed at the local exchange and at the user's premises, where conditions are considerably less harsh, and powering is much easier and more efficient. Power consumption of

broadband optical line terminals is considerably less than of their electrical counterparts. So optical access equipment consumes considerably less materials and powering, thus contributing to sustainability in the important mass-deployment area of access networks.

Low Power Photonic packet switching

- The growth of the Internet has led to the introduction of very large packet routers. Today's internet routers massively use fast electronic switching and buffering techniques, which consume huge amounts of power. These routers dissipate so much power that further scaling appears to become impossible. Optical switching technology can reduce the power consumption in packet routers, as research trends point out that the power consumption of elementary fast optical switch devices is substantially lower than of their electronic counterparts, and their power consumption increases much slower with increasing data rates. Moreover, optical circuits are not susceptible for electrical crosstalk fields, which allows much denser packing without extra shielding needs than for electronic switching circuits. Hence optical switching requires less power (and thus also less cooling efforts), plus less volume (and thus less housing materials).

  Low power photonic packet switched networks require innovations in several disciplines ranging from networking and systems, circuit and devices, to materials. System groups should contribute by realizing all-optical packet network architectures that allow for digital photonic processing in the physical layers. Technological breakthroughs should also emerge from the field of photonic integrated circuits. Very Large Scale Integrated (VLSI) photonic circuits will play an essential role in future generations ultra-fast digital telecommunication nodes. Challenges on the road towards VLSI photonics are related to the realization of photonic gates with sizes in the nanometer range, and to open the field VLSI photonics by interconnecting large amounts of these gates. Finally, innovations in materials are required. Photonic gates with nanometer dimensions require materials fabricated with nano-precision. Ultimately control of the growth of materials at the single-photon, single electron, single spin level is required to reduce the power consumption to its ultimate.

Bio-based polymer optical fibre

- BiOPOF, polymer optical fibre from (harmful) organic waste! The BiOPOF project is a multidisciplinary co-operation of Chemistry and ICT scientists from the WUR and TU/e. The aim of the project is the development of biobased polymer optical fiber. As outlined before, bio-based optical fibre offers the advantages of recycling natural materials in combination with the fundamentally reduced power consumption needs of optical broadband ICT equipment. BiOPOF, like other polymer fibre types, is easier to install than silica fibre (which requires skilled personnel and accurate equipment), and hence saves on installation efforts.

Optical fibre-supported wireless communication

- By transporting radio signals over fibre to antenna sites, a considerable amount of signal processing no longer needs to be done at those sites. Thus the (traditionally located at the antenna site, extensive and expensive) base station equipment can all be consolidated at a central site. From there, the radio signals are distributed by fibre to much simplified antenna sites. This offers significant advantages in material savings, in easier maintenance, and in reduced powering (such as reduction of the powering needs

at the antenna stations). Optical radio-over-fibre architectures allow smaller radio cells, which means also lower radio radiation powers; this contributes to reducing the (yet unknown, but often suspected) health hazards of the always-on radio waves transmission by antenna sites.

Research topics

Some research & development challenges are:

R & D challenges

- To investigate and design optical access network architectures, optimising the sharing of physical architecture on one end, and the provisioning of adequate capacity to the users on the other end. This optimisation involves both the physical layout and the multiple access control strategies.
- To investigate and design optical access network equipment operating at minimum power consumption, while offering high burst-mode data throughput.
- To investigate and design ultra-fast low-power optical signal processing circuits, and scalable optical packet switches.
- To design and develop polymer optical fibres made from biological materials and optimised for use in short-range applications, with a performance exceeding that of commercially-available polymer fibres.
- To investigate and design radio-over-(polymer) fibre techniques and systems, aiming at smaller radio cells with less radiation load on the users, yet delivering broadband capacity and supporting mobility of users. Augmented with optical routing, this will enable a more efficient use of radio spectrum and the delivery of capacity on demand, thus optimising the utilisation of network resources.

4.2b Sustainable wireless Communications

Improvement of power efficiency in wireless technology can lead to a massive reduction of power consumption.
Because of continuous growth of wireless communication, shielding or amplifying characteristics of materials will become more and more important

A number of developments and trends make the need for sustainable communication urgent:

Improvement of power efficiency

- The share of global energy consumption due to ICT systems is increasing rapidly and has already reached a significant level. Since the cost of energy is rising rapidly and the resources we use now to generate energy are getting depleted, there is a powerful incentive to reduce energy consumption of present and planned communication systems. Energy consumption has not been a major issue in designing communication systems up to now, so considerable gains could potentially be achieved here. This does not only apply to telecommunication systems, but also to embedded communication found in many distributed ICT systems.

Massive growth of wireless devices

- The number of wireless devices is bound to grow tremendously. It is predicted by the Wireless World Research Forum that, 10 years from now, there will be 7 trillion wireless devices serving 7 billion

people, i.e., on the average 1000 wireless devices per person. [10] This will have several consequences: the usage of radio spectrum will also increase tremendously and, to a level where it will be impossible to connect these devices using the present radios and frequency allocation techniques. Radio spectrum is a finite resource. It will have to be used in a different way to allow a sustainable growth of the wireless systems as is foreseen by the WWRF.

Need for energy efficient mobile devices

- The growth of wireless devices will largely be due to battery powered devices. The reliance on battery power is a major weakness of wireless systems: they have a relatively low lifetime and create an environmental burden. To allow a sustainable growth of wireless devices it is mandatory that energy consumption of battery-powered wireless systems is drastically reduced, so that battery lifetimes are significantly extended.

Preventive approach of EMF exposure

- The predicted increase in wireless communication will also increase the exposure to radio-spectrum electromagnetic fields in the environment, in cars, homes and buildings. Although health hazards caused by radio systems have not been demonstrated, it may be wise to work on ways to decrease this exposure in the light of the expected tremendous growth of radio communication. Such a preventive reduction is likely to be an additional benefit of using the spectrum more efficiently, and of reducing the energy consumption of wireless systems.

Research topics

Examples of topics belonging to Sustainable Communications are:

R & D challenges

- Development of routing protocols that require least overhead (for example combining geographical position information with traditional IP routing);
- Integration of multi-hop solutions into cellular networks, when multi-hoping has energy conservation benefits;
- Development of energy efficient medium access protocols;
- Development of new concepts for telecommunication based on opportunistic access when these concepts result into less energy consumption.
- Work on energy efficient modulation and coding schemes, including network coding.
- Cross-layer design methods and strategies to have relevant information available where it matters in order to reduce overhead, unnecessary retransmissions, and delays caused by traditional OSI design.
- Virtualisation: assignment of network functionalities (for example gateway functionality) to devices forming a (personal) network in the most energy efficient way; creating the illusion that all network nodes have access to virtual entities offering required network functionalities, regardless of the actual physical location of nodes offering these services.
- Efficient use of radio spectrum, including:

[10] Nigel Jefferies, “Global Vision for a Wireless World”, Wireless World Research Forum, 18th WWRF meeting, June 2007, Helsinki, Finland.

- theoretical spectral efficiency bench marks for ad hoc temporal and spatial (re)use of the frequency spectrum,
- fast wideband scanning receiver techniques, transceiver architectures and antenna solutions and their implementations,
- signal processing for wideband scanning,
- fully and partially distributed transmit power control schemes for ad hoc spectrum (re)use,
- adaptive modulation schemes, probably based on OFDM (Orthogonal Frequency Division Multiplexing) type of signals to allow frequency diversity,
- multi-antenna/MIMO (multi Input Multi Output) issues.

4.3 ICT for Sustainability (policy)

The working group ICT for Sustainability (policy) has been founded to further research into how ICT policy can contribute to a more sustainable world. The objective of the working Group is the exchange and dissemination of knowledge in the area of the deployment of ICT for increasing the sustainability performance of organizations and households by conducting joint pre-competitive research. The exchange of knowledge will take place within the working group, but also with the outside world by publications, symposia, workshops and other forms of knowledge exchange.

making business processes more sustainable

In the eyes of the working group, ICT and sustainability on the one hand deals with the impact of ICT equipment, and on the other hand deals with deploying ICT for making business processes of organizations more sustainable. The impact of ICT equipment is strongly related to the lifecycle of the equipment: production, use (especially energy use), and (e-)waste. The focus of the working group ICT for Sustainability is based on the idea that the deployment of ICT in organizations can yield large savings in resource use.

Recently, TNO, Telematica Instituut, ICT-Regie, and EPN have calculated that the use of ICT could decrease the energy use of Dutch households, offices and trade organizations.[11] The working group carries out projects that contribute to that reduction.
As of yet, there are no clear standards and approaches for the implementation of ICT for increasing of sustainability performance.

In addition, the effect on the sustainability performance of organizations is not always clear. There are some questions under which conditions teleworking or office work in smart office centres is more sustainable than regular office work. In the scope of the working group, projects will be carried out to investigate what the actual effect of such solutions is, and an inventory is made of best practices of deploying ICT in the most sustainable way in organizations (IT-sourcing). In reaching these objectives, the working group thinks it is important to involve end users in order to realize the implementation of solutions and demonstrate the proof of concept.

Objective of the working group

The objective of the working group is the exchange and dissemination of knowledge in the area of the deployment of ICT for increasing the sustainability performance of organizations and households by conducting joint pre-competitive research. The exchange of knowledge

[11] https://doc.telin.nl/dsweb/Get/Document-84503/Energiebesparing%20door%20ICT.pdf

will take within the working group, but also with the outside World by publications, symposia, workshops and other forms of knowledge exchange.

Research topics

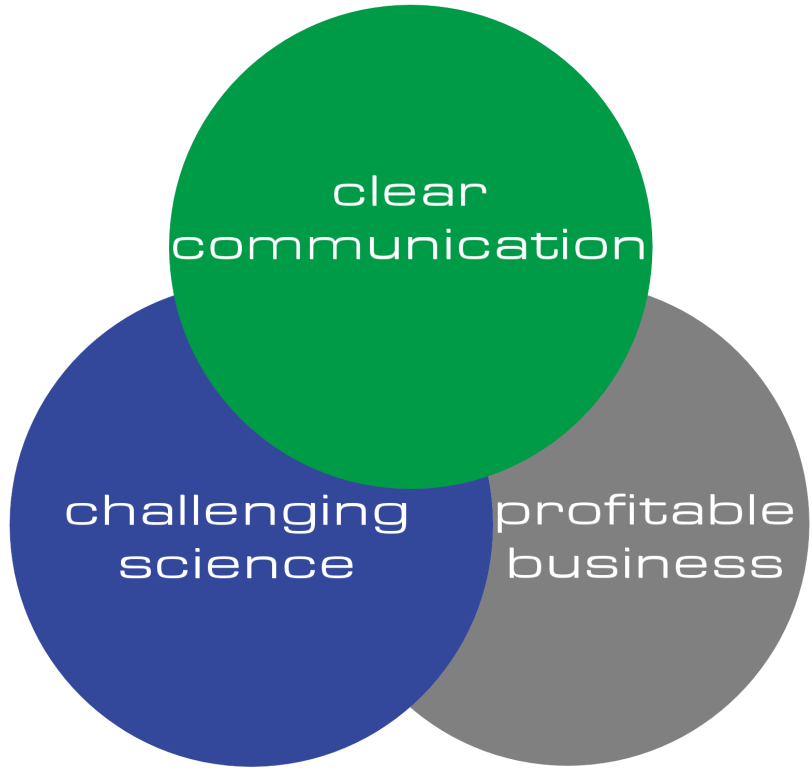
R & D challenges

Some Research and & Development challenges (project ideas) are:

- IT for mobility budget for commuting traffic
- IT for personal CO_2 budget
- Green data centres
- Energy performance of software labels such as Service Oriented Architecture (SOA) and 4th Generation Language (4GL)
- ICT for increasing sustainability performance of auctioning and logistics in the horticulture industry

4.4 Sustainable ICT and Communication

The working group Sustainable ICT and Communication[12] has been founded to further research into how communication can contribute to a more environmentally friendly use of ICT.



Facilitate and stimulate communication

In addition, the working group will facilitate and stimulate open and meaningful communication between the technical working groups of the IIP Duurzame ICT and external stakeholders, including investors, policy makers, students and the general public.

[12] In Dutch: Duurzame ICT en Communicatie (DI & C)

By doing so, the working group seeks to support the creation of a research and innovation agenda for the IIP Duurzame ICT.

Open dialogue between science and society

Regardless of their field of expertise, it's always good for researchers to maintain close contact with the society that they seek to serve, to ensure that their innovations will be socially and commercially relevant. But when those innovations address the greater good, as is the case with sustainability, an open dialogue with society is simply paramount.

For decades, even centuries, humanity has been aware that our planet has its limits. Fertile ground turns barren when overworked, oil wells dry up, and mines become depleted. Yet we happily continue to consume these precious resources with wild abandon, seemingly oblivious to the consequences this may have for ourselves and future generations. For a hypothetical outsider, it must be one of the most difficult questions to answer about our race: why are we so keen on destroying the planet that sustains us?

Left to its own devices, innovation in any marketplace will gravitate towards technologies that yield economic benefits and meet consumer demands – higher profits, efficient processes, greater wealth, more comfort and the like. Sustainability, however, does neither, or at least not directly. It primarily benefits the public interest, and as such is often classified as 'somebody else's problem' by the individual consumer or organization.

The necessity of a DI & C working group from a psychological point of view

"*Global warming is a global problem. Tackling it requires cooperation by all countries on earth. Is that feasible? German researchers tried to replicate that question in a economic game. The participants were given money and then had to contribute to a public good - in this case the collective goal to reduce global warming by up to 2 degrees Celsius. There were 30 groups of six students each. The results, published in February in the Proceedings of the National Academy of Sciences, are not encouraging. Only fifteen out of the thirty groups achieved the collective goal, but only when the participants were really aware of the seriousness of the threat, and the damage it could bring. When they perceived the potential damage as limited, none of the groups reached the goal. According to the researchers, it is crucial for the success of climate policy to convince people that missing targets will lead to great financial losses. Two years ago the same researchers did another study, also focused on the climate issue. They made participants contribute to a collective purpose, and told them that the invested money would be used to convince people to reduce their consumption of fossil fuels. It turned out that participants contributed more to the collective goal when they were kept informed of the progress of climate research. And the contributions increased remarkably when the participants could invest publicly in the protection of the environment. In this way the contributors improved their reputation. It also stimulated the rest of the participants to increase their investments. The bigger the reputation effect, the sooner people will invest. The researchers end their articles with a tip for policy makers: put people who genuinely invest in the protection of the environment on a pedestal.*"[13]

Crucial are public awareness and political backing

Hence, public awareness and political backing are crucial to the success of any sustainability-related initiative. Unfortunately, history teaches us that humanity has a tendency to ignore potential problems until after they have manifested themselves. Firewalls are purchased after a virus has

[13] NRC Handelsblad, wetenschap & onderwijs, Saturday 3 May 2008 (originally in Dutch)

brought down the company network, flood protection becomes an item after the dikes have broken. And indeed, only in recent years, when rapidly rising energy prices have begun to threaten our very way of living, has sustainability managed to gain a foothold on the political agenda.

When looking at the urgent need for a more sustainable way of working and living, we may count ourselves lucky with the newfound attention. However, considering the pace at which public and political priorities change, it would be naïve to assume that sustainability will remain in the spotlights indefinitely. That's why it is imperative for sustainability researchers not to lock themselves up in an ivory tower, but to actively engage the wider community – companies, government bodies and consumers – in their activities.

Green-washing

This is not as easy as it may seem, particularly when it comes to sustainable ICT. Communicating about technology is difficult enough in itself; many ICT-related innovations require so much industry-specific knowledge that even insiders sometimes find it difficult to understand them. Further compounding the problem is the widespread practice of green-washing, caused by overly eager marketing departments jumping on the green bandwagon. With a little bit of creativity, any technology that makes a process or a system more efficient can be portrayed as green – which is exactly what is happening right now.

As a result, it may become nearly impossible for relevant parties to distinguish between real innovations and marketing-inflated claims, let alone understand them. Ultimately, this could cause sustainability to become a hollow term that sooner sparks aversion among the public than sympathy.

Increased and continued public awareness for sustainable ICT

These are the issues that the Sustainable ICT and Communication working group seeks to address. Among other things, this should lead to increased and continued public awareness for sustainable ICT among students, investors, politicians and the general public, as well as new ideas and technology.

Activities

To strengthen the IIP Duurzame ICT platform community bond and generate external exposure, Sustainable ICT and Communication is working closely with major players in the field of ICT communications and public relations. To date, several initiatives have already been launched:

First workshop

- Maiden workshop 18 January 2008. Successful interactive workshop with six presentations by participants from both scientific and commercial parties.

Online presence

- Online presence:
  - Website including dedicated hosting and domain name, www.iipduurzameict.nl.
  - LinkedIn Group IIP Duurzame ICT
  - YouTube channels
    - http://www.youtube.com/IIPDuurzameICT
    - http://www.youtube.com/DuurzameICT

Written media

- IIP Duurzame ICT ICT newsletter
- IIP Duurzame ICT folder

Promotion

- Ongoing promotion via networking, presentations, media and attendance at scientific research and industry events, including ICT Delta 2008 conference

Liasion with government

- Liasion with Ministry of Economic Affairs Directorate General Energy and Telecom (DGET). The Dutch Ministry of Economic Affairs has been consulted to avoid both parties, The Ministry and IIP Duurzame ICT, heading for different directions. Although the time horizon of the Ministry of economics Affairs is much shorter (2 years maximum) than the time horizon of the IIP Duurzame ICT, consultation on regular bases will be useful.
- Consultation, fine tuning and cooperation with EGL ICT

Future activities

Activities in consideration, being planned or developed:

- IIP Duurzame ICT Wiki environment
- Dedicated event program in co-operation with Media Plaza. Media Plaza is an experienced partner that has proven itself as a valuable communication channel.
- 'Meeting of the minds' event for all interested parties.
- Workshops regarding sustainable ICT and communication
- Consultation, fine tuning and cooperation with European Platforms.

Research topics

R & D challenges

The working group Duurzame ICT and Communication is also looking into the possibility to generate multi-disciplinary research in the cross-over field of ICT, sustainability and communication.

Some R&D challenges (project ideas) are:

- Creation of a comprehensive framework that puts all aspects of ICT-related sustainability in context, thereby enabling more effective communication
- Development of 'green communication' best practices
- Research into what motivates people to use ICT in an environmentally friendly way, and how to trigger this behavior
- Research into how new media tools such as blogs and social networks could be employed to stimulate 'greener' behavior

5. Organization

5.1 introduction

Open alliance between researchers, businesses, social institutions and users

The IIP Duurzame ICT is an open alliance between researchers, businesses, social institutions and users. It aims to encourage and promote sustainability in and through information and communication technology among others by the joint development of a theme-based Strategic Research Agenda. It is also to the participants how to give further details. One can think of topics such as energy efficiency, recycling, sustainable software, innovative materials, and (standards) sustainable (wireless) network infrastructure and components. Participation in the IIP Duurzame ICT is in principle open to all commercial, public and academic organizations active in this field.

5.2 The organizational structure of the IIP Duurzame ICT

The IIP Duurzame ICT consists of a steering committee and several theme related interests groups. The theme related interests groups are the forerunners of the project groups, which are responsible for topic specific scientific research.

The steering committee

Steering committee

The steering committee[14] is the core of the IIP Duurzame ICT. It contains representatives of all kinds of parties involved. The members are representing equally scientific research and innovation as well as commercial research and innovation.

Current members of the steering committee (in alphabetic order) are:

- Mr. Roel L. Croes (GreenICT foundation)
- Prof. ir. Ton Koonen (Eindhoven University of Technology)
- Prof. dr.ir. Ignas Niemegeers (Delft University of Technology)
- Dr.ir. Anwar Osseyran (SARA)
- Prof. dr. ir. Gerard Smit (University of Twente)
- Ing. Fred Snijders / Prof.dr. Emile Aarts (Philips)
- Martijn de Weerd (Media Plaza)
- Drs. Mark van der Wolf (Lewis PR)

The theme-related interests groups

Interests groups

The theme-related interests groups are the forerunners of the project groups, which are or will be responsible for topic-specific scientific research.[15] The current (nascent) working groups are:

- Sustainable in-house network technology
- Sustainable ICT infra room technology (server farm / computer

[14] In Dutch: " kernteam".
[15] E.g. the BiOPOF project does have its own project group already.

room)
- Sustainable ICT and Communication (DI & C)
- ICT and Energy
- ICT for Sustainability (policy)

The names in Dutch are Duurzame in-house netwerktechnologie, Duurzame ICT infra room technologie, Duurzame ICT en Communicatie (DI & C), ICT en Energie, ICT voor Duurzaamheid(beleid) respectively.

Project groups

The project groups

One could consider the theme-related interests groups as breeding-places and nurseries for theme-related projects.
One project has already been started. The BiOPOF initiative does have its own project group already.

Active participants

5.3 Members of the IIP Duurzame ICT

Current participants are scientific, not-for-profit as well as commercial organizations.[15] All these organizations have actively contributed to the formation of the IIP Duurzame ICT and continue to provide input, advice and support in many different ways.

Scientific organizations:

- Delft University of Technology
- Eindhoven University of Technology
- Fontys Hogescholen
- Hogeschool van Arnhem en Nijmegen
- University of Twente
- Wageningen University and Research centre

Commercial organizations:

- Atos Origin
- Capgemini
- Cisco Systems
- Cleanbits
- Fomax
- GetronicsPinkRoccade
- HP
- IBM
- KNP
- Lennox Benelux
- Lewis PR
- Media Plaza
- Microsoft Nederland BV
- Philips
- Rabobank
- SARA Reken- en Netwerkdiensten
- TNO
- Toltech Solutions
- Turtlestep

[15] Situation at 01 March 2008. The list of participating organizations is still growing.

- WebEx Communications B.V.

Not-for-profit organizations:

- GreenICT foundation
- IMEC Nederland

All above mentioned organizations are represented by at least one representative. A large majority considers the IIP Duurzame ICT quite important. This is also the reason why these organizations make use of two (or more) representatives.

5.4 Supporters

Besides the support of the participating organizations as mentioned above, the ICT Innovation Platform Duurzame ICT is supported by:

- Prof. Emile H.L. Aarts, Philips Research
- Prof. Peter G. M. Baltus, Eindhoven University of Technology
- Ass. Prof. Henrie P. A. van den Boom, Eindhoven University of Technology
- Hans L. van den Broek CTO technological Solutions Group, HP Nederland
- Prof. Harm J.S. Dorren, Eindhoven University of Technology
- Prof. Sonia M. Heemstra de Groot, Delft University of Technology
- Ass. Prof. Ramin Hekmat, Delft University of Technology
- Ass. Prof. Gerard J.M. Janssen, Delft University of Technology
- Ass. Prof. André B.J. Kokkeler, University of Twente
- Prof. Daan Lenstra, Dean faculty Electrical Engineering, Mathematics & Computer Science, Delft University of Technology
- Anwar Osseyran, managing director SARA
- Ass. Prof. Peter F.M. Smulders, Eindhoven University of Technology
- prof. Anton G. Tijhuis, Eindhoven University of Technology
- Prof. Jaap van Till, Hogeschool van Arnhem en Nijmegen
- Ass. Prof. Huug de Waardt, Eindhoven University of Technology
- Martijn de Weerd, Directeur Media Plaza