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Deliverable DN3.5.4: Study of Environmental Impact

Initiatives Undertaken in GN3

Deliverable DN3.5.4

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Abstract

This deliverable is the final document in a series of four that describes a wide range of initiatives undertaken by the partners in the Green GÉANT team to reduce environmental impacts in general, and emission of greenhouse gases in particular. The areas covered are: green network management systems, power usage efficiency, virtualisation, energy-aware traffic engineering, videoconferencing, distance working, dematerialisation, green public purchasing, purchasing green electricity and disseminating green ICT in the HE community. Recommendations are made at the end of each topic, which align with best current practices drawn from recent publishing research and the partners' work.

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Executive Summary

This deliverable provides a condensed list of topics and recommendations from a range of initiatives undertaken by the partners in GN3 Networking Activity 3 (Status and Trends), Task 5 (Study of Environmental Impact) (NA3 T5) to reduce environmental impacts in general, and emission of greenhouse gases (GHGs) in particular.

It provides an update to the previous deliverable ("DN3.5.3: Study of Environmental Impact"), expanding some of the research ideas and providing commentary on new findings. Topics covered include: environmental policy, GHG audits and reports, green network management systems, Power Usage Efficiency (PUE), virtualisation, energy-aware traffic engineering, videoconferencing, distance working, Green Public Purchasing (GPP), green electricity, energy source choices or options, and disseminating green ICT in the Higher Education (HE) community.

Recommendations are provided for each topic, which are relevant to the GN3 project, the National Research and Education Network (NREN) community, their users, and the ICT sector. This document also encourages NRENs to actively engage with HE users to share knowledge and experience, and raises awareness of other international support programs that may better address user needs.

Elements of telecommunications infrastructure, such as data centres and networks, have traditionally focused on creating the best possible solutions for their clients, but have shown little or no thought for the environment in their business models and development. During the last few years, however, there has been a noticeable increase in environmental awareness, and NA3 T5 formed a team to build on this awareness and develop best practices. This group quickly became known as the "Green GÉANT" team, which is a good indicator of how these developments have raised awareness. All research and case studies described in this document follow on from the establishment of externally verified climate accounts amongst the six T5 NRENs: HEAnet, PSNC, NORDUnet, GRNET, NIIF and SURFnet.

Key recommendations drawn from the partners' work include:

1. Having a written environmental policy is a sensible first step towards a raised environmental awareness and reduction in environmental impacts. (Only six GN3 peer NRENs are reported to have environmental policies in place, of which only two have published their policies on their websites.)
2. Establishing a dedicated green network management system, and using it to identify problem areas and potential solutions, is recommended as an operational second step. (Only one of the GN3 partner NRENs is known to have such a system in place.)

3. Despite the first two recommendations, there are no formal preconditions for making environmental improvements, as the achievements of the Green GÉANT partners demonstrate, many changes are easily implemented.
4. Production of IT equipment is demanding for the environment, so ensuring a long lifetime with high-quality, needs-based functionality is crucial. Selecting new equipment with integrated eco-power-saving-semiconductor technologies that will implement new power monitoring and support sleep-when-not-in-use architectures will be essential to reduce the total lifecycle costs of such an equipment deployment. Service demand for bandwidth is also not growing as rapidly as once anticipated, which reduces the pressure for more frequent updating of networking equipment.
5. Videoconferencing remains a powerful tool for sharing information and cutting commuting time and emissions. Although new advances in medical procedures benefit from HD broadcast, solutions can also be basic, PC-based set-ups and still be effective.
6. The savings envisioned in the SMART 2020 report [SMART2020] require that stakeholders at all levels are aware of the mitigation possibilities provided by high-performance data centres and networks.
7. Working together is still one of the most powerful ways to combat GHG emissions. NRENs are well placed to share information, expertise and to collaborate with partners. Supportive forums enabling such exchanges are provided by the ongoing work of the GN3 project and TERENA.
8. Dematerialisation using new ICT based resources will making a major impact in reducing the consumption of resources.
9. NRENs are potentially well placed to take a lead in industry initiatives to promote sustainable policies.

The fourth year of the GN3 project has shown that awareness raising and the reduction of GHG emissions requires ongoing effort. Action is now required, and there are networking tools and advances in the design of new, eco-friendly semiconductors that are more energy efficient, which will help improve the likelihood of reducing GHG emissions. Promotion of procurement policies that focus on environmental considerations will also help NRENs influence equipment manufacturers to supply more power-usage metrics and include techniques to interactively measure power consumption while the equipment is in use. We are well placed to share the learning from the project and the industry, which will ultimately result in innovative solutions for the NREN community.

1 Introduction

The report “SMART 2020: enabling the low carbon economy in the information age” [SMART2020], published in June 2008, found that, although ICT products and services contribute only 2% of global greenhouse gas (GHG) emissions, a future-oriented ICT industry can respond quickly to the challenge of global warming. This is reiterated by the latest version of the report, “GeSI SMARTer 2020: The Role of ICT in Driving a Sustainable Future” SMARTer2020, which says in its Foreword that ICT provides the intelligence to manage and even lessen the imminent threat to our existence from climate change. “Rising temperatures are recognised as a national security issue, destructive force, and threat to national economies.” ICT can offer potential abatements of approximately 17% in transport, 22% in power usage, 15% in agricultural production and roughly similar magnitudes of reduction in manufacturing and buildings. SMARTer2020 was published in December 2012, by the Climate Group, on behalf of the Global e-Sustainability Initiative (GeSI), sponsored by over 12 major telecommunications manufacturing companies and providers. It asserts that this industry has a critical role to play, in designing and deploying the solutions needed to create a low-carbon society.

Most groups refer to the SMART2020 document when referring to environmental policies, but there are other organisations, whose mission is environmental protection, with programmes from which we can take significant lessons and formulate best practices, Greenpeace began evaluating global ICT brands through its “Cool IT” leader board in May 2009, in order to identify which companies were actually leading the efforts to drive change in the energy sector [COOLIT]. In this review, Greenpeace examines how it uses its influence to change government policies that will drive clean energy deployment, and which companies were simply “hand waiving” on the transformative potential of ICT energy solutions, and not seriously pursuing these opportunities. It also ranks 20 of the larger ICT companies against each other to use peer pressure and market forces to force these companies to change. In Version 5 of the leader board, Greenpeace see a steady increase in the quantity and strength of energy-solutions offerings from many companies such as Cisco, IBM, Ericsson and Fujitsu, but they also see a significant reduction in policy advocacy to change the rules to drive investment in clean technology and renewable energy deployment, which is a worrying trend for the future [COOLITLeaderboardv5].

The Study of Environmental Impact Task was introduced in GN3 to achieve the following objectives:

- Ensure that GN3 services meet ambitious sustainability goals.
- Promote energy-saving and ecologically sound applications layered over the GÉANT infrastructure.

By implementing an audit programme, it aimed to provide a clear account and understanding of total direct energy expenditure (e.g., energy consumed by the GN3 infrastructure), indirect energy savings caused by virtual meetings and other “dematerialisation” measures (e.g., by replacing travelling with Web communication when possible) and systematic effects due to, for example, the change in commuting distances due to mobile communication and the use of online resources. In addition, the Task aimed to support the NRENs' efforts to promote the positive effects of networking in reducing climate change; help them set up sustainable programmes in this area; and disseminate best practice and recommendations on environmental sustainability from strategic, operational and service perspectives.

Four years after the introduction of a GÉANT team to study environmental awareness, it is important to ask "How has the whole ICT industry that we support changed/progressed?" and "How can we enhance the knowledge of NREN teams to drive environmental awareness, practices and competencies forward within this community?" Through the investigation of these questions, it is possible to start to develop a road map against which to establish, implement and measure the success of the GÉANT Environmental team. It is important to study change within the supported business needs, as well as change within other responsible groups, such as: environmentalists, clients, supply companies, service providers, government viewpoints and policies. We have to introduce initiatives to support best green practices, and change attitudes and policies towards resource usage and wastage, while supporting the needs of the education and research community we serve. One of the Environmental team's plans for the future is to develop an online audit tool, which could be used by all NRENs to help quantify the impact of their work on GHG emissions and attempt to deduce their carbon footprint.

This document has evolved from the previous deliverable published in August 2012, "DN3.5.3 Study of Environmental Impact" [DN3.5.3]. It evaluates the initiatives taken and summarises best practice to apply to each of the areas included in the report. It follows a similar style and has some content in common with the previous version, in order to determine and promote GÉANT's best practice in these areas. Changes within the operating environment have not been dramatic in the past year. A new section on the team's work on dematerialisation has been added, which promises to make major savings in the production of school books and to pilot digital exams for our more technically aware student base.

The following areas are covered by the report:

- An **Environmental Policy** (Section 2) is a document that can help any organisation to demonstrate its commitment to support good environment practices, and defines the scope where the organisation will proactively interact with the ICT industry, stakeholders and users, to respect and sustain natural resources during their normal operations. The policy motivates staff and provides a mandate for innovation, while encouraging prudent use of resources.

- **GHG Audits and Reports** (Section 3). Knowing where energy is being consumed in normal daily activities, and how this energy usage translates into GHG emissions, helps to prioritise areas where initiatives to reduce resource usage can be demonstrated. Measuring and monitoring GHG emissions is an essential step to actively influence how work practices can be changed to reduce these harmful emissions. Using a standard template, proposed by the GÉANT Environmental team, allows NRENs to benchmark their activities against each other, identify how much energy is used to sustain their business activities, and focus team efforts on areas where improvements can be made.

- **Green Network Management Systems** (Section 4). At present, the Network Management System tools that are widely used by NRENs for provisioning do not offer facilities for energy monitoring or control. The test cases are discussions by NRENs that have developed such tools and are sharing their experiences to raise awareness among their peers to implement equivalent tools or negotiate with their suppliers for this capability. These tools can be useful to quantify energy usage and offer control mechanisms to engineers to deterministically influence the energy usage of the networking equipment in use in operational networks.

- **Power Usage Efficiency (PUE)** (Section 5) is a well-known key factor in all networks and data centres, from both an environmental and economic point of view. Energy consumed in data centres is one of the largest contributors of GHG by NRENs, so this is an area that merits attention. Data centres created to house the explosion of virtual information currently consume 1.5–2% of all global electricity; this is growing at a rate of 12% a year. Data centres take several years to plan and build, and their clients have multiple-year contracts that require continuous service. Therefore, it is not very easy to retrofit an existing data centre nor is it easy to move to a more efficient facility (one with a lower PUE value). It is very difficult to describe universal solutions because of differences in topology, but the report presents examples of what the partners have done, along with the achieved or expected results with respect to reductions in energy consumption and GHG emissions.

- **Virtualisation** (Section 6) is becoming more and more interesting from an environmental point of view, on a regional, national and global level. Demand for cloud-type services has greatly increased for NRENs, who struggle to keep up with user demand for centralising or outsourcing such services. The carbon footprint of most NRENs is still increasing, or, at best, is similar to what it has been in the past, thanks to the measures taken by an NREN to make reductions. This section provides an introduction to the subject and describes some of the Environmental team's partners' ongoing initiatives. Efforts devoted to quantification of the benefits from such services so far have not resulted in energy savings.

- **Energy-aware traffic engineering** (Section 7) is an application of network traffic engineering that includes in its objectives the energy consumption of a network in order to develop mechanisms that achieve the same performance, at a lower overall energy consumption. GRNET participates in the ECONET project [ECONET], which aims at re-thinking and re-designing wired network equipment and infrastructures, as well as developing energy-aware traffic engineering mechanisms, geared towards the creation of more energy-sustainable and eco-friendly networks.

- **Videoconferencing** (Section 8). With high-quality equipment, videoconferencing can replace face-to-face meetings that otherwise would require short- or long-distance participant travel, often by high-energy-demanding transport modes, such as airplanes. This section gives selected examples of the partners' conferencing systems, and applies information on usage patterns to give a very crude estimate of the environmental savings that can be achieved by NRENs using videoconferences and promoting this technology solution to their users.

- **Distance working** (Section 9) is made possible through ICT solutions, thereby avoiding commuting between work and home. Transportation accounts for a large share of society's GHG emissions, but how important is it for an institution with 20+ employees? This section presents an example of what was achieved in a single campaign, including the finding that most employees appreciate the social function of a shared workplace.

- **Dematerialisation** (Section 10) means doing more with less. ICT brings enormous benefits to the education sector, especially for the children of the digital age who have grown up with technology. Savings can be made if institutions review how teaching materials are used or generated and how other paper-based practices such as examinations are carried out to suit the needs of a more digitally aware audience. Such changes can also reduce consumption of valuable resources and environmental impact.

- **Green (Public) Purchasing (GPP)** of IT equipment (Section 11) holds the possibility of acquiring IT equipment that is less demanding for the environment, not only with respect to energy consumption but also in relation to other types of impact. This section introduces the EU guidelines for GPP and Danish Green IT guidelines, which have a somewhat broader perspective.

- **Green Electricity and Energy Source Choices**, or more power sourced from renewable energy resources (Section 12), are seen by many companies and institutions as a good way to decrease the environmental impact of their activities. In practice, however, determining which types of green power actually have a beneficial effect on global climate change is a very complex issue, including both environmental and political aspects. GÉANT Environmental team partners, and other NRENs and organisations, are researching methods of dynamically allocating network resources to maximise the use of renewable energy. This section presents a short overview of the most commonly discussed possibilities, authored by FORCE Technology, the third-party, independent audit company that provided guidance in the compilation of the early DN3.5.2 report [DN3.5.2].

- **Disseminating Green ICT** (Section 13). At present, an NREN's responsibility lies in providing networking connectivity and supporting the ICT services provided over its network, and ends more or less at the campus border. Both NRENs and their supported users are proactive in their activities to increase environmental awareness, as shown in the case studies included in this section. SURFnet effectively worked with their users on joint activities in a number of areas described in the report. HEAnet identified that a significant number of their users are engaged in a program monitored by another national body, An Taisce, which is committed to conserving and protecting Ireland's heritage and environment. Greater synergy will be gained from actively partnering with An Taisce and its promotional, audit and award program, which is integrated with other equivalent international programs. Both approaches are good examples of NRENs interacting with their client community to promote good environmental practices and sustainable resource reduction programs.

A definition of key terms used is provided in Appendix A.

2 Environmental Policy

NRENs as well as the clients they serve have a role in promoting sustainable development across their activities, and a responsibility to society to do so. This means that teaching, research, services and administrative operations should be conducted in a manner that protects and enhances the environment, conserves natural resources, reduces greenhouse gas emissions, and supports the community and society as a whole. This can be reflected as a Sustainable Development Policy for clients who have large campuses and are continually changing those campuses to reflect daily business needs. NRENs should also work towards generating such a Sustainable Development Policy and one of the major components of this has to an Environmental Policy, which can be customised to meet its own requirements.

According to the 2012 TERENA Compendium, only 6 out of 32 GÉANT partners have an environmental policy, and the Environmental team is aware of two others who have generated environmental policies. This number has increased slightly since 2010; however, further action is required to stimulate such policies. It is not known whether the situation is different from that in other sectors, but it is a strong indication of environmental issues having a low priority in most of the partner institutions. One of the emerging initiatives from the Environmental team will be to increase that number dramatically in the next two years. One approach to this might be to encourage GÉANT itself to design its own environmental policy, and encourage other NRENs to sign up to this central policy, unless they wish to have their own version.

To further this goal, the Environmental team propose to hold a workshop prior to the 2013 TERENA Networking Conference (TNC2013) in June, to encourage NRENs to generate such a policy and to obtain a consensus on what would be expected in a common GÉANT Environmental Policy. Most environmental policies have common themes such as measuring and reducing energy usage, reduction of waste, promoting awareness within their community and using best practices to sustain the organisation’s business while taking into account the impact on the environment.

Figure 2.1 below shows an example of an environmental policy – that of GRNET.

Environmental policy of GRNET

Energy consumption of the Internet will be one of the main challenges that technology will have to face in the future. Current and planned evolutions of the Internet, although they plan for a variety of improvements like increased capacity, easier manageability, and stronger security & privacy, do not address energy consumption issues.

As a National Research and Education Network (NREN), we have the vision of developing Education and Research in Greece along with the equal participation of our organizations in the Pan-European society of knowledge with the provision of modern, advanced and reliable Internet services to all the Educational and Research Institutions.

By taking into account the above-mentioned considerations and by recognizing that our operations have an effect on the local, regional and global environment, we are committed to include innovative green technologies in our networking and computing infrastructure and reduce our yearly greenhouse gas emissions footprint. In order to achieve that, environmental regulation, laws and codes of practice will be highly regarded when assessing standards of environmental performance.

Towards this direction, our environmental policy will be based on the following axes:

- upgrade our networking and computational infrastructure with energy efficient equipment,
- deploy energy consumption monitoring infrastructure for the real time monitoring of energy consumption in our Points of Presence (PoPs) and Data Centers,
- participate in research activities for the design of energy aware mechanisms for the operation and control of the network,
- improve energy efficiency in our data centers (low Power Usage Effectiveness - PUE values) through the application of innovative energy aware techniques,
- increase environmental awareness of the Greek research and academic community through the dissemination of "green" best practices,
- reduce travel necessarily incurred as part of work by using videoconferencing tools,
- minimize environmental pollution through the reduction, reuse or recycling of materials as much as possible.

To this end, we will measure and periodically report on our progress in realizing these commitments.

Figure 2.1: Environmental policy of GRNET [GRNETPOLICY]

As part of their research to understand how their clients' campuses are engaged in environmental management, HEAnet are working with An Taisce, who are local representatives for the Federation of Environmental Education (FEE). They discovered that all the clients who are engaged in the Green Campus program had a Sustainable Development Policy; one example is the policy of Trinity College Dublin (TCD), who have now achieved Green Campus Status (details of this program are expanded in Section 12).

TCD is committed to:

- Balanced development with regard to the environment, economy and society.
- Managing its campuses in a manner that protects and enhances the local and global environment by establishing quantitative goals for environmental performance.

- Developing its buildings and services with due consideration for the environment using life-cycle analysis.
- Reducing greenhouse gas emissions.
- Promoting intelligent resource use, namely sustainable transport use, minimisation and reuse of products, environmentally preferable procurement, recycling of waste streams, energy management and water conservation.
- Incorporating the principle of sustainable development into the teaching, training and research activities of the College as far as possible.
- Continuous environmental improvement and pollution prevention throughout its activities.

2.1.1 Recommendations

- **Each NREN should draw up an Environmental Policy** that can be customised to meet its own requirements. The GÉANT Environmental team will draw up a generic policy for those NREN organisations that do not have resources available so that they can sign up and practise this common policy.
- On its website, GÉANT should have a **shared, environmental area**, clearly identifying the aligned NRENs. A separate page in this area would display the logos of NRENs that have their own policy, and include a link to the URL of the NREN's environmental policy documentation.

3 Greenhouse Gas Auditing

Within the GÉANT Green Team, several GHG audits have been carried out, and associated reports have been produced by participating NRENs (see [GHGACCT]). Data from these reports provides a basis for comparing annual GHG emissions, for each part of the network. Based on this data, several graphs were produced, showing trends regarding the percentage of energy consumption in diverse NREN activities – which is increasing as demand for cloud-based services and associated connectivity needs grow – as well as the change in energy consumption during the previous audit periods.

A common scheme or template for preparing GHG reports for NRENs has been adopted, to enable the audits to be carried out in a methodical and consistent manner. This also enables comparisons within and between NRENs, with a view to identifying key areas that need attention.

3.1 GHG Audit Process and Report

The first step to performing a GHG assessment is to measure and record all the GHG emissions in the NREN's sphere of operations. Measurements are recorded in a common template, and then a third-party verification body performs a pre-validation in which potential hot-spots are identified as part of a verification checklist. The NREN must clarify the issues in the checklist, and then a verification report is prepared that describes any deviations (omissions or changes from stated measurement standards) and provides remarks for extra guidance on deployed policies. The NREN then performs potential corrections in order to "close down" potential deviations from the standard approach applied by the auditor throughout the audit, and clarify any guidance.

The primary goal of this assessment is to account for the GHG emissions according to the ISO 14064:2006 Part 1 standard, which calls for the creation of climate accounts. The report is divided into the five following sections:

1. Introduction.
2. Inventory Design and Development.

   This section includes information regarding the organisational and operational boundaries, the responsible party, the reporting period covered, the base years and their changes and recalculations, and details regarding the compliance and verification statement.

3. Calculating GHG Emissions.
   a. Greenhouse gases and CO_2-eq definition.

b. Data used for calculating GHG emissions.
c. Impact of uncertainties on the accuracy of the data.

4. Scope 1: Direct GHG Emissions.
5. Scope 2: Indirect GHG Emissions.

The methodology used to quantify energy-indirect GHG emissions, by sector, within NREN boundaries is described in this section. Indirect GHG emissions are caused by using energy produced by others (e.g. electricity or heat).

Scope 2 GHG emissions for the offices, the backbone network and the data centres must all be recorded.

a. Quantification Methodologies.

In this inventory, only recurrent emissions are considered. The embedded energy and consequent GHG emissions from building and production of facilities and equipment are not included. Indirect emissions are calculated from activities in three main categories. For each category the NREN should provide information regarding: the facilities, the measurement method, sample and possible exclusions:

i. The office.

Indirect emissions in this area originate from:

a. Electricity usage for the office itself. (Electricity is used for lighting, air conditioning and ventilation, desktop/laptop computers (not the network), coffee machines, displays, computer projectors, etc.).

b. Electricity for building services.

Note: If the NREN has a small part within its office building that is used as a computer room (where servers/network components needed for daily operation are hosted), the energy consumed there should be included in the office electricity usage or measured separately and then abstracted from the total amount in order to avoid double counting.

All GHG emissions are indirect, and may result from the consumption of electricity for power, lighting, heating and cooling, support building services, such as lifts, and/or from the consumption of oil for heating. The NREN must add the number of units used per bill for the corresponding year to arrive at the yearly amount. Then the total amount must be converted to tonnes CO_2-eq based on how many kg CO_2-eq correspond to 1 KWh for their country in the specific year. The procedure is similar for the oil consumption.

ii. Backbone Network.

Here energy consumption and emissions related to the backbone network are recorded. The network (or backbone) includes all the Points of Presence (PoPs) where network equipment, owned by the NREN, is located. This equipment may consist of:

— Optical network equipment consisting of optical amplifiers, (de)multiplex devices, wavelength switches, optical controllers and Dense Wavelength-Division Multiplexing (DWDM) equipment.
— IP network equipment consisting of routers.
— Layer 2 network equipment consisting of switches.

For all network equipment, energy consumption values can be calculated from supplier documentation or, more preferably, as a result of real-time measurements.

iii. Data centres.

Energy consumption and emissions from data centres that are caused by the storage, computing and networking equipment, as well as supporting infrastructure such as cooling, ups, etc., are recorded in this section of the template.

The data for these locations for all the types of equipment (in the backbone network and in the data centres) can be based either on measured values (if at possible) or on their typical energy consumption, as detailed in the manufacturer's datasheets. Total kilowatt hours are again converted into tonnes CO_2-eq, based on how many kg CO_2-eq correspond to 1 KWh for their country in the specific year and on the PUE factor.

b. Reasons for Selection of Inventory Sectors.

Justification for the selection of the distinct categories should be provided.

6. Scope 3: Other indirect GHG emissions.

GHG emissions due to forms of transport are considered in two categories, and apply to all employees of the NREN: commuting to and from work, and travel “on mission” as part of one's duties to the NREN. NREN staff need to use transport to commute to and from work; transport “on mission” during work is measured separately, and involves attending project meetings, or carrying out on-site maintenance at a network PoP. Such travel involves the use of transport which consumes fuel and so, either directly or indirectly, is responsible for GHG emissions.

In GRNET's GHG audit (for the period January 2010 to December 2010, documented in [GHGREPORT]), none of the vehicles involved belonged to GRNET, so these emissions were categorised as “other indirect”. These emissions arose from the following sources:

- Gasoline and diesel fuel: used by private cars, motorbikes, taxis, buses, and trains.
- Aviation fuel: used by aircraft for air travel.
- Electricity: used by trains and trams.

For transport associated with commuting to and from work, all employed GRNET staff answered a questionnaire regarding how they reach the office based on the area where each employee lives. The approximate distance for each staff member's daily journey was taken from Google Maps [GOOGLEMaps] and was categorised by walk/cycle, train, metro, bus, motorbike, taxi and car.

It was assumed that each employee completes a round trip on the days they commute to the office and 220 working days per year. Daily kilometres per category were calculated and were multiplied by 220 days to get the annual figure.

The corresponding emission calculations were taken from the following sources:

- Cars: from [GREENPEACECalc] according to the type of the car and the travelled distance.
- Metro: from [CFOOTPRINTCalc] according to the travelled distance.
- Buses: from [CFOOTPRINTCalc] according to the travelled distance.
- Motorbikes: from [CFOOTPRINTCalc] according to the type of the motorcycle and the travelled distance.

The approximate emission of each flight was calculated from [ICAOCalc].

Audits are carried out on a bi-annual basis by the Environmental team NRENs; most of these have completed two audits and will be carrying out their third audit over late spring or summer 2013, as shown in Table 3.1 below.

Date	NREN/ Organisation	Audit	Comment
By end of June 2013	HEAnet	3rd – 2011/2012	Depending on the development progress of the tool, HEAnet expect that the audit will be produced / reported in both styles (manually/paper-based and with the online tool).
	SURFnet	3rd – 2012	–
	GRNET	3rd – 2012	GRNET aim to carry out annual audits in future.
By end of September 2013	DANTE	2nd audit of the full GÉANT backbone	Has been delayed due to the major upgrade that DANTE is making.
To be scheduled	New Environmental team members	1st	To be scheduled at face-to-face workshop 18–19 April 2013.

Table 3.1: Forthcoming audits

3.2 Example Findings: GRNET

The first GHG emissions report for GRNET [GHGREPORT] covered the period January 2010 to December 2010 and was verified according to the ISO 14064:2006 part 1 standard. GRNET have now have proceeded to the preparation of similar reports for 2012 in order to monitor the trends in the evolution of energy consumption in GRNET in the different parts of the computational and networking infrastructure. Energy consumption is monitored in the GRNET network, the data centres and the offices; emissions due to personnel travel are also reported. Based on the available results (the reports are due to be finalised by the end of March), there is an increasing trend in the energy consumption in GRNET data centres that is mainly due to their continuous expansion and the hosting of further computational and storage equipment. It should be noted that the energy-consumption monitoring infrastructure in the GRNET data centres has been upgraded and the Power Usage Effectiveness (PUE) indicator has been significantly improved and is constantly below 1.8. Energy consumption in the remaining parts of the GRNET infrastructure does not present major differences. However, since the networking infrastructure is going to be totally upgraded within 2013, it is envisaged that the energy consumption will be reduced while advanced energy consumption monitoring mechanisms will be supported.

3.3 Future Plans

The GÉANT Environmental team have plans to develop a web tool for the online completion of GHG Reports by NRENs. This tool will be able to support the automatic extraction of statistics, the automatic conversion to CO_2 emissions and comparisons between different NRENs/sectors/years/metrics, etc. Statistics could be derived automatically based on NRENs' reports (GHG emissions per metric, GHG emissions per year, GHG emissions per Pbyte, GHG/M budget, electricity usage and GHG emissions percentages). Statistics will be displayed automatically in the form of graphs. The online tool will facilitate the completion of the reports and should prove extremely useful, especially for the new members of the team. Specific guidelines will be provided for each step, combined with predefined conversion factors based on the available data in each country.

The proposed timeline for developing the tool is given in Table 3.2 below:

Activity	Completion Date	
	Project Month	Calendar Month
Requirement analysis	M2	May 2013
Definition of metrics and type of graphs	M3	June 2103
Collection of data for conversion factors per country, global factors, etc.	M3	June 2103
Workflow definition	M4	July 2013
Development phase	M10	January 2014
Testing – pilot use	M11	February 2014
Final version	M12	March 2013

Table 3.2: Proposed timeline for web-based audit tool

3.4 Recommendations

- The GHG Audit approach is now well documented, and GÉANT needs to **set targets for the number of additional NRENs that will comply and carry out audits** in their own networks.
- **Promotional incentives need to be identified** that would encourage NRENs to participate in the audit programme.
- As the audits to date have been validated by a third-party, Force, an **evaluation** needs to take place to determine whether external validation is a practical solution for the future.
- **An internal audit team can be identified** and offered as a preliminary audit resource or as the final audit verification group.
- A normalisation process needs to be agreed to **benchmark audit results**, as NREN networks vary in size, geographic distribution, technologies employed, and energy sources. Countries with a heavy

dependency on fossil fuel resource should not be discriminated against; therefore, the process should also include compensations.

- GÉANT needs to set up specific **pages on its website to display audit results and develop communications materials** to highlight activities and progress.
- A **Wiki Repository should be identified** to hold support documents and work-in-progress files.
- The **new audit tool** should be used by NRENs performing audits from mid 2013.
- The current **audit approach now needs to be benchmarked against NRENs' approaches in other regions of the world** such as the US, Asia and Africa.

4 Green Network Management Systems

Organisations looking for savings in their operational fields, beyond the regular hardware renewal cycle, seek to reduce power consumption as a significant part of their costs. This includes power consumed by network infrastructure, servers and storage, as well as cooling systems and auxiliary devices. Many organisations have quickly become receptive to “green IT” because of its potential for energy savings. This also fits with societal pressure for every organisation to care about sustainability and social responsibility.

According to the standard ISO 14001:2004 “Environmental management systems: Requirements with guidance for use” [ISO14001], having an environmental policy or having established a baseline GHG account “may not be sufficient to provide an organisation with the assurance that its performance not only meets, but will continue to meet, its legal and policy requirements.” To be effective, they need to be conducted within a structured management system that is integrated within the organisation.

ISO 14001 and the EU Management and Audit Scheme (EMAS) [EMAS] are widely used management tools for companies and other organisations to evaluate, report and improve their environmental performance. Both tools require a strong commitment and the willingness to use the necessary resources to build and maintain a formalised and certifiable system. Establishing a formalised and certifiable management system is not, however, a precondition for identification of improvement possibilities – or for their implementation. But writing and using a set of procedures is often helpful in the process, especially if you want your colleagues to actively participate.

The case study presented in the following section describes some of the important steps that form a workflow that can be anchored in a management system, focusing on energy reductions in data centres and other organisations with an increasing need to easily access and manage the data and power needed to support equipment.

4.1 Case Study: Green Networking at Poznan Supercomputing and Networking Centre (PSNC)

4.1.1 NMS and Green Workflow

Poland’s national network, Verax, worked to enhance its Network Management System (NMS) with green workflow policies together with the PSNC Network Operations Centre (NOC), which monitors and manages its network. The chosen NMS was selected for its ability to implement a set of rules (scripts) that build energy-saving workflows, where human involvement is reduced to a minimum:

- It gathers measurements from managed devices via built-in and/or external probes and built-in performance counters.
- Probe and performance-counter data is persistent and contains aggregated historical data.
- It contains effectors (metric value triggers and decision points), helping to define actions on network element management.

However, in order to provide power management at the service level, Verax has extended its NMS with a rules-based engine that will communicate with NMS core internals. A built-in analytical module allows:

- Measurement of power consumption of each managed element.
- Visual presentation of energy consumption per logical block of IT infrastructure.
- Detection of abnormal power consumption and generation of power-related alarms based on historical data.
- An optimisation module that supports reconfiguration actions required to minimise power consumption.

When monitoring energy consumption of individual devices Verax's NMS can activate custom-defined, non-disruptive energy management policies, including:

- Remote hibernation for computers.
- Switch to standby mode or off for server.
- Use more energy-efficient servers first.
- Actively optimise load distribution.
- React to abnormal power consumption.

All the policies described above are quite simple when considered individually, and each of the policies will lead to a reduction in overall energy consumption, because most of the individual hardware elements provide some kind of energy-saving mechanism.

Trying to manage energy consumption at the service level is complex and requires a holistic approach, which can lead to more energy savings. A scenario under such an approach might look like the following: "If the number of active sessions drops below a certain threshold, then move one of the virtual machines from server X to server Y, as this will produce more energy-efficient load distribution." As can be seen from the example above, in order to execute even such a simple scenario, complex interactions between hardware, software and the network are required.

Such interactions are composed into a decision-making green workflow, based on the current state of the hardware and software elements used to provide the service. However, to make a decision, multiple sensors are required to monitor each element of the service (e.g. server load, traffic, temperature, etc.). Based on sensor input (measurements), historical data and rules, special policy agents can then decide what actions should be taken. Once the decision has been made, a number of effectors are required to implement configuration change requests (e.g. move a virtual machine image, shut down a cluster host, etc.).

4.1.2 Optimisation

All major modern operating systems feature sophisticated power management capabilities based on open industry standards. While these features can reduce the power consumption of a running machine, they do not address the problem of computers that are idling. A typical desktop PC, according to PSNC's measurements, can consume between 100 and 140 watts while idling without any gain in productivity. The issue can be mitigated by suspending or shutting down idling machines, although such a solution entails the problem of waking the machines up afterwards. Moreover, computers and other electronic devices can draw a significant amount of power even when they are turned off, but still connected to utilities [KUROWSKI**KUROWSKI**]. Figure 4.1 below shows that the power-consumption assumptions average for an idling PC is 105W, and for a LCD display 25W.

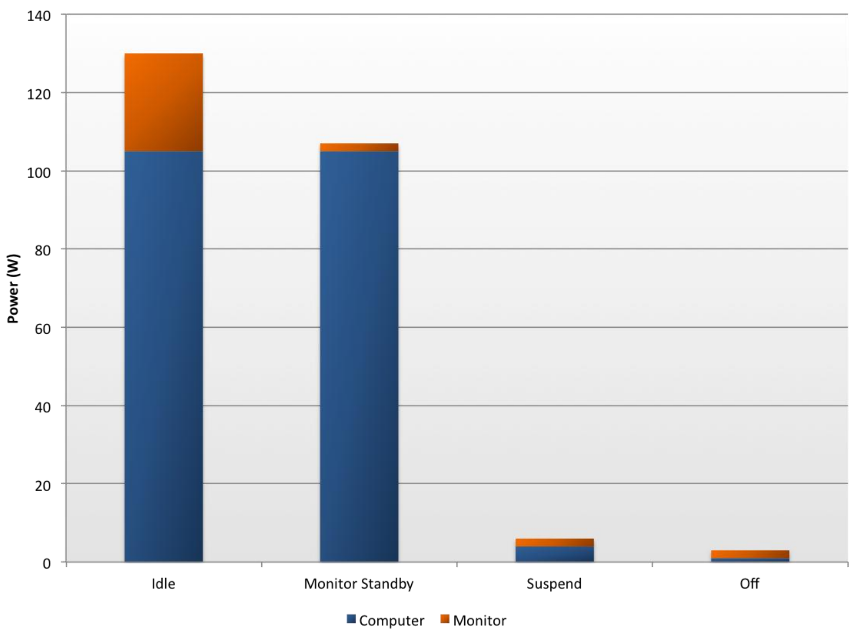


Figure 4.1: PC and monitor power consumption at different levels of energy management

Implementing this type of power-saving policy within the whole organisation, using simple built-in power management features or even using the Verax NMS's built-in simple hibernate feature is not effective in large multi-vendor and cross-platform environments. To overcome this problem, PSNC has developed a special platform, Green IT Control and Management Platform (GICOMP) [GICOMP]. It allows the network administration team to easily manage hundreds of computers in the network from one location with a given power-saving policy, regardless of the operating system. A small program is installed on every computer, which barely uses any of the machine's resources, does not display any messages and never interrupts user work. The component constantly monitors the computer by checking the computer's utilisation, observing user activity, and collecting energy consumption statistics. The resulting information is gathered centrally and may be displayed to the administrator and exchanged with NMS. Based on this input, the component communicates with remote nodes and manipulates computer settings, such as monitor brightness, power modes of whole computers or specific components (e.g. hard drive), etc.

Using GICOMP power management policies for unused computers in organisations can reduce power consumption by suspending machines left on by employees outside of office hours (given the general habits of office workers and the big difference in power consumption of an idling computer, compared to a suspended one). The potential savings can be enormous in large-scale organisations (Figure 4.2). The additional advantage of GICOMP, compared to GreenUP, for example (see Section 6) is that its centralised architecture can manage distributed environments. Also, different metering devices can be used to support better power management.

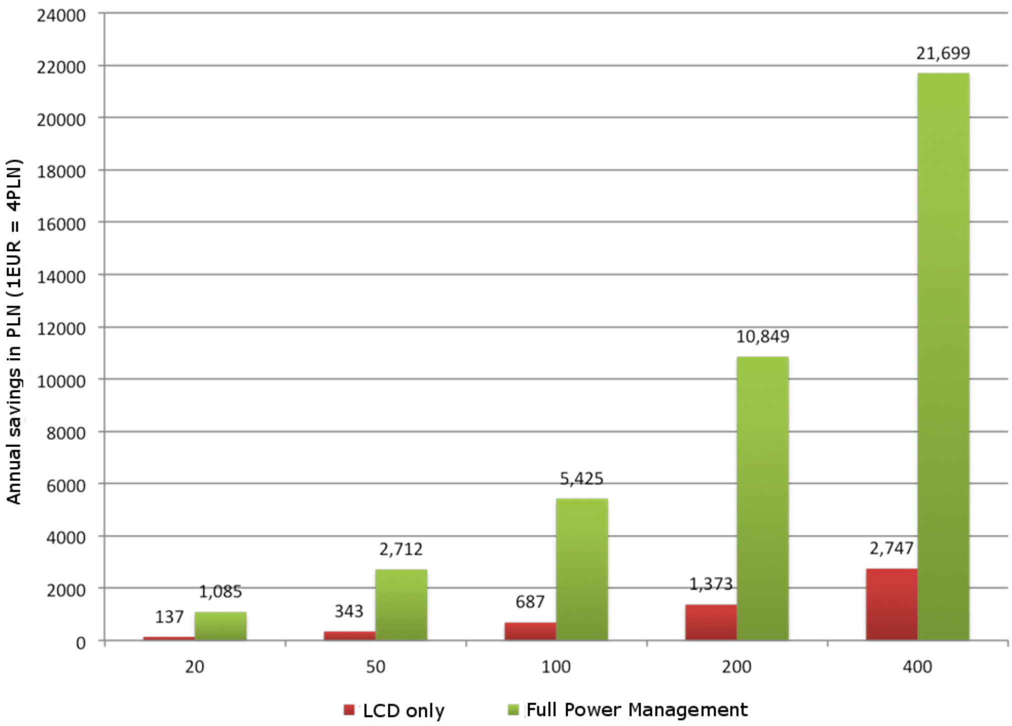


Figure 4.2: Savings estimation with increasing number of computer nodes

Similar considerations can be applied to the servers. Once a workflow has been defined and the script is in place, the power management system can use recorded usage records as well as planned/forecast usage to switch active servers on, put the servers that are ready to be used in standby, and switch off all the rest. Because PSNC's measurements show that the energy consumption of powered-off servers varies between 4% and 10% of a fully loaded machine (Figure 4.3), the power management system should also be able to physically cut off the power supply in order to maximise power savings on unused nodes (and manage power at outlet level). It is also able to decide which servers should be activated and so use the more energy-efficient servers first.

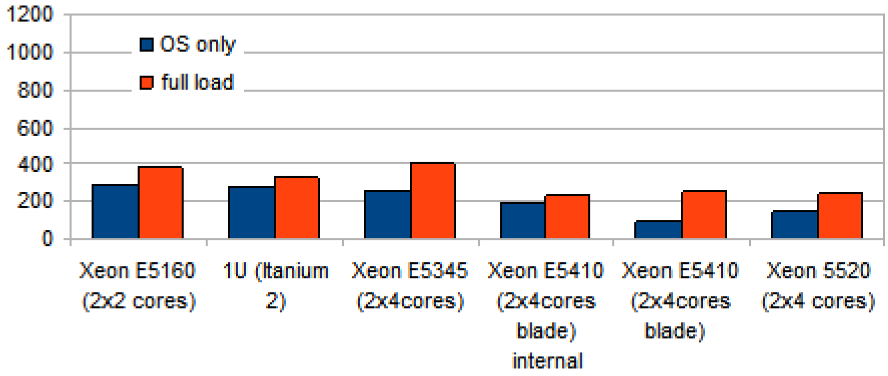


Figure 4.3: Power consumption of x86 machines installed in PSNC (W)

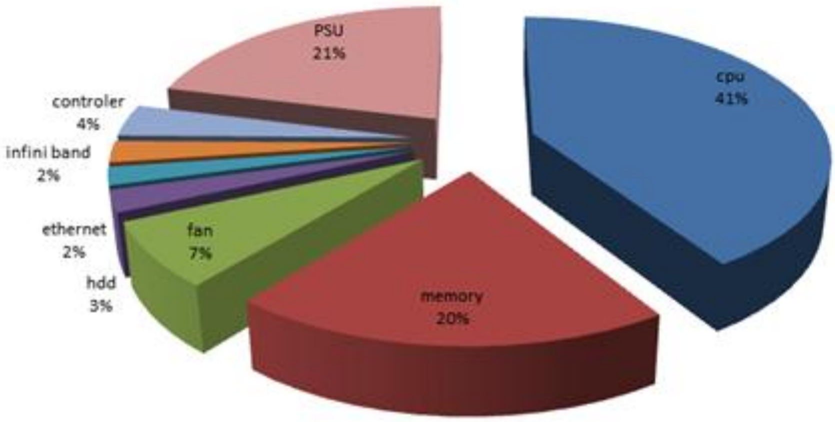


Figure 4.4: Typical power distribution of x86 machines

The next step is to analyse load distribution between servers. Because overloaded servers are not energy efficient (the parts of the machine that consume the most energy are CPU and memory, as shown in Figure 4.4), it is worth considering moving some virtual machines to other, underutilised servers, taking into account current, historical and planned resource utilisation, as well as energy consumption aspects. Such optimisation of load distribution is also a source of power savings.

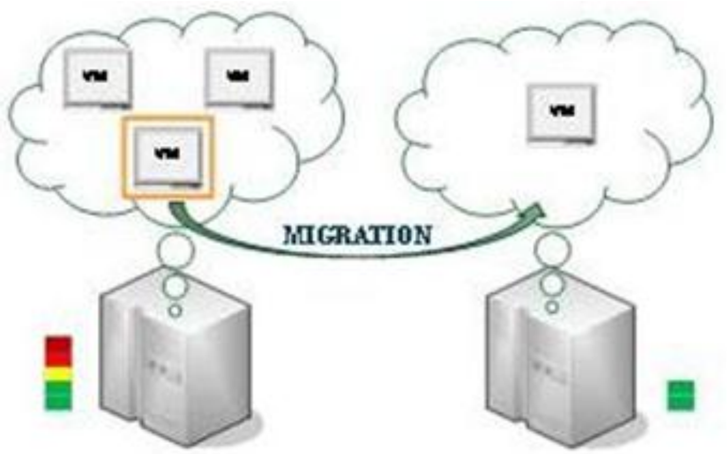


Figure 4.5: Optimised load-balancing between servers – an example of virtual machine migration

The last step is to monitor overall energy consumption and react to abnormal energy consumptions. By measuring and analysing power consumption in a data centre, there will always be abnormal behaviour, such as a huge increase in power consumption over a given period of time. Such situations should be carefully analysed to determine whether this is caused by abnormal user behaviour or is related to specific hardware or software.

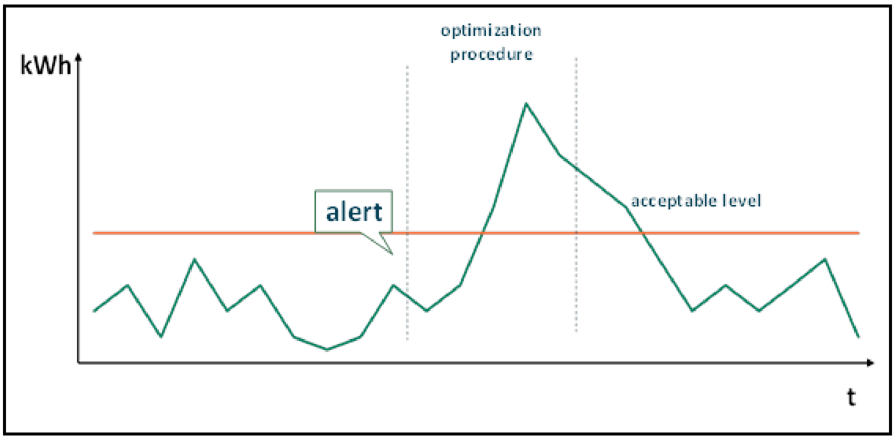


Figure 4.6: Continuous monitoring of overall power consumption

4.1.3 Think Ahead

To benefit from the continuous monitoring of overall power usage, the steps to employ are:

- Optimise/replace sub-optimal software, taking note that an optimum solution could be version or technology dependent.

- Replace sub-optimal computers and infrastructure elements (multi-criteria assessment: historical data if the elements are currently used, planned usage, power management rules, power profile of new equipment, return of investment prediction).

Optimising or replacing software requires more effort because it requires monitoring of the energy consumption on the software level. Different applications cause different computer loads, which of course leads to various power-consumption levels. Moreover, the same equipment using different versions of the same software may give significantly different results in the context of performance and thus the energy efficiency. As a result, determining energy efficiency at purchase phase may ensure the best match. Figure 4.7 shows the required power to complete the same test compiled with different compilers. As can be seen, the difference between the worst and the best case is more than 30%.

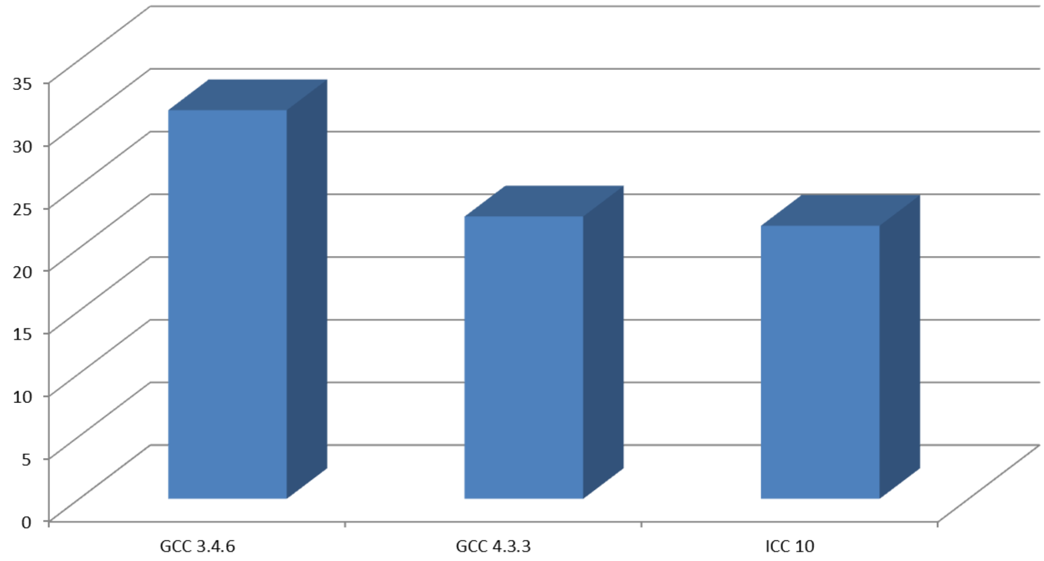


Figure 4.7: Example of software energy consumption compiled with different compilers (Wh)

Tools such as Verax will need to have the capability and resolution to monitor smaller amounts of power utilisation to be of value after several technology refresh programmes, and should be enhanced with utilities that run simulations and modelling features to show a return on investment.

The next elements to analyse are infrastructure elements. We should monitor infrastructure elements' utilisation and related energy consumption, as in Figure 4.8, below, which shows an example analysis of utilisation and energy consumption by sub networks and devices. This will help to identify the least-efficient devices. Once we identify them, we can consider moving them to another part of the network (where they can be better utilised), eliminating them (if they are not needed) or replacing them.

Location	Devices	Ports	Used ports	Used ports %	Unused ports	Unused ports %	Total power (kW)	Power per used port (W)
Subnetwork A	11	237	115	48	131	46	3.6	36
Subnetwork B	20	623	72	42	531	88	1.1	18.5

Device name	Description	Ports	Unused ports	Unused ports %	Device power (W)	Power per used port (W)
Subn_B_Switch_1	ZKO-32	100	50	50.1	400	33.33
Subn_B_Switch_3	SWW-123	6	0	0	120	20
...						

Figure 4.8: Example of information on energy consumption at national and device level

Due to the experimental status of PSNC's use of the Verax NMS, there is no definitive set of case study results, as one would expect, since the experimentation has been very fluid. Instead, some general suggestions are put forward to show energy-saving possibilities. This demonstrates the importance of making a start towards using and assessing the NMS energy-saving potential. Covering even single areas of the proposed workflow can cause significant savings in energy consumption.

4.2 Recommendations

- GÉANT should define a **power-saving policy** based on inventory as an anchored part of the environmental policy. This first step in implementing a green workflow will help to define what metrics to follow.
- Implement mechanisms that will allow **suspension of computers and servers**. In the case of servers, these should also manage power at outlet level.
- Control overall energy consumption and **identify the reasons for abnormal consumptions**.
- Make an **energy-efficiency assessment** when purchasing new **software** or **optimise software** for further significant energy savings.
- Have a schedule for **IT infrastructure replacements,** taking into account energy efficiency proven by an independent entity or with Ecolabels.
- GÉANT should plan or discuss how it will deploy or enhance its new network solution to **use a Green Network Management solution**. This will probably require a special **Test Case Document** to be produced.
- **ISO 14001 and the EU Management and Audit Scheme documents should be made available** via GÉANT under control restrictions.

5 Data-Centre Optimisation: Power Utilisation Efficiency (PUE)

5.1 Measuring PUE

Power consumption at data centres is one of the main sources for emission of greenhouse gases in the ICT industry. As for any other type of consumption, the more effective the utilisation, the smaller the emissions from electricity production.

The energy efficiency of a data centre is commonly measured and reported as the Power Usage Efficiency, (PUE). As a general rule, the PUE is determined by dividing the amount of power entering a data centre by the power used to run the computer infrastructure. PUE is therefore expressed as a ratio, with overall efficiency improving as the quotient decreases toward 1.

PUE = Total Facility Power / IT Equipment Power. [GREENGRID_2]

Determining the total amount of power entering a data centre is often very straightforward, e.g. from utility bills. The amount of power used to run the computer infrastructure is, however, much more difficult to assess, according to the Green Grid's white paper, "Data Centre Infrastructure Efficiency (DCiE) Detailed Analysis" [GREENGRID_3], which shows a phased approach representing three levels of refinement with increasing detail and precision. The levels are: Uninterruptible Power Supply (UPS) level (basic); Power Distribution Unit (PDU) level (intermediate); and Server level (advanced) [GREENGRID_4]. These levels also represent different levels of investment in equipment to facilitate the measurements needed. Table 5.1 depicts the key features of the three levels introduced by the Green Grid.

	Level 1 Basic	Level 2 Intermediate	Level 3 Advanced
IT equipment power consumption	UPS	PDU	Servers, etc.
Total facility power consumption	Data centre input power	Data centre input power less-shared Heating, Ventilation, and Air Conditioning (HVAC)	Data centre input power less shared HVAC plus building lighting, security, etc.
Minimum measurement	Monthly/weekly	Daily	Continuous

	Level 1 Basic	Level 2 Intermediate	Level 3 Advanced
interval			

Table 5.1: Key features of PUE-estimations according to Green Grid white paper

Measurements at PDU level are now recommended as a global standard, and Level 3 is expected to replace the PDU level in the near future. In practice, however, the measurements must be made on the most suitable meter, defined as the meter closest to the IT equipment, and corrections made for known error sources. Corrective measures should for example be taken if the UPS also provides energy to the cooling system, or if nameplate energy consumption is used for the calculations. According to the Uptime Institute (a third-party data centre research, education and consulting organisation, focused on improving data centre performance), many planners use 70% of nameplate effect for their calculations, but measurements made by one of the Green GÉANT partners (GRNET) shows that the average real-time consumption of their network routers in general is less than 40% of the nameplate specifications (see Section 5.2.2).

Determining the PUE of a data centre is still a long way from being an exact science, unless an advanced system of measurement devices is deployed at the sites of all relevant power-consuming units, and even in this instance there would be an at least 1.5 % inaccuracy in the captured values. The individual topology and function of a data centre, together with the inherent possibilities of making qualified measurements, mean that PUE comparisons with other data centres should not be made without knowing that it is exactly the same elements that are the subject of the calculations.

However, each data centre can monitor its PUE over time and use the chosen calculation procedure to measure the effects of different design and operational decisions. The following section shows some of the initiatives undertaken by the Green GÉANT partners and indicates the results obtained.

5.2 PUE in Practice

A detailed description of how PUEs are determined can be found in the white papers from the Green Grid, especially "Data Centre Infrastructure Efficiency (DCiE) Detailed Analysis" [GREENGRID_3]. The suggested Green Grid approach means that the procedure can be agreed upon and the results verified by auditing parties, if so desired.

An important European initiative under development, "The EU Code of Conduct for Data Centres" [EUCODE], is a collection of guidelines and best-practice documentation, which is also useful for acquiring up-to-date knowledge of establishing and maintaining European data centres. This document can also be used as a compliance standard for vendors involved in delivering design and equipment for the construction of new data centres.

PUEs are not unequivocally defined, and it is therefore not relevant to give standard values for a PUE. According to the Uptime Institute, the typical data centre has an average PUE of 2.5. This means that for every 2.5 watts *in* at the utility meter, only one watt is delivered *out* to the IT equipment. The Uptime Institute also estimates most facilities could achieve 1.6 PUE using the most efficient IT equipment and best practice, without major changes to their physical infrastructure.

As a part of the NA3 Task 5 work, the partners have measured or estimated PUEs in several contexts. It is outside the scope of this report to provide extensive technical detail regarding the measurements, but the key findings and their backgrounds are reported in the following sections.

5.2.1 Case Study UNI-C

For the past five years, UNI-C – the operator for one of the partners in NORDUnet – has monitored the energy consumption at its main location at the Danish Technical University in Lyngby, Denmark. The measurements are of different quality, due to the mix of equipment, facilities and business models. Monitoring of the electricity consumption is done at all three levels of the refined approach, mentioned above. In Sector 1 and 2 of the data centre, the differentiation is mainly between the load of the IT-equipment cooling system, and security and monitoring equipment, lighting, etc. In Sector 3 and 4 the measurement is detailed to the level of single units or groups of units of IT equipment. All measurements are continuous and integrated in a single system, making online alarms and immediate appropriate actions possible.

The information is subsequently used to calculate the PUE for a given period of time. Table 5.2 below shows the energy consumption (MWh) distributed on relevant elements for the five-year period. It appears from this table that the PUE has decreased by at least 8.5% from 2007–2011.

Two factors have been important in decreasing the value of PUE:

1. The implementation of a virtualised server environment which has a more effective use of electrical consumption through an automatic power-saving feature integrated in the system. This makes possible a moderate increase in power consumption in spite of an increase in the number of servers.
2. An effective cooling system known as “free cooling”, which utilises the outdoor climate to cool the four sectors to an acceptable temperature. The use of “cool” and “hot” corridors in the facilities where the IT equipment is placed also helps to keep the electrical consumption of the cooling systems at an acceptable level.

The drop in UNI-C’s PUE values from 2007 (1.89) to 2009 (1.65) is mainly due to putting the free cooling system into use in 2008. This new system was established by improving an already existing cooling unit on the roof with new cooling surfaces and installing a valve allowing the cooling water to be piped through the open air unit instead of the compressor units.

Year	Total	Ups	Equipment	Cooling	Lighting+Office	PUE
2007	3354	195	1777	1271	109	1,89
2008	3695	216	2139	1237	103	1,73
2009	4183	258	2531	1307	96	1,65
2010	4084	248	2423	1270	71	1,69

Year	Total	Ups	Equipment	Cooling	Lighting+Office	PUE
2011	4325	263	2500	1443	86	1,73

Table 5.2: Energy consumption in MWh at UNI-C in Lyngby, Building 304

During 2008 and 2009, the system was tuned by choosing optimal values for the machine-room air temperature, the cooling-water temperature and the set point where the valve automatically opens for piping to the free cooling unit. The current value for the specific set point is 5°C outdoor temperature, but tuning has proved to be more difficult than expected, due to the two different types of cooling units.

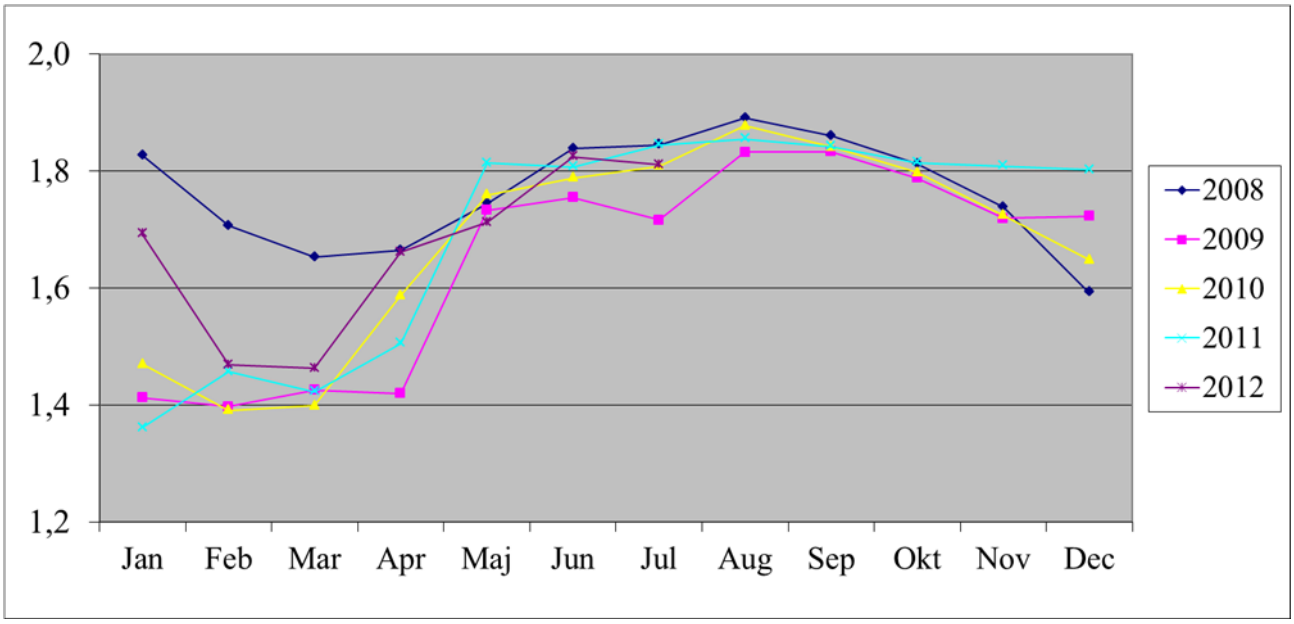


Figure 5.1: Monthly calculation of PUE (as shown in Y axis) in UNI-C

Figure 5.1 illustrates the overall beneficial effect of free cooling on PUE. As soon as the outside temperature drops below 5°C, the free cooling starts automatically. The fluctuation in the data between winter and summer is mainly due to the free cooling system having an impact on the overall PUE values. It was especially challenging to adapt the older cooling system to ensure the maximum efficiency and response to the outside environment.

It should be noted that the efforts to improve the efficiency of the data centre are inspired by the EU Code of Conduct initiative, although UNI-C is not (yet) an endorsing member. It should also be noted that there is a large economic benefit from the improvement in efficiency. The total price for this rebuilding amounted to about EUR25,000, saving already in the first year (about 2000 MWh * (1.89–1.73) = 320.000 kWh), thus paying back the investment in less than a year.

Of course the reduction in PUE (and power consumption) has had a significant impact on the emission of greenhouse gases. In Denmark, average electricity from the grid has been calculated to emit 0.766 kg CO_2 equivalents/kWh. [ELCD] The reduction in GHG emissions thus amounts to about 245 tons of CO_2 equivalents or about 8% of the total GHG emissions from UNI-C data centre. This data centre uses free-air cooling, so conditions will vary each year. As we can see in the last year, the total power consumption increased by 6%. The equipment only accounts for 3% of the rise, but the cooling power consumption rose by 14%, as the winter of 2012 was milder than the previous two winters.

More information about the projects at UNI-C can be obtained from Ole Frendved Hansen (ole.frendved.hansen@deic.dk).

5.2.2 Usage Study: GRNET Network

An ongoing study at GRNET considers the energy consumption of a number of devices in the GRNET core and access network, while it provides related information for the current and planned GRNET data centres and grid nodes [HELLASGRID]. The study is in the initial stages, and in the months to come will be extended in order to include further details, as well as information regarding the GHG emissions and removals in the GRNET network, nodes and premises. The results presented here primarily demonstrate the initial efforts made with respect to energy consumption and the first thoughts about how the most efficient cooling technology can be achieved.

GRNET owns two data centres where high-density computational and storage equipment is installed. The first data centre is hosted in the National Hellenic Research Foundation. This data centre hosts the GÉANT PoP in Athens, as well as a HellasGrid site (Grid node). For the GÉANT PoP, there are 4 racks with servers and 14 racks with telecoms equipment. These racks are loaded at a percentage of 60%. Furthermore, a grid node exists in this data centre with 6 racks hosting servers and storage equipment. Average energy consumption for the GÉANT PoP is 63kW and for the Grid node it is 67kW.

The second GRNET data centre is located within the premises of the Greek Ministry of National Education and Religious Affairs in Athens. The data centre is currently equipped with 28 racks for installing servers and storage equipment. The average energy consumption of the equipment hosted at this data centre is currently around 200kW, but it is estimated to increase considerably in the upcoming period, when the data centre will work under full load. This data centre has been designed and implemented following high standards regarding the cooling efficiency, taking into account the environmental conditions in Greece. The PUE in the data centre is monitored and is currently 1.82.

GRNET plans to install a green data centre in the northwest part of mainland Greece, close to a power production hydroelectric plant. The green data centre will host at least 14 racks of storage and computing equipment, while also serving as a disaster discovery site for the GRNET data centres in Athens, ensuring the business continuity of the cloud computing services in GRNET.

Water from the nearby river will be used to cool the equipment within the data centre, using water-cooled racks adapted for this purpose. The maximum energy consumption for the equipment hosted at this data centre is estimated to be around 400kW, and the achieved PUE is expected to be among the most competitive (GRNET's target is a PUE below 1.2). The reason for selecting water cooling is that it provides greater effects regarding power usage efficiency than the use of air cooling, which is the traditional data centre cooling and refrigeration technology. To this end, large-scale data centres have been starting to develop water-cooled refrigeration system since 2006 [ZHANG]. However, since water-cooled systems release heat in the water (in the case of air cooling the heat is released in the air), environmental concerns for water heat pollution have to be taken into account.

Furthermore, GRNET plans to expand the current data centre in Athens and to create separate zones for hosting cloud computing and high-performance computing equipment. The reason for creating separate zones is to increase energy efficiency in each zone by installing suitable cooling infrastructure based on the optimal environmental conditions for the operation of each type of equipment.

More information about the projects can be obtained from GRNET, Anastasios Zafeiropoulos (tzafeir@admin.grnet.gr) or Constantinos Vassilakis (cvassilakis@admin.grnet.gr).

5.2.3 Case Study: SURFnet HE Clients

SURFnet and the NL Agency conducted a survey to investigate reductions in power consumption in data centres at HE institutions. The study was done with the aid of the Open Data Centre Measure of Efficiency (DCME) model [OPENDCME]. Using 16 Key Performance Indicators (KPIs) helped to indicate the energy efficiency of a data centre. In 2010, the average electricity efficiency (the Data Centre infrastructure Efficiency or DCiE) was very low, at only 50% (PUE = 2). This is in stark contrast to the standard that environmental services impose for newly built data centres, namely 71%. The low electricity efficiency at the institutions was mainly due to the low temperature in the data centres: at an average of 20°C, this is cooler than necessary. Modern equipment can cope perfectly well with a temperature of 25°C.

5.3 Case Study: HEAnet Network TCD Client

As the NREN in Ireland, HEAnet has a number of heterogeneous clients in the educational sector, which illustrates different levels of sophistication in relation to focus and measurement of PUE. One example of such a client host who has established a new data centre is Trinity College Dublin (TCD). TCD selected an approach which focused on a range of factors, including the selection of a predefined PUE value, and then employing the newest technological design and equipment to support this strategy.

TCD relied heavily on the EU Code of Conduct [EUCODE] as a guideline for the proposed solutions for a new data centre. TCD used this document to formulate design requirements, as well as to establish tender evaluation criteria to compare deliverable-scored responses with PUE, across the envisaged load range. Vendors were requested to demonstrate EU Code of Conduct PUE compliance across the load range during commissioning.

The requirements to the vendors therefore specified a low PUE as an important parameter. The provided data centre solution had to demonstrate measurable deliverables in terms of energy efficiencies, reduction in carbon footprint, return on investment (ROI) and reduced year-on-year operational expense. It was explicitly stated that vendors had to demonstrate context adherence to the above-mentioned “EU Code of Conduct for Data Centres” as a minimum requirement. It was also stated that it was expected that the selected design-build contractor would have to implement working knowledge and best-practice skills, and should provide details of all standards to which their proposed data centre would be designed.

The major sub-systems or tasks envisaged in the project were: utility interface(s), power distribution, UPS, backup generator, computer racks, cooling systems, routes, ducts and containment, fire detection/suppression, ventilation and breathable air if required, access, physical security and alarm integration, CCTV, general room refurbishment, and improvement of the aesthetics of impacted areas. An important dimension of the requirement was management and monitoring of equipment, environment, and reporting of vital environmental statistics, including: granular energy utilisation, integration with existing Building Management System (BMS) and onsite energy monitoring.

TCD focused on reduced carbon footprint and lower operational and running costs, as stated in the TCD Strategic Plan [TCDPLAN]. Furthermore, the data centre power and cooling infrastructure had to be designed to be fully scalable, such that it can be deployed in multiple phases, delivering PUE efficiencies better than 1.5 across an IT equipment power dissipation range of 25KVA to 250KVA in 25KVA increments.

Tender response evaluation criteria were scored on design PUE across the above-referenced power points, and the winning bid included the design PUE figures shown in Table 5.3 below.

IT Load	25kW	50kW	75kW	100kW	125kW	150kW	175kW	200kW	225kW	250kW
PUE annualised	1.43	1.26	1.22	1.21	1.2	1.2	1.2	1.2	1.2	1.2
Estimated @ 13C Ambient	1.38	1.21	1.18	1.16	1.15	1.15				

Table 5.3: TCD power load versus PUE-value specification

TCD also required that the winning vendor produce evidence of PUE values in practice during the commissioning stage using dummy loads. It was only possible to do this at an ambient temperature; annualised PUE will be determined following one year of operation. The actual PUE figures observed during commissioning @ 1C are shown in Table 5.4 below.

IT Load	25kW	50kW	75kW	100kW	125kW	150kW	175kW	200kW	225kW	250kW
PUE annualised	1.43	1.26	1.22	1.21	1.2	1.2	1.2	1.2	1.2	1.2
Estimated @ 13C Ambient	1.38	1.21	1.18	1.16	1.15	1.15				
Actual @ 13C Ambient	1.36	1.17	1.15	1.16	1.13	1.13				

Table 5.4: TCD Power load versus measured PUE values

Thorough testing of the measured figures revealed the impact of the energy accounting in the data centre. The actual resource utilisation, however, has yet to prove consistent in the changing environment of the location (specifically, the outdoor climate, and probably a more heterogeneous, ”real-life” measurement of indoor equipment).

5.4 Recommendations

PUE is a simple way to measure the effectiveness of the consumption of energy to run a data centre. It also shows the relationship between the energy consumption of IT equipment and everything else related to the use and maintenance of this environment, making it necessary to focus on the entire context of the data centre. Although it does not indicate the total level of consumption of the IT equipment, but only shows the relational *proportion* between this and the HVAC and other equipment, once understood, the PUE serves as an important tool in the hands of host organisations to minimise the consumption of energy and consequently, the emission of CO_2.

In summary:

- NRENs should **ask data centre providers where they co-locate** equipment **to supply PUE figures** for these centres.
- **Reference and use the document** "2012 Best Practices for the EU Code of Conduct on Data Centres", version 3.0.8 Dec. 2011, published under the European Codes of Conduct for ICT [EUCODE] when considering data-centre selection, retrofit or making recommendations to any data centre being used whether for NREN or client usage.
- For data-centre selection or contract renewal NRENs should **consider the lifecycle cost benefit of using a data centre with lower values**.
- If at all possible, **choose data centres that use water cooling,** as this will considerably reduce PUE values for a data centre.
- Treat data centres that are powered or supplemented by **renewable energy supply** more favourably in any selection process.
- Locate data centres in areas **close to renewable energy-supply generation**.

If practical:

- NRENS should use a **"Hot-and-Cold" aisle approach** to racking their equipment.
- **Follow the good practice** of fully populating racks, and using filler panels and doors.

6 Virtualisation

Virtualisation is the technology that combines or divides resources to present one or many operating environments [VMWARE, VMWARE_2, DELL]. Examples of virtualisation include: the creation of virtual versions of operating systems, servers, storage devices or network resources. According to VMware, for every server virtualised, customers can save about 7,000 kWh for a PC with an 800W power supply, or 4 tons of CO_2 emissions, every year. (VMware said it calculated the figures by using the average electricity consumption of servers and multiplying it using industry standard metrics.)

To date, approximately six million desktop computers and servers have been virtualised using VMware software. VMware says this has saved approximately 36.9 billion kWh of electricity each year, which is more than the electricity used for heating and cooling the entire country of Denmark.

6.1 Server Virtualisation

Platform (or Server) virtualisation refers to the division of a hardware platform (host) into several isolated virtual environments (virtual machines, guests, instances) through the use of host software. The main benefits of utilising platform virtualisation for implementing a server consolidation strategy may be summarised as follows:

- Reduced hardware maintenance costs from retaining a lower number of physical servers.
- Efficient utilisation of hardware resources, reduced total cost of ownership (TCO) and faster return on investment (ROI).
- Reduced administrative costs when different applications/services are running isolated in their own virtual servers, by preventing one application from impacting another when upgrades or changes are made.
- High diversity of Operating Systems (OS) hosted on a single platform.
- Reduced server deployment by having a standard virtual server build that can be easily duplicated.
- Increased flexibility/agility exploiting the fact that virtual machines may easily migrate to another host server either to illustrate reliability, quality of service or other business strategies (such as strategies to reduce required operating energy cost e.g. powering down or making servers sleep).
- Increased space utilisation efficiency in the data centre.
- Highly reduced energy consumption as a result of operating fewer physical servers while requiring less energy for cooling at the data centre.

6.1.1 Reduced Energy Consumption

According to the SMART 2020 report [SMART2020], virtualisation in data centres is expected to lead to an emission reduction of 27%, compared to the business-as-usual scenario, corresponding to 111 MtCO2e on a global scale. The theoretical potential to save energy by virtualisation is much higher.

IBM has claimed companies can realise energy savings of 80% and space savings of 85% by moving to a virtualised infrastructure and taking advantage of emerging hybrid systems that use special-purpose processors to improve performance and reduce energy consumption [IBM]. The savings are achieved by consolidating workloads onto fewer physical processors.

One of virtualisation's main benefits is significantly increasing server utilisation. IBM presents a compelling comparison, stating that instead of the 5% to 12% of capacity typically used by systems, the IBM mainframe's use of virtualisation allows clients to reach maximum server utilisation.

Consulting Professor at Stanford University, Jonathan Koomey stated that the energy use of data centres is much lower than previously predicted on both a global scale and in the US [STANFORD]. According to Koomey, data centre energy doubled from 2000 to 2005, but in the next five years slowed down considerably to 56% worldwide and just 36% domestically. A number of reasons were cited that led to this situation, including the lowered demand for computing, the 2008 financial crisis, and the emergence of more efficient technologies, such as computer chips and computer server virtualisation.

Computer usage and power usage will unarguably keep increasing as more of the world becomes technology dependent in the business and enterprise sector. What allows us to keep up with this trend and slow the rate at which energy use is consumed on a large (data centre) scale is new technology, such as more localised cooling by higher efficiency air-handling units.

In the world of data centres, virtualisation is a key component in achieving this. Server and storage virtualisation provide vast amounts of savings in maintenance, power and cooling, not to mention providing environmental and "green" benefits as well.

6.1.2 Energy-Saving and Live-Migration Techniques

Virtualisation of servers allows more efficient use by introducing technologies such as live migration. Live migration makes it possible to move a running virtual machine or application between different physical machines, without disconnecting the client or application. This feature has facilitated a number of proposals targeted to improve energy efficiency when operating a series of servers illustrating a number of services.

Large enterprises, such as universities, can save a significant amount of energy and money by putting idle desktop machines to sleep. The special hardware, disruptive virtualisation technology or dedicated per-subnet proxies needed to facilitate this require investment, however, and may present an obstacle to IT departments' take-up of this technology. Researchers at Microsoft, Princeton University and in Brazil have proposed GreenUp, a minimal software-only system that allows any machine to act as a proxy for other sleeping machines in its subnet [GREENUP].

A somewhat different approach is taken by LiteGreen [DAS], which requires each user's desktop environment to be in a virtual machine (VM) implementation. This VM is live-migrated to a central server when the desktop is idle, and brought back to the user's desktop when the user returns. The main drawback of this system is the need to deploy VM technology on all desktops, which can be quite disruptive. The user's desktop environment is "always on", fully maintaining its network presence, even when the user's physical desktop machine is switched off and thereby saving energy (see Figure 6.1). The research group's experience shows energy savings of up to 74% with LiteGreen, compared to the 32% that can be saved through traditional manual power management in a Windows environment.

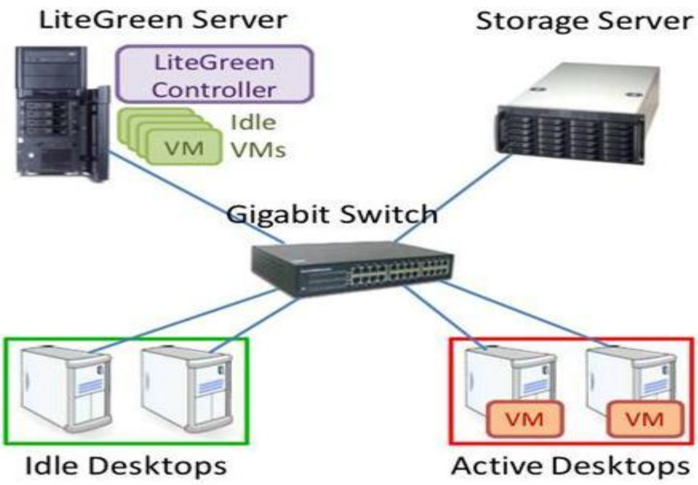


Figure 6.1: LiteGreen architecture [DAS]

Another example is SleepServer technology, in which lightweight virtual images of sleeping PCs are created, and these paired-down images maintain connectivity and respond to applications, such as VoIP services, on behalf of the sleeping PCs [AGARWAL]. According to the measurements presented (derived from a SleepServer deployment in a medium-scale enterprise with a sample set of 30 machines), significant energy savings (ranging from 60% to 80%) may be achieved for PCs, depending on their use patterns. The SleepServer system uses application stubs to run specially modified applications on a sleep server, while the host machine sleeps. While this allows applications, such as BitTorrent, to keep sessions alive, it requires modifying code and developing stubs for each application, which is a significant barrier to deployment.

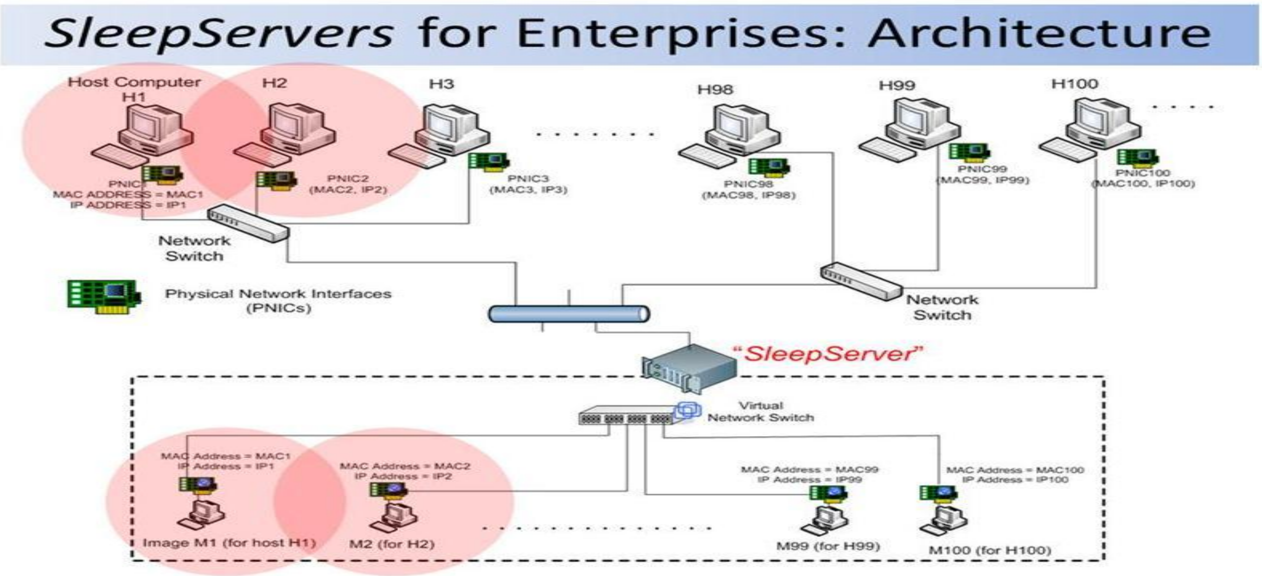


Figure 6.2: SleepServer architecture [AGARWAL]

A critical factor for both LiteGreen and SleepServer and similar approaches is the time required to wake up and make the original working PC functional (time to resume). On average, both approaches require about 20 seconds to resume the original working environment, leaving room for optimisation. The rapidly expanding cloud computing technology is also based on virtualisation, and makes it possible to run applications on unknown servers "in the cloud". A recent proposal considering energy efficiency in virtualised cloud data centres takes advantage of the live migration technology to induce energy savings by continuous consolidation of VMs according to current utilisation of resources, virtual network topologies established between VMs, and the thermal state of computing nodes [BELOGLAZOV].

Any such workflow scheduling in private clouds should have the following features to gain maximum efficiency and not disturb regular work practices:

- Intrusion is not accepted.
- Workflow attributes (e.g. scale, sparseness) regularly change.
- Conserving energy while keeping response time too long should not be considered.
- Any scheduling algorithm must be lightweight in resource utilisation.
- Any further optimisation or consolidation during a migration phase should be applied very cautiously.

6.2 Network Virtualisation

Network virtualisation refers to the virtualisation of network elements building a network. Network consolidation strategies have proved to provide significant benefits. The core building block of network consolidation is the virtual router. A virtual router is defined to be an isolated logical router process that acts just like a physical router. There are two main techniques for creating virtualised router entities as defined by their physical and operational characteristics: a Hardware-Isolated Virtual Router (HVR) has hardware-based resource isolation between routing entities, whereas a Software-Isolated Virtual Router (SVR) comprises software-based resource isolation between routing entities [CISCO_2]. Table 6.1 presents a comparison of the characteristics of the two architectures.

Category	Hardware-Isolated Virtual Router	Software-Isolated Virtual Router
Control plane resources (CPU, memory)	Dedicated	Shared
Data plane resources (forwarding engine, queues)	Dedicated	Shared
Chassis resources (forwarding engine, queues)	Shared	Shared
Management, configuration	Dedicated	Typically shared, but varies, depending on the degree of virtualisation
Connections between virtualized routing entities	Typically external	Typically internal, but possibly external
Per-chassis scalability (routing adjacencies, prefixes)	Increased with additional logical routers	Unaffected by additional virtual routers

Table 6.1: Comparison of virtualised routing architectures [CISCO_2]

The concept of logical systems offers the possibility to partition a single router into multiple logical devices that perform independent routing tasks with the JUNOS software from Juniper Networks. Because logical systems perform a subset of the tasks once handled by the main router, logical systems offer an effective way to maximise the use of a single routing or switching platform. Service provider network design traditionally requires multiple layers of switches and routers. These devices transport packet traffic between customers.

Logical systems perform a subset of the actions of the main router and have their own unique routing tables, interfaces, policies, and routing instances. The most popular routing protocols, Layer 2 Multi-Protocol Label Switching (MPLS) architectures, cross-connect switching and Layer 2 circuits and LAN services can all now be assigned to different logical routers and Graceful failover can also be asserted within these router or switch instances. Tools such as Mantychore and OpenNaaS (discussed later in Section 6.4) also enhance an equipment provider's resources.

Figure 6.3 presents an example of vertical and horizontal consolidation at a PoP. Horizontal consolidation is the combination of multiple platform functions such as provider (P) and provider edge (PE), or core and edge, into a single platform. Vertical consolidation is the combination of multiple single-purpose devices, such as multiple PE routers, into a single platform. Together, horizontal and vertical consolidation of network elements can reduce the complexity and cost of PoP architectures [JUNIPER]. The benefits, with respect to energy consumption, are similar to those of platform virtualisation, irrespective of consolidation of network elements at the PoP or at the data centre being considered. See [QURESHI] and [JUNIPER_2].

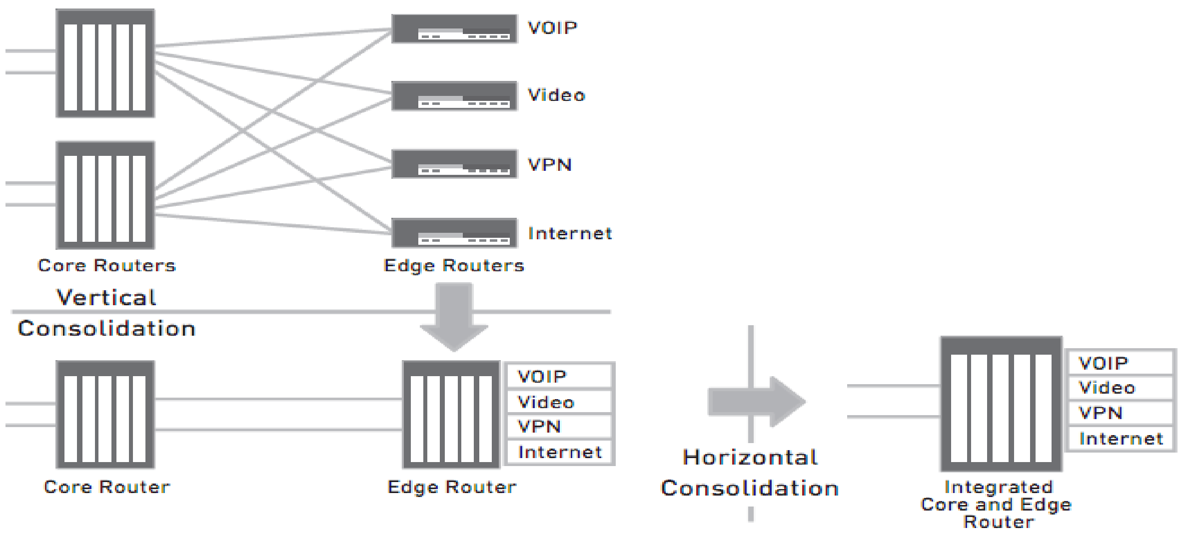


Figure 6.3: Horizontal and vertical consolidation [JUNIPER_3]

Quantifying energy savings from virtualisation is often difficult, because virtualisation is often introduced together with other IT initiatives. Members of the GÉANT network have already gained some experience with virtualisation and are working on providing virtualisation-based solutions to their customers. Selected examples are described in the following paragraphs.

6.3 Server Virtualisation at UNI-C

UNI-C[1] started introducing virtualisation in 2008–09. In spite of a continuous rise in demand for server capacity, UNI-C successfully broke the corresponding yearly increase in power consumption in 2010. Without virtualisation, a projection of the consumption rise from the previous years would have reached 3000 MWh/year, which is very close to the physical limit of UNI-C's power supply when adding the cooling consumption. Instead, by introducing virtualisation, the energy consumption of the equipment actually dropped from 2500 MWh in 2009 to 2400 MWh in 2010. In 2011, a considerable number of new host servers were added as virtual machines. Because of the virtualisation program, however, the power consumption only rose to 2500 MWh.

6.4 Network Virtualisation – Network as a Service

In order for NRENs and operators to be able to deploy and operate innovative Network as a Service (NaaS) offerings, an appropriate tool set needs to be created. With such a goal in mind, Mantychore FP7 [MANTYCHORE] has created the OpenNaaS framework [OPENNAAS].

[1] UNI-C is the Danish Agency for IT and Learning under the Danish Ministry of Children and Education. It promotes digital development within the area of children and education, and its primary focus is to increase the use of IT for education and to support effective management of institutions by using IT.

OpenNaaS was developed with the aim to create an open source software project community that allows several stakeholders to contribute to and benefit from a common NaaS software stack. OpenNaaS offers a versatile tool set for the deployment of NaaS-oriented services. The software is released with a dual L-GPL/ASF licensing schema that ensures the platform will remain open and consistent, while commercial derivatives can be built on top. This open schema allows trust to be built on the platform, as NRENs and commercial network operators can rely on the continuity, transparency and adaptability of the platform.

In that sense, each network domain would be able to use its own OpenNaaS instance to:

- Get resources from the network infrastructure: routers, switches, links or provisioning systems.
- Abstract them to service resources, independently of vendor and model details.
- Embed instantiation of virtualised resources in the regular Business Support System (BSS) workflows.
- Delegate management permissions over the infrastructure resources they own so that “Infrastructure integrators” can control them when required.

OpenNaaS offers a powerful remote command line, as well as web-service interfaces, which offers the possibility both to build a Graphical User Interface (GUI) and to integrate with existing middleware applications already deployed in the virtual research organisations.

Networks can now be dynamically built, acquiring resources as needed, and setups could be more short term in nature, saving the energy that would be required for periods of long deployment.

6.5 OpenNaaS Extensions

Several extensions for OpenNaaS are being developed inside the Mantychore FP7 project. Beyond that, other extensions are being created in parallel projects, leveraging the same core components and bringing reusability across distinct research efforts. As of version 0.9, OpenNaaS supports the following abstracted resources:

- Routers.
- Reconfigurable Optical Add-Drop Multiplexers (ROADMs).
- Bandwidth on Demand (BoD) domain services.
- IP networks.

For the router resource, a driver for JUNOS has been implemented, which supports virtualisation (interfaces and routing instances), IP, routing (static and Open Shortest Path First (OSPF)) and Generic Routing Encapsulation (GRE) tunnels. More capabilities will be added in the near future, such as IPv6 and firewalling. The ROADM extension allows dynamic modification of the ROADM switching table between optical channels.

On the other hand, the BoD domain represents an opaque domain, controlled by a provisioning system that the user can call to obtain L2 links. The current implementation supports GÉANT BoD [BoD] (AutoBAHN).

The IP network resource groups together routers and BoD domain resources into a logical unit, while adding a topology. This allows users to manage all the resources in an organised way (currently, network-wide OSPF configurations can be deployed). Furthermore, it allows configuration rights to be delegated to users in an aggregated mode, instead of dealing with individual infrastructure resources.

6.6 OpenNaaS User Community

The OpenNaaS user community can be split into three different roles:

- **Infrastructure Providers**: Those who own a network infrastructure (NRENs or telecoms operators) and need enhanced flexibility in order to lease virtualised slices.
- **Service Providers**: While traditionally overlapping with the infrastructure provider, this emerging role is composed of those who aggregate third-party virtual infrastructure resources, in order to add value for concrete customers or vertical markets. A service provider needs to maintain tight control of what resources are being consumed and the management rights delegated to end users.
- **End User**: The NaaS end user may have sophisticated needs that go beyond the pure consumption of the networking infrastructure. Complex and demanding applications not only need a certain degree of management control over the resources, but also quick, on-demand provisioning.

With this in mind, the following user groups can benefit from OpenNaaS:

- Network and data centre operators who seek to provide richer virtualisation services to their customers.
- Infrastructure management software, i.e. cloud managers, provisioning systems or simple software projects, which can benefit from extended infrastructure management and awareness.
- Research groups or individuals who would like to use a virtual infrastructure and reuse the framework in order to focus use of resources applicable to their own business needs.
- Equipment manufacturers and solution providers who seek added value through integration and interoperability.

The European project FEDERICA [FEDERICA] exploits virtualisation technology to offer virtualised infrastructures to researchers investigating future Internet technologies. FEDERICA uses virtualisation in computing and network systems to create a technology-agnostic and neutral infrastructure which allows researchers to test Internet technologies in a network separated virtually from other networks. Thus, the researchers have full control of the allocated virtual nodes and network and can access specific network-monitoring information. Disruptive experiments are also possible, since no other users will be affected. Although such an approach was not initially targeted to energy efficiency when implementing network infrastructures, the energy savings are obvious, since providing an Infrastructure as a Service (IaaS) provides aggregated energy savings from both network and platform consolidation compared to physically implementing each distinct hosted infrastructure.

6.7 GreenStar Network and Mantychore FP7 Project

The Mantychore and GreenStar Network (GSN) projects [MANTYCHORE, GREENSTAR] collaborated to create an experimental network environment, from which to derive best practices and guidelines when building green data networks. The network design follows the Infrastructure as a Service paradigm, with the objective of minimising the networks' carbon footprint. Mantychore and GSN have interconnected hubs in Europe and Canada, which are connected to nodes leveraging virtualisation techniques in each region powered by renewable energy sources. This allows users to manage the migration of VMs contained in the data centres following green energy source availability, such as solar and wind power.

Using NaaS as a network management framework facilitates the selection of a location, where renewable energy is being used within GSN. Integrating this with Mantychore allows NRENs to provide a complete, flexible network service that offers research communities the ability to create an IP network under their control, where they can configure the infrastructure at multiple network layers.

Converging server and network virtualisation allows the migration of virtual data centres over network nodes to happen as part of virtual infrastructure management. Mantychore can dynamically set up the infrastructure to maximise the use of renewable energy sources, while GSN provides network architecture built with multiple layers to control and monitor a large number of such resources. No operator intervention is required to restart applications or switch data-centre locations in moving virtual infrastructures to more carbon-friendly energy power sources. Virtualised management has been proposed for service delivery regardless of the physical location of the infrastructure, which is determined by resource providers. Resources are only allocated according to user requirements, which allows high utilisation and optimisation levels to be achieved.

The Mantychore–GSN collaboration bridges the abstract concepts of network virtualisation and green computing. It delivers an experimental proof of concept for use in and beyond the academic and research environment, to the commercial world.

6.8 Recommendations

There are a number of recommended actions:

- **Virtualise as many servers as possible** to reduce the number of machines in use.
- **Apply a maximum rule of numbers of virtual servers** per every new service instance, and review this rule on an annual basis.
- **Maximise server utilisation** in order to facilitate the above.
- **Evaluate the lifecycle costs** of virtualised servers as part of the total cost of ownership, especially those where it was decided to virtualise to reduce server numbers and save power.
- Have a regular scheduled **replacement program for servers**, every three years.
- **Optimise the numbers of servers** per rack.
- **Use filler panels** in racks that are not full.
- **Segregate client-hosted virtual servers** from network operational and maintenance server equipment and use PDUs with power-monitoring facilities to determine energy usage.
- Consider implementation of **Network as a Service functionality**.
- Allow tools such as OpenNaaS to have server access to build logical virtual networks.

- New virtualisation requirements, such as cloud storage services, are emerging as services needs for NREN clients, so groups with this experience should **promote the activity and share best practices** experiences with other NRENs.

7 Energy-Aware Traffic Engineering

Network traffic engineering is a method of optimising the performance of a network. Until now, its main consideration has been performance and the use of network resources, while following a procedure that involves dynamically analysing, predicting and regulating the behaviour of data transmitted over the network. Energy-aware traffic engineering takes traditional network traffic engineering one step further by considering and embedding into its objectives the energy consumption of a network in order to achieve the same performance as the energy-oblivious approaches, but at a lower overall energy cost (see [VASIC]).

There are three areas of design that may be recognised as affecting the overall energy consumption in a network (see [CHABAREK]):

1. Power-aware **system design** refers to energy-related improvements in network equipment design. According to Juniper [JUNIPER_2], at the highest level, they can be classified as organic and engineered. Organic efficiency improvements are commensurate with Dennard's scaling theory: every new generation of network silicon packs more performance within a smaller energy budget. Engineered improvements refer to active energy management including, but not limited to: idle state logic, gate count optimisation, memory access algorithms, I/O buffer reduction, and so forth.
2. Power-aware **network design** refers to the design of a network in terms of topology, equipment selection, placement and configuration so as to minimise the network's overall energy footprint. This area of design clearly includes also network consolidation strategies exploiting virtualisation capabilities of network equipment as previously documented in Section 6.
3. Power-aware **protocol design** basically refers to mechanisms for reducing the energy consumption of network components by changing their operation state (possibly at the expense of performance) or even putting them (in whole or partially) to sleep, according to their usage.

All three design areas are considered equally crucial to achieving considerable energy savings. Furthermore, the energy cost for the associated heat dissipation solutions should be taken into account. Clearly, energy-aware traffic-engineering approaches fall into the third category of power-aware protocol design, considering the implemented network while exploiting the power-aware capabilities of the network components to build mechanisms to effectively serve traffic while reducing the network's overall energy footprint.

Energy-aware traffic engineering is targeted to allow networks to become energy-proportional to the traffic served. Networks are designed with two basic principles in mind: redundancy and bandwidth over-provisioning, which enable them to tolerate traffic variations and faults and work around the Internet's lack of Quality of Service (QoS). While these design features allow network operators to achieve the service level objectives, networks end up being underutilised most of the time, with network equipment typically running at its least energy-efficient operating point [VASIC_2]. The idea is to dynamically adapt the power consumption of a network by carefully selecting the minimal subset of network elements that satisfies the current traffic demand. In this approach, one would need to collect information about the current traffic conditions and compute the minimal set of network elements that can accommodate the current traffic, while letting the remaining equipment enter power-saving mode. However, putting interfaces on switches or routers to sleep requires additional considerations since it can have serious side-effects because of the manner in which various protocols work [GUPTA].

In [VASIC_2], Energy Proportional Networking (EPN) is targeted to achieve both optimisation and responsiveness by taking a hybrid approach in which: a) as much routing information as possible is pre-computed offline and installed in a small number of routing tables, and b) a simple, scalable online traffic-engineering (TE) mechanism is used to deactivate and activate network elements on demand. The high-level overview of this approach to achieving energy-proportionality in networks is shown in Figure 7.1. Evaluation of ISP and data-centre topologies shows that EPN achieves energy proportionality, while producing substantial savings (up to 42%).

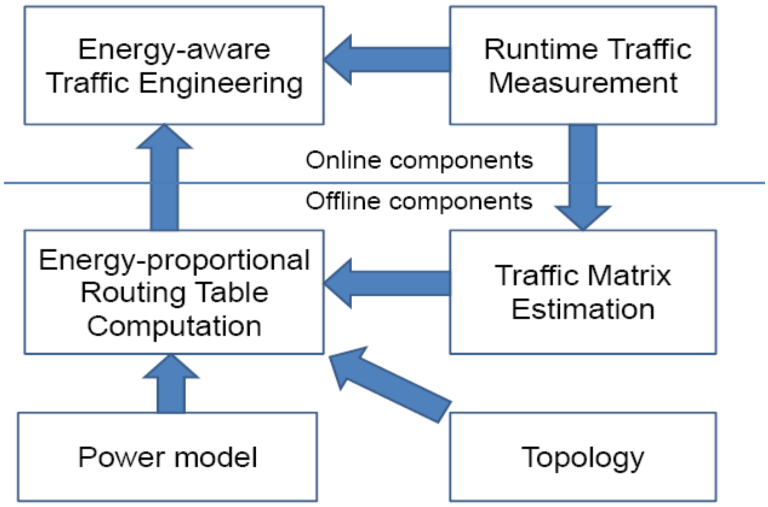


Figure 7.1: An energy-aware traffic-engineering approach (from [VASIC_2])

Maruti Gupta and Suresh Singh quantify some of the savings that are possible due to inter-packet gaps (i.e., packets not continuously arriving at full speed) [GUPTA]. Interfaces are put to sleep based on an estimate of the expected inter-arrival time. Savings are highly dependent on the traffic pattern, and such opportunistic sleeping intervals might be too short in many cases. In Nedevschi *et al.*, the authors quantify the energy savings when the packets are briefly queued in “upstream” routers, to give “downstream” network elements a chance to sleep longer [NEDEVSCHI]. According to the presented results, proposed algorithms may even halve energy consumption for lightly utilised networks (10% to 20%).

7.1 GreenTouch Consortium

In response to the dramatic increase in consumption, GreenTouch was set up, a consortium spanning the ICT industry, academia and other research groups that is dedicated to fundamentally transforming communications and data networks, including the Internet, and to significantly reducing the carbon footprint of ICT devices, platforms and networks. GreenTouch's goal is to deliver architecture, specifications and roadmaps for technologies needed to increase network energy efficiency by a factor of 1000 from 2009 levels (see [GREENTOUCH]).

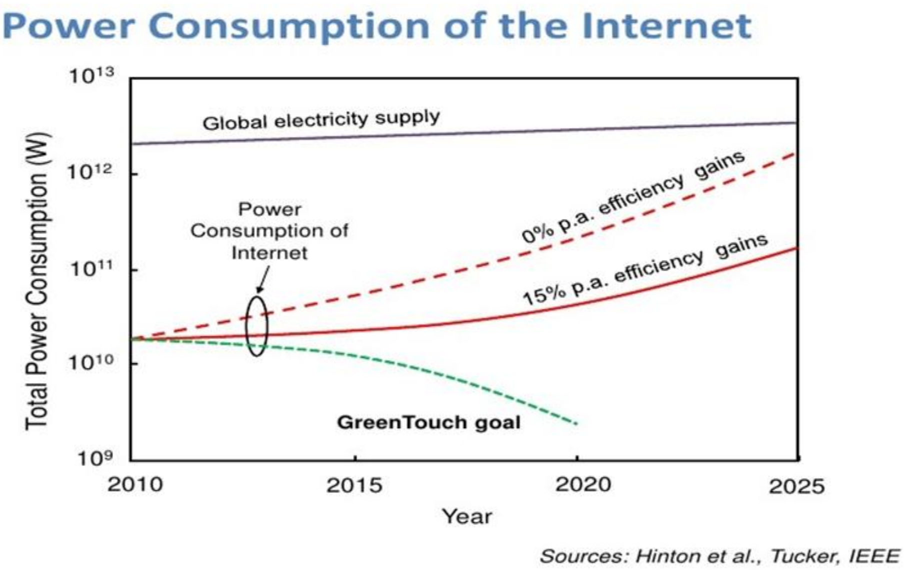


Figure 7.2: GreenTouch's prediction on the power-consumption needs of the Internet [KLEIN]

Using GreenTouch's technology implementation of networking equipment such as routers and switches, power consumption is predicted to drop by a factor of ten rather than increasing at roughly the same rate.

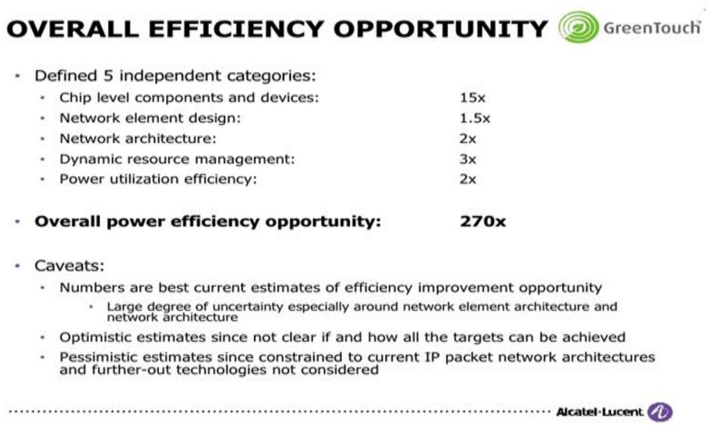


Figure 7.3: GreenTouch's latest progress on router power design efficiencies in 2012 [KLEIN]

One example of how GreenTouch is progressing towards its goal of reducing power consumption by a factor of 1000 is new router design (shown in Figure 7.3 above), which has currently been shown to reduce power consumption by a factor of 270 over a two-year period. Other technology areas are demonstrating the same sort of design-efficiency improvements, including mobile networking. Activities also include designing new network architectures at the IP and lower optical layers, such as Wavelength Division Multiplexing (WDM), and designing protocols to maximise energy efficiencies.

7.2 GRNET and the ECONET Project

In the framework of the FP7 low Energy COnsumption NETworks (ECONET) project [ECONET], GRNET is working on the design of novel, energy-aware traffic-engineering mechanisms. These mechanisms will deploy network-wide, existing and newly developed dynamic adaptive technologies for network devices capable of reducing their power consumption either by scaling down performance or by going on standby when underutilised or not used at all. In their current work, GRNET have examined empirically the energy-saving margins of such mechanisms using extensive data from the GRNET and GÉANT networks. They have analysed the dependence of such margins on several parameters, including the level of energy proportionality, QoS constraints and the geographic span of a network. The findings reveal that with existing devices, smart powering-off can save more than 50% of currently consumed energy, and that energy-aware traffic engineering has still quite a way to go before it can be made redundant by improvements in the energy proportionality of devices.

Although it may seem tangential, the semiconductor industry is also playing its part, which has an impact on networking equipment made from its components. One example is from Samsung, which has published details of the Eco-Design Management Process and Eco-rating system (see [SAMSUNG]). Each newly developed product receives an eco-rating (Eco-Product, Good Eco-Product, or Premium Eco-Product) based on strict evaluation criteria. Samsung has set a goal to ensure 100% of products exceed Good Eco-Product criteria by 2013. This will include introducing eco-friendly evaluation for products in the R&D stage, enhancing energy efficiency, and increasing the use of recyclable and eco-friendly materials.

7.3 Recommendations

While traffic engineering can be shown to offer potential network efficiencies, it is difficult for NRENs to employ advanced techniques to achieve increased efficiency if the hardware being manipulated has limited features. Designing a new **traffic-profiling and capacity-management tool is essential** for all NRENs to optimise the use of their networks, and these networks, traffic profiling and capacity management should be maintained at as low a level as possible within the network. **Regular monitoring tools** such as Cacti, Multi Router Traffic Grapher (MRTG) and other equivalents provide the background data to consider, where optimisation is possible.

These tools offer **facilities to monitor the internal sensors and registers in the hardware for temperature and resource utilisation**. Some basic energy-usage parameters are available at present, but these usually only show basic power consumption on modules with little resolution or historical recording. Future networking products will incorporate more feature sets to allow more in-depth monitoring of power usage, so having a **consistent approach to enable monitoring and deployment** is a good start, supplemented by other solutions that are more integrated into Network Management Systems.

perfSONAR [PERFSONAR] may also be used for **performance monitoring of international links**, and offers the potential to look at service type applications, such as cloud and virtualisation.

Power distribution units can be monitored regularly for power using tools that are provided by the suppliers of these products, such as APC's StructureWare [STRUCTUREWARE], Avocent Rack Power Manager [AVOCENT] and there are many other equivalent manufacturer solutions. Such solutions have the disadvantage that they mainly work with vendor-specific hardware, but compatibility with other manufacturers is being introduced. A further difficulty arises with equipment deployed in a data centre.

The providers or operators of these centres may wish to use their own **solution for monitoring and controlling the data centre** and all resources deployed there to maximise its efficiency and attempt to reduce its PUE value. NRENs should then **ask to be supplied with all monitored results** and try to obtain as rich a dataset as possible to help them formulate energy-management strategies for the future.

NRENs who are gaining experience testing and deploying energy-efficient strategies, such as rerouting traffic over energy-efficient paths, while shutting down others (resulting in energy savings) need to continually **highlight their progress to other peer organisations**. The Environmental team recommend that a process is set up to compile a set of case studies that can be frequently updated without an exhaustive review process. These should be presented to a large audience as part of ongoing work reviews.

Major design enhancements to components should be frequently monitored, and NRENs should have the opportunity to **speak to equipment manufacturers** and enquire about the range of advanced, eco-friendly technologies integrated into network solutions (including asking for a breakdown of the benefits of deploying such technologies).

Challenging equipment suppliers to use the more eco-friendly technologies in their products should also be a part of any equipment procurement process.

8 Videoconferencing

Today's work environment is comprised of partners, peers and clients around the world. Videoconferencing allows these people from different locations to meet without the need to travel. In these green-conscious times, this is a vital, environmentally responsible use of technology, helping to lower the organisation's carbon emissions, as well as drastically reducing the cost of travel (airline or rail tickets, vehicle rentals, hotel stays and meals) and time spent travelling. With the development of efficient video technologies and high-speed networks, desktop and laptop videoconferencing enable face-to-face sessions for teleworkers and non-campus-based students.

The benefits of videoconferencing include:

- Reduced environmental impact through less travel.
- More productive use of time (eliminating wasted travel time).
- Reduced pressure, stress and fatigue from travel.
- Better support for teleworking.

NRENs have, for many years, featured videoconferencing as a service based on their network infrastructure. Videoconferences can have very different formats, from a one-to-one conference to the advanced transmission of speeches and debate, to a broad audience located all over the world. However, end-user devices have become more powerful and have integrated cameras and audio solutions offering a quality of experience to end users. Now one-to-one videoconferences are commonly handled by using personal computers and a program such as Skype.

Videoconferencing solutions comprise:

- Group video systems installed in dedicated video meeting rooms.
- Dedicated videoconferencing equipment using custom-built hardware.
- Using IP networks or dedicated ISDN circuits to host video calls.
- Conducting formal scheduled video meetings.
- Mostly communications with peers internal to organisations or projects.

In December 2011 Wainhouse Research [WAINHOUSE] surveyed approximately 300 videoconferencing users and found that:

- 35% of video meetings include only one external site.

- Only about 16% have deployed mobile VC capabilities.
- Education end users are the largest group of users with about 60% of users having participated in VCs.

This latter figure is indicative of the capability of education facilities to interconnect to other similar facilities. Clients of the European NRENs connect through the GÉANT network, with the dedicated onward connections to NRENs in North and South America, Africa, and the Asia-Pacific region, making high-quality connectivity available to researchers around the world. The map in Figure 8.1 shows the scale of the global research Internet, with dedicated, high-speed links to various regions in the world.

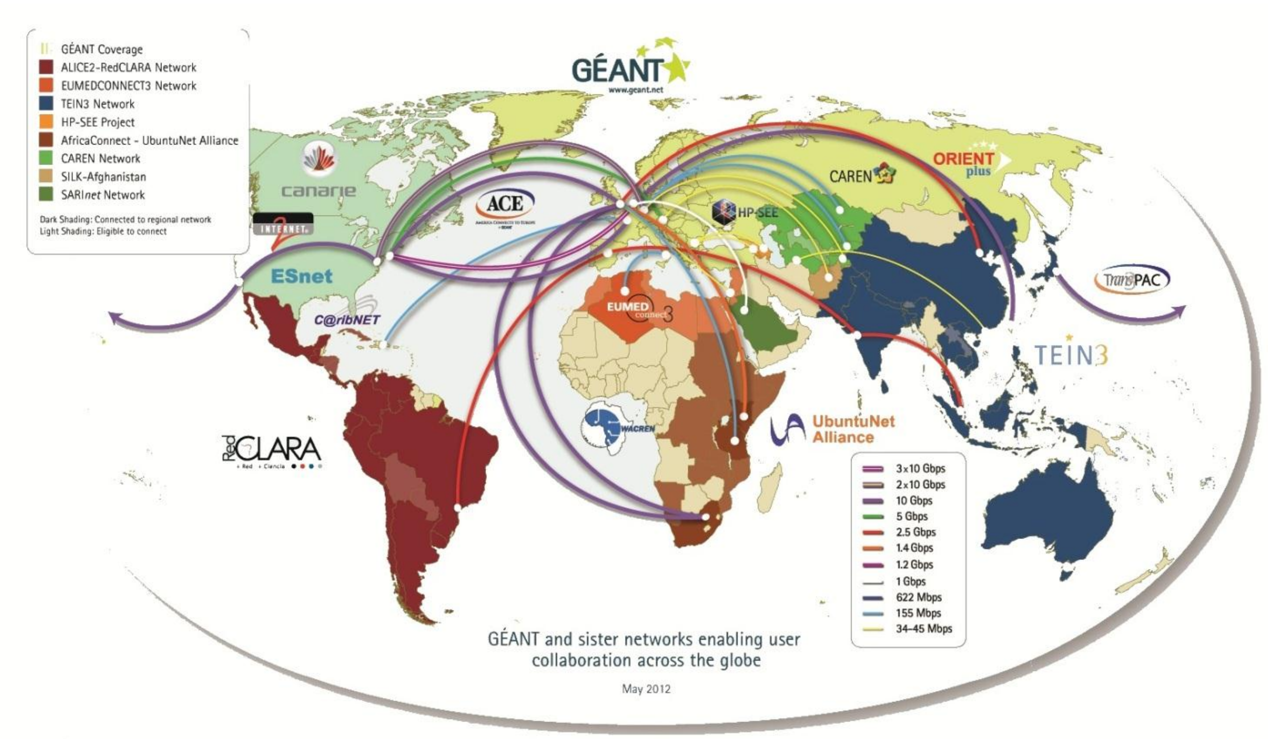


Figure 8.1: Map of interconnected global research networks [NETWORKS]

Having such a globally interconnected network promoting videoconferencing offers great opportunities for reducing travel which in turn bring environmental benefits. Several studies were referenced in the earlier reports [DN3.5.2, DN3.5.3] showing the beneficial impact of videoconferencing on carbon emissions, including the UK Works and Pension Study as well as the Smarter2020 study [SMARTer2020]. The latter describes how BT used a Life Cycle Assessment approach to guide the estimation of changes to a business-as-usual system resulting from the adoption of videoconferencing. The final result of the study showed a total of 9850 tons of CO_2e of GHG abatement, which was equivalent to an 83% reduction of the business-as-usual scenario (i.e. flying to meetings). The evaluation was carried out for 36 systems across 17 countries.

The following paragraphs describe two selected case studies from Green GÉANT, with very different scopes. The first example quantifies, in detail, the beneficial effect of videoconferencing caused by a small group of people (10 persons) dispersed in Ireland, using equipment provided by HEAnet to manage the pre-defined tasks of board meetings. The second example illustrates how a larger, international scientific community can use videoconferencing for dissemination of knowledge to colleagues all over the world. The scientific benefits are large, and so are the benefits for the environment. It makes no sense to quantify either because of the complexity of each particular case.

8.1 Case Study: HEAnet – Videoconferencing by a Closed, Dispersed Group

8.1.1 Scope

The study is based on the use, by a closed but geographically dispersed group, of videoconferencing for a specific activity. The group comprises the board members of the National Digital Learning Repository (NDLR) [NDLR], and the activity is the set of board meetings scheduled during a defined time period of one year, October 2008 to September 2009. In the past year, NIIF have produced a calculator which analyses the benefits of using VC rather than travelling to meetings [NIIFVC_CALC]. The location data supplied below has been entered into the program and the resultant benefits have been calculated as shown in Table 8.4.

8.1.2 Logistics

The main benefit of videoconferencing for the purpose of meetings is to reduce the amount of travel and its concomitant effects: cost, time and greenhouse gas (GHG) emission, with the latter being the main focus of this study. To calculate the savings in GHG emission, information about the distance travelled by each board member is needed, as well as on the mode of transport.

The home institutions of the board members are shown in Table 8.1.

Name of Institution	Location	Location Code
Dublin City University	Dublin	D
Dublin Institute of Technology	Dublin	D
HEAnet	Dublin	D
Institute of Art, Design and Technology, Dun Laoghaire	Dublin	D
Institute of Technology, Tallaght	Dublin	D
National University of Ireland, Galway	Galway	G
National University of Ireland, Maynooth	Maynooth	M
Trinity College Dublin	Dublin	D
University College, Cork	Cork	C
University College, Dublin	Dublin	D

Name of Institution	Location	Location Code
University of Limerick	Limerick	L

Table 8.1: Home institutions of NDLR board members

8.1.3 Data from Board Meetings

There were six board meetings from October 2008 to September 2009. The venues are shown in Table 8.2, together with the distances travelled by members physically present and not travelled by members attending by videoconferencing equipment.

Date	Venue	Members present	Members via VC	Distance travelled (km)	Distance not travelled (km)
7 Nov 2008	NUIG (G)	4xD, 2xG	4xD, 2xL, 1xC	1504	2120
9 Jan 2009	TCD (D)	6xD, 1xM	1xD, 1xC, 1xG, 1xL	48	1156
5 Feb 2009	UL (L)	4xD, 2xL, 1xC	2xD, 1xG, 1xM	1586	1158
2 Apr 2009	TCD (D)	7xD, 1xC, 1xL, 1xM	1xD, 1xG, 1xL	828	726
18 Jun 2009	UCC (C)	1xC, 1xL	5xD, 1xG, 1xL, 1xM	186	3080
18 Sep 2009	NUIM (M)	3xD, 1xL, 1xM	1xD, 1xG, 1xC	460	788
Total distance (km)				**4612**	**9028**

Table 8.2: Attendance at board meetings with induced and avoided travel distances

8.1.4 Results

While the initial study showed results for both car and train for inter-city journeys, the NIIF calculator only calculates for road and air travel and is being re-evaluated to see if there is a methodology to include a calculator for rail. The conversion factor for transport by train is 44 g/km. In the case of a private car with a 1.6 litre engine the factor is 170 g/km. These values have been used to calculate the GHG emissions, actual and potential, for the NDLR board meetings in the original study (Table 8.3).

Transportation mode	GHG emissions (kg CO_2 equiv.) induced by travelling to board meetings	GHG emissions (kg CO_2 equiv.) avoided by using videoconferencing equipment
Train	203	397
Car	784	1535

Table 8.3: GHG emissions induced by travelling to board meetings, and GHG emissions avoided by using videoconference facilities

In each case, the amount of GHG emissions saved by the use of videoconferencing is about twice the level of emissions due to actual transport to meetings. There is a saving of 66% of the total GHG emissions due to transport as a result of the use of videoconferencing for NDLR board meetings in the period studied. The absolute value of the saving is at least 397 kg of GHG emission, assuming substitution of the form of public transport with the lowest GHG emission levels (train). Using private cars, the saving was originally estimated at 1,535 kg of GHG emission. Using the NIIF calculator, the savings may now be as much as 1896 kg of GHG emission, just calculating how much saving was made by using VC; had all attendees used VC rather than travelling, a further 1918 kg of GHG could have been saved.

Date	VC savings kg/Co2	Non VC Cost kg/Co2
07-Nov-08	444.31	301.65
09-Jan-09	235.65	404.47
05-Feb-09	243.07	317.44
02-Apr-09	143.39	756.21
18-Jun-09	666.79	38.13
18-Sep-09	163.71	100.33
Totals	**1896.92**	**1918.23**

Table 8.4: NIIF VC GHG emissions calculator results

In reality the actual savings lie somewhere between these values, but the NIIF tool is useful to quickly assess the impact on GHG emissions savings by hosting meetings using VC technology.

8.1.5 Other Observations

The study has not taken into account the amount of time or money saved by the use of videoconferencing. However, the NIIF tool can also calculate time savings based on route-planning tools. The time saving is significant to members. Time spent on trains can, to an extent, be used to read reports, and perhaps even to work online using 3G access. However, time spent travelling by car is considered as lost time.

8.1.6 Limitations of the Study

The initial study results did not take account of the operational impact of videoconferencing on the environment. However, the NIIF tool does factor in the operational impact of using such tools. An MCU, VC equipment at each end point, and network infrastructure to interconnect all the elements are all needed to run a videoconference. All of these items consume electrical power, and also require cooling, which entails an additional level of power consumption.

Production, transportation and disposal of the equipment are not accounted for, e.g. considering how much GHG emission is involved in the life cycle of the products required for a videoconference. According to Apple, production of an iPad causes emission of 75 kg CO_2, and if a direct relationship between area and emissions is assumed, then production of a 46" monitor will cause emissions of about 1200 kg CO_2 equivalents.

This is a large figure, which has not been considered in the SMART2020 report. It indicates that there should be a real need for videoconferencing before investments are made, otherwise the good concept may not prove beneficial to the environment. This need for adequate videoconferencing facilities is obvious in data centres and NRENs, but many research and educational institutions can probably improve their current pattern, e.g. by using environmental arguments when motivating researchers and other users.

The large figure for equipment-related environmental impacts also indicates that investments should preferably be made in high-end technology with an assumed long lifetime. If the purchased equipment is of relatively low quality, its users will soon require that new equipment is installed, and this is of course an additional burden for the environment.

8.2 Case Study from Poznan Supercomputing and Networking Centre

The PLATON Service Platform for e-Science project is funded by EU and Polish Ministry of Science funds under the Operational Programme Innovative Economy 2007–2013. The objective of this project is the development of the national ICT infrastructure for science (PIONIER network) to provide applications and services to support research and development by Polish research teams for the innovative economy. Two of these services are:

1. **Videoconference Services**: realised by building a high-quality, secure videoconference system in the PIONIER network, which will enable point-to-point connections as well as connections between multiple locations simultaneously, but also give the possibility of recording and replaying particular videoconferences.

2. **Science HD TV Services**: the national platform offering interactive science high-definition (HD) television, which delivers services in the PIONIER network, and is based on high-definition digital content for both education and the popularisation of science and telemedicine.

8.2.1 Technological Solution

The **videoconference services** aim to establish audio-visual communication between the Metropolitan Area Networks (MANs, orange circles in Figure 8.2) and the High Performance Computing Centres (HPCCs, blue circles), members of the PIONIER network. Connections are supported using its own network infrastructure operating in IP technology. Since the PIONIER network, as well as most of the MANs, have a fast 10 Gigabit Ethernet skeleton, there are no significant limits on the available bandwidth and transmission delays for videoconferencing.

Figure 8.2: Locations of installed VC infrastructure in the PIONIER network

Communication is established using videoconference rooms specially designed and arranged in order to obtain the best quality of video and audio broadcast. It is also possible to move the terminal to other facilities (laboratories, lecture halls, etc.). Simultaneous videoconferences may be held between all the MAN centres, as well as many concurrent videoconferences in smaller groups. The conference is also archived, and may be replayed after the event.

Devices that control the collation of the connections (MCUs) are located in two PIONIER network nodes. One node acts as a primary server and the second one as a backup. Since the two nodes are identically equipped, and since both nodes are active, it is possible to pursue a parallel scenario consisting of the simultaneous use of both servers for a larger load.

A web portal makes it easy for network users to make VC reservations and allows advanced resources administration. Users can also obtain information about active resources, statistics and device monitoring. Telemedicine offers a matchless way of combining the advances of modern communication technology and information technology with biomedical engineering and medical sciences to deliver healthcare services on an anytime, anywhere basis.

This PSNC system has been heavily used for telemedicine-based e-learning events. Since 2009, the Poznań Clinic has carried out eight live surgical sessions, Surgery Live, as part of the LION project using technology based on the transmission of the Poznan Supercomputing and Networking Centre (PSNC). This case study is described below.

8.2.2 e-learning Example Using Telemedicine

A real-life example of the telemedicine and e-learning area is the Live International Otolaryngology Network Project (LION). The essence of the project is an interactive, simultaneous live transmission from the operating tables of various parts of the world. Interactive, because delegates are able to question doctors via moderators. It is dedicated to promoting medical and surgical high-quality Continuing Education programmes to improve the knowledge, skills and discipline of current otolaryngologists, while introducing innovative programmes designed to provide worldwide education, including in developing countries.

The aim of LION is to create a permanent, interactive, worldwide high-speed network for continuing education in otolaryngology (ear, nose and throat (ENT) medicine), and to promote distance learning using modern videoconferencing technologies. The programme is focused on Otology-Neurotology, but it will grow to include other fields of ENT medicine. Modern telemedicine-specific hardware and software tools such as digital stethoscopes (to listen to the heart and lungs), digital otoscopes (to see the inside of the ear), oxygen saturation probes (to assess the oxygen level in the patient), and blood-pressure monitors are making telemedicine consultation more scientific and data-based as well as presenting an opportunity for doctors and students to see meaningful real-time data capture.

8.2.3 LION Network Configuration

The LION network can be used interactively for live surgery, panel discussion and formal conferences with presentations. There are two types of sites: Faculty sites and Distant sites:

- A Faculty site is an operating theatre, and/or any site worldwide from which a faculty member of LION will perform live surgery, give a lecture, lead a conference or participate in a panel discussion.
- A Distant site is any conference room or computer worldwide from which delegates will follow the LION session and interact with the faculty.

The central point connecting Faculty and Distant sites is Eurohub (MCU provided by SURFnet, the Dutch educational ISP), located in Utrecht. An overview of the infrastructure of LION can be seen in Figure 8.3.

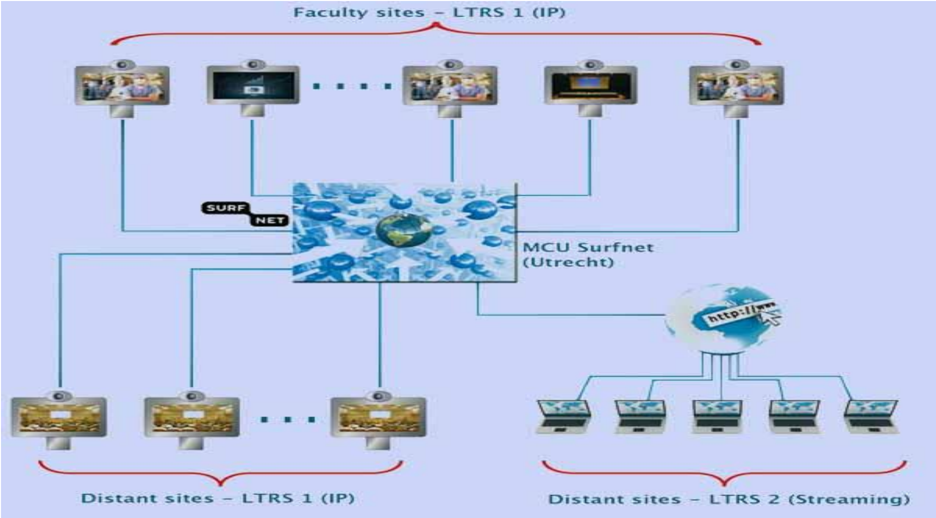
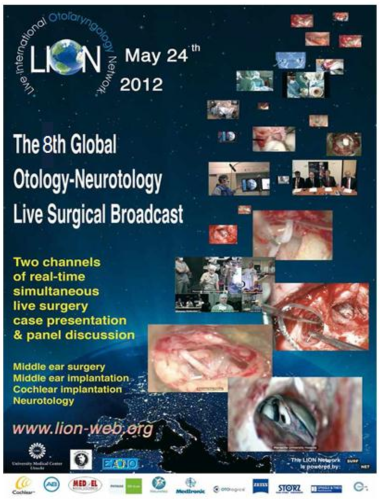


Figure 8.3: Basic infrastructure of LION

SURFnet's MCU is used to interconnect all sites during each multi-centre session of LION. The Eurohub moderators, who are world-leading, specialist surgeons, will be located at the SURFnet MCU. There is a LION Technical Requirements Standard (LTRS), which defines two levels of connection, level 1 and 2:

- **LTRS1 – IP connection**: this configuration is mandatory for all Faculty sites and is also recommended for all distant sites to offer real-time interaction between the faculty and the delegates in the conference room facilities. LTRS1 requires the use of professional videoconference equipment.
- **LTRS2 – Live Internet streaming**: this is powered by SURFnet and offers high audio-visual quality. Direct questions to the faculty cannot be asked from those distant sites which are below the LTRS2 level. Interaction with the faculty will be possible by email or with the chat room via the moderators located at the MCU.

Figure 8.4 shows the poster, reach and broadcast image of an example LION event, the 8th Global Otology-Neurotology Live Surgical Broadcast on 24 May 2012.



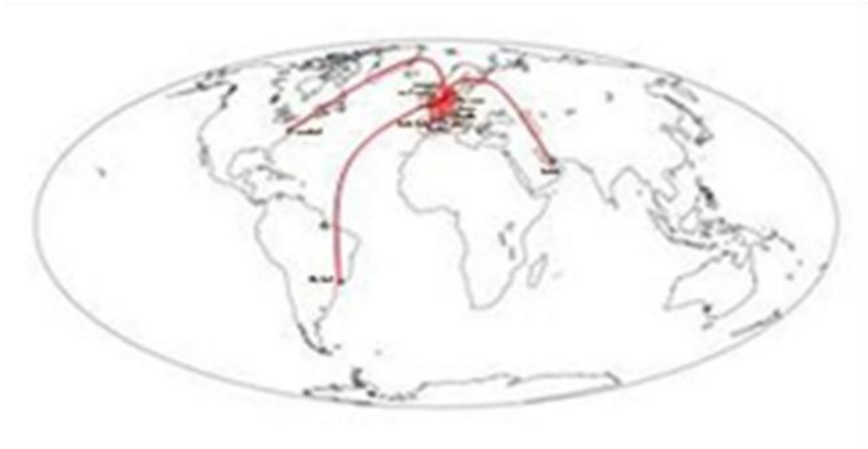


Figure 8.4: The 8th Global Otology-Neurotology Live Surgical Broadcast 24 May 2012

During this event, 32 operations carried out in 18 medical centres across the world were shown. Two operations for the treatment of hearing defects were carried out in the Poznan University of Medical Sciences: doctors from Poznan broadcast on the network as they conducted an operation to implant the hybrid cochlear in the ear and performed otosclerosis surgery during which the damaged stapes was replaced with a prosthesis.

These transmissions are designed to help physicians, especially in developing countries such as India, China and Pakistan, where such demonstrations are held in cinemas. Each broadcast operation included commentary by the practitioner and a discussion by scientists from the UK and the Netherlands who observed the procedure in the studio and asked questions about the operation sent to them from doctors around the world. At the end of all transmissions, a videoconference is conducted with doctors who reflect on their work.

The video signal was broadcast in High Definition quality (HD), because of the crucial importance of image quality during the medical operation. Two channels of videoconferencing were available for the participants, who came from Austria, France, Brazil, Poland, Germany, Belgium and UAE. A number of NREN networks were used to access the demonstration. Mobilising such a team of medical experts would not normally be possible and VC capability not only saved a considerable amount of time but also contributed to extensive carbon emissions savings.

Using the NIIF calculator, the Environmental team estimates that over 7 tonnes of GHG would have been saved using the telemedicine VC if only one client attended from each of these locations: Zürich, Switzerland; Antwerp, Belgium; Brussels, Belgium; Vienna, Austria; Tübingen, Germany; Utrecht, Netherlands; Sienna, Italy; Béziers, France; Hannover, Germany; Sao Paulo, Brasil; Istanbul, Turkey; Ankara, Turkey; Warsaw, Poland; Poznan, Poland; Barcelona, Spain; Dubai, UAE; Sydney, Australia; and Lyon, France.

In addition, at least 10 days' working time was saved just by not travelling to get to the location.

Such technology could also play an important role in developing countries, perhaps saving infrastructure set-up costs for medical centres or reducing the need to send patients out of these countries to specialist surgeons abroad.

According to Vishal Gupta, Cisco VP/GM of Global Healthcare Solutions [TELEMED], "Telemedicine should create a level playing field where access to quality and affordable healthcare can become a right for every Indian just like the right to education. The most important thing is to enable healthcare for the over 600 million Indians who live in villages. The primary Health Centres (over 60,000 in India) that support villages are not able to attract doctors and the problem is especially acute for specialists."

8.3 Recommendations

There are a number of recommendations for this section:

- **Actively promote videoconferencing facilities** for e-learning opportunities.
- For teams that are geographically dispersed and need to have regular team meetings, hold a face-to-face meeting initially to get to know participants, and have an **agenda item on how to mobilise and best use videoconference facilities**.
- Encourage regular users to **set up rooms to cater for their videoconference and publicise these settings** in their communications.
- NRENs should monitor usage of supported videoconference equipment and **publish the metrics**.
- **Run a competition** that shows the most innovative use of videoconferencing and reward the users with publicity.
- Highlight team use of videoconferencing and show the time and travel distance saved and CO_2 emission figures, **building mini case studies** for each organisation.
- Promote **one-to-one videoconference** usage.
- **Encourage videoconference usage** as part of remote or teleworking.

9 Distance Working

Distance working or telecommuting (working from home or from a “remote workstation”) has received increasing attention across Europe and the US in the last ten years, as well as growing acceptance by organisations. People commute in cars, buses, planes and trains, to work and to other places on a regular basis; commuting is part of our lives. However, the actual necessity to physically change location in order to accomplish such tasks has recently been challenged on the basis of concerns for energy conservation, the impact on our environment, a need to refocus on family values, and other issues. Energy utilisation will continue to grow as we expand our industries and improve our standard of living, therefore the efficient use of energy will always be of prime importance. For NRENs, there is continuous demand to increase the number and type of clients supported, and to provide connectivity to more-dispersed campuses. As a result, staff have had to travel more to cover/support the expanding network. In order to decrease energy usage, opportunities to reduce or conserve energy are offered by telecommuting to work (working from home) instead of travelling to work.

The benefits of a distance-working programme include:

- **Conserving energy** since less energy is used as people are not commuting to work on a daily basis.
- **Preserves the environment** by reducing land-use requirements for road expansion and by reducing slow-moving automobile emissions.
- **Promotes safety**. Reducing road usage by people rushing to get to work will decrease traffic-related deaths every year.
- **Improves health** by reducing stress related to compromises made between family and work.
- **Allows closer proximity to and involvement with family**.
- **Allows selection of a remote worksite that is mutually acceptable to all family members** and allows the spouse an opportunity to pursue his/her career.
- **Allows employees freedom** to choose an environment that is more suitable from a social and economic standpoint and to live in an area with people of common interests.
- **Improves productivity**. Time saved can be used to improve productivity.
- **Reduces number of people “job hopping”**, decreasing training requirements.

A very recent study published in late 2012 by researchers at Stanford University [STANFORD_CTRIP] considered the implementation by a Chinese travel agency, CTrip, of a home-working trial. The trial ran over a nine-month period and involved 500 workers split equally between a test and control group. The study found that home working led to increases in performance and job satisfaction, with less attrition from the firm, though workers felt that their promotional chances were reduced.

The study showed a 13% performance increase, of which about 9% was from working more minutes per shift (because the workers took fewer breaks and sick-days and were probably less tired because of not having to commute) and 4% from more calls per minute (attributed to having a quieter working environment). Home workers also reported improved work satisfaction and the company experienced 50% less turnover of staff. However, the workers felt their performance-based promotion opportunities fell due to reduced visibility of their efforts in the organisation. These particular jobs, which were call-centre support, were particularly suited to distance working and employees gained benefits from not having to commute to work for 4 out of the 5 days they were scheduled to work each week.

9.1 NREN-Based Distance Working Study

UNI-C was the only NREN in the GÉANT Environmental team who had undertaken a study of how distance working using ICT can reduce some of the environmental impacts of commuting. The primary goal of the study was to evaluate the claim in the SMART2020 report by comparing it to the present use of teleworking at UNI-C.

The study results showed the very large variations observed between individual employees and focused on the use of distance working by a group of 30+ employees at UNI-C's data centre in Lyngby. All used employer-provided broadband connections and computer equipment at home, making it as easy and efficient to work at home as at the office. The study was performed during a defined period of five weeks from 22 January to 28 February 2010. During this time, each employee kept a record of the number of days working from home. To calculate the savings, the same key figures as in the "GN3 Study of Environmental Impact, Inventory of Greenhouse Gas Emissions and Removals – NORDUnet" (2010) were used, i.e. 42 g/km for transport by regional train, 175 g/km for private cars, for buses 90g/km and for S-tog or Metro 16 g/km [NORDUNET]. Walking and cycling is regarded as CO_2-neutral, 0 g/km. The study did not take account of the operational impact of working at home, possibly requiring increased heating and lighting during the daytime hours and electricity consumption of the utilised computer equipment. The study also did not account for the corresponding savings of office heating, lighting and electricity consumption.

9.1.1 Results

The total amount of CO_2-emissions estimated to have been saved was 309 kg, corresponding to 1.5 tonnes when scaled proportionally to the full 52 weeks of a year. In rounded figures, each Danish citizen accounts for a yearly emission of 10 tons CO_2. This amounts to 300 tons for 30 employees at UNI-C Lyngby, meaning that the 3 tons saved by distance working corresponds to a 1% saving for each employee at UNI-C in average. In comparison, the 0.26 $GtCO_2$ saving of the SMART 2020 report is as mentioned only 0.5% of the 51.9 $GtCO_2$ estimate of "business as usual" anno 2020.

9.2 Other Studies in ICT Technology-Based Companies

9.2.1 O2

On 8 February 2012, UK telecoms giant O2 sent nearly 3,000 staff based at its Slough office home to telecommute for the day. The results of the experiment [O2REMOTE] help to illustrate the benefits of flexible working. O2 found that:

- Telecommuting staff saved £9,000 in reduced commuting costs.
- 1,000 hours that were usually spent commuting were instead spent working, while staff also gained an additional 1,000 hours of sleep.
- 14% said they saw more of their families.
- More than one in three (36%) said they were more productive than when at work.
- 12.2t of CO_2 was saved in one day, which is equal to CO_2 emissions from driving 42,000 miles in a medium-sized diesel car.

9.2.2 Telstra

Telstra in Australia [TELSTRA] found that distance working delivers the greatest environmental benefits when a normally office-based employee is commuting a total daily return distance greater than 34 km. The further an employee has to commute, the greater the environmental benefit of distance working.

It can save an average of up to 242 kg of GHG emissions per employee, per year. For example, if 10% of a 5,000-employee company teleworked, as indicated in the report, they would save 121,000 kg of GHG emissions per annum.

The Telstra study also noted some key factors which influenced their results, including:

- Energy efficiency of buildings. The less energy efficient the company office is, the greater the environmental benefits of teleworking. Even if the company office reduces its energy consumption by 75%, there may still be environmental benefits from teleworking.
- Home energy efficiency. The more energy efficient the home office is, the greater the benefits of teleworking. Only when energy consumed in the home office increases to greater than 1,212 kWh of energy per year (40% above baseline), the impact associated to teleworking surpasses the impact of working in the office.
- Clean energy. The more the home office is relying on “cleaner” energy sources (for example, using gas for heating, rather than electricity generated from coal), the greater the environmental benefits of teleworking.
- Space gain. The more space that can be saved within the office as a result of fewer workers requiring office accommodation in any one day, and hot-desking becoming the norm, the greater the

environmental benefits of teleworking. If 50% of the original space occupied by teleworkers was consolidated immediately, the global warming benefit increases from 242 kg CO2e to 1,624 kg CO2e.

If the outcomes of Telstra's "Teleworking Life Cycle Analysis" study were applied across the working population of Australia (assuming 5% of the working population work remotely), it would save almost one million tonnes of greenhouse gas being released to the atmosphere.

9.2.3 Cisco

In late 2008, Cisco conducted its own survey into distance working to evaluate a number of telecommuting topics, including: commuting patterns, technology barriers, work quality and productivity, environmental impacts, and advantages and disadvantages of the flexible lifestyle, as well as overall employee satisfaction [CISCO_1]. Cisco found:

- That year Cisco teleworkers saved 47,320 metric tons of GHG emissions from being released into the environment as a result of teleworking, with a fuel cost savings of USD10.3 million.
- The average distance for a round-trip commute for the Cisco staff varied by global regions: from about 23 km in the Asia-Pacific region up to 74 km in Europe.
- Approximately 69% of the employees surveyed cited higher productivity when working remotely, and 75% of those surveyed said the timeliness of their work had improved. They indicated that telecommuting is somewhat or very important to their overall job satisfaction.

By 2011, 70% of Cisco employees were working from home at least one day a week and 40% of Cisco employees did not work in the same location as their manager [CISCO_3].

9.2.4 Orange

Telecoms services provider Orange has made a tool available that allows companies to assess how much greenhouse gas they can save using teleworking, showing the savings in relation to the number of households or car usages, air travel or barrels of oil being used [ORANGETOOL].

9.3 Recommendations

- Encourage your NREN organisation to **publish a full procedure for distance working** or telecommuting, and apply this procedure as widely as possible throughout the organisation.
- **Motivate staff who may engage in distance working** to set up comfortable, office-style accommodation at home.
- **Review employee network connectivity services** to maximise the advantages of distance working.
- For short stays at the office, including partial days, encourage **practical usage of distance working**.
- **Document all benefits accrued** from this policy on a six-month basis.

10 Dematerialisation

Dematerialisation is defined primarily as the decline over time in the weight of materials used in industrial end products or in the “embedded energy” of the products. More broadly, dematerialisation refers to the absolute or relative reduction in the quantity of materials required to serve economic functions. Dematerialisation matters enormously for the human environment. A lower materials intensity of the economy could reduce the amount of waste produced, limit human exposures to hazardous materials, and conserve landscapes. ICT and the good network connectivity offered by NRENs to their clients provide opportunities to review how teaching materials are used or generated and how other paper-based practices such as examinations are carried out to suit the needs of a more digitally aware audience as well as reducing consumption of valuable resources and reducing environmental impact.

Several case studies have been evaluated as part of the dematerialisation work in NA3 T5. One of the concepts of dematerialisation is to move from old paper-based procedures to new digital solutions and new procedures, and in the process save some resources. The resources can be time, money, persons, electricity, transportation, and CO_2.

10.1 Case Study: UNINETT – Digital Exams

This case study is based on the ongoing work on digital exams done by Norwegian universities and UNINETT’s eCampus project. The normal method of evaluating students in Norwegian higher education is by written school exams. Written school exams consume large amounts of resources in preparation and evaluation. There is a lot of manual handling of paper and manual work, and all this manual work results in errors, dropped exams, wrong grades, mixed-up results, and cancelled exams. Students of today are classified as “digital natives”. They request their education to be available in a digital format. They also request exams in a digital format.

10.1.1 Scope

The study is based on ongoing work in UNINETT’s eCampus program. The main goal of this study is to identify and reduce the resources consumed on written school exams. The work is divided into several technical work areas, looking at desktop technology, home exams, bring your own device (BYOD) and the workflow for grading digital exams. Due to all the manual handling of written school exams and manual registering of grades, the people operating the central student database (FS) estimate an error rate on a student’s report card of 5%, which is mostly due to manual registration of grades in the system.

10.1.2 Cost of Written Exams

The University of Tromsø, with 9535 students, have done their own investigation of the costs related to written school exams (spring 2012) The number of courses, candidates and days used for written school exams is increasing for each semester. Table 10.1 below shows the extent of written exams at the University of Tromsø.

	Autumn 2010	Spring 2011	Autumn 2011	Spring 2012	Autumn 2012
Number of courses	368	409	416	476	424
Number of candidates	6482	8289	7828	8645	9433
Days with written exams	67	70	64	89	63

Table 10.1: Number of courses, candidates and exam days at the University of Tromsø

In addition to written school exams, several other evaluating/grading procedures are used for course assessments. At the moment the written school exams are still the main evaluating procedure for half of the university's courses.

Cost elements for written school exams	Cost per year
Salary for extra people during the exams	€560000
Rent for additional premises	€134000
Paper for written exams (makes 3 copies)	€30000
Overtime for staff, related to exams	€15000
Courier service	€5000
Cost for exams at faculty, censoring, packing and shipment	€250000*
Cost for planning exams, premises, candidates, guards	€250000*
Cost for exams outside Tromsø	€250000*

Table 10.2: The costs of exams

Key:

* Representative estimate used to show impact

The University of Tromsø have identified the centrally funded part of the costs for written school exams. The local cost at each faculty is a big part of the total cost, but it is not identified in this phase of the project. As a very conservative estimate, the local cost at the faculty is about the same size as the central cost for each written school exam.

Cost element	Written school exam	Digital exam on Uni. PC	BYOD
Planning of exams, premises, guards, candidates	+	++	0
Cost for paper	+	0	0
Salary for guards, administration, training	+	++	0
Rent for premises	+	+	0
Courier service	+	0	0
Overtime for staff	+	+	0
Check and administration of legal aids/tools	+	+	0
Cost for exams outside Tromsø	+	+	+
Cost for network, power	0	+	+
Cost for check of PCs	0	+	+
Cost for help desk during exams	0	+	-
ICT response team	0	+	-
Cost of failed exams due to technical reasons	0	+	+
Cost for development of exam solution	0	+	++
Cost for training guards	0	+	0

Table 10.3: Comparison of cost between written school exams and digital exams

Key:

0 No cost.

+ There is a cost every year.

++ There is a start-up cost, and a yearly re-occurring cost.

Table 10.3 shows that there are costs related to a transition from written school exams to exams on university-controlled equipment (PCs), and additional costs to cater for handling “bring your own device” equipment which would be used by students.

Although holding exams on university-controlled equipment will increase their cost, the quality of the exams will increase as everything is handled in digital form, which will reduce the amount of errors caused by manual processing of answers and grades. It may also reduce the time it takes to mark such exams, as there will be fewer problems trying to decipher bad handwriting.

Exams taken on BYOD devices may offer the best solution for reducing consumption of resources and hopefully the cost to the hosting facility.

10.1.3 Technical Solution: Virtual Desktop Interface (VDI)

The University of Agder are also involved in a project on digital exams, and have set themselves a goal to provide school exams, oral exams and assignments in digital format to all their students by autumn 2014.

As the first step in this process, the Agder group tested a Virtual Desktop Interface (VDI) solution from VMware [VMWARE_3] on the university’s own PCs, for approximately 600 exam candidates in the autumn of 2012. The VDI solution produced satisfactory results, but some minor challenges were encountered associated with logging and control of the equipment being used.

The biggest challenge they now face is to implement this new solution, while modifying their old procedures for exams which may have to cater for both digital and written examinations for a period of time.

In addition to this work at the University of Agder, the eCampus project at UNINETT has started a further investigation of large-scale implementation of a VDI solution for digital exams.

10.1.4 Technical Solution: Computer Lock-Down Using AD Profiles

Another contributor to the research on digital exams and associated procedures is the Faculty of Law at the University of Oslo who have done a lot of work on computer lock-down with profiles in Active Directory (AD). In addition to the lock-down of computers for students to work on during exams, they are looking at digitising the whole process for exams. As part of their research, they propose a new (reduced) workflow for handling digital exams. The full official workflow for written school exams still consists of 19 elements, and could potentially take up to 11 months to complete.

10.2 Case Study: PSNC – e-Books Project

A second case study being actitively encouraged by the GÉANT Environmental team is the work being carried out by PSNC in the area of e-book generation.

The features and architecture of the e-book model depend on the technological capabilities of the platform serving educational resources. At the design stage, six important features had been defined:

- Openness, which means supporting appropriate standards of open access.
- Cross-platform, which means availability on different devices.
- Flexibility, which means the ability to specify different user modes.
- Modularity, which is the assumption of the coexistence of different versions and functions of each e-book.
- Security of data and infrastructure with current diagnostic mechanisms.
- Scalability, which means taking into account dynamic changes in the number of users, resources and services available.

Currently PSNC is working on the first version of the user interface, which has to be intuitive and easy to use. It must allow users to choose a class, lectures, and lessons, for a particular chapter. This version will have mechanisms for cross-platform support, will be designed to automatically adjust (scale) content depending on the resolution and file formats supported on the device. In parallel, in cooperation with the partners responsible for the content of the first e-books, tools are being created to support editing and composing content. A decision on which functions will be included in the pilot and which will be in the final version of an advanced platform for e-books will be made during implementation work.

The first e-book for mathematics should be ready by the end of 2013. By June 2015, the pilot should include 18 text books. It is a very short timeframe, but it should be enough to successfully implement this new idea of digital Polish schools.

The result of all this dematerialisation work is less consumption of resources and it will offer significant opportunities to save GHG and improve the quality of the country's universities.

10.2.1 E-Book Usage in Other Locations

Other NRENs and their educational systems are also seeing a growing impact of e-book digitisation. Some schools in Ireland are using Intel-based Fizzbook Spin with a full range of Edco e-books (Edco is one of the largest schoolbook publishers in Ireland). The Fizzbook Spin is the first PC specifically designed for the Irish education system and is based on the Intel Classmate PC design architecture. Using the device in this way offers a total classroom solution with netbook, e-reader and touchscreen tablet functionality together with full PC capability, including word processing, spreadsheet and art software packages [SPIN_PC].

In developing regions of the world, e-books will make the greatest impact as many of these locations have under-resourced school systems. In Africa, Intel has been advising African governments and helping them buy entry-level computers [INTEL_AFRICA]. In Nigeria, Intel brought together MTN, a telecom carrier, and Cinfores, a local publisher, to provide exam-preparation tools over mobile phones, a service that has become hugely popular. Such success shows that even those with limited financial resources are willing to pay for digital education – as they already do for the conventional kind. In Kenya, eight out of ten parents pay tuition for courses outside school.

A bigger question is whether digital tools will actually improve education. Early results are encouraging. In Ghana, reading skills improved measurably among 350 children who had been given Kindle e-readers by the charity Worldreader. In Ethiopia, researchers found that even in the absence of teachers, children figured out how to use tablets provided to them by One Laptop per Child, another charity, to teach them to read. Lots of NRENs are working as part of AfricaConnect projects to build NREN competency and get better network connectivity to this region of the world. It is encouraging to see that others are offering solutions that can utilise this infrastructure and hopefully in such a way that minimises the impact on the environment.

10.3 Recommendations

- Promote activities that reduce materials usage by clients in their daily activities.
- Encourage education suppliers to contact their local NREN to clarify how connectivity could be set up on a peering basis.
- NRENs, through frameworks for software procurement, may be able to negotiate better group terms for access to this type of resource.

11 Green Public Purchasing (GPP)

"Sustainable procurement (or Green procurement) is a spending and investment process typically associated with public policy, although it is equally applicable to the private sector. It is linked to the wider agenda of sustainable development. Organisations practising procurement compatible with environmental sustainability meet their needs for goods, services, utilities and works, not on short-term, cost-benefit analysis, but with a view to maximising net benefits for themselves and the wider world." [GREENPROCURE]

11.1 EU GPP Guidelines

Green Public Purchasing is defined in the Communication from the EU Commission "Public procurement for a better environment" [COM40] as "a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured."

From 2003 onwards, in its "Communication on Integrated Product Policy" (IPP) [IPP], the European Commission encouraged Member States to draw up publicly available, National Action Plans (NAPs) for greening their public procurement. The NAPs are not legally binding but provide political impetus to the process of implementing and raising awareness of greener public procurement. They were designed to allow Member States (MSs) to choose the options that best suit their political framework and the level they have reached.

11.1.1 Example of a Green Procurement Action Plan

Ireland's first Green Public Procurement Action Plan, called "Green Tenders" [GREENTENDERS], focused on eight priority areas, which included Energy and ICT. The ICT section includes:

- The reduction or elimination of environmentally hazardous materials.
- Design for reuse and recycle.
- Energy efficiency.
- End-of-life management for reuse and recycling of materials.
- Environmental stewardship in the manufacturing process.
- Packaging.

Areas of focus are:

- Reduction of energy consumption.
- Reduction of environmental impacts over the whole product life cycle.
    - The Electronic Product Environmental Assessment Tool (EPEAT) Certificate [EPEAT] or EU Ecolabel [ECOLABEL] will be accepted as proof of compliance (discussed further in Section 11.5 and 11.3 respectiviely).
- Power management capabilities.
- Compliance with Waste Electronic and Electrical Equipment (WEEE) regulations.

This concept of a GPP is viewed by many authorities and private institutions as a promising way of achieving environmental improvements for a broad range of product groups, including IT equipment, and focusing on office electronics such as computers, monitors and printers. NRENs are constrained to work in this space and usually attempt to give input into such policies as they are being drafted.

In the 2008 Communication “Public Procurement for a Better Environment” [PPBE], the European Commission set an indicative target that, by 2010, 50% of all public tendering procedures should be green in the EU, where “green” means compliant with endorsed common core EU GPP criteria for ten priority product/service groups.

In 2011, the EC commissioned a study with the aim of measuring whether their targets had been met. The Centre for European Policy Studies and the College of Europe conducted a survey in which over 850 public authorities from 26 Member States participated. The respondents provided detailed answers regarding the use of core GPP criteria in the last contract they had signed for one of the ten product/service groups and gave more general information on the “greenness” of their overall procurement in the period 2009/2010.

Although the uptake of Green Procurement in the EU is significant, it appears that the 50% target has not been met. Of the last contracts signed in the 2009–2010 period by public authorities in the EU, 26% included all surveyed EU core GPP criteria. However, 55% of these contracts included at least one EU core GPP criterion, showing that some form of green procurement is being done at a large scale. NRENs can contribute here by developing their own GPP guidelines, which should be linked to their Environmental Policy. Other approaches that could be taken are to have a separate set of Procedures and Guidelines available to all staff involved in the procurement process and have unique environment constraints included in all templates for tender documents, which are revised frequently.

11.2 Other EU GPP Guidelines

To assist Green Public Procurement further, the European Commission published a fully revised version of “Buying Green! – A Handbook on green public procurement” [BUYGREEN], which is also available in a summarised version, in 22 languages.

More specific guidelines have been designed for standby and off-mode electrical power. Office equipment is now addressed in a chapter in the report “Guidelines for Sustainable Public Procurement” [PPGUIDELINES], which deals with generic office equipment. A total of 48 case studies are available, with 21 participating countries. The report also contains evaluation exercises including purchasing electricity from renewable sources, cleaner vehicles selection, sustainable furnishing, etc.

11.3 Ecolabel

The EU Ecolabel is a voluntary label recognised throughout Europe that promotes environmental excellence and helps to identify products and services that have a reduced environmental impact throughout their life cycle, from the extraction of raw material through to production, use and disposal. Different countries have developed their own programmes with special emphasis on electrical and IT products and recommended specifications for IT equipment that are similar to the criteria for award of the EU Ecolabel flower symbol. Examples include the Nordic Ecolabel “The Swan” and the German “Blaue Engel” labels for relevant product groups.

A more internationally based programme is the “Energy Star” [ENERGYSTAR] programme, which was established to:

- Reduce greenhouse gas emissions and other pollutants caused by the inefficient use of energy.
- Make it easy for consumers to identify and purchase energy-efficient products that offer savings on energy bills without sacrificing performance, features, and comfort.

The Energy Star site has several calculators, such as the energy calculator for PC equipment and an equivalent energy calculator for imaging equipment. Both can be used for comparison of typical IT equipment selections and provides yearly operations costs and a breakdown of “On Mode” versus “Sleep Mode” energy usage.

11.4 Danish Green IT Guidelines

As part of their efforts to stimulate Green Procurement in ICT, Denmark’s Ministry of Science, Innovation and Higher Education (formerly known as the Ministry of Science, Technology and Innovation) have published a document [GREENIT_2] which has two objectives.

- The use of IT by citizens, businesses and public authorities should be greener.

  The public must grow better at using IT in an environmentally friendly way, and it should be made easier for the public to choose energy-efficient IT products. Corporate IT use must become greener and Green IT must be incorporated into corporate social responsibility, along with other environmental issues. Finally, the public authorities need to grow better at saving power and choosing energy-efficient IT solutions.
- IT should help bring about a reduction in overall energy consumption.

  Smarter IT solutions can, in many instances, help to reduce energy consumption and thus CO_2 emissions. For example, intelligent management of electrical devices in businesses and in private homes can ensure that energy-consuming equipment is not switched on when not in use. New research must be initiated to refine existing IT-based solutions and to develop completely new IT-based solutions for a sustainable future. For this reason, the Danish Government has set up a Project Office with the idea of professionalising the management of Government IT projects [DANISHGREEN_1, DANISHGREEN_2].

11.5 Other Green Registry Solutions and Benchmark Sources

The Electronic Product Environmental Assessment Tool (EPEAT) provides a global registry for greener electronics, an easy-to-use resource for purchasers, manufacturers, resellers and others wanting to find and promote environmentally preferable products. This promotes a global environmental rating system for electronic products, helping to advise purchasers on environmentally preferable choices, and thereby benefiting producers who demonstrate environmental responsibility and innovation.

As data centres are one of the largest users of energy in the ICT sector, the EU's "2012 Best Practices for the EU Code of Conduct on Data Centres" is a useful guide to reference when benchmarking and selecting a data centre [EUCODE]. In its section on the selection and deployment of new IT equipment, it has a link to the Energy Star [PPGUIDELINES] or SPECPower guidelines [SPECPower]; the latter is the first industry-standard Standard Performance Evaluation Corporation (SPEC) benchmark that evaluates the power and performance characteristics of volume server class and multi-node class computers. With SPECpower_ssj2008, SPEC is defining server power measurement standards in the same way they have done for performance.

The drive to create the power and performance benchmark comes from the recognition that the IT industry, computer manufacturers, and governments are increasingly concerned with the energy use of servers. Currently, many vendors report some energy efficiency figures, but these are often not directly comparable, due to differences in workload, configuration, test environment, etc. Development of this benchmark provides means to measure power (at the AC input) in conjunction with predefined performance metrics. This should help IT managers to consider power characteristics along with other selection criteria to increase the efficiency of data centres. These are published quarterly and most leading manufacturers' servers are reviewed, so it should be considered a good business practice to refer to this site for current or future server procurement.

Another useful site that brings together all the necessary information to make sustainable purchasing easier is the Sustainable Procurement Resource Centre [SPRC] which is designed as a one-stop access point for procurers, policy makers, researchers and other stakeholders. The resource centre contains key knowledge on how to effectively undertake sustainable procurement, saving public authorities money and driving the market towards sustainable solutions. It provides the latest news and describes events focused on sustainable procurement, and has an extensive searchable database containing:

- Procurement criteria.
- Policies and strategies.
- Tools and guidance.
- Good practice cases.
- Projects and initiatives.
- Studies and reports.
- Ecolabels and other labels.
- Useful links

11.6 Recommendations

- **Check local green procurement rules** and policies.
- When considering new procurements, **use the European Commission publication** “Buying Green! – A Handbook on green public procurement” and the associated test cases as a reference to making equipment or services quotes, tenders or purchases.
- Attempt to always **buy equipment that has ecolabels**, such as Energy Star or its European equivalents.
- Another useful source to consider is **EPEAT, the global register for greener electronics**.
- **Check the Sustainable Procurement Resource Centre** to see whether it can provide helpful source suggestions.

12 Green Electricity and Energy Source Choices

According to Smarter2020, the power sector represents over 21% of global GHG emissions. The ICT sector is totally dependent on power no matter how it is produced. For NRENs, whose business is like others in the ICT sector, electricity is by far the most important consumable, and is the cause of the largest amount of GHG emissions. Countries that have availability of varied energy sources usually base their electricity generation on such availability, so countries that are not fortunate enough to have many renewable energy resources will have a high CO_2 factor (unit: kg/kWh), which indicates how much CO_2 is produced for every kilowatt hour of electricity generated in the country. NRENs based in countries with better access to, or production of, renewable energy (such as Iceland, Norway or Denmark) will score better in audits than those where energy is generated from more fossil-fuel based sources.

The Smarter2020 report has estimated that ICT can help reduce the inefficiencies of the power sector with an abatement potential of 2.0 $GTCO_2e$. Levers to achieve this saving are

- Using smart grids.
- Integrating renewable energy sources into the grid.

The market for generating and trading all types of electricity is complex, especially as these markets have been de-regulated to stimulate more competition. NRENs, like all electricity users, cannot influence these business practices but they do have to live with their outcome. However, NRENs' users expect continuous connectivity, so networks have to be designed to be resilient enough to tolerate power-transient conditions. Generation of green electricity from renewable sources is complex, because such electricity production and GHG emissions are influenced by political decisions and targets. While consumers such as NRENs have the possibility to choose their electricity supplier, thereby choosing "green electricity", the grid operators have to devise tariff schemes that compensate producers for investing in plant to generate power from renewable sources while maintaining a stable electricity grid.

Some countries, such as Ireland, are now promoting the development of renewable energy as an integral part of sustainable energy objectives and climate change strategy. Renewable energy contributes to meeting all three energy policy goals: energy security, cost competitiveness and protection of the environment through the reduction of GHG emissions. With lower or no net emissions from renewable energy sources compared to fossil fuels, renewable energy sources contribute to the de-carbonisation of the energy supply and reduction in greenhouse gas emissions.

In 2010, Ireland produced 10% of its energy from wind turbines and Greece produced 3.7%. At present, the target for these two countries is to use, respectively, 37% and 23% wind-based power in their electricity grid networks by 2020. This is an extremely large step to try to achieve, as technologies supporting national grids will have to be re-designed to cater for such large spikes in production. Frequency ranges in the grid are guaranteed by the electricity grid provider and are usually restricted to plus or minus 0.5 Hz, as frequency increases in proportion to the amount of wind-generated power supplied to that grid.

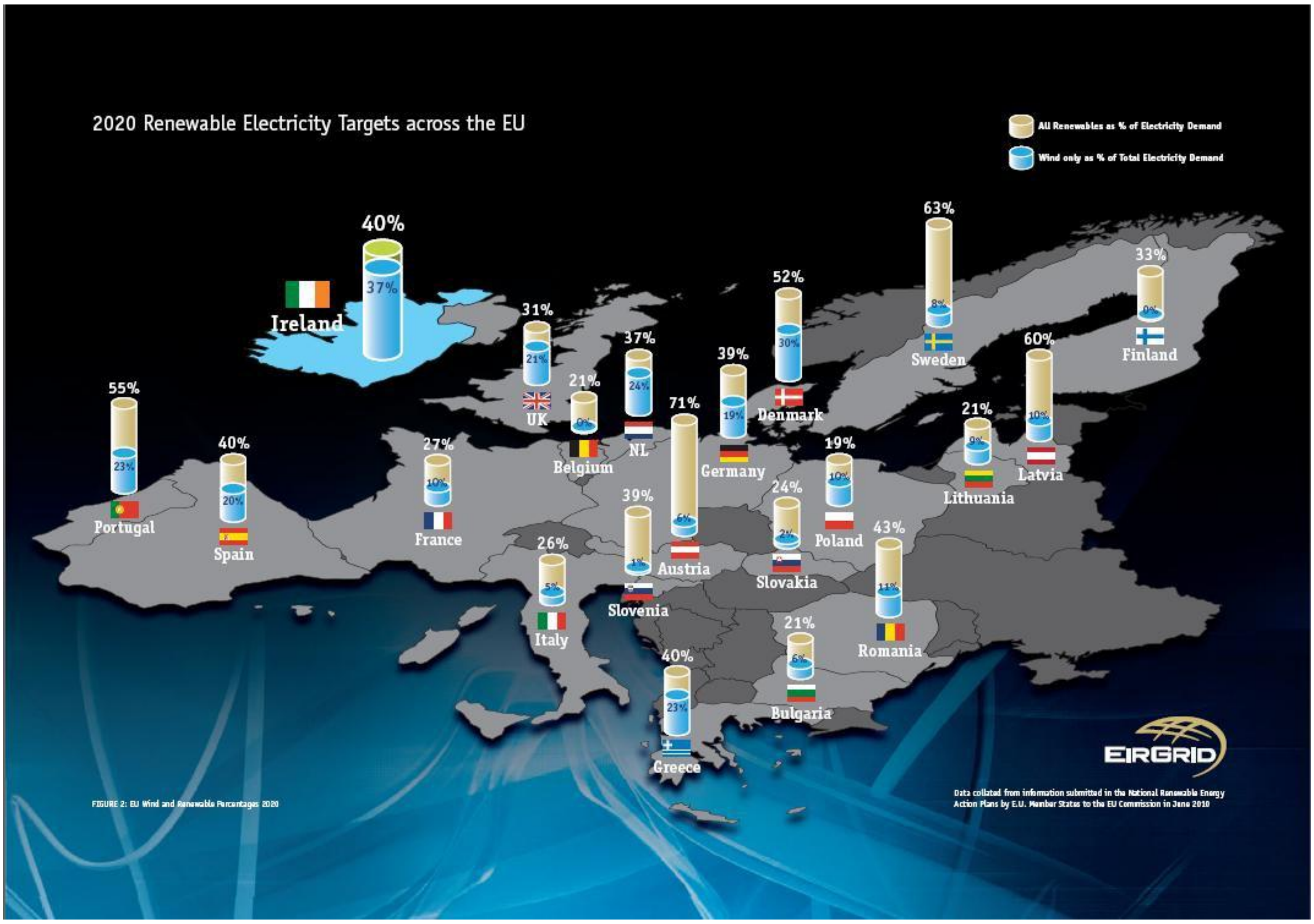


Figure 12.11: Electricity production in 2020 shown by quantity of renewable energy (Source: Eirgrid analysis) [EIRGRID]

While NRENs want to promote greater use of renewable energy to power the data centres housing their equipment, and even to power the equipment at other locations to which they provide this network, such a policy could cause them operational difficulties in the future. If the national grid to which the NREN connects cannot dissipate this intermittent power source almost instantly, it could cause disruption to those sections of the grid. For grids that use renewable energy, disruption in the form of overwhelming supply is possible, for instance, in the form of a violent summer storm with strong winds generating large amounts of power greater than can be dissipated in the grid, at the same time as demand dramatically lagging behind the supply.

In such a situation, regions could have excess power in certain section of their grid, which, if it cannot be dissipated fast enough, or if the excess cannot be consumed or transported to other grids, will trip out the power in these regions. NREN clients in these regions could lose total connectivity, without power on campus or at the regional PoPs to support them, no matter how well the NREN had designed its network for equipment, path, power and PoP resilience. In addition, NRENs are now tasked to provide continuous network connectivity to their users, so could not tolerate supply disruptions.

As a result, interconnection facilities between grids have to be capable of moving power spikes to supply other grids that have a need of these energy supplies. A High Voltage Direct Current (HVDC) grid [AHMED] offers the capability to instantaneously switch such loads, but other grids have to be able to absorb and use this capacity.

Most of the non-renewable-energy generating stations do not have the ability to turn down capacity at short notice. Part of a longer-term solution will therefore need to consider the scenario of over-capacity, so that the technology of the wind turbine will be capable of being switched or turned out of the wind more frequently and in a controlled fashion, rather than just when the wind speed exceeds the design parameters of the turbine.

Now consideration is being given to compensating producers for the full capacity of their generating plant when it is most practical to take only 80% of the power being generated, since that offers a more stable frequency of supply.

12.1 Test Case: NRENs Generating Renewable Energy to Power their PoPs

If renewable energy sources are a solution to reducing energy costs and GHG emissions, is it possible that an NREN could generate their own power? HEAnet investigated the possibility of using a renewable energy source to power a regional PoP, which would house two racks of equipment, with a total load of 6kw. This PoP consumes in the region of 26,260kWh, and would emit 14,138kg CO_2 in Ireland per year in 2011. A wind turbine with a rated power in the region of 20kW to 30kW would be required to offset the annual consumption of a PoP. The setup up of a wind turbine generation facility would require an area of 40 m by 40 m, as the wind turbine would be positioned on a 15-metre-high mast and have 3-metre turbine blades.

NRENs do not wish to own parts of real estate, with most sharing communication-room facilities at the campuses they serve or co-locating with third-party service providers.

Another exercise was carried out to see whether it was possible to power a subset of the equipment power required at a PoP from a client site which has a large amount of PV solar panels. Again, the large amount of real-estate space – roughly the same as the wind turbine requirements – and the low efficiency of the PV panels at around 16% made this an impractical solution for an NREN to adopt.

Alternatively, NREN clients with large campuses could set up renewable-energy generation facilities, especially if they are constructing new buildings on campus. A very good example of such a programme is Monash University, in Australia, with a dispersed campus that has at least six campus buildings with large solar panel arrays. The university can produce 50 GWh from these facilities in the peak month of January. They have set an internal goal to purchase 15% of green power from renewable energy resources. Monash had committed to a target of 20% reduction (from 2005 levels per gross floor area) in energy consumption across all Australian campuses by 2010. Building on this success, further initiatives were introduced in 2011.

12.2 Policy Framework – the EU Emission Trading Scheme

The Kyoto Protocol introduced specific GHG-emission reduction targets within the UN, and has been accepted by most countries, with the exception of the US, while Canada and New Zealand have since pulled out of the scheme. In Europe, these targets were implemented by the introduction of the EU Emissions Trading Scheme (ETS). EU ETS works on the "cap and trade" principle. This means there is a "cap", or limit, on the total amount of certain greenhouse gases that can be emitted by the factories, power plants and other installations in the system. Within this cap, companies receive emission allowances that they can sell to or buy from one another, as needed. The limit on the total number of allowances available ensures that they have a value.

At the end of each year, each company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. The flexibility that trading brings ensures that emissions are cut where it costs least to do so.

The number of allowances is reduced over time so that total emissions fall. The target for 2020 is that emissions will be 21% lower than in 2005.

Such a mechanism allows the emission reductions to happen where they are cheapest. With time, the number of allowances available will be reduced, forcing the GHG emitters to find solutions to reduce emissions. Unfortunately, the economic crisis has resulted in a surplus of allowances on the market, and their price has been significantly reduced, temporarily removing the incentive to cut emissions in this way.

As there is a fixed amount of CO_2 allowances available, introducing more renewable electricity will, in the short term, not lead to lower GHG emissions, because allowances not used in the electricity sector will be used elsewhere. In the longer term, however, the possibility of producing more renewable electricity may contribute to lowering the amount of allowances further, or earlier, than would otherwise be possible.

The European Commission have recently developed and now operate a new central Union Registry system. The registry records:

- The carbon dioxide allowances that installations are allocated.
- Annual verified emissions data provided by operators.
- All transactions from each country's own registry.
- Annual reconciliation and allocation of allowances.

Having a central Registry should enable better control in this marketplace for the future and will provide data that can be used to change policies faster depending on supply and demand.

12.3 The Concept of Additionality

Purchasing of green electricity products actually affects the electricity market and the global GHG emissions, which introduces the concept of additionality. In this context, additionality is the reduction of GHG emissions that are *in addition to* the reductions already planned or determined to happen due to political target setting.

Additionality is the fundamental principle of carbon finance, and, simply put, is the ability to demonstrate that, without the intervention, it would not happen. For instance, without the funding provided from carbon levies or taxes, the project could not have proceeded. One example of how a scheme would qualify is shown in woodland carbon sequestration, where the Forest Carbon Group in the UK [FOREST50] defined that any such scheme must be able to demonstrate additionality in three ways:

1. **Financial**, i.e. that it could not proceed without the additional funding delivered through the sale of the carbon capture arising from the planting. The appraisal method used to demonstrate the financial barrier to creating the woodland will depend on the landowner's particular situation, e.g.:
   - Cashflow – carbon finance can overcome the barrier of a relatively short-term cash deficit. An example is where a Government-sponsored forestry commission that grants aid for woodland creation only pays out after the trees are in the ground.
     - Negative net financial position – an example the effect on land value where permanent woodland is planted has to be taken into account.
     - The opportunity cost – the permanent loss of land with potentially more profitable uses.

2. **Legal**: a tree-planting scheme is not "additional" if the landowner is facing an obligation to plant those trees, e.g. the re-stocking of a felled area. The same would apply to a property developer whose planning permission required the provision of a woodland area.
3. **Behavioural**: an existing woodland creation plan that lacks a proven intent to plant for the purpose of carbon capture will not qualify as an additional scheme, i.e. if a scheme was already conceived or underway for aesthetic, commercial or other reasons, it cannot be "rebranded" as a carbon woodland scheme.

There are many measurement challenges with Carbon Offsetting. Some of these issues include:

- Baseline determination.
- Double counting.
- Permanence.

While these types of solutions seem a natural balancing act to neutralise the carbon emissions we produce, they are far from simple in many different business areas that are emerging. NRENs will hardly be negotiating for carbon offsets to mitigate against their activities, but should be aware that the data they provide to central governments should be accurate as it helps scale any government programme for such activities with an example of correct reliable data.

Selling electricity from an existing hydropower plant would most likely *not* change the amount of renewable electricity produced, and is thus not additional. To create a real GHG emission reduction, purchasing green electricity should result in a reduced production of electricity based on fossil resources. Europe needs initiatives such as the GreenPower Programme in Australia [GREENPOWER], which is a government accreditation programme that enables an energy provider to purchase renewable energy on a customer's behalf. The programme was developed in consultation with the energy industry and various non-government organisations, including: the Australian Consumers Association, Greenpeace, the Australian Conservation Foundation and the World Wide Fund for Nature.

The programme has the following aims:

- To encourage growth in consumer demand for renewable energy.
- To provide consumer choice for, and increase confidence in credible renewable energy products.
- To increase consumer awareness of renewable energy and greenhouse issues.

The participating renewable-energy generators generate electricity from sources like mini hydro, wind power, solar, biogas and biomass, which produce no net greenhouse gas emissions.

12.4 Initiatives to Achieve Green Electricity

12.4.1 Buying Certified, Renewable Electricity

In future, NRENs may have to negotiate for credits to buy renewable-energy sourced electricity, so it is useful to appreciate the currency units and practices involved in this complex market place. It is possible for a supplier of renewable electricity to obtain a certificate demonstrating to the customer that the electricity they have bought is renewable. The certificates are called Renewable Energy Certificates (RECs) [RECS] and each represents the generation of 1MWh of renewable electricity. Buying RECs increases the demand for renewable energy, and the extra cost for the consumer should support the extra cost of establishing new renewable energy facilities. However, the main drawback of these certificates is that, in the short term, there will be no changes in the amount of fossil electricity produced. A customer may buy greener electricity with the effect that customers buying average electricity will receive less green electricity. In the longer term, the certificates may play an important role in lowering the overall GHG emissions from electricity production by generating an increased demand for renewable energy. Should an NREN invest as a partner in generation of electricity at a client site using renewable energy, this is a quick description of how such energy is accounted for in the whole power-generation system.

12.4.2 Investing in New, Renewable Electricity

An obvious solution to reducing GHG emission from data centres, etc. is to invest in one's own wind turbine, solar cells or similar initiatives. Investment can also happen through the energy supplier, who may donate part of the income to, for example, a renewable-energy investment fund. It sends a strong signal that you want to make a difference and one would intuitively believe that this would definitely bring more renewable energy onto the market. However, this should be seen in the context of the EU 2020 targets.

The EU has set a target that 20% of the energy consumption should be based on renewable energy in 2020. Each Member State has different targets, and all activities, no matter whether they are introduced by private initiatives or public projects, count.[2] Unfortunately, this means that many private investments in renewable-energy facilities cannot be considered additional. However, such investments may result in earlier and cheaper compliance with the targets, and future target setting may as a result become more ambitious.

12.4.3 Securing Greener Electricity Production outside the UN

The mechanisms of the Kyoto Protocol allow companies to reduce GHG emissions by investment in renewable energy projects in so-called Non-Annex 1 countries as defined in the Kyoto Protocol. The idea behind these Joint Implementation (JI) or Clean Development Mechanism (CDM) projects is to help developing countries secure natural resources and ecosystems and obtain cleaner production technologies or more renewable energy production. From a global perspective, these projects support the mechanism of reducing GHG emission where it is most feasible. At the same time, the projects assist parties included as part of Annex I countries in achieving compliance with their quantified emission limitation and reduction commitments.

Many organisations offer carbon credits resulting from such projects to companies, and the market is full of certification systems. In recent years, many projects have been criticised for not being sustainable or additional, so it is important to carefully select a collaborating organisation. The Ecological Council in Denmark recommends systems such as the Gold Standard (developed by WWF), Social Carbon (developed by the Brazilian NGO the Ecologica Institute) and Plan Vivo (developed by the Scottish charity Plan Vivo Foundation). Other systems may be equally good, but it is strongly recommended to take a close look at the potential solutions before choosing.

12.4.4 Carbon Trading and Cancellation of Emission Permits

A popular way of obtaining carbon neutrality for a product or a company is to buy emission permits and cancel them. It means that a certain amount of CO_2 will never be released to the environment. In theory, this is a direct measure to reduce GHG emissions within the ETS system. Nevertheless, the market is currently flooded with emission permits due to the significant reduction in productivity as a result of the global financial crisis, and companies are allowed to save the permits for use until 2020.

12.5 Green Power Purchasing: Recommendations

Buying green electricity is not as simple as it sounds. Political targets and politically controlled systems are set up, because GHG emission reductions and a shift to renewable energy cannot happen by private initiatives alone. Some of the systems, however, appear to make many of the private, national initiatives more or less futile. But the world is still learning, and there is definitely a hope that future political initiatives and adjustments of current legislation and systems will make it easier to contribute to the fight against climate change.

[2] Unless national governments have decided that private initiatives are not included, which is allowed according to the EU directive on renewable energy.

For the time being, it is not possible to ensure that the electricity you buy is indeed additional green electricity, but investing in new renewable-energy facilities within the ETS system or carbon-reduction projects outside the UN will directly or indirectly contribute to reduction of GHG emissions on a global scale. Within a short period of time, cancelling emission allowances may also become attractive again. Tariffs are also being considered to maximise the use of Renewable Energy sources such as wind turbines, which offer a good economic return to energy generators while not taking their maximum capacity to offset other issues with the grid connection systems.

12.6 Recommendations

- **Purchase electricity / energy supplies from certified renewable-energy suppliers** or those companies who actively promote such energy generation. Encourage clients with large campuses to actively pursue renewable-energy generation projects.
- **Plan for network outages or disruptions** should your energy suppliers aggressively target and integrate large proportions of renewable energy supply into their networks.
- **If applying for Carbon Offset, ensure such solutions are permanent**, not double counted, and have a valid baseline determination.
- **Highlight any decisions** taken in your NREN's GHG audit programme for selection of power source or contracts engaged in for Carbon Trading.

13 Disseminating Green ICT in the Higher Education Community

13.1 The Role of NRENs

Currently, the NRENs' responsibility lies in providing networking connectivity and supporting the ICT services provided over the NREN's network, and ends more or less at the campus border. Both groups, the NREN and their client, are proactive in environment awareness activities. SURFnet have given examples of areas where they work with their clients on joint activities (see Sections 5.2.3 and 13.2) and have highlighted achievements. HEAnet have identified that a significant number of their clients are engaged in a program monitored by another national body, An Taisce, who are committed to conserving and protecting Ireland's heritage and environment. Greater synergy will be gained from actively partnering with this group and their promotional, audit and award program, which is integrated with other equivalent international programs. Both approaches are good examples of NRENs interacting with their client community.

First, the NRENs' equipment initially appears to be part of the carbon footprint of HE institutions, but the current audit philosophy followed in Section 3 implies that the NRENs take account of their own footprints to provide these connectivity services. However, the HE community needs an equivalent set of equipment to interface with the NREN equipment, so the NREN is still conscious of, and should feel some responsibility for, helping the HE institution make its own operations as sustainable as possible. Initiatives, such as using virtual customer premises equipment (CPE) with multiple functionality, such as that proposed by Mantychore, start to offer opportunities to reduce the total hardware footprint with adaptable solutions, which still preserve the demarcation of functionality.

Second, NRENs are uniquely positioned to provide centralised ICT services, ranging from mail filtering and videoconferencing, to high-performance computing. Even though these services may increase the absolute energy usage of an NREN, they tend to save this extra consumption many times over because of scale. Centralising means, among other things, that it is not necessary for individual institutions to set up their own dedicated servers (redundantly!), which probably includes an overcapacity provision as well. In addition, NRENs could place extra focus on those services, again such as videoconferencing, which have additional benefits for the environment as well, in this case, reduced travelling. Translating these benefits to actual numbers may be complicated, but can be done (see Section 4).

NREN clients are already taking advantage of these centralised services such as hosting web application servers, media hosting, Virtual Learning Environment (VLE) hosting and software mirroring.

Furthermore, NRENs could provide a forum where members of the HE community could meet and share their experiences in greening their institution with the use of ICT. Off-campus meetings with peers interested in a particular topic can usually be very productive, especially with the well-informed, neutral support of both organisations, which could also provide resources to model new approaches.

Some examples of such initiatives are discussed in the next few pages.

13.2 Using Green ICT in the HE Community

SURFnet and the NL Agency commissioned a study that reported that Dutch HE institutions could reduce more than 40% of the amount of energy consumed by the ICT equipment at their workstations and data centres [SURFNET_2]. This was the main conclusion of an ICT survey carried out at nine higher education institutions involved in the experiment, which include a mix of both research universities and "universities of applied sciences".

From the survey, 22% of the total electricity consumption is accounted for by ICT. Workstation equipment represented more than 13% of total consumption and data centres 9%. While ICT electricity consumption will continue to increase, HE institutions can still make large efficiency gains with sometimes relatively easy steps. A combined saving of 44% is possible on total energy consumption of workstations and data centres, representing annual savings of at least EUR100, 000 per institution (given the survey data of the participating institutions).

13.3 ICT's Role in Reducing Carbon Emissions in the HE Community

In the Netherlands, institutions reported that roughly 60% of their total carbon footprint can be linked to mobility, mainly the commuting of students and personnel. The use of smart ICT solutions can make a big impact on mobility issues. Examples include using web lectures to (partially) replace physical classes, smart scheduling of courses to minimise travelling for teachers *and* students (instead of for teachers only), and making highly specific technical equipment remotely available for scientists. Some of these solutions can be provided by NRENs, such as videoconference services. Chapter 8 shows that these services can make a difference in terms of reducing carbon footprints.

13.4 Challenges and Motivation for ICT Departments

For many ICT departments of institutions, energy efficiency is not an issue, because they do not pay the electricity bill; this is usually managed by a centralised facilities department or real-estate office. As deployers of technology, ICT departments just want the cheapest and fastest equipment, without taking into account the energy the equipment uses while turned on. The biggest challenge, therefore, is to make ICT departments responsible for their energy needs. Make them pay for increased energy usage, but reward them when they become more energy efficient. If they then make use of Total Cost of Ownership (TCO) analyses, they should come up with more energy-efficient ICT solutions. The easiest way to do this is to make use of internal billing: take the last full year as a base year and assign a budget equal to the electricity expenses of ICT to the ICT department. This makes sure that in a situation where nothing changes physically, nothing changes financially (i.e. if the electricity expenses are the same as in the base year, it will not cost the ICT department extra) while creating room to make a profit where the real funds must be transferred together with the “paper” budget, i.e. responsibility for this to work with energy efficient solutions, which the department can spend however they want.

13.5 How to Measure ICT Energy Use

Institutes for higher education can compare their energy efficiency with:

- Their own energy efficiency in the past (e.g. in a previous year, month, day).
- Their own energy efficiency before a particular energy efficiency measure was applied.
- A desired energy efficiency, in order to track progress towards a target.
- Energy efficiency of other (similar) institutes in higher education.

(Adapted from [SURFNET]).

13.6 Best Practices for the Higher Education Community

Educational institutions have the clear responsibility of training people with specific sustainable (or green) ICT competences. Businesses, government bodies, and civil-society organisations are increasingly looking for graduates with such knowledge and skills in the field of sustainable development. Sustainable development, therefore, needs to be given a fundamental place in the curriculum at education institutions and is being incorporated into syllabi at such institutions educating the next generation on how to create new and innovative solutions for a low-carbon society.

13.6.1 Data Centres

As previously mentioned (in Section 13.2 above and in more detail in Section 5.2.3), the SURFnet / NL Agency survey investigated reductions in power consumption in data centres at HE institutions. In 2010, the average electricity efficiency was very low, at only 50%; the standard that environmental services impose for newly built data centres is 71%. The low electricity efficiency at the institutions was mainly due to the low temperature in the data centres. Two further reasons were:

- Low average floor usage. The institutions have consolidated a large number of servers in recent years. That trend – which is a positive one – means that the rooms within the data centres are too large for the quantity of equipment installed there. This in turn means that the energy consumption of the air-conditioning is not ideal.

- Long economic life of ICT hardware. A write-off period of 4 to 5 years is (too) long; older equipment is less energy-efficient than new equipment. Server equipment especially, for which the energy usage makes up a large proportion of the cost compared to procurement (sometimes a ratio of 9:1), could easily be replaced every two years and still reduce costs as well as carbon emissions. Redundant servers can be recycled through WEEE-supported recycling programmes [WEEE], or can be donated to charitable organisations that can benefit from using such hardware.

13.6.2 Workstation Equipment

Many institutions need to adopt use of energy management for their workstations (for example, automatically switching PCs to standby mode when they are not being used). They usually do not have any “switch-off” policy either. PCs at institutions that do have a switch-off policy run for an average of 2000 hours per year. In the case of PCs that are only switched off at weekends, the average is 6000 hours per year, which is very high .The University of Liverpool developed its own PC power-management tool, called PowerDown (see [POWERDOWN]). This has been made available free online. The University wanted to achieve significant power savings on computers that have been idle for a certain length of time, without danger of loss of data, and without an unacceptable number of error messages or other unfavourable user interaction. After studying the available options, they found that they could develop a simple tool that addressed their wishes without paying for licences.

After the tool was installed, the University saw that in an average month, 1600–1900 student wake-up PCs and 2000–2500 staff PCs experienced shutdowns initiated by PowerDown. Even with only this many computers participating, they save over 1,000,000 hours per month. A lot of the unnecessary uptime comes from the student PCs. The typical student PC is in a building that is locked except during business hours, yet the PCs were previously left running 24 hours a day. Out of a 168-hour week, only a maximum of 40 hours were useful, leaving 128 hours of unnecessary uptime. That’s more than 200,000 hours per week, or more than 800,000 hours per month, and before including any staff PCs. This could reduce CO_2 emission by as much as 600 tons at this particular site for a whole year.

13.6.3 Cloud Computing

Education institutions are turning to cloud computing to reduce their infrastructure expenditure as well as to offer new resources for data storage, eLearning services and other applications such as email. In principle, cloud computing offers an increase in the scale of the environment, leading to an increase in energy efficiency. Of course, cloud computing also offers other benefits to these institutions, such as flexibility of use (on demand), which means that more and more institutions are moving their ICT services off premises and into the cloud.

The energy consumption of a cloud depends mainly on the efficiency – for example, on whether all the ICT equipment is fully utilised. An unused server could be turned off or phased out. Cloud computing offers the possibility of utilising dynamic ICT resources, i.e. it enables resources to be turned on and off as and when necessary. It also enables optimally utilising the ICT resources that are available. Often the use of cloud computing alone implies improved efficiency. The effectiveness of the energy consumed – effectiveness being the proportion of the energy used for ICT and how much is needed for cooling systems and other support equipment – is also relevant. Another factor that needs to be taken into account concerns the emissions resulting from the energy consumption.

Specifically for cloud computing, location also plays a role. A cloud is characterised by storage and processing taking place at a certain distance from the end user. Therefore, the energy that networks consume in order to transport the data must also be taken into account. Cloud computing also enables storage and processing to take place at a location where energy – i.e. locally generated energy – is cheapest (including the transport costs) and greenest.

An institution that intends to make use of "green clouds" will likely assess cloud providers by means of frameworks such as the CO_2 Performance Ladder [CO2PerfLadder] (Table 13.1). For cloud providers, some of the main considerations for providing "green clouds" will be promoting efficient use and implementing effective capacity management. For cloud customers, energy efficiency, energy effectiveness, and emissions by the services utilised should be considered in internal (TCO) calculations.

Since HE institutions can take the role of both provider and customer, both inside and outside the campus, the imminent move to cloud services (private, public or federated) provides an opportunity to take greenness into consideration with little extra cost.

Level	Description
5	The company has a CO_2 emissions inventory of its most important suppliers. The company can demonstrate that the objectives for levels 3 and 4 have been attained. The company is publicly committed to a government or NGO CO_2 reduction programme, and is able to demonstrate that it is making a relevant contribution to an innovative CO_2 reduction project.
4	The company has identified its chain emissions in outline terms, and chain analyses have been carried out for two relevant chains. The company has quantitative objectives for its chain emissions. The company is in dialogue with relevant parties (government bodies and social organisations) and can demonstrate its role as the instigator of sector and chain initiatives in the field of CO_2 reductions.
3	The company has an official CO_2 emissions inventory that has been drawn up in accordance with the ISO (GHG) standard, and which has been verified by an independent organisation. The company has quantitative objectives for its own (scope 1 and 2) CO_2 emissions. It communicates – internally and externally – in relation to its CO_2 footprint on a structural basis and actively participates in at least one sector and chain-based CO_2 reduction initiative.
2	The company has quantified its energy flows and formulated a qualitative objective for saving energy and using renewable energy. Internally, the company communicates its energy policy on a structural basis and takes a passive role in at least one sector and chain-based CO_2 reduction initiative.
1	The company has identified its energy flows in qualitative terms and has a list of potential options for saving energy and using renewable energy. Internally, the company communicates its policy in relation to energy-saving and renewable energy on an ad hoc basis and is aware of sector and chain-based CO_2 reduction initiatives.

Table 13.1: The CO_2 Performance Ladder [CO2PerfLadder]

13.7 Case Study: SURFnet and the Dutch Community

After completing the previously mentioned survey in 2010, SURFnet hosted a symposium to present the results, focusing on topics that were of most interest to the HE community [SURFNET_2]. One hundred participants attended the event, all eager to learn about and do more with green ICT, which encouraged SURFnet to create a Special Interest Group (SIG) on green ICT and sustainability, marking the start of the green ICT HE community in the Netherlands.

SURFnet then started a LinkedIn group [LINKEDIN] to provide a place where members of the SIG could meet and discuss various topics, to stimulate sharing of knowledge and experiences. Two years later, in 2012, the group had grown to well over 300 members, The role of SURFnet as an NREN has therefore been to facilitate and catalyse this process by organising meetings and producing documents such as best-practice guides and studies on specific questions from the community to help convince others to invest in Green ICT solutions. For example, in one publication SURFnet showed that the average institution could easily save tens of thousands of Euros by implementing PC power-management software [SURFSITES_1]. (See also SURFSITES_3 and SURFSITES_4].)

While SURFnet does invest effort in generating knowledge, the end goal is to create an active community that produces such documents itself. From experience, it takes a couple of years to reach this kind of maturity in a community. Already, members are gathering around certain topics and starting to share experiences themselves. Recently they asked for a wiki environment to help further this process. Topics that gather most interest are: green data centres, PC power management, sustainable ICT in curricula, sustainable ICT procurement, and green cloud computing.

Aside from creating a community environment, SURFnet also provides funding for innovative sustainability projects [SURFSITES_1]. These projects all aim to reduce carbon emissions in some way, be it direct or indirect, and the results are shared under an open licence to stimulate spreading knowledge about the topics. This funding arrangement has run for two years now and led to quite an interesting and successful array of projects, as shown in Table 13.2:

2011	2012
Sustainable ICT education	Sustainable software
Paper reduction (dematerialisation)	Sharing green ICT practices
Digital mobility in education	Virtual teaching
Sustainability in e-Science	Smart data storage
Visualisation of personal energy consumption	Using gamification for awareness

Table 13.2: SURFnet interaction projects with HE

While not everything has worked as well as hoped for, the overall result is that there is an increasing awareness in the Dutch HE community on green ICT and sustainability in general. SURFnet is of course happy to share the lessons learned with other NRENs who want to set up similar communities.

13.8 Case Study: HEAnet's Liaison with the Green Campus Programme

HEAnet also started to investigate some outreach activity with their university and higher education institute clients and quickly found that many of them (35%) were actively involved in the programme called "Green Campus", run by An Taisce. The relationship has grown stronger over the past year and HEAnet will seek Green Campus recognition status in 2013/2014; they are also planning a number of joint workshops for both groups' mutual clients.

Five institutions in Ireland have achieved full certification and been awarded a Green Campus Flag. One of these clients, University College Cork, are now registered as an ISO50001 campus and have made savings of over EUR 1 million because of initiatives taken by students and staff.

The Green Campus initiative is based on the success of the Green Schools and International Eco-Schools programmes. It has been piloted and amended for implementation in post-secondary and tertiary-level educational institutions. The Green Campus programme encourages a partnership approach to environmental management in third-level institutions, and aims to ensure that members of a campus community can engage in a meaningful way to enhance sustainability on their campus. This is an enhancement of traditional environmental management systems, which tend to be management driven. The Green Campus programme identifies the campus as a community and places significant importance on the inclusion of all sectors of the campus community in its environmental management and enhancement.

It must be noted that the Green Campus programme does not reward specific environmental projects or implementation of a new technology. Instead, it rewards long-term commitment to continuous improvement from the campus community in question. In order for a campus to qualify for the Green Campus award, a committee representative of the campus community must be formed. This committee must then register its intent to implement the Green Campus programme with the Environmental Education Unit at An Taisce. Committees must be registered for a minimum of one academic year and have successfully implemented all seven steps of the programme before applying for the award.

The seven steps of the programme are:

1. Establishing a Green Campus committee incorporating student and staff representatives.
2. Undertaking an environmental review.
3. Implementing an action plan.
4. Monitoring and evaluating actions carried out.
5. Linking the programme to learning on campus.
6. Informing and involving the campus and wider community.

7. Developing a Green Charter.

These seven steps focus on areas such as

- Litter and waste prevention.
- Reduction / management.
- Energy conservation/reduction.
- Water.
- Travel.
- Biodiversity.
- Procurement and environmental risk.

As stated earlier (in Section 2), the Environmental Education Unit within the An Taisce organisation is the national operator in Ireland for all international environmental education programmes of the Foundation for Environmental Education (FEE) (see [FEE]). The An Taisce group have welcomed HEAnet's involvement as they see that IT can be one of the most important enablers for success and they as a group now have access to a source of technical knowledge that is independent of local campuses and can provide visibility and advice that will be readily accepted by all parties.

FEE is a non-governmental, non-profit organisation promoting sustainable development through environmental education. Established in 1981, FEE was originally a European initiative, primarily active in environmental education through internal meetings, external seminars and conferences, and in a number of publications. Today FEE operates globally and is mainly active through its five environmental education programmes: Blue Flag, Eco-Schools, Young Reporters for the Environment, Learning about Forests, and Green Key. As this is an international programme, which is being readily accepted by the NREN clients, any support given to such a programme can be amplified by introducing more competitiveness between organisations that are part of FEE.

FEE are now starting to investigate opportunities to work with some of the other NRENs who are part of the GÉANT Environmental team and contacts will be established in some of these countries to investigate what opportunities are available to work towards the common goal of more sustainable campuses in the education arena.

13.9 Recommendations

Sustainability is concerned with looking at the whole system and optimising results at the systemic level. Only then can one see the possibility of NRENs providing excellent green solutions that may increase the energy consumption of NRENs but reduce it in tenfold at their institutions. NRENs should therefore not optimise locally and for themselves only but try to look at the bigger picture and the role they play. Because of their nature and the collaborative environment in which they work, NRENs, with their community, have excellent opportunities to do this and to set the example for the rest of society to follow.

Specific recommendations for disseminating green ICT in the HE community include:

- Plan for **dissemination activity with clients** in all areas of experience.
- Be open to **showing best practices and case studies** in all areas of experience.
- **Align with national or international programmes** that supply client organisations.
- **Highlight achievements** in any PR publications and **develop relationships** with other programme sponsors and local client teams.

Note that many environmental awareness programmes may have a broader focus than those practised at NRENs, so there is an opportunity to gain knowledge and promote the networking competency that NRENs have as a core skill to maximise the benefits from such environmental programmes, bringing savings to the client institutions and also reducing GHG emissions.

14 Conclusions

In conclusion, we look back at a phased programme of engagement with the environmental aspects of Research and Education networking by the GN3 project and specifically NA3 Task 5. In Year 1 we began with a benchmark measurement or audit of our carbon footprint. The ISO 14064 standard was adopted for this purpose, which provided a level of quality assurance, as well as the ability to assess, compare and reduce levels of greenhouse gas emission. Most NRENs who are part of the Environmental team have either completed three audits or are in the final stages of completing their third audit.

The findings are that energy usage is still growing, but in a more controlled fashion, with greater amounts of traffic flowing in the network due to the increase in demand for outsourced services. Virtualisation has made a big impact on the amount of energy used at data centres, but NRENs' clients have demanded that more resources are hosted off campus and the NRENs themselves have picked up a large part of these hosting needs.

The audit process stimulated ideas for GHG reduction, and also for smart use of the network and its layered services. This helped to drive the second phase of the programme, in which the partners developed case studies to show what NRENs could do to reduce GHG emissions in the extended communities they serve. Where possible, we have applied metrics to any savings made, and compared these with recognised projections, such as those of the SMART 2020 report.

Throughout the four years of NA3 Task 5, the team have been keen to keep in touch with the wider NREN community, and indeed, with the commercial ICT sector. Environmental activities are clearly not confined to the members of the NA3 Task 5 team. Significant initiatives are under way in other NRENs and in their client institutions, and learning from these is part of our remit. The team are trying to leverage other group initiatives to maximise the amount to which we can outreach to our community.

As we finish the fourth year of the GN3 project, the outlook is that much remains to be done in raising awareness and in helping each other in the common task of reducing the likelihood of increased GHG emissions. There is a real need to mainstream this project activity, however, and to make GÉANT as sustainable as the high-end network services for our users. The team have suggested that we create a GÉANT environmental policy, and lobby other NRENs to use this as a starting point (NRENs may also wish to create their own customised versions). Further key points arising from the team's work are as follows:

- The Environmental team has to decide whether to focus on energy reduction, which saves money but does little for the environment, or target other ways to reduce GHG emissions.

- If the reduction of GHG emissions becomes the primary purpose of this Task, the team may also feel daunted by the realisation that many green IT efforts could be meaningless or counter-productive against the enormous scale of the ongoing challenges. We have to find different ways to adapt our operational environment to the new challenges that have to be faced in the future, which may require greater sharing of resources across national boundaries, and use of new technologies to minimise the amount of technology deployed or using it in a more productive manner, to reduce the carbon footprint of our networks.
- The Environmental team proposes to hold follow-on workshops at both NREN national conferences and GÉANT group symposiums, and to participate in large conferences that are associated with any of the topics of energy conservation and carbon emissions. The first event chosen for this activity is TERENA 2013 where the Environmental team will hold a workshop to motivate NRENs to develop a common environment policy.

Just as GÉANT and its members have developed world-class e-infrastructure for research and education, so too can we show the way in harnessing smart networking to combat climate change.

Appendix A Terminology

Term	Definition
Additionality	The principle that only those projects that would not have happened anyway should be counted for carbon credits. [ISOHelp]
Dematerialisation	The decline over time in the weight of materials used in industrial end products or in the “embedded energy” of the products. More broadly, dematerialisation refers to the absolute or relative reduction in the quantity of materials required to serve economic functions.
Direct emissions	GHG emissions caused by the combustion of fuels or direct emissions of GHGs.
Energy-aware traffic engineering	Takes traditional network traffic engineering one step further by considering and embedding into its objectives the energy consumption of a network in order to achieve the same performance as the energy-oblivious approaches, but at a lower overall energy cost.
Green electricity	Generation of electricity from renewable sources, with minimal impact on the environment.
Greenhouse Gases (GHGs)	Gases that contribute to climate change. Those named in the Kyoto Protocol include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Not all global warming causing molecules are gases (e.g. soot and other particulates). Usually these are referred to as warming agents. For the sake of simplicity, we use the term greenhouse gases (GHGs) to refer to all warming agents. [ISOHelp] The GN3 GHG audits divide the emissions into 4 classes: office, data centre, backbone and transportation.
Green Information Communication Technology (ICT)	Green ICT is the study and practice of designing, manufacturing, using and disposing of computers, servers and associated subsystems-such as monitors, printers, storage devices and networking and communications systems efficiently and effectively, with minimal or no impact on the environment. Green ICT includes the dimensions of environmental sustainability, the economics of energy efficiency and the total cost of ownership, which includes the cost of disposal and recycling. Green ICT benefits the environment by improving energy efficiency, lowering greenhouse gas emissions, using less harmful materials and encouraging reuse and recycling. Green design, Green manufacturing, Green use, Green disposal are complementary paths of green ICT. Only by focusing on these four fronts can we achieve total environmental sustainability from the IT side and make IT greener

Term	Definition
	throughout its entire lifecycle. [CEPIS]
Green Network Management System (NMS)	A Network Management System that helps reduce energy consumption and minimise impact on the environment.
Green Public Purchasing (GPP)	"a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured." [COM40]
Indirect emissions	GHG emissions associated with the generation of imported electricity, heat or steam.
Power Usage Efficiency (PUE)	A method for measuring and reporting the energy efficiency of a data centre. As a general rule, the PUE is determined by dividing the amount of power entering a data centre by the power used to run the computer infrastructure. PUE is therefore expressed as a ratio, with overall efficiency improving as the quotient decreases toward 1. PUE = Total Facility Power / IT Equipment Power. [GREENGRID_2]
Virtualisation	The technology that combines or divides resources to present one or many operating environments.

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Glossary

AC	Alternating Current
AD	Active Directory
ASF	Apache Software Foundation
BMS	Building Management System
BoD	Bandwidth on Demand
BSS	Business Support System
BYOD	Bring Your Own Device
CDM	Clean Development Mechanism
CEPIS	Council of European Professional Informatics Societies
CO_2	Carbon Dioxide
CPE	Customer Premises Equipment
DC	Direct Current
DCiE	Data Center infrastructure Efficiency
DCME	Data Centre Measure of Efficiency
DWDM	Dense Wavelength-Division Multiplexing
ECONET	low Energy COnsumption NETworks
EMAS	EU Management and Audit Scheme
ENT	Ear, Nose and Throat
EPEAT	Electronic Product Environmental Assessment Tool
EPN	Energy Proportional Networking
ETS	Emissions Trading Scheme
EU	European Union
FEE	Federation of Environmental Education
FP7	European Union 7th Framework Programme for Research and Technological Development
GeSI	Global e-Sustainability Initiative
GHG	Greenhouse Gas
GICOMP	Green IT Control and Management Platform
GN3	The GN3 Project (Third GÉANT project year)
GPP	Green Public Purchasing
GRE	Generic Routing Encapsulation
GSN	GreenStar Network
GUI	Graphical User Interface
HD	High Definition
HE	Higher Education
HPCC	High Performance Computing Centre

HVAC	Heating, Ventilation, and Air Conditioning
HVDC	High Voltage DC
HVR	Hardware-Isolated Virtual Router
IaaS	Infrastructure as a Service
ICT	Information Communication Technology
I/O	Input/Output
IP	Internet Protocol
IPP	Integrated Product Policy
ISDN	Integrated Services Digital Network
ISO	International Standards Organisation
ISP	Internet Service Provider
JI	Joint Implementation
KPI	Key Performance Indicator
L*n*	Layer *n*
LAN	Local Area Network
L-GPL	GNU Lesser General Public Licence
LION	Live International Otolaryngology Network Project
LTRS	LION Technical Requirements Standard
MAN	Metropolitan Area Network
MCU	Multi-Conferencing Unit
MPLS	Multi-Protocol Label Switching
MRTG	Multi Router Traffic Grapher
MS	Member State
NA3	GN3 Networking Activity 3 Status and Trends
NA3 T5	NA3 Task 5 Study of Environmental Impact
NaaS	Network as a Service
NAP	National Action Plan
NDLR	National Digital Learning Repository
NGO	Non-Government Organisation
NMS	Network Management System
NOC	Network Operations Centre
NREN	National Research and Education Network
OS	Operating System
OSPF	Open Shortest Path First
P	Provider
PDU	Power Distribution Unit
PE	Provider Edge
PoP	Point of Presence
PSNC	Poznan Supercomputing and Networking Centre
PUE	Power Usage Efficiency
PV	Photovoltaic
QoS	Quality of Service
REC	Renewable Energy Certificate
ROADM	Reconfigurable Optical Add-Drop Multiplexer
ROI	Return on Investment
SIG	Special Interest Group

SPEC	Standard Performance Evaluation Corporation
SVR	Software-Isolated Virtual Router
TCD	Trinity College Dublin
TCO	Total Cost of Ownership
TE	Traffic Engineering
TNC2013	TERENA Networking Conference 2013
UPS	Uninterruptible Power Supply
URL	Uniform Resource Locator
VC	Videoconference
VDI	Virtual Desktop Interface
VLE	Virtual Learning Environment
VoIP	Voice over IP
WDM	Wavelength Division Multiplexing
WEEE	Waste Electronic and Electrical Equipment
WWF	World Wide Fund for Nature