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Deliverable DN3.5.3 Study of Environmental Impact: ICT Best Current Practice

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Abstract

This deliverable is the final document in a series of three, which 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: power usage efficiency, virtualisation, energy-aware traffic engineering, videoconferencing, distance working, green public purchasing, and purchasing green electricity. 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 describes a wide 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 in particular.

It provides an update to the previous deliverable ("DN3.5.2: 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 also provided for each topic, which are relevant to the GN3 project, the NREN community, their users, and the ICT sector. This deliverable also encourages NRENs to actively engage with Higher Education 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. During the last few years, however, there has been a noticeable increase in environmental awareness, and NA3 T5 formed a team to increase awareness and develop best practices. This group quickly became known as the "Green GÉANT" team, which is a good measure 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 six NRENs.

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, which has integrated eco power-saving technologies and will implement new power monitoring and support sleeping mode when not in use, will be essential to reduce the total lifecycle costs of such a deployment. Service demand for bandwidth is also not growing as rapidly as once anticipated, which reduces the pressure for frequent updating of networking equipment.
5. Videoconferencing remains a powerful tool for sharing information and cutting travel time and emissions. Although new advances in demonstrating 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 require that stakeholders at all levels are aware of the possibilities provided by high-performance data centres and networks.

7. Working together is still one of the most powerful ways to combat greenhouse gas (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. NRENs are potentially well placed to take a lead in industry initiatives to promote sustainable policies.

9. The third 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 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* found that, although ICT products and services contribute only 2% of global GHG emissions, a future-oriented ICT industry can respond quickly to the challenge of global warming. See [SMART2020]. This industry has a critical role to play, in designing and deploying the solutions needed to create a low-carbon society. The report was published in June 2008, by the Climate Group, on behalf of the Global e-Sustainability Initiative (GeSI), and its first major exposure to telecommunications operators was at the ITU's international symposium, "ICT and Climate Change", held in London on 17–18 June 2008.

Most groups refer to this 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. See [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.

Three 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.

This document has evolved from the previous deliverable published in May 2011, *DN3.5.2 Study of Environmental Impact*. 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. The GÉANT team has undergone some staff transition, and its focus during year four of the project is to improve communication with other teams who are influencing new work practices, such as the TERENA Task Force TF-MSP [TF-MSP], whose role is to promote collaboration between research and education networking organisations in Europe in the area of service portfolio management. The Environmental Team is also seeking to setup a Green ICT & Sustainability Task Force and is in the process of submitting such a proposal to TERENA.

The following areas have been chosen for inclusion in this 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) Measuring and monitoring GHG emissions is an essential step to actively start to influence how work practices can be changed to reduce these harmful emissions. Knowing where energy is being consumed in normal daily activities, and how this energy usage translates into these GHG emissions, helps to prioritise areas where initiative to implement policies to reduce resource usage can be demonstrated. Using a standard template as proposed by the GÉANT Environmental team allows NRENs to benchmark their activities against each other and knowing what energy is used to sustain these business activities focus team efforts on areas where then can strive to make improvements.

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

- **Power Usage Efficiency (PUE)** (Section 5) is a well-known, key factor in all networks and data centres, both from 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 which merits attention. Data centres created to house the explosion of virtual information currently consume 1.5% to 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 or 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. 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. Demand for cloud type services have 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 the NREN to make reductions.

- **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) is seen by many stakeholders as an important way of reducing environmental impacts and climate change. With high-quality equipment, videoconferencing can replace face-to-face meetings that would otherwise require short or long participant travel, often by high-energy-demanding transport modes, such as airplanes. This section gives selected examples of the partners' conferencing systems, and uses information on usage patterns to give a very crude estimate of the environmental savings that can be achieved by NRENs using videoconferences themselves and promoting this technology solution to their clients.

- **Distance working** (Section 9) is made possible through ICT solutions, thereby avoiding commuting to work and home again. Transportation accounts for a large share of society's greenhouse gas (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 mutual workplace.

- **Green (Public) Purchasing (GPP)** of IT equipment (Section 10) 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 general power from renewable energy resources (Section 11), is seen by many companies and institutions as a good way to decrease the environmental impact of its activities. In practice, however, determining which types of green power actually have a real 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 who were the third-party independent audit company and who provided guidance in the compilation of the early DN3.5.2 report.

- **Disseminating Green ICT** (Section 12). At present, the NRENs' responsibility lies in providing networking connectivity and supporting the ICT services provided over the NREN network and ends more or less at the campus border. Both NRENs and their supported users are proactive in environment awareness activities. SURFnet show examples where they work with their clients on joint activities in areas described in the report and highlight achievements. HEAnet identified that a significant number of their clients are engaged in a program monitored by another national body, An

Taisce, which is committed to conserving and protecting Ireland's heritage and environment. More synergy will be gained from actively partnering with An Taisce 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 promoting good environmental practices and sustainable resource reduction programs.

1.1 Recommendations

The report does not offer firm conclusions. A few basic recommendations can, however, be extracted from the work of the Green GÉANT partners:

Producing a written environmental policy is a practical first step towards raising environmental awareness and striving for a reduction in environmental impacts. These statements are all usually quite general and they focus the minds of staff to engage in analysis and measuring of their contribution to usage of precious resources. A generic environment policy for a particular area of business, such as that of an NREN, could be applied.

To improve any situation one must first **know its current status and then plan to go forward from that point with available metrics** to guide progress. Establishing a dedicated management system for monitoring energy usage at PoPs and data centres, and using it to identify problem areas and potential solutions is recommended as an operational second step. NRENs can take steps to lead to the development of such a solution, which can focus on activities, which are easy to identify and measure. The level of ambition does not need to be very high; 'low-hanging fruit' can often give significant improvements at an early stage prior to the implementation of any management system. Measuring power usage per rack or socket grouping indicates which groups or services consume what levels of power. Full control of all elements may require a full retrofit of all Power Distribution Units (PDU), and selection of an integrated solution and will also cause service disruption. Equipment with proven self-monitoring capability is not yet available in the marketplace, and is also reliant on technology refresh/replacement programs within the NRENs.

There are no formal requirements to making environmental improvements. **If you get a good idea, try to apply it as soon as possible**. Having a formal system, such as a measurement system, may be of great help, but it is also possible to achieve large benefits without such a system. The report provides a number of examples of ideas and programs which have been carried out by the GÉANT Environmental Team, some of which are readily implemented while others require efforts at a monitoring and control system level. More inspiration can be found in the Danish "Green IT guidelines for public authorities" [DANISHGREEN] and in the pamphlet "Green IT for your company" [GREENIT], which contains a wide range of proposals and inspiring case stories.

Production of IT equipment is demanding for the environment, therefore, ensuring a long-lifespan of the equipment is crucial. With NRENs' service demand for Internet bandwidth not increasing as fast as previously anticipated, there is less pressure to update networking equipment in the same aggressive timescales. Ensuring that purchased equipment fulfils your needs for as long as possible is a key challenge. Lifecycle costs of running and maintaining the equipment are also vital considerations during the initial purchase evaluation.

Users need to understand the potential benefits of videoconferences. Having high-quality equipment at hand does not help the environment if it is not used – rather the opposite, as the manufacturing and delivery of the equipment to the site produced carbon emissions. Access to lower-quality solutions can help raise awareness of the potential for these solutions, and can be complimentary. These solutions are usually PC-based and are widely accessible.

The savings envisioned in the *SMART2020* report require that **stakeholders at all levels are aware of the possibilities made available by having access to high-performance data centres and networks.** By identifying and quantifying the environmental benefits, NRENs can recruit support from clients and end-users. As usage of these services increases, NRENs must have the capability to quantify how the services are being used, how much information is being shared or transferred and determining the energy consumed and other costs associated with providing such services.

NRENs, with their open collaborative approach, adaptive mind sets and policies, offer **great scope for sharing information, as well as sharing the results of collective actions and measuring deterministic values in trials and test cases for innovation. Self-improvement workshops can stimulate and support research programs within their own and their user-supported communities**. The concerted action on the network audits of GHG emissions showed what could be achieved by working together and sharing resources such as the ISO14064 standard, and the carbon accounting tool developed by UNI-C. Measuring power usage of the technologies being deployed and working out new usage practices stimulates and influences the industries which provide these solutions. TERENA provides a forum for NRENs and industry, which has been used to support concerted efforts in delivering technical services. In the same way, the environmental objectives of members could be better achieved by sharing expertise and resources.

NRENs are well placed to take a lead in industry initiatives to promote sustainable policies. In Section 12, we also show how NRENs can support their client community by promoting initiatives on campus, or with co-operating bodies, such as An Taisce in Ireland or with partners, to achieve environmental best practices. With due regard to their neutrality and not-for-profit character, NRENs can work with ICT partners in reducing emissions and in promoting the beneficial uses of network technology. Where possible and practical, **NRENs should collaborate with industry and with government to tackle problems on a global scale**.

1.2 Links to GHG Accounts

The team has established a GHG audit mechanism to assess the climate performance of an NREN, in terms of CO_2 emissions, and has produced a design template that is adaptable enough to fit most areas of the current NREN business. Six of the Green GÉANT partners have currently made such an audit according to the methodology of ISO 14064-1, which defines a standard at the organisation level for quantification and reporting of GHG emissions and removals. This is in-line with the objectives of the Environmental Team, whereby each member has agreed to seek independent validation of their own network's carbon audits and they have had the results verified by an independent third party in order to ensure high-quality, uniform results. The GHG accounts are available online. See [GHGACCT].

In ICT, resilience is created by redundancy, with multiple, diverse systems providing back up should one system fail. Efficiency concerns can, however, reduce the degree of diversity in the system, which declines closer to the end user; it is difficult to assess the diversity of an entire system. End users are demanding greater visibility to both the diversity and resilience in the networks to which they are connecting because they rely on the network for outsourced services. If network connectivity is lost, sometimes thousands of users can be affected and become unproductive. In the strict regulatory sense, different aspects of the infrastructure need to work together on questions of resilience and set the appropriate standards required to maintain dependable systems that can be setup in an eco-friendly manner.

In emergencies, there is frequently excess demand on communications, particularly on mobile networks. There have already been efforts to deal with this issue, with priority given to text messages, to facilitate communications in high-demand periods. Climatic events can place extra demand on services provided by the network, which has to tolerate disruptions from such demand as part of its resilient layout.

So as ICT users would benefit from an early warning system to highlight the potential of catastrophic weather events, and weather prediction in general, there is an opportunity for ICT networks to provide such information. Information relating to climate change could also be included. Such provisions will have an impact on available network capacity, however, which is why NRENs may be slow when considering network modifications, ways to influence client usage or alterations to the network architecture currently deployed. In future, weather conditions could dictate changes in the way energy is supplied to the power grids, for example, how supply frequency increases as the proportion of wind generated increases.

Research efforts to determine the effect of this type of change are under way in Future Internet projects, such as those involving Future Internet for Smart Energy (FINSENY), (see [FINSENY]). NRENs will have to keep their networks operating regardless of supply deviations.

In 2011, Greenpeace released its report *How Dirty is your Data?,* which is just one of a selection of reports regarding energy choices made by IT companies in the environmental sector. Both Yahoo! and Google seem to understand the importance of a renewable energy supply, with Yahoo! siting most of its data centres near sources of renewable energy, and Google directly signing power purchasing agreements for renewable energy and investing in solar and wind energy projects in many US states, and Germany. Their models should be employed and improved upon by other Internet ("cloud computing") companies. But all technology companies are not as environmentally proactive, Facebook, one of the fastest growing and most popular destinations on the Web, is unfortunately on track to be the most dependent cloud-computing companies on coal-powered electricity, with over 53% of its facilities estimated to rely on coal to power the Facebook cloud. The environmental team does not recommend that NRENs support such a benchmarking / comparison list of how environmentally friendly each NREN is, as such a community, we are a long way off having audits completed for all NRENs. However, we can share knowledge of suppliers' environmental practices with all members of the NREN community.

2 Environmental Policy

An environmental policy is usually concerned with the management of actions in order to conserve resources, reduce waste and generally minimise the impact of any man-made changes on the environment. The GÉANT Green Team have aligned their environmental strategy with ISO14001, [ISO14001] as its definition is more focused and more aligned to our organisational needs: “the overall intentions and direction of an organisation related to its environmental performance as formally expressed by top management”. This deterministic type of environmental policy provides a framework for action, to set environmental objectives and environmental targets. NRENs have the advantage of not operating in industries where licensing of their activities for example, sourcing or disposing of materials used in their work processes would immediately dictate that such a licence was required, and this later licensing process would have compelled the organisation to have an applicable environmental policy in most countries.

According to the 2011 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.

As previously stated, no legislation or other formal requirements are obliging NREN organisations to have an environmental policy. However, environmental specialists recommend – and environmental standards require – that organisations start out with the adoption of an environmental policy as an important first step towards environmental improvements. When a company or institution publishes its environmental policy, it shows that its top management is committed to the environment, and it also sends a clear signal to stakeholders and employees about its environmental standpoint as well as its objectives and targets. A good example of an environmental policy can be seen in Figure 2.1, from one of the Green GÉANT partners, 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]

Environmental policy of HEAnet

HEAnet is aware of the impact of greenhouse gases (GHG) on our climate and on prospects for society now and in the future. It accepts that people and organisations at all levels have obligations to control GHG emissions and to act responsibly in our lives and our businesses. Further, HEAnet has a special position due to its national standing and its advocacy of leading-edge technology and applications. In this sense, we have a duty both to adopt best environmental practice, and to promote appropriate networking technology as an alternative to practices which act as large GHG sources.

Conscious of the need to operate within budget and to get value for money, HEAnet will use good environmental practice within its business activities. It will:

Respect the environment and emphasise every employee’s responsibility to improve environmental performance;

Align with client corporate policies on the environment and work with them to fulfil targets to reduce GHG emissions;

Consider environmental issues in all our business activities, including procurement decisions for goods and services;

Observe prudence in our use of resources, reduce wastage as far as economically possible, and monitor and review progress periodically;

Promote the use of appropriate networking technology as an environmentally positive alternative;

Work with others in the NREN community to raise standards and carry forward greater enhancements in environmentally sensible practices;

Save energy by ensuring that equipment is switched off when not needed, by monitoring and controlling usage, and by using sustainable forms where possible;

Support staff in the use sustainable transport for commuting and work-related travel;

Help to achieve relevant targets set for sustainable operations and development; and

Re-use and recycle where possible, and dispose of what is left in a responsible way.

Figure 2.2: Environmental policy of HEAnet [HEANETPOLICY]

A simpler operational environmental policy is published by JANET (UK).

Environmental policy of JANET(UK)

"JANET(UK) will integrate environmental best practice into its business activities while maintaining an appropriate balance between environmental and economic considerations."

Accordingly, Janet(UK)'s policy is to:

- Apply responsible standards in areas not already covered by existing laws and regulations;
- Respect the environment and emphasise every employee's responsibility to improve environmental performance;
- Integrate environmental considerations into all of our activities including considering the environmental impact of products and services in our purchasing decisions;
- Minimise our use of resources and wastage of materials as far as economically and practically possible, undertaking appropriate reviews to measure progress;
- Save energy through the monitoring of unnecessary use of energy sources and ensuring equipment is kept switched off when not needed;
- Share experiences with others to foster wider improvements within the community and communicate with the Research and Education community on environmental matters.

Figure 2.3: Environmental policy of JANET UK [JANETPOLICY]

Just because an NREN does not have an environmental policy, it does not mean that NRENs cannot establish environmental considerations in their business or at the institutions of the client they serve. It also does not mean that the top management are not committed to looking after the environment. The partners in Green GÉANT, for example, work together in trying to find ways of reducing energy consumption and GHG-emissions. In 2010, they took the important first step to make a verified GHG account according to ISO 14044, and at the same time, they have initiated a wide range of both informal measures, (e.g. the UNI-C investigation of the effect of distance working), and more formal initiatives aimed at GHG reduction, e.g. GRNET has been a part of the ECONET project for some time.

This report contains many examples of initiatives that have been taken without a formal policy or management commitment are not any less effective, and the results are probably the same as they would have been if an environmental policy had been published.

Although, in this context it is important to note that publishing an environmental policy in itself does not make the work happen. It requires a series of steps formulated by a strategy and action is needed at all levels of the organisation. Successes should be made known (or pointed out) by dedicating a chapter (or a few pages) in the annual report to describing the initiatives and achievements in the previous years. Not only is this motivating, it also sends a very positive message out to the organisation stakeholders, who are usually the government and client policy makers.

It is possible for environmental policies to begin with just one initiative being identified and some scope and measurement performance indicators included to define the task boundaries and to measure success. These measures can then be expanded with the next set of initiatives taken. Having an environmental policy helps to reinforce a continuous focus and commitment from the management team and offers good starting point to define structured efforts and approaches to making environmental improvements.

The three sample environmental policies shown in Figure 2.1, 2.2 and 2.3 are typical of what would be required by most NRENs. It is easy to see repetition between these samples, indicating NRENs' common pressures to reduce the use of materials and energy, or to use them with proper consideration of the environment in which they are placed.

Many initiatives to reduce the effect of GHG have been taken without a formal environment policy or management commitment. These are discussed in the following sections. Most of these initiatives were started on the basis of stakeholder support. Some initiatives and results have prompted further interest in this emerging area of social consciousness, which has led to the adoption of policies to promote and measure future efforts.

2.1 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 practice this common policy.

GÉANT should display a **common environmental website**, clearly identifying the aligned NRENs. A separate area on this website would display the logos of NRENs that have their own policy, and include a link to the URL of their policy documentation.

3 GHG Audits and Reports

Environmental protection is increasingly at the centre of public attention. Where do NRENs begin the journey to demonstrate active involvement influencing environment conditions within the boundaries of their activity? Measuring and monitoring GHG emissions are essential features of any strategy to reduce such emissions. By enabling network operators to understand the relationship between the network and CO_2, the measurement process provides an insight into where reductions can be made without affecting NREN service levels. The ISO-14064 standard is an idea mechanism on which to base measurement and audit programmes, and has been found to be extremely flexible and adaptable as a standard approach for the NREN community.

Several gases contribute to climate change, but the biggest pollutant is carbon dioxide (CO_2). The measure of GHG emission is usually expressed as tonnes of carbon dioxide. It is therefore not surprising that reducing CO_2 emissions has become the de-facto goal for most groups trying to improve environmental practices.

Within the GÉANT Green Team, several GHG audits have been carried out, and associated reports have been produced by participating NRENs. Data from these reports provides a basis for comparing annual GHG emissions, for each part of the network. Based on these data, several graphs were produced, showing trends regarding the percentage of energy consumption in the diverse NREN's activities 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. In Section 3.2, the latest GRNET audit serves as a case study that describes the entire process in detail.

3.1 Description of GHG Verification Process

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 into a verification checklist. The NREN must clarify the issues in the checklist, and then the verification report is prepared that describes any deviations (omissions or changes from stated measurement standards) and provide remarks for extra guidance notes to policies deployed. The NREN then performs potential corrections in order to 'close' down potential deviations from what the auditor is applying as the standard approach throughout the audit, and clarify any guidance received from the auditor. At this point, the final verification report is prepared by the verification body, along with the verification statement (as shown in Figure 3.1).

The primary goal of this assessment is to account for the greenhouse gas (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

   The section includes the motivation that led to the conduction of the report and its scope, an extensive description of NREN's purpose and profile with emphasis on green activities.

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 gasses and CO_2-eq definition

      The audit attempts to quantify the following greenhouse gasses (GHGs) which are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

      When GHG emissions are calculated, the impact of each GHG is transformed to a CO_2 equivalent. This is done by multiplying the emissions of a GHG by a factor that represents the effect of the GHG on climate change. These effects are based on the IPCC GWP100 factors. The effect of CO_2 is 1, since by definition effect of CO_2 is 1 CO_2-eq.

   b. Data used for calculating GHG emissions

      In this section, the NREN describes in detail the different data sources used in order to calculate the GHG emissions of the distinct categories (e.g. office, data centres, backbone network and transportation).

   c. Impact of Uncertainties on the Accuracy of the Data

      The impact of uncertainties is described in this section or the report to quantify the accuracy of the GHG emissions data. It is a section of high importance, where specific percentages for each uncertainty should be provided. One typical uncertainty exists in the estimation of emissions that are due to transportation, since the accurate and updated emission factors per type of transportation are not available. Thus, emission factors are based on existing carbon footprint calculators.

      Another uncertainty appears when real-time monitoring of energy consumption of the computational, storage and networking equipment is not available. In these cases energy consumption is based on typical energy consumption, as detailed in the manufacturer's datasheets and therefore, deviations may be present between the estimated and the real energy consumption. In cases where data is available for a specific node (e.g. a grid node) assumptions can be made in similar nodes in other areas where power monitoring infrastructure is available.

4. Scope 1: Direct GHG Emissions

   Direct (Scope 1) GHG emissions are defined as emissions caused by the combustion of fuels or direct emissions of GHGs. These emissions are characterised as Scope 1 according to ISO 14064. The section also includes information regarding GHG removals, possible exclusions and direct CO_2 emissions from the combustion of biomass.

5. Scope 2: Indirect GHG Emissions

   The methodology used to quantify energy-indirect GHG emissions, by sector, within NREN boundaries are 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 data centres and the backbone network 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 and 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 in its office hosts a small part within the building that is used as computer room (where are hosted servers/network components needed for the daily operation), the consumed energy 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 be resulting 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 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 DWDM equipment.
- IP network equipment consisting of routers.
- Layer2 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 in 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, concerning 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 projects' meetings, or in 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.

None of the vehicles involved belongs to GRNET, so these emissions are categorised as "other indirect".

The sources of these emissions arise 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 staff answered a questionnaire regarding how they reach office based on the area where each employee lives. The approximate distance for each staff member's daily journey is taken from http://maps.google.com and is categorised by walk/cycle, train, metro, bus, motorbike, taxi and car.

It can be 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 are calculated and are multiplied by 220 days to get the annual figure.

The corresponding emissions derive from:

- Cars: from http://www.greenpeace.org/greece/el/getinvolved/137368/137462/ according to the type of the car and the travelled distance.
- Metro: from http://www.carbonfootprint.com/calculator.aspx according to the travelled distance.
- Buses: from http://www.carbonfootprint.com/calculator.aspx according to the travelled distance.
- Motorbikes: from http:// carbonfootprint.com/calculator.aspx according to the type of the motorcycle and the travelled distance.

The approximate emission of each flight is calculated from http://www2.icao.int/en/carbonoffset/Pages/default.aspx.

3.2 Sample: Summary of GRNET's GHG Emissions

A recently completed GHG report was conducted by GRNET, and may be found here [GHGREPORT].

Table 3.1 below shows the summary of GRNET's GHG Emissions.

Item	Energy source	Energy consumption	CO_2 factor	PUE factor	Total (tons CO_2 eq)
Scope 1 – Direct Emissions					
Office					0
Scope 2 – Indirect Emissions					
1. Offices					
Office 1 – electricity	Electricity	137.440 KWh	1,021 kg CO_2-eq per KWh		140,33
Office 2 – electricity	Electricity	2.164 KWh	1,021 kg CO_2-eq per KWh		2,21
Network excluded in the Office	Electricity		1,021 kg CO_2-eq per KWh		
Office1 – service	Electricity	81.992,3 KWh	1,021 kg CO_2-eq per KWh		83,71

Item	Energy source	Energy consumption	CO_2 factor	PUE factor	Total (tons CO_2 eq)
Office2 – service	Electricity	41,8 KWh	1,021 kg CO_2-eq per KWh		0,04
Office2 – Heating	Oil	1.346 lt	3,0595 kg CO_2-eq per oil lt		4,1
2. DataCentres					
DataCentre NHRF – GÉANT PoP	Electricity	551.880 KWh	1,021 kg CO_2-eq per KWh	2	1.126,94
HellasGrid Node NHRF	Electricity	586.920 KWh	1,021 kg CO_2-eq per KWh	2	1.198,49
DataCentre GMNERA	Electricity	788.400 KWh	1,021 kg CO_2-eq per KWh	2	1.609,91
HellasGrid Node Forth	Electricity	209.806 KWh	1,021 kg CO_2-eq per KWh	2	428,42
HellasGrid Node IASA	Electricity	313.783 KWh	1,021 kg CO_2-eq per KWh	2	640,74
HellasGrid Node AUTH	Electricity	349.217 KWh	1,021 kg CO_2-eq per KWh	2	713,10
HellasGrid Node CTI	Electricity	293.941 KWh	1,021 kg CO_2-eq per KWh	2	600,23
HellasGrid Node NCSR	Electricity	138.504 KWh	1,021 kg CO_2-eq per KWh	2	282,83
3. Backbone Network					
Routers	Electricity	105.873,36 KWh	1,021 kg CO_2-eq per KWh	2	216,19
Switches	Electricity	122.363,18 KWh	1,021 kg CO_2-eq per KWh	2	249,87
DWDM	Electricity	217.103,46 KWh	1,021 kg CO_2-eq per KWh	2	443,33
Scope 3 – Other Indirect Emissions					
Transport					
Commuting					
Private Cars	149.910 km				24,21
Metro	29.615,2 km				2,18
Bus	6104,8 km				0,91
Motorbikes	30.604 km				3,81

Item	Energy source	Energy consumption	CO_2 factor	PUE factor	Total (tons CO_2 eq)
On mission					
Flights					93,70
Total CO_2 – eq					**7.865,25**

Table 3.1: GRNET CHG emissions Audit Results 2011

Upon completion of the auditing process a positive statement was issued by the verification body, as shown in

FORCE TECHNOLOGY

Verification Statement

ISO 14064:2006 (1)

It is hereby verified, that

GRNET
56 Mesogion Av.
11527, Athens
Greece

has performed a climate accounting for the year

2010

in accordance with ISO 14064:2006 – part 1 "*Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*". The verification was performed under a limited level of assurance.

The reported amount of emitted CO_2e is:

7865 tonnes

GRNET's climate account: *"GRNET-Report-20120222", received on 23-02-2012.*
Related verification report: *FORCE Technology, Verification report, dated 29-02-2012.*

Remarks associated with the statement: *none.*

Approved:

29/2-2012 Maria Sherdan

Date *Primary verificator*

Verification body: FORCE Technology • Department for Applied Environmental Assessment • Hjortekærsvej 99 • DK-2800 Kgs. Lyngby • Tel +45 7215 7700 • Fax +45 7215 7701 • www.forcetechnology.com
This is a non-accredited verification (accredited verifications are not yet possible within ISO 14064-2006)

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FORCE TECHNOLOGY

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Remarks associated with the statement: *none.*

Approved:

29/2-2012 Maria Sharda

Date *Primary verificator*

Verification body: FORCE Technology • Department for Applied Environmental Assessment • Hjortekærsvej 99 • DK-2800 Kgs. Lyngby • Tel +45 7215 7700 • Fax +45 7215 7701 • www.forcetechnology.com.
This is a non-accredited verification (accredited verifications are not yet possible within ISO 14064-2006).

Figure 3.1: Example verification statement

3.3 Recommendations

The GHG Audit approach is now well documented, and GÉANT needs to **set targets for 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 were validated by a third-party, Force, an **evaluation** needs to take place to see if this 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 CO_2 emissions figures are calculated from the type and ratios of the source fossil fuels from which they are energised. Countries with a heavy dependency on fossil fuel resource should not be discriminated against, therefore, the process should also highlight compensation. GÉANT needs to setup specific pages on its website to display audit results and develop communications materials to highlight activities and progress.

A **Wiki Repository should also be identified** to hold support documents and work in progress files.

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

According to ISO, [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 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 data and power needed to support equipment.

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

With the growing price of energy and growing awareness regarding sustainability and the 'green world', the power consumption of infrastructure elements has become one of the organisation's most important items of operating expenditure (opex). Many of the other items can be controlled or deferred, but energy costs are unpredictable and at present, continue to rise.

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.

4.1.1 Green IT

But what is described above "green IT"? Green IT is any action intended to reduce or eliminate environmental damage and increase savings within IT. Such a goal can be achieved in several ways, e.g. reducing power consumption by using efficient energy management, changing the structure of data centres, server virtualisation, proper sorting and waste disposal, using renewable energy sources, or telecommuting. The optimisation of the network is a major challenge. Fortunately, it does not need to involve huge costs. The very change in the structure of servers and the replacement of the cooling system with a row and rack setup can yield energy savings of up to 35%. Intel has calculated that replacing servers with newer ones can bring the same efficiency with 90% energy savings, or result in an efficiency increase with a 20% cost reduction (see [INTEL]). The payback period should be less than one year.

4.1.2 Hardware

Considering green technologies, the next area that comes to mind is recycling or energy efficient hardware. This area is the one that the most initiatives are usually taken in. For example, power supply units (PSUs) are generally 70% to 75% efficient, dissipating the remaining energy as heat. In recent years, there has been an initiative called "80 PLUS" that certifies PSUs that are at least 80% efficient. Similarly, the use of LEDs in the new generation of monitors aims at reducing the amount of electricity used. Returning old/obsolete hardware to a special electronic waste management company is also highly recommended.

4.1.3 Network Management

Describing and implementing a network management system enhanced with green networking measures is strongly recommended as the important step towards environmental improvements.

Green network management systems aim not only to increase infrastructure efficiency by reducing energy consumption (which also reduces electric bills) but also to protect the environment through utilisation of the management features offered by these solutions. This can be achieved by server virtualisation (several servers may be located on one machine), algorithms' performance control or the use of thin client technology, which shifts the computing from the client to the server side. The deployment of such terminals can save up to 85% to 90% of energy, compared to the use of ordinary workstations. An Advanced Configuration and Power Interface (ACPI) is also typical for disabling or hibernating components, which are currently not in use.

4.1.4 Network Challenge

Whereas most of individual hardware elements provide some kinds of energy saving mechanisms, it is difficult to manage energy consumption on an entire service basis. A complex interaction between hardware, software and network is required. Such a great number of elements need an intelligent workflow that will, through a decision-supporting agent, base all the actions on the current state of environment (in this case, hardware and software elements used to provide the service).

For the purpose of significant savings on the energy consumed, Poznan Supercomputing and Networking Center (PSNC) is collaborating in the field of network management systems with locally based Verax Systems, which has been developing its own network management system (NMS) capable of running defined green workflow scripts.

4.1.5 Green Network Management

Poland's national network, Verax, worked to enhance its NMS with green workflow policies with the PSNC Network Operations Centre (NOC), which monitors and manages its network. Although the system is currently still under development and in the testing phase, it is managing part of the Polish NREN, PIONIER's, networking equipment.

The chosen NMS was selected for its ability to implement a set of rules (scripts) that built 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 on the service level, Verax works to extend its NMS with a rules-based engine that would 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.

Verax's NMS when monitoring energy consumption of individual devices 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 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 on 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 in 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.).

4.1.6 Green Workflow

While network management systems are able to increase their infrastructure efficiency and maximise the use of resources, (which also implement consistent Green IT goals) the latest advances in energy-efficient hardware and services can also help to achieve significant savings.

Simple steps can be taken to implement best energy usage practices, which can be described as the 'green workflow' but these steps affect each other when considered at service level. Like any other business improvement program that would use a similar approach, cost savings are made possible through optimisation and planning, (Figure 4.1). We have defined the sub-tasks that are part of each major activity at PSNC, and describe them in the following section.

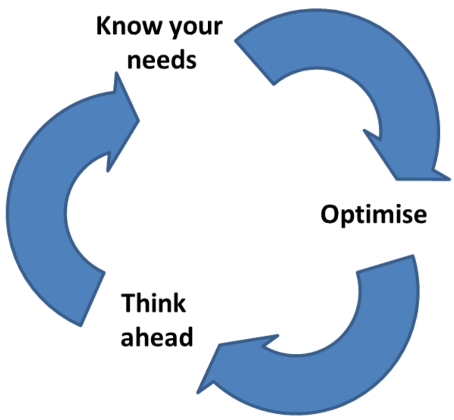

Figure 4.1: Recurrent model of a business improvement process, such as green workflow

4.1.7 Know Your Needs

The first step is to create a set of detailed rules for power management: a power saving policy. If an organisation has an Environmental Policy, then the power saving policy should be anchored to it. To create such a power-saving policy, the collection and manipulation of a dataset is required that will:

- Analyse power supplies.
- Analyse data centre infrastructure.
- Create utilities power and usage profiles.
- Create application power profiles.

4.1.8 Optimise

Having power saving policy the next step is optimising IT infrastructure with:

- Power management for computers and servers.
- Server load balancing.
- Use the more energy efficient computer first.
- React to abnormal energy consumption.

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 which are idling. A typical desktop PC, according to PSNC 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 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]. (Figure 4.2, power consumption assumptions average PC – 105W, LCD display – 25W).

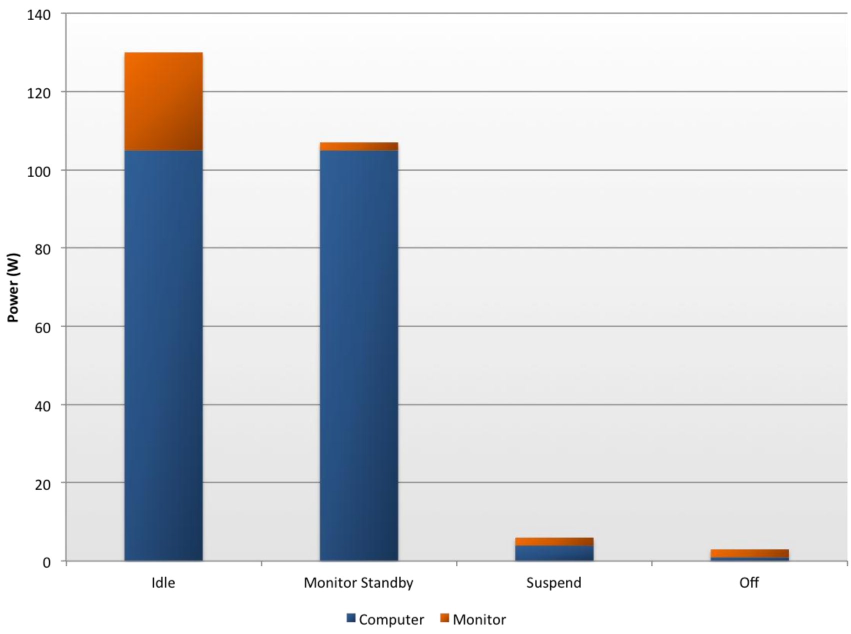

Figure 4.2: PC and monitor power consumptions at different levels of energy management

Implementing this type of power-saving policy within whole organisation, using simple built-in power management features or even using built-in Verax NMS simple hibernate feature is not effective in large multi-vendor and cross-platform environments. To overcome this problem PSNC developed a special platform, Green IT COntrol and Management Platform (GICOMP) [GICOMP]. It allows the network admin 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 4.3). The additional advantage of GICOMP, compared to GreenUP, is that its centralised architecture can manage distributed environments. Also, different metering devices can be used to support better power management.

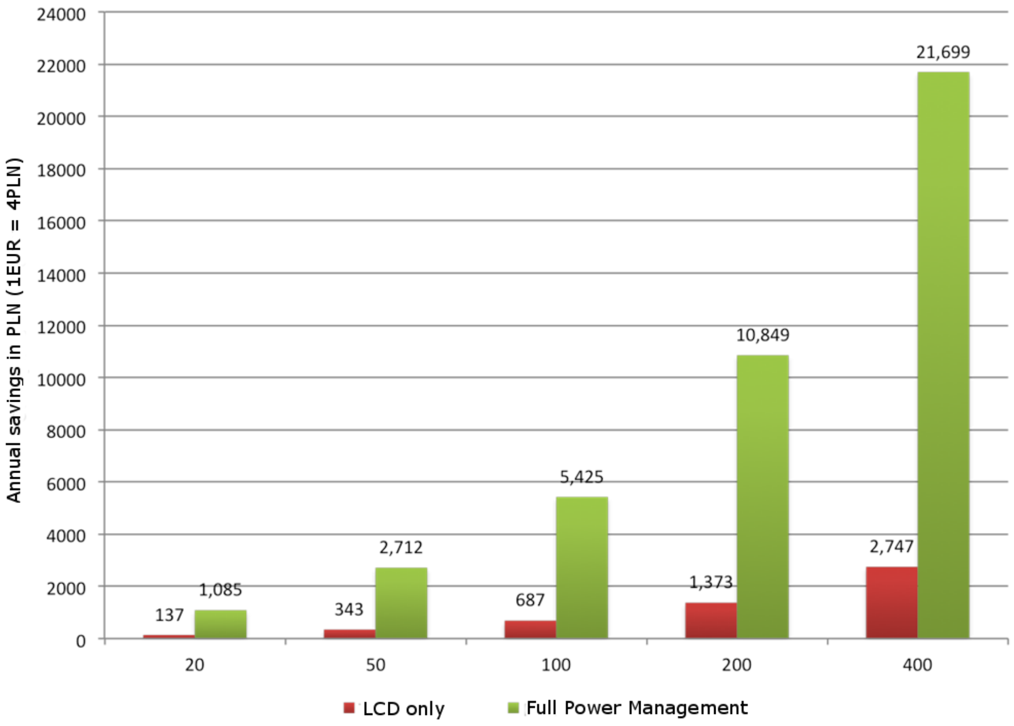

Figure 4.3: Savings estimation with increasing number of computer nodes

Similar considerations can be given to the servers. Once a workflow has been defined and 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 measurement shows that the energy consumption of powered off servers varies between 4% and 10% of a fully-loaded machine, 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 use the more energy-efficient servers first.

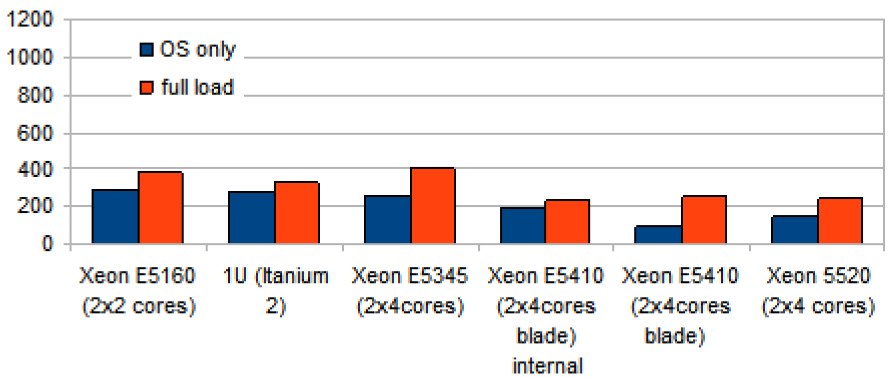

Figure 4.4: Power consumption of x86 machines installed in PSNC [W]

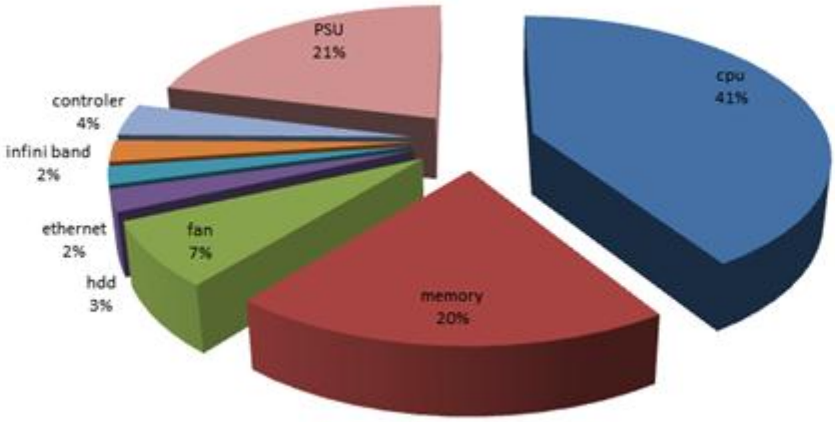

Figure 4.5: Typical power distribution of x86 machines

The next step is to analyse load distribution between servers. Because overloaded servers are not energy efficient (the most consuming parts of the machine that consume the most energy are CPU and memory, as shown in Figure 4.5), 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.

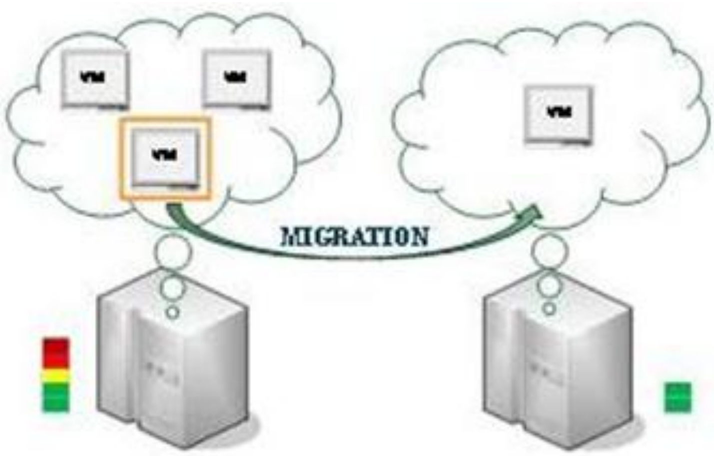

Figure 4.6: Optimise – balance load between servers appropriately – an example of virtual machine migration

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.

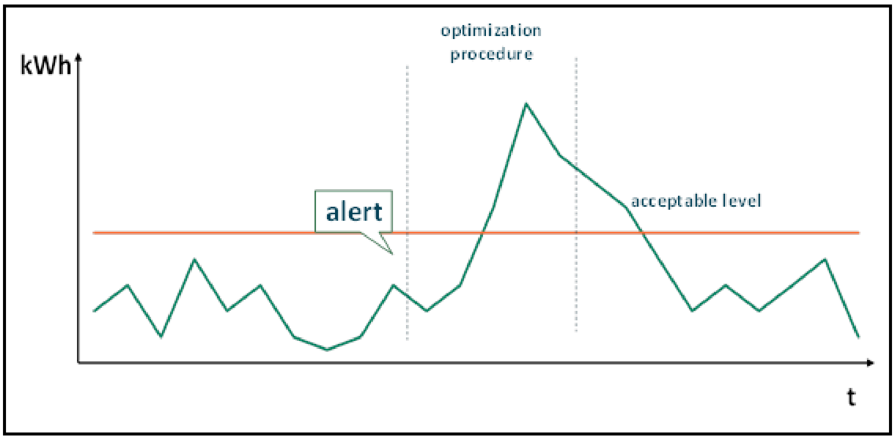

Figure 4.7: Continuous monitoring of overall power consumption

4.1.9 Think Ahead

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

- Optimise/replace suboptimal software taking note that an optimum solution could be version or technology dependent.
- Replace suboptimal computers and infrastructure elements (multi-criteria assessment: historical data if currently used elements, 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 4.8 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%.

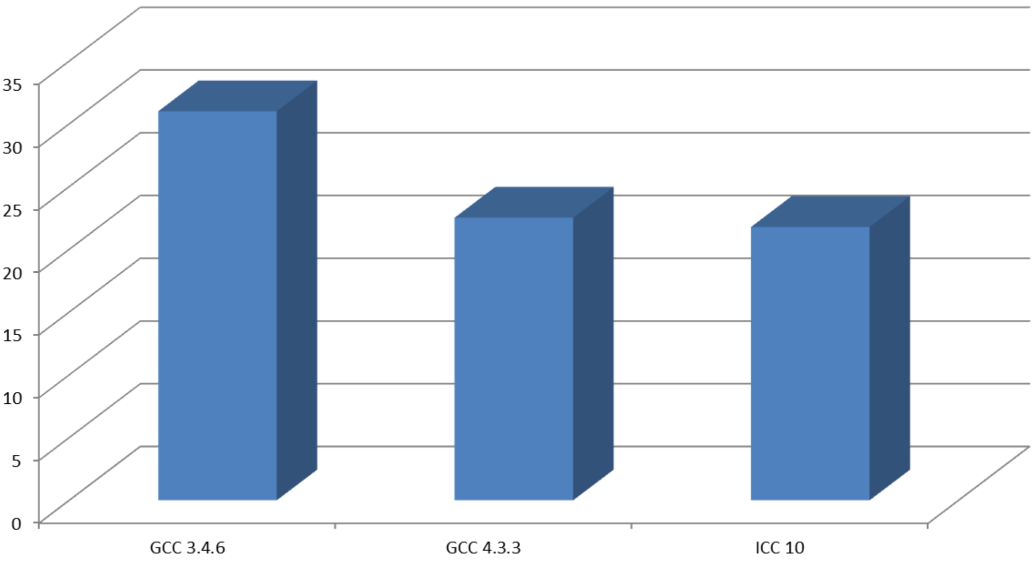

Figure 4.8: Example of software energy consumption compiled with different compilers [Wh]

Replacing sub-optimal computers and/or servers requires simulation to examine the impact on overall energy consumption. The general rule is to replace the least energy-efficient computer, if this is economically viable. However, it is not a simple process. When deciding to replace computers, one should also consider the real energy efficiency of the new computer (as examined by an independent entity), its historical and planned usage, and the required capacity. It is a multi-criteria assessment that comes out of Return of Investment (ROI) prediction. Any mistake in the analysis can potentially lead to an increase of overall power consumption because there will be new energy-efficient computers at our disposal, although they won't be utilised to best advantage. Wear and tear on PC components, such as fans and disk drives on older machines, consume extra power, so updating worn components will immediately bring a small level of benefit. Desktops and laptops, which consume less energy, should be considered first as replacement. For servers, virtualisation of the whole server function and aggregation onto a shared virtual server platform should also be considered. 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 4.9, 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 4.9: Example of information on energy consumption at national and device level

Due to the experimental status of PSNC's use of Verax NMS, there is not a set of case study results, as one would expect, as the experimentation is very fluid, but 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 environmental policy. This first step in implementing green workflow will help to define metrics to follow.

Implement mechanisms that will allow **suspension of computers and servers**. In the case of servers, to also manage power at outlet level.

Control overall energy consumption and **identify the reasons of 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 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 Power Usage Effectiveness (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 Effectiveness, (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 Center 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: UPS-level (basic); Power Distribution Unit (PDU) level (intermediate) and Server level (advanced). [GREENGRID_4] These levels also represent different levels of investments 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 HVAC	Data centre input power less shared HVAC plus building lighting, security, etc.
Minimum measurement interval	Monthly/weekly	Daily	Continuous

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 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 5.3).

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, means that PUE comparisons with other data centres should not be made without knowing that it is exactly the same elements that are 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 will show some of the initiatives made by the Green GÉANT partners and indicate the results obtained.

5.1 PUE in Practice

A detailed description of how PUEs are determined can be found in the white paper from The Green Grid [GREENGRID_3], especially *Data Center Infrastructure Efficiency (DCIE) Detailed Analysis*. 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 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 their 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 electric 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 load of the IT-equipment cooling, and security and monitoring equipment, light, etc. In Sector 3 and 4 the measurement is detailed to the level of single units or group 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 periods 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 with at least 8.5% from 2007–2011.

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

1. The implementation of virtualised server-environment which has a more effective use of electrical consumption through an automatic power saving features 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 help 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 piping the cooling water 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
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.

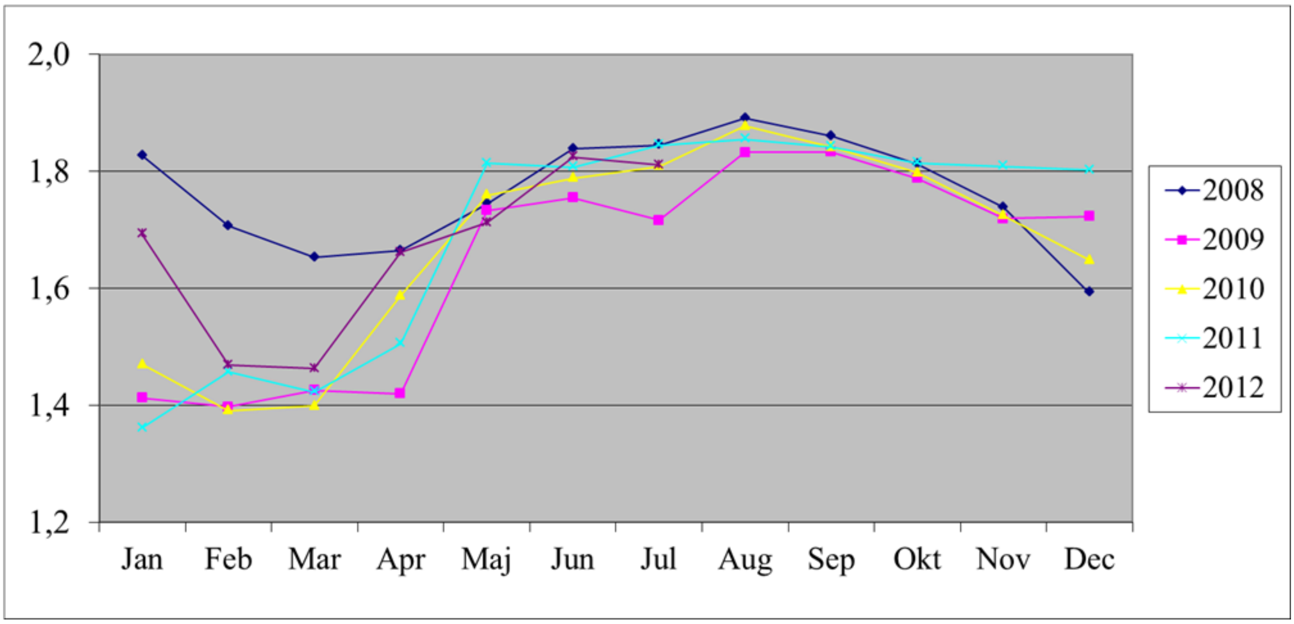

Figure 5.1: Monthly calculation of PUE (as shown in Y axis) in UNI-C

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. Especially challenging is to adapt the older cooling system to ensure the maximum efficiency and response to the outside environment.

It is noted that the efforts to improve the efficiency of the data centre is inspired by the EU Code of Conduct initiative, although UNI-C is not (yet) an endorsing member. It is also 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 (GHG). 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@uni-c.dk).

5.3 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 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.

The results in Table 5.3 show that product specification ratings nameplate effect is a bad measure in relation to real-time router power consumption. It is therefore not recommended for use, unless the utilisation ratio (= nominal effect/real-time effect) is used for corrections. With this knowledge, GRNET will, of course, use the corrected data to assess the effect of their initiatives outlined below.

GRNET Network Router	Vendor/Model	Nominal Nameplate Effect (Watt)	Average Real Time Effect Uptake (Watt)	Utilisation ratio
athens-3	Cisco 12416	3000	2537	0.85
eie-1	Cisco 12406	3000	1073	0.36
eie-2	Juniper T1600	8000	1915	0.24
heraklio-2	Cisco 12410	3000	1014	0.34
Ioannina-2	Cisco 12406	3000	939	0.31
koletti-1	Juniper MX960	5450	1513	0.28
larissa-2	Cisco 12406	3000	923	0.31
patra-2	Cisco 12410	3000	1154	0.38
Syros	Cisco 12406	3000	1029	0.34
thessaloniki-2	Cisco 12410	3000	1428	0.48
xanthi-2	Cisco 12406	3000	1023	0.34
Average utilisation ratio				**0.38**

Table 5.3: Utilisation rate in GRNET network routers

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 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 Power Usage Effectiveness (PUE) in the data centre is monitored and currently the PUE is 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 it will serve 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. Towards this direction, large-scale data centres started 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 the creation of 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).

5.4 Case Study: HEAnet Network TCD Client

As the NREN in Ireland, HEAnet has a number of heterogenic 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 heavily relied 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 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 should 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 reference power points, and the winning bid included the following design PUE figure (Table 5.4).

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 5.4: TCD Power load versus PUE-value specification

TCD also required that the winning vendor evidence PUE 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 were as follows.

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 5.5: TCD Power load versus measured PUE values

Thorough testing of the measured figures reveals 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 a probably a more heterogeneous, 'real-life' measurement of indoor equipment.

5.5 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 doesn't 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 organisation to minimise the consumptions of energy and consequently, the emit of CO_2.

PUE also presents a practical problem due to the lack of compatible systems across different types of organisations, regions and geographical conditions. The means of obtaining a low PUE may vary, depending on the infrastructure and layout employed in of the data centre. A value of PUE on one site is not directly comparable to a data centre on another site, but as a vertical or directly comparable measurement of development of efficiency, the PUE is a competent tool.

As it is clear in the three case studies, pursuing a low PUE demands investment in software and hardware systems to measure, collect, compare and take action on energy related incidents, which is not an exact science. Once the scale of these cycles is considered, taking a strategic approach when establishing a new data centre will save the host organisation from many of the problems that older and diverse installations face when upgrading an existing system. Consulting the best practices and current standard, as shown in the EU code for data centres design and employing the suggested layout suggestions, is a necessity to obtain a low PUE, and this figure functions as a guideline to evaluate the state of the entire data centre's energy efficiency.

In summary:

- NRENs should **ask data centres 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 good practice** of full-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. See [PCWORLD].

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 coming from utilising platform virtualisation for implementing a server consolidation strategy may be summarised into the following points:

- 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 having different applications/services running isolated in their own virtual servers by preventing impact of one application to the other when upgrades or changes are made.
- High diversity of Operating Systems (OS) hosted at 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 related or other business strategies (such as strategies to reduce required operating energy cost such as powering down or making servers sleep).
- Increased space utilisation efficiency in the data centre.
- Highly reduced energy consumption coming from operating less physical servers while requiring less energy for cooling at the data centre.

6.1.1 Reduction of Energy Consumption

According to Barroso & Hölzle, even an energy-efficient server consumes almost 50% of full power when idle (see Figure 6.1). [BARROSO] It is also a common observation that servers are rarely completely idle and seldom operate near their maximum utilisation. Instead, they operate most of the time at between 10% and 50% of their maximum utilisation levels (see Figure 6.2). Thus, it is clear that the majority of cases of server consolidation may provide significant reduction in energy consumption.

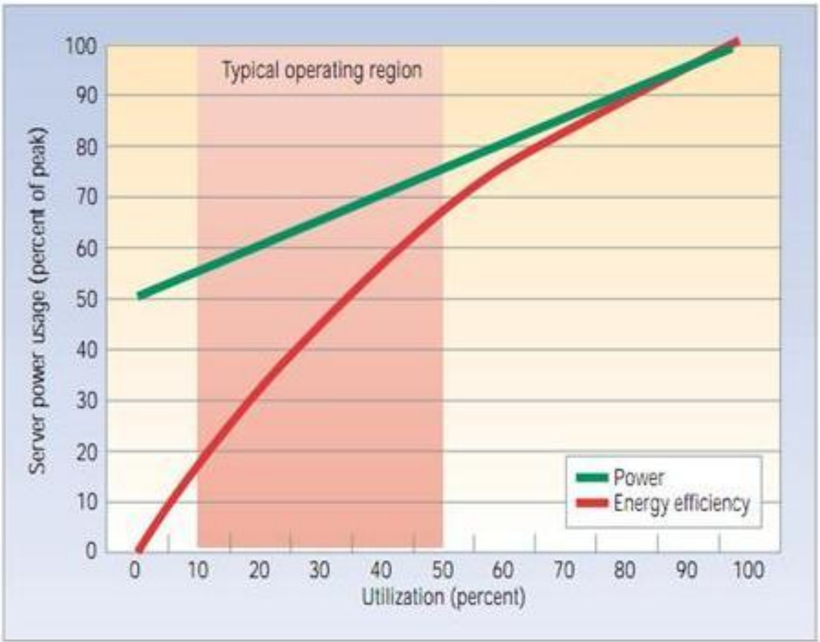

Figure 6.1 Server power usage and energy efficiency at varying utilisation levels, from idle to peak performance [BARROSO]

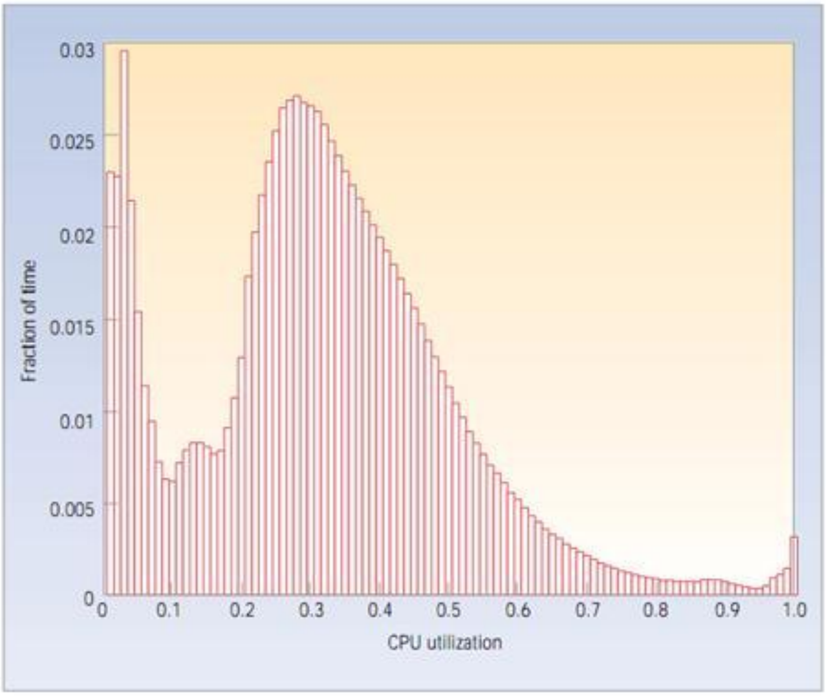

Figure 6.2: Average CPU utilisation of more than 5000 servers during a six-month period [BARROSO]

Besides the energy consumption of the servers, further energy is required for cooling (see Section 5 on PUE considerations). This means that direct reductions in server energy consumption actually pays back with a factor of 1.6–2.5.

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. However, a serious obstacle mentioned in the report is the fact that ICT services are structured in a way so the person paying for the IT equipment is not the one paying for the energy consumption of that equipment.

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. The IBM virtualisation technology also supports client data centre mainframes, UNIX and x86 operating systems, as well as storage systems.

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.

This last point is the most relevant. Computer usage and power usage will unarguably keep increasing as more of the world becomes technology dependant 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 for 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 the 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, may present an obstacle of 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]

The key idea behind GreenUp is that any machine can act as a sleep proxy for one or more sleeping machines on the same subnet. Whenever a machine falls asleep, another one starts acting as a sleep proxy for it. If the sleep proxy itself falls asleep, another sleep proxy rapidly takes over its duties. Network reconfiguration is not required or extra steps to virtualise the desktops and adding or modifying applications.

First, machines are on the same subnet, so they can efficiently broadcast to each other and wake each other up. Second, GreenUp does not require a strongly consistent view of the system. Third, GreenUp runs on end-user machines, making them sensitive to load and inherently unreliable, that is, their users will not tolerate noticeable performance degradation (or disruption) should they go to sleep at any time. GreenUp was tested on over 1000 machines at Microsoft, and by using GreenUp rather than keeping machines awake, sleep time was increased by approximately 31% per day. If the average idle power consumed by desktops is 65 W, then GreenUp saves approximately 175 kWh per machine, per year.

A somewhat different approach is taken by LiteGreen, [DAS] which was referenced in the previous version of this deliverable, *DN3.5.2 Study of Environmental Impact,* requires each user's desktop environment to be in a virtual machine 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 6.3).The research groups 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.

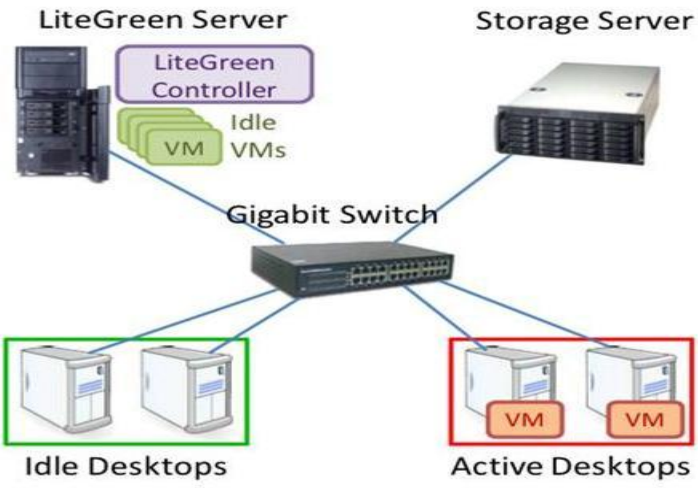

Figure 6.3: LiteGreen architecture [DAS]

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] Each virtual PC image can also enable remote access to the sleeping PC it represents via protocols such as Remote Desktop, Virtual Network Computing (VNC), and encrypted connections using Secure Shell (SSH). SleepServer seamlessly wakes up the physical PC when its owner tries to remotely connect to the machine from home, thus enabling a remote connection without requiring the PC to remain on for the entire night or weekend. SleepServer will also wake up the physical PC when the user needs to remotely access stored files and media (see Figure 6.4). According to the measurements presented in [AGARWAL], (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.

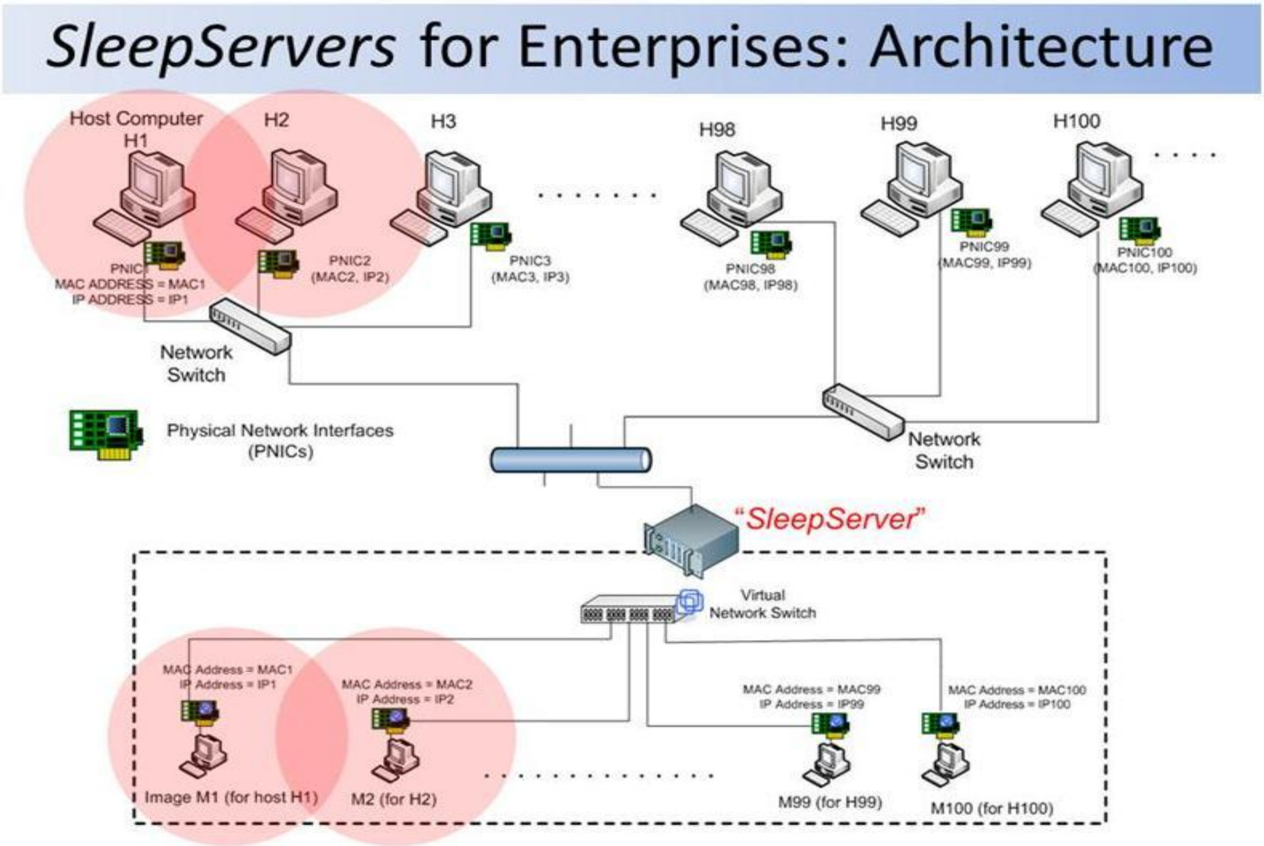

Figure 6.4: SleepServer architecture [AGARWAL]

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 technology 'cloud computing' 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 virtual machines (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 to disturb regular work practices.

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

Virtualisation may be initiated and controlled through the Network Management System described in Section 4 , but only if the usage of the system in an organisation is quite mature and that other, easier to achieve benefits, have been first been obtained from the system.

6.2 Network Virtualisation

For many years, engineers have combined power supplies, routing hardware and software, forwarding hardware and software, and physical interfaces into the networking device known as the router. Networking vendors have created large routers and small routers, but all routers have been placed into service as individual devices. As a result, the router has been considered a single physical device for most of its history.

The concept of logical systems breaks with this tradition. It is possible 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.

However, this complexity can lead to challenges in maintenance, configuration, and operation. To reduce such complexity, Juniper Networks supports logical systems. 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 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) also enhance an equipment provider's resources.

Network virtualisation refers to the virtualisation of network elements building a network. Network consolidation strategies prove 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] In Table 6.1, a comparison of the characteristics of the two architectures is presented.

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]

In Figure 6.5, an example of vertical and horizontal consolidation at a PoP is presented. 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], [JUNIPER_2].

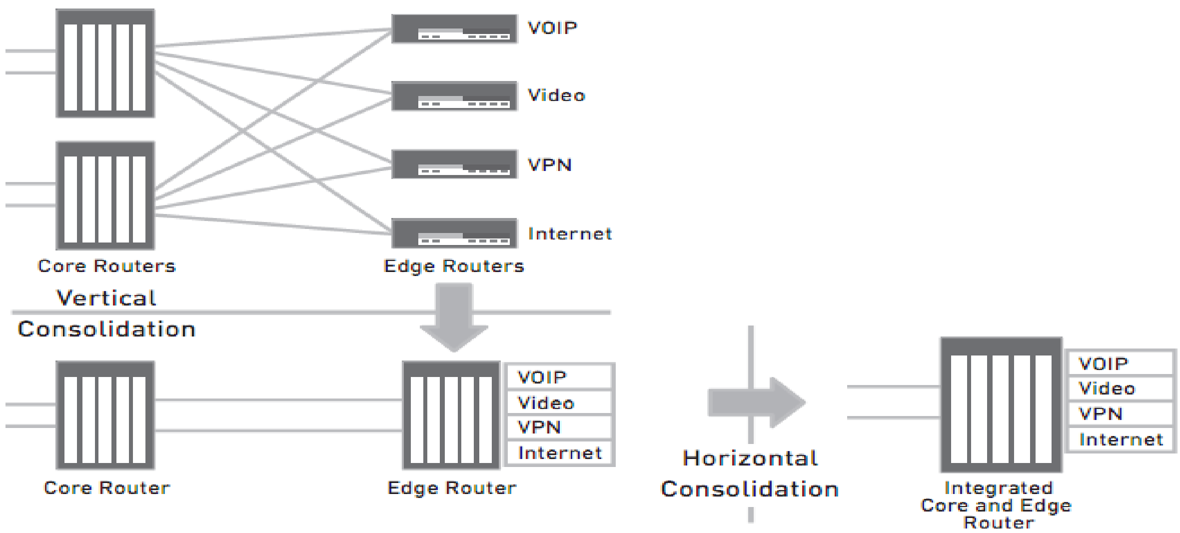

Figure 6.5: Horizontal and vertical consolidation [JUNIPER_3]

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 started introducing virtualisation in 2008–09. In spite of a continuous rise in demand of 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 reach 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 toolset needs to be created. With such goal in mind, Mantychore FP7 [MANTYCHORE] has created the OpenNaaS framework.

OpenNaaS was born with the aim to create an open source software project community that allows several stakeholders to contribute and benefit from a common NaaS software stack. OpenNaaS offers a versatile toolset for the deployment of NaaS oriented services. The software is released with a dual L-GPL/ASF licensing schema that ensures that 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 BSS workflows.
- Delegate management permissions over the infrastructure resources they own so that “Infrastructure integrators” can control them when required.

With an eye on versatility and smooth integration, OpenNaaS offers a powerful remote command line, as well as web-service interfaces. This web-service interface will offer the possibility to both build a GUI and integrate it 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 deployments. Setups such as this have occurred in the past due to the extra effort required to provision these networks initially and especially the difficulty to provision across several independent domains.

6.5 The 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
- ROADMs
- 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 OSPF) and GRE tunnels. More capabilities will be added in the near future, such as IPv6 and firewalling. The ROADM extension allows dynamically modifying 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 delegating configuration rights to users in an aggregated mode, instead of dealing with individual infrastructure resources.

6.6 The OpenNaaS User Community

The OpenNaaS user community could 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 slides.

- **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 on 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 the virtualisation technology to offer virtualised infrastructures to researchers investigating future Internet technologies. The infrastructure is based on the multi-domain European National Research and Education Networks (NRENs) and the GÉANT2 backbone. FEDERICA uses virtualisation in computing and network systems to create a technology agnostic and neutral infrastructure. It 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 aggregate energy savings from both network and platform consolidation compared to physically implementing each distinct hosted infrastructure. In the next section, we see how intelligence within the network itself can control the use of virtual nodes, rather than this being done by the intervention of users or network operators. We will see how protocols are being developed to make routing decisions based on green and economic factors.

6.7 The GreenStar Network and Mantychore FP7 Project

The Mantychore and GreenStar Network (GSN) projects [MANTYCHORE] [GREENSTAR] are collaborating 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 an IaaS 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. Mantychore dynamically provisions the connections for the infrastructure, and GSN uses it to migrate VMs based on the availability of renewable energy.

Mantychore provides the flexible network connectivity platform to move GSN virtualised data centres towards network nodes powered by green energy sources distributed in a multi-domain network, particularly between European and North American domains. Integrating both Mantychore and GSN resource provisioning solutions demonstrates the feasibility of powering e-Infrastructures in multiple domains worldwide with renewable energy sources. Management and technical policies are being customised to leverage new virtualisation approaches, which will help to migrate resources from one site to another based on power availability without suffering connectivity interruptions.

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:

- **Layer 1** is the optical link level in which allowed users will be able to gain access control over optical devices, such as optical switches to configure interface cards and ports using an integrated L1 service.

- At **Layer 2** users can control Ethernet and MPLS (Layer 2.5) switches to configure different services to manage or to setup the connection paths to transfer VMs and applications. The integration of Bandwidth on Demand (BoD) services within the Mantychore suite has been demonstrated, and will eventually use the NSI protocol when it becomes available.

- The Mantychore software suite includes **Layer 3** features to create, modify and delete all resources (interfaces, routers), both physical and logical, in order to:
    - Configure the proposed virtual network.
    - Configure any required physical interfaces to build the network.
    - Map internal and external routing protocols to activate the network.
    - Support QoS and firewall services to ensure quality and to protect the network.

GSN is an *IaaS Framework* middleware solution, developed by a Canadian partner that provides extensions to manage servers, virtual machines as well as power meters and PDUs. Mantychore's network management API is called by GSN's own variant of this functionality to build tunnels in order to transfer VMs to locations selected by the GSN *Cloud Manager*, which is focused in optimising the use of renewable energy resources. The GSN *Controller* is the intelligence module for this infrastructure, and is responsible for planning and executing the migration of virtual machines across GSN facilities, according to the availability of renewable green energy. This is exposed as a network service by its own *Network Manager*. GSN also provides a *Facility Manager* module which can be used to predict the availability of power from renewable energy resources and will also be interrogated as part of the decision making process for transferring VMs to GSN nodes.

Converging server and network virtualisation allows for the migration of virtual data centres over network nodes to happen as part of virtual infrastructure management. Mantychore can dynamically setup the L3 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 allow 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 EduStorage: HEAnet's Network Cloud Data Storage Service

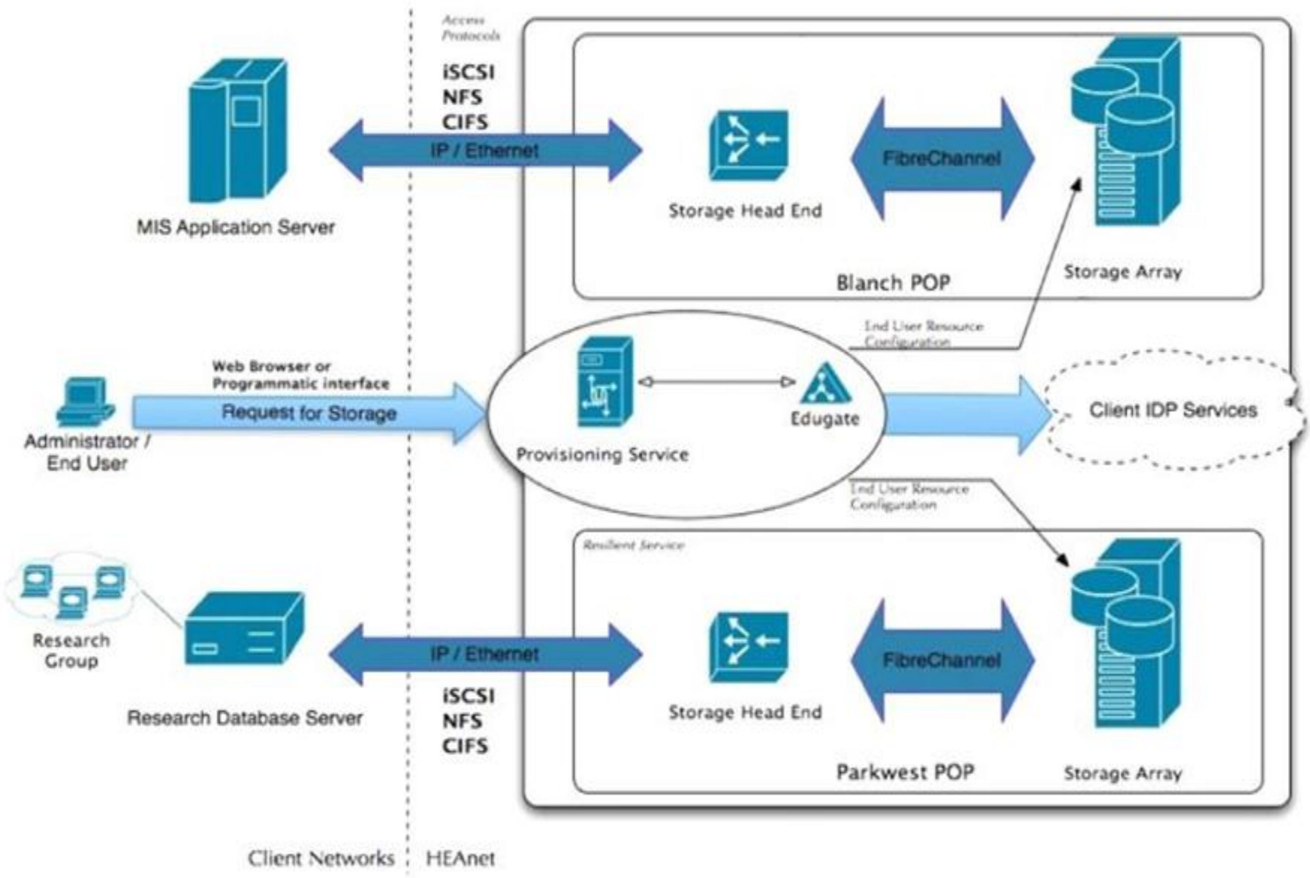

Figure 6.6: EduStorage architecture [EDUSTORAGE]

EduStorage is HEAnet's new network cloud data storage service. It provides:

- Over-the-network access to the new HEAnet resilient SAN infrastructure.
- General-purpose block storage via iSCSI from either/both of the HEAnet two data centres (directly to client servers on the university or college campus LAN).

EduStorage allows users to create remote disks, which can then be mounted on their server, wherever it is physically hosted.

The server operating system can be configured to mount the disk using an in-built iSCSI initiator, no extra hardware or software is required. Once created and mounted, the network-mounted disk volume can be treated just like locally attached storage.

Some typical uses might include:

- As a virtual machine disk resource for IT Departments.
- Researchers' processing of data sets.
- LAN administrators looking for backup disk space.
- Expert users looking to replace local SAN equipment.
- Off-site backup.

In summary, any user looking for disk resources where ultra-low latency block transfers are not critical will be able to make good use of the service.

This service has been setup mid-2012, and the GÉANT Green Team will monitor the impact it will make in the area of virtualisation and shared resources.

6.9 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 TCO especially those where it was decided to virtualise to reduce server numbers and save power.
- Have a regular schedule **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**.

- Allowing 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

The energy consumption of networks, especially the Internet, is exploding, due to the increase of the number of devices connected to it, as well as an estimated 40% per-annum increase of traffic volume fuelled by mobile data and video applications. Consequently, it is crucial to improve network efficiency to prevent the Internet from being throttled by an energy bottleneck.

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 forward 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 achieve 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 which 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 remaining equipment enter the 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 optimality 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%).

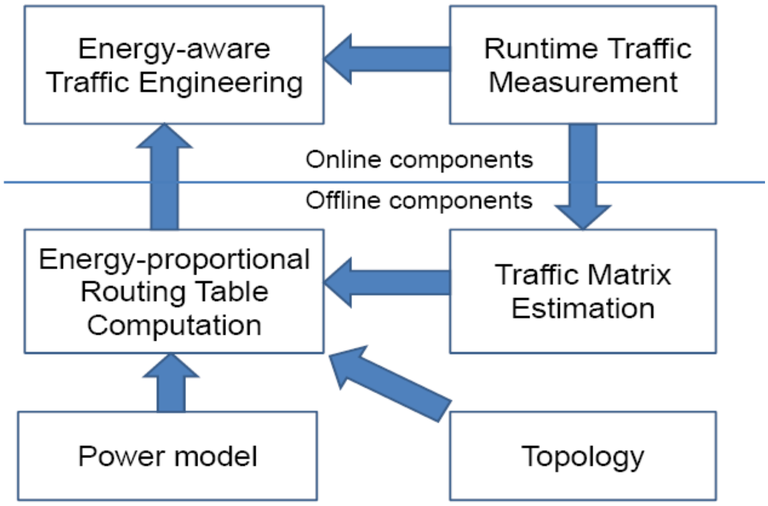

Figure 7.1: An energy-aware traffic-engineering approach (from N. Vasic, D. Novakovic et al., 2010)

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% to20%).

7.1 The GreenTouch consortium

In response to the dramatic increase in consumption, GreenTouch was setup as, 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 of technologies needed to increase network energy efficiency by 1000 from 2009 levels. See [GREENTOUCH].

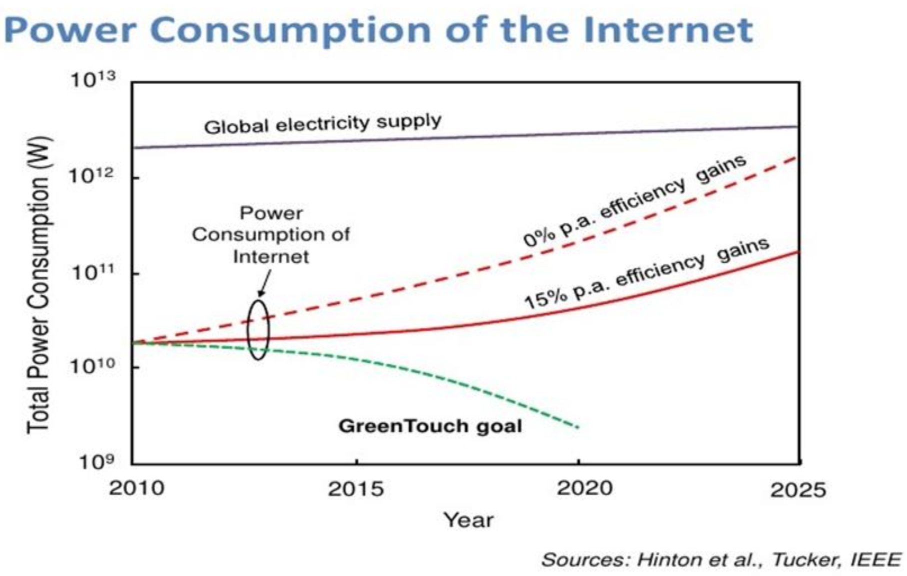

Figure 7.2: GreenTouch's prediction on the power consumption needs of the Internet [KLEIN]

Using Green Touch'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.

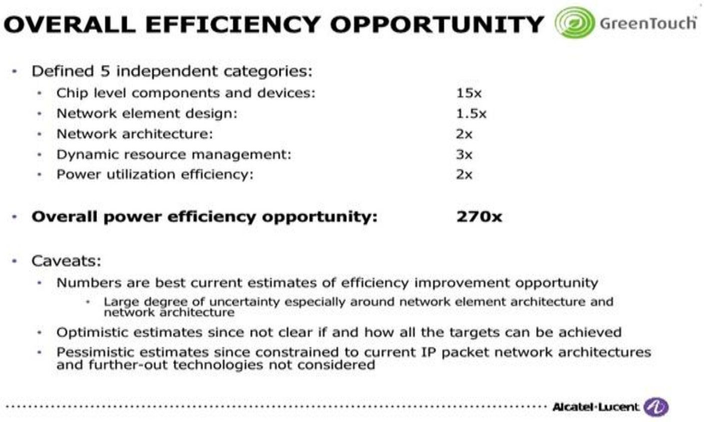

Figure 7.3: GreenTouch's latest progress on router power design efficiencies in 2012 [KLEIN]

One example of how GreenTouch is progressing towards its goal of reducing power consumption by a factor of 1000 is for new router design (shown above), which has currently been shown to be reduced 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 WDM, and designing protocols to maximise energy efficiencies.

7.2 GRNET and the ECONET Project

GRNET participates in the FP7 ECONET (low Energy COnsumption NETworks) project [ECONET], which aims to study and exploit dynamic adaptive technologies (based on standby and performance scaling capabilities) for wired network devices that allow saving energy when a device (or part of it) is not used. At the same time, ECONET aims at re-thinking and re-designing wired network equipment and infrastructures towards more energy-sustainable and eco-friendly technologies and perspectives.

The GRNET network is a new generation optical fibre network based on Wavelength Division Multiplexing (WDM) technology at extra high speeds (1–10 Gbps). All the nodes are based on routers of Gigabit speeds interconnected with a 2.5 Gbps-speed network over DWDM technology with leased wavelengths. Since 2008, GRNET dark fibre network extends over Greece, with total length of dark fibre more than 8500 km, and optical equipment able to support speeds up to 21x10 Gbps. The GRNET network topology is shown in Figure 7.4.

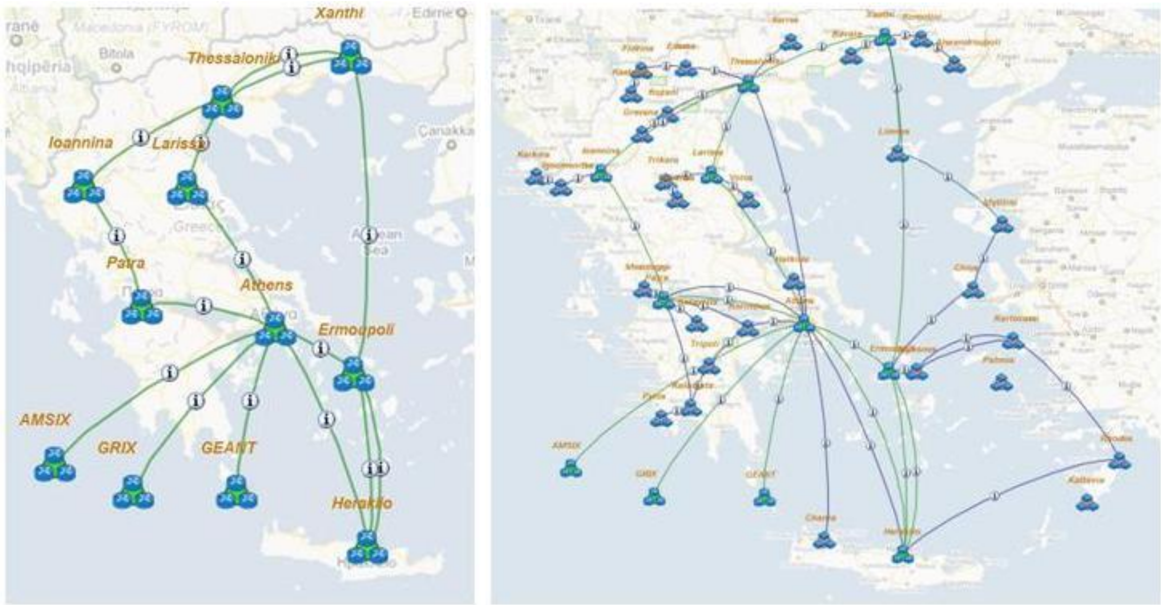

Figure 7.4: GRNET IP network topology (left) and network topology (right))

In the framework of the ECONET project, GRNET is currently 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.

A detailed profiling of the current traffic, as well as a prediction for future volumes, is required in order to be able to consider the potential of deploying energy-efficient strategies, such as rerouting traffic over energy-efficient paths while shutting down others to save energy. To this end, and in absence of a unified method for data flow statistics collection in GRNET’s network, traffic matrix estimation methodologies are applied, having as input the distinct link loads in order to be able to determine network flows between all source-destination pairs. These traffic matrix estimation methodologies are expected to be assisted by limited data flow statistics collection in order to produce more accurate estimates.

Regarding the collected statistics, average and maximum throughputs as well as link utilisation are recorded on a monthly basis. Traffic volumes per network segment are also measured. Traffic variability may be observed for indicative core and access network equipment. The following figures show the daily, weekly and monthly variations from the core network equipment.

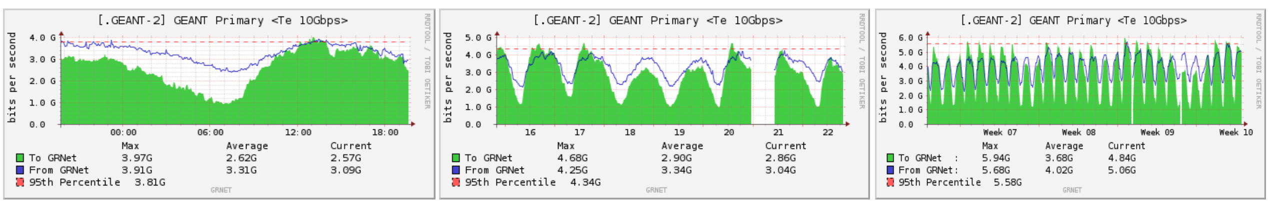

Figure 7.5: Traffic profile of core GRNET network router (peering with GÉANT): daily (left), weekly (centre), monthly (right)

Similar information is available for network routers, as shown in Figure 7.6.

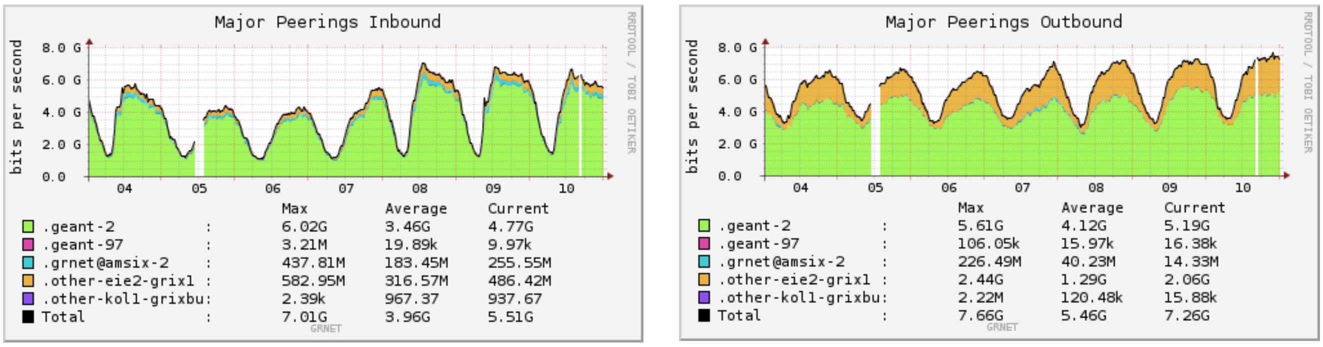

Figure 7.6: Network routers (left) and GRNET large bandwidth users (right)

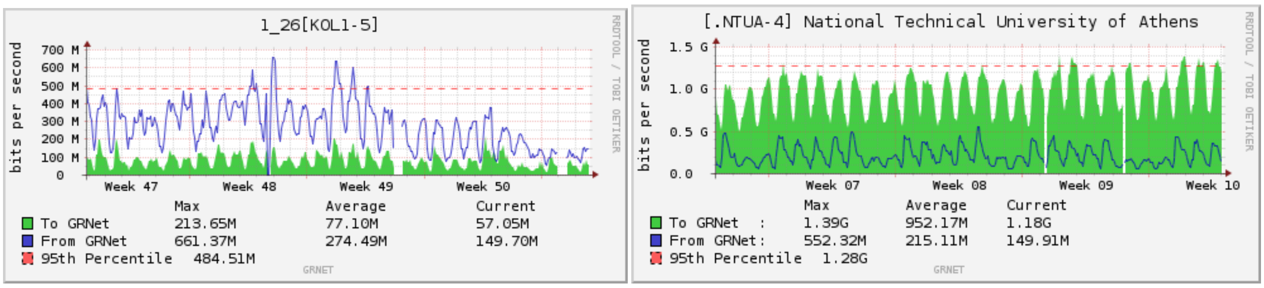

Figure 7.7: Daily traffic profile of access network switch (left) and a GRNET heavy user (client connected at 10 Gbps)

Based on these collected statistics and diagrams, it could be argued that the traffic in GRNET network nodes follows a homogeneous pattern, giving the first indications that there is room to deploy smart energy-efficient strategies, and thus improve the energy efficiency of the network. Using new routers, that employ technologies such as GreenTouch, will offer power reductions of at least 270% (as shown in Figure 7.5 , could offer very large reduction in energy usage.

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

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 and 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 APCs 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 setup 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

Videoconferencing allows people in 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 enables face-to-face sessions for teleworkers and non-campus based students.

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.

One-to-one videoconferences are commonly handled by using personal computers and a program such as Skype. When more people participate in a videoconference, the need for efficient hardware and software solutions increases. In recent years, two developments have significantly improved the quality of videoconferencing and extended its reach in the global academic and research communities.

First, high definition standards of resolution, aspect ratio and bandwidth have transformed the experience of videoconferencing and made it a viable alternative to face-to-face meetings and events. Second, the interconnection of European NRENs through the GÉANT network, and the dedicated onward connections to NRENs in North and South America, Africa, and the Asia–Pacific region, has made 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]

All Green GÉANT partners use videoconferencing extensively for their own communication purposes, and they also put their advanced facilities at the disposal of their clients. The full benefits of videoconferencing are not realised by the NRENs alone but can be achieved when equipment for high-quality conferencing is available to a broad audience.

Examples in the UK that show the impact of videoconference on carbon emissions include:

- At several UK government departments, including Work and Pensions and Justice and Health, financial/emission-based cutbacks were made, with the departments saving around 232,000 tCO_2 in total. A videoconferencing system at the Ministry of Defence eliminated 761 return journeys, saving 27.2 tCO_2, since it became operational in February 2010.

- BT saved approximately EUR250 million in reduced travel costs and improved productivity as a result of its increased use of video conferencing technology. [BTVC] The organisation cut travel and other associated costs by approximately EUR140 million and saved EUR108 million worth of productive time by using videoconferencing, most notably through the 20 Cisco TelePresence suites that BT operates around the world. The company said that the technology has also eliminated more than 860,000 face-to-face meetings and cut BT's carbon footprint by at least 97,000 tonnes of CO_2.

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 this 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), and the activity is the set of board meetings scheduled during a defined time period of one year, October 2008 to September 2009. NDLR holds many other meetings – seminars, training sessions, exhibitions, etc. – at which some or all of the board members may attend. These, however, are not included in this case study.

The NDLR [NDLR] is a project funded by the Higher Education Authority [HEA], and open to all Irish universities and institutes of technology. Its mission is "to promote and support higher education sector staff in the collaboration, development and sharing of learning resources and associate teaching practices." It has 21 academic partner institutions, together with HEAnet as a technical partner. It is governed by a board made up of representatives of ten of the partner institutions, together with the Project Coordinator, the Chairman and a representative of HEAnet.

8.1.2 Logistics

An early decision of NDLR was to share the task of hosting meetings of the Board. Thus, the venue for meetings changes from one institution to another through the year. Another decision, in keeping with the mission of NDLR and the ethos of its partners, was to use information and communications technology (ICT) as much as possible in carrying out its business. Thus, in the past two years, venues for NDLR Board meetings must be equipped with videoconferencing facilities, so that members can participate remotely.

HEAnet has played a leading role in the promotion and provision of multimedia services, including videoconferencing, in Ireland in recent years. It has allocated videoconference units to qualifying clients, including a tranche of 25 HD (high definition) units in 2009. Its central service includes a multi-conferencing unit (MCU), with HD capability for several concurrent conferences, and with recording options, a global dialling system (GDS) directory service, and gateway facilities for calls via ISDN, and even voice-only PSTN participants. In this way, all NDLR-partner institutions now have at least one HD videoconference unit available to staff.

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	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
University of Limerick	Limerick	L

Table 8.1: Home institutions of NDLR Board members

Each board member is represented by the code letter for his/her home city. Similarly, the venue for a board meeting can be represented using the same scheme. Table 8.2 shows the matrix of inter-city distances used to calculate the distance travelled, or that would have been travelled.

	C	D	G	L	M
C	-	215	166	93	206
D	215	-	188	175	24
G	166	188	-	71	164
L	93	175	71	-	158
M	206	24	164	158	-

Table 8.2: Intercity distance matrix

If a person from D (Dublin) physically attends a meeting in G (Galway), the travel distance is 2 x 188 = 376 km. If a person from D attends a meeting in D, zero travel has been assumed. This is in most cases an underestimate, but they are neglected here because the impacts from travelling short distances are assumed to be negligible.

8.1.3 Data from Board Meetings

There were six board meetings from October 2008 to September 2009. The venues are shown in Table 8.3, 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 8.3: Attendance at board meetings with induced and avoided travel distances

8.1.4 Results

For inter-city journeys, rail and private transport are the two options in Ireland. Where possible, public transport is the option preferred by NDLR Board members. The conversion factor for transport by train is 44 g/km. In the case of a private car with 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. (Table 8.4)

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 8.4: GHG emissions induced by travelling to Board meetings, and GHG emissions avoided by using videoconference facilities

The results in Table 8.3 are calculated for all inter-city transport, assuming that either train or private car is used in all cases. 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). Were private cars to be used, the saving would be 1,535 kg of GHG emission. The actual savings lie somewhere between these values.

8.1.5 Other Observations

While Board members find the use of videoconferencing very helpful, they might not use it for all meetings; attendance in person for at least some meetings during the year is of social and business importance.

The study has not taken into account the amount of time or money saved by the use of videoconferencing. The time saving is significant to members. Time spent on trains can, to an extent, be used to read reports, and perhaps even work online using 3G access. However, time spent travelling by car is considered as lost time. All board meetings were scheduled from 10:00 to 16:00, so those attending would often have to travel the day before and stay overnight in order to be present from the start. Even discounting such cases, the average travel time saved by those attending by videoconference was about 16 hours per person, which is equivalent to two working days a year. Anecdotally, board members remarked on the difference videoconferencing makes to their working lives: it saves them precious time and enables them to combine work at their home institution with the remote collaboration needed in projects, such as NDLR.

Some of the locations, such as the National University of Ireland, Maynooth, are not easy to get to or from by train. In such cases, driving by car is seen as the only realistic means of travel.

Transport costs involved in attending a meeting can be of the order of EUR100, covering train, taxi and bus, for a person from a city other than that of the meeting.

8.1.6 Limitations of the Study

The results do not take account of the operational impact of videoconferencing on the environment. 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. At this stage, we do not have measurements for any of these service elements. Production, transportation and disposal of the equipment accounted for, e.g. considering how much GHG emission is involved in the life cycle of the products required for a videoconference.

There is very little public information available on this subject. A crude estimate of the GHG emissions from production of a 46” HD monitor can be established by scaling the impacts from production of an iPad. 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 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 prove not to 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 preferably should be made in high-end technology with as assumed long life time. 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 in 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.

The PLATON Project aims to create and activate five services based on the PIONIER network. 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. **eduroam Services**: simple and secure roaming for people from the scientific and academic community in Poland by launching secure systems of access to the wireless network in every MAN network and HPC centre.
3. **Campus Services**: services offered on the basis of an innovative computing-service infrastructure of nationwide reach which delivers applications on demand, capable of providing a wide range of users from the scientific and research community with flexible and scalable access to specific applications, both in MS Windows and Linux systems (taking into consideration the needs of professional groups in these environments, including the implementation of an integrated system of services managing the grid resources).
4. **Archiving Services**: available at a national level, offering remote archiving and backup as added value to the national, academic and research PIONIER network. Archiving services, which increase real-time data protection, are one of the elements necessary to increase the functional reliability of each user community, and are addressed to the academic environment, including the higher education system, research and development units, and hospitals dependent on universities and medical universities.
5. **Science HD TV Services**: the national platform offering interactive science 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.

The Quality objectives of the PLATON programme include:

- Increasing the quality of services offered by academic units.
- Improving working conditions of people employed in scientific community.
- Modernising the educational base.
- Extension to wider education community and raising the awareness of the benefits of the whole network services.

8.2.1 The Technological Solution

The **videoconference services** aims 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 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 conference.

The videoconference system solution is flexible and allows other potential applications such as training, distance education, and other forms of collaboration (including providing an alternative communication option for those with hearing impairments), as well as the subsequent extension of the system. Apart from the main monitor of at least 52 inches, it is possible to connect the terminal to the second monitor or projector for computer presentations. The camera can be remotely controlled with a wide range of choice of direction, tilt and zoom, with the possibility of remembering frequently used settings. Other than the main camera and microphone, it is possible to connect an additional PC, second camera, DVD player, etc.

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 users and allows advanced resources administration. Users can also obtain information about active resources, statistics and device monitoring.

8.2.2 Use Pattern

Typical usages of the videoconferencing infrastructure include:

- Scientific discussions.
- Virtual science conferences.
- Telementoring (i.e. remote access in surgical operation).
- E-learning (remote interactive learning).

Some statistics from the multi-conferencing unit (MCU) are shown below in Figure 8.3:

- Observed period: 6 months.
- Number of videoconferences: 299 VC.
- Total number of hours: 854 hours.
- Total number of participants: 1870 participants (sites).

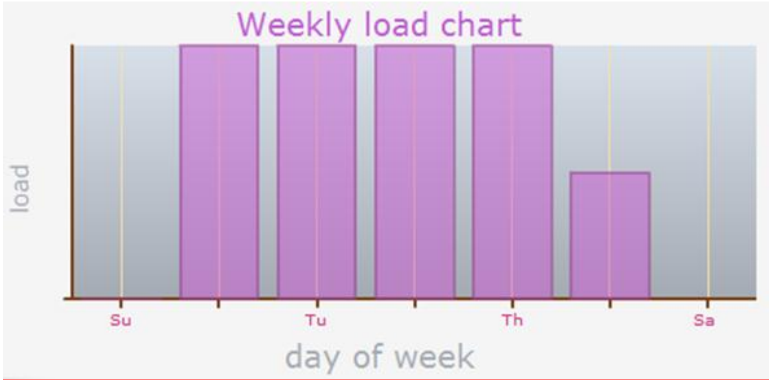

Figure 8.3: There is an average of two VCs every weekday

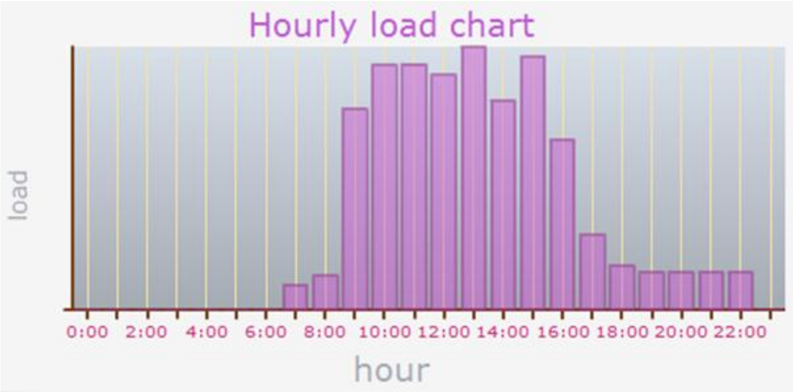

Figure 8.4: Hourly load of VCs during observed period

8.2.3 e-learning Example

Telemedicine offers a matchless way of combining the advances of modern communication technology, and information technology, with biomedical engineering and medical sciences to deliver the healthcare services on an anytime, anywhere basis.

A real-life example of 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. The project also demonstrates the idea of applying new technologies to education, and creates archive material that can be used by students of medical sciences and reference material by other doctors. It is dedicated to promote medical and surgical high-quality Continuing Education programmes. LION was envisaged in order to improve the knowledge, skills and discipline of current otolaryngologists, while introducing innovative programmes designed to provide worldwide education, including developing countries.

The aim of the LION is to create a permanent, interactive, worldwide high-speed network for continuing education in otolaryngology (ear, nose and throat medicine (ENT)), 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. The project provides a focus for training, as well as for an enhanced professional experience using data communications infrastructure and interactive videoconferencing system essential to the development of the global otolaryngological community and known global videoconference network for otolaryngology.

The use of newer technologies such as telemedicine-specific hardware and software, rather than just a video conferencing link, can lead to increase in the scientific value of the telemedicine consultation. Modern tools such as digital stethoscope (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.

8.2.4 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 8.4.

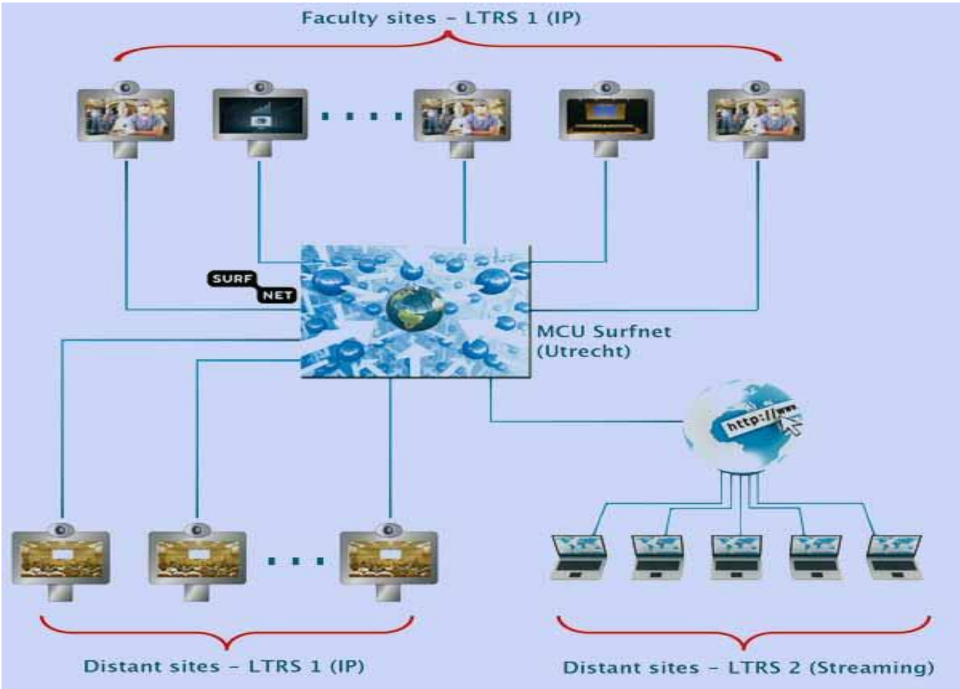

Figure 8.4: Basic infrastructure of LION

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) levels 1 and 2:

LTRS 1 – IP connection: this configuration is mandatory for all faculty sites and is also be recommended for all distant sites to offer real-time interaction between faculty and the delegates in the conference room facilities. LTRS1 requires the use of professional videoconference equipment.

LTRS 2 – 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 will be under LTRS 2 level. Interaction with the faculty will be possible by email or with chat room via the moderators located at the MCU.

Example LION Event

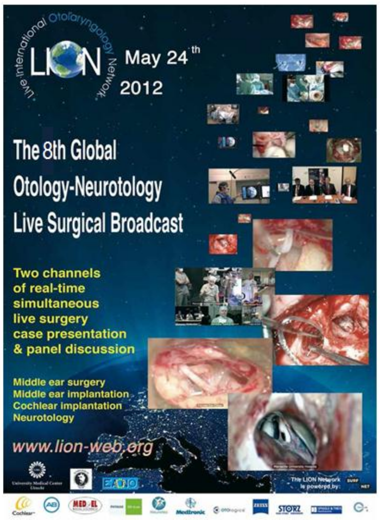

Figure 8.5: The 8th Global Otology-Neurotology Live Surgical Broadcast took place on 24 May 2012

During this event, 32 operations carried out in 18 medical centres in the world were shown. Two operations for the treatment of hearing defects were carried out in 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 performing 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. In the last year 50,000 registered doctors watched broadcasts.” said Head of the Department of Otolaryngology and Laryngological Oncology, University of Medical Sciences, Prof. Witold Szyfter.

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. Since 2009, Poznań Clinic has carried out eight live surgical sessions Surgery Live. Doctors cooperate in accomplishing the transmission of the Poznan Supercomputing and Networking Center (PSNC).

The video signal was broadcasted in High Definition quality (HD), because of the crucial importance of image quality during the medical operation. There were two channels of video conferencing 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.

Examples of where 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.

“Telemedicine should create a level playing field where access to quality and affordable healthcare can become a right for every Indian just like 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.” according to Vishal Gupta, Cisco VP/GM of Global Healthcare Solutions. [TELEMED]

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, distance-travel 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 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 activities on a regular basis; commuting is part of our lives. However the 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. Some advantages/opinions of distance working, as held by workers and society are presented below.

- **Conserving Energy**. 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 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 three, major areas where energy can be conserved are:
    - Vehicle-related materials and resources.
    - Road and Infrastructure-related materials and resources.
    - Office-related materials and resources.
- A tremendous amount of energy is required to produce cars, buses, trains and aircraft. If telecommuting is promoted, there will be less use of this equipment and less energy will be required for its production, maintenance and repair. Fuel resources needed to operate this equipment will be reduced. The building and repair of roads and other infrastructure and maintenance consumes a great deal of energy, not only in the operation of the highway construction and repair equipment, but also in the manufacture and transportation of the required materials. An increase in the percentage of people telecommuting to work will decrease the need for expanded highways and associated road maintenance. Once a person arrives at work in a central office location, he or she represents another energy consumer; often times magnified many times over what would be required at home. The office building has heating, cooling and lighting needs, and the materials to build it and maintain it require energy in their production and transportation. Working from home only requires modest incremental demands on energy for heating, cooling and lighting needs, and makes effective use of existing building space and facilities.
- **Preserves the environment** by reducing land use requirements for road expansion and by reducing slow-moving automobile emissions. Road and parking lots continue to consume large quantities of our land surface area. If a larger percentage of people telecommuted, existing roads could be reduced in size or at least only stay at their current size. One of the largest sources of pollution is the car. This is especially true of slow-moving cars that often exist in heavy, congested rush hour traffic. Of course, one solution to this problem is increasing the size and number of our roads, but an even better solution is to encourage those who can to telecommute, so we will not need additional highways, parking lots, and airports in the future.
- **Promotes safety** by 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. The stress associated with commuting to work away from the home is real, and telecommuting offers a renewed opportunity for workers to rediscover the joys of working from their homes.

- **Allows closer proximity to and involvement with family.** Working in the home offers people a greater opportunity to share quality time with family members, to promote family values and develop stronger family ties and unity.

- **Allows selection of a remote worksite that is mutually acceptable to all family members** and allows spouse an opportunity to pursue his/her career.

- **Allows employee 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. Telecommuting affords an employee the freedom to look for another place to live, where he or she can feel comfortable both from a social, as well as an economic standpoint and live near people that have common interests. All this, while remaining loyal and productive for their employer.

- **Improves productivity**: Time saved can be used to improve productivity. Much time is spent on unnecessary activities by people who commute back and forth to work in the conventional manner.

- **Reduces number of people 'job hopping'**; decreasing training requirements. Many people job hop each year, and much of this 'job hopping' is the result of people wanting to move to a new location. They enjoy their work, and they would keep working for their present employer, but they do not like their present location. If people could move without losing their jobs, because they could telecommute, the amount of retraining would be reduced substantially. This would increase overall employee productivity while keeping loyal and productive employees on board.

As NRENs are part of the ICT industry as major telecoms service providers, it was important to check the status of other large players in the industry to see how practical telecommuting is for the whole industry that promotes its technical products and service to sustain distance working. A good example was BT's Flexible Working policy, where UK telecoms operator, BT, operates what it is believed to be one of the largest flexible working projects in Europe called BT Work style [BTWORKSTYLE] "Flexible working is available to almost everyone and the company now has more than 70,000 flexible workers. Already seven out of 10 people work flexibly and nearly 10% are home based. It has saved the company millions in terms of increased productivity and cut costs. It has also motivated our people and released more potential."

BT identified that their workers fell into three categories: mobile, home based, and office based. Each of these categories overlapped and a procedure based on flexibility, as opposed to grade, job function and location was deemed the best approach.

Mobile telecoms provider T-Mobile actively advertises that the services they provide enable distance-working.[TMOBILEDW]

NRENs are small in size compared to these large service providers and many have policies to facilitate distance working where part of the week is spent working from more remote locations. Others are in the progress of finalising such procedures and policies within their organisation. Some NRENs are more challenged by existing national works legislation, and will be slower to enable such official policies. Lots of NRENs work with ad-hoc policies based on employee and their supervisor's judgment about daily activities and perhaps local climate concerns at the time.

A good example of the impact of distance working in a small NREN which has active programmes and policies for teleworking is at UNI-C in Denmark.

9.1 Case Study: Reducing the Environmental Impact of Commuting at UNI-C in Lyngby

UNI-C has 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 is presented in some detail, showing the very large variations observed between individual employees.

The study is based on the use of distance working by a group of 30+ employees at UNI-C's data centre in Lyngby. All have their 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. Table 9.1 shows the individual commuting pattern for each employee, the number of days they chose to work from home and the individual and total savings in CO_2-emissions during the five-week study period.

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 does 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 does not account for the corresponding savings of office heating, lighting and electricity consumption.

9.1.1 Results

The total amount of CO_2-emissions being 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.

	Commuting pattern (in kilometres)							
Employee	Walk	Bicycle	Car	Bus	Train	S-tog and Metro	# Days at home	CO_2-saving (kg)
1	2	14		10	200	80	2	21.2
2			44				5	38.5
3			32				1	5.6
4							8	0.0
5			5				3	2.6
6	2			6			1	0.5
7							4	0.0
8							3	0.0
9		11			54	37	11	31.5
10			30				1	5.3
11			63				2	22.1
12			50				1	8.8
13							0	0.0
14							0	0.0
15				24			5	10.8
16			25				2	8.8
17							0	0.0
18				28			4	10.1
19					280		3	35.3
20			50				5	43.8
21			16			16	4	12.2
22			13				5	11.4
23			166				1	29.1
24			15	2		13	4	12.1
25							0	0.0
26							0	0.0
Total							**75**	**309.0**

Table 9.1: Commuting pattern, number of days working at home and CO_2-savings

One employee (No. 23) alone accounted for 10% of the reduction achieved in the study period, which was reached by working at home just one day. In theory, a similar reduction could be achieved by using public transportation, and the results clearly demonstrate that personal transportation by car can give a very high contribution to GHG-emissions on both the individual and the company level.

The amount of time and money saved by the use of distance working was not directly assessed in the study. Estimating the average travel time saved is about one hour, per day, working at home, this is equivalent to 75 hours for the five-week study period, or **21 working weeks** when scaled to a full year.

In the *SMART 2020* report, it is claimed that "currently the largest opportunity identified within dematerialisation is teleworking – where people work from home rather than commute into an office". [SMART2020] The report estimates this saving to account for 0.26 GtCO2 out of the total anticipated "business as usual" emission of 51.9 GtCO2 in year 2020, or about 0.5%. Other studies that have taken place in the ICT industry also show equivalent findings

9.2 Other Studies

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 was usually spent commuting was 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.

Other studies by Telstra in Australia [TELSTRA] also 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.

Key factors influencing these results included:

- 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 the *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.

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] 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 23km in the Asia–Pacific, up to 74km in Europe.
- Approximately 69% of the employees surveyed cited higher productivity when working remote, and 75% of those surveyed said the timeliness of their work had improved and they indicated telecommuting is somewhat or very important to their overall job satisfaction.

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

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

9.3 Additional Remarks

All the above studies show that there are significant environmental benefits attached to distance working, and we have enough resolution in the details in the UNI-C study to show that there are very large differences between individual employees. One individual, driving 166 km per day to and from work in a private car, can realise a much larger savings potential than his colleagues using bicycles or public transportation. The results can thus be used as an awareness-raiser for people trying to find a way of reducing their personal carbon footprint – and for organisations trying to do the same at a higher level. Some of the partners in Green GÉANT have therefore also made carbon low (or carbon neutral) transportation easier for their employees, e.g. by having bicycles at the disposal of the employees for short-distance transportation when at work.

9.4 Other Observations

It was a general observation that while the employees found the possibility of working at home very helpful, they might not use it to its full potential, attendance in person at the main office is regarded as of great social importance.

It was also evident from interviews that the saving of transportation time is of real significance to people. Time spent on trains can to an extent be used in reading reports and perhaps even doing work online using internet access. As previously mentioned, however, time spent travelling by car is considered as lost time. Other social advantages were identified earlier in the article. One study in the UK revealed some interesting social findings that nearly 1 in 5 workers aged over 55 already work regularly from home, part of a growing trend for working from home that has seen numbers rise by over 25% in the last decade. [TUCSTUDY]

According to the UK Trade Union Council TUC, the older age group from its study is more than twice as likely to work from home than their younger counterparts, which it puts down to barriers affecting younger workers, such as finding space in the home in which to set up a work area and early-years, child-care commitments.

In the UK, the Business Secretary, Vince Cable, has announced plans to give every employee the right to request a flexible work pattern which may include Distance or teleworking if practical by 2013. [DFT]. The UK government also actively promoted workers to work from home during the Olympic Games in London in summer 2012. [WFH]

9.5 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 the benefits accrued** from this policy on a six-month basis.

10 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 practicing 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]

10.1 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) 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 (MS) to choose the options that best suit their political framework and the level they have reached.

10.1.1 National Action Plans (NAPs) – the Status in EU Member States

The document National GPP action plans (policies and guidelines) contains a comprehensive overview of the state of affairs in the 27 EU Member States (last updated in June 2012).

The following table summarises the status of the NAPs as of September 2010, which is the last published status, and has been included to illustrate the maturity of the Green Procurement Process in 27 member states of the European Union.

GPP element	Member State implementation (June 2010)
National Action Plan or equivalent document adopted	21: Austria, Belgium, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, UK
NAP in process of preparation	6: Bulgaria, Estonia, Greece, Ireland, Hungary, Romania
Targets/criteria adopted	21 MS
Market analysis conducted	9 MS
Communication and dissemination activities	9 MS
Training activities	18 MS
Monitoring	11 MS
GPP - Legally binding	Portugal, Germany (for wood and LCC use), Czech Republic (IT)

Table 10.1: Status of EU -27 Members Green Public Procurement Policy activities

Ireland is listed as one of the countries in the process of generating a National Action Plan' and in January 2012, the Irish government launched Ireland's first Green Public Procurement Action Plan called "Green Tenders" .[GREENTENDERS] This initial action plan has focused on eight priority areas, which included Energy and ICT.

In the ICT section, environmental considerations constitute a subset of award criteria for this framework, in particular, seeking:

- 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 EPEAT Certificate [EPEAT] or EU Ecolabel [ECOLABEL] will be accepted as proof of compliance, (discussed in Section 10,5)

- Power Management capabilities
- Compliance of WEEE regulations

This concept of GPP is viewed by many authorities and private institutions as a promising way of achieving environmental improvements. National and supranational guidelines for GPP have been developed 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 this study with the aim of measuring if their targets have been met. Since there are no systematic statistics on GPP in the Member States, 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.

10.2 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 dealt with in a chapter in the report "Guidelines for Sustainable Public Procurement" [PPGUIDELINES] which dealing with generic office equipment. A total of 48 case studies are available, with 21 participating countries.

Evaluation exercises range from purchasing electricity from renewable sources, cleaner vehicles selection, sustainable furnishing, etc.

10.3 Ecolabel

The EU Ecolabel 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. Recognised throughout Europe, EU Ecolabel is a voluntary label promoting environmental excellence which can be trusted. Different countries have developed their own programmes with special emphasis on Electrical and IT products. In short, the recommended specifications for IT equipment are similar to the criteria for award of the EU Ecolabel "The Flower", the Nordic Ecolabel "The Swan" and the German "Blaue Engel" Ecolabel for relevant product groups.

A more International 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.

10.4 Danish Green IT guidelines

The last version of this deliverable document referenced the Danish “Green IT guidelines for public authorities” had a broader outlook than just purchasing of equipment. This document has now been superseded by a new document [GREENIT_2] published by Denmark’s Ministry of Science, Technology and Innovation, and this new plan has two objectives.

- Citizens, businesses and public authorities' use of IT 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.

Smart 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. Furthermore, the use of electronic mail and eGovernment by public authorities can save both paper and transportation. Therefore, new research must be initiated to refine existing IT-based solutions and to develop completely new IT-based solutions for a sustainable future.

With a broad outlook, the Danish Government setup a Project Office with the idea of professionalising the management of Government IT Projects. [DANISHGREEN]

10.5 Other Green Registry Solutions and Benchmark sources

As previously mentioned, EPEAT, is a global registry for greener electronics. It’s an easy-to-use resource for purchasers, manufacturers, resellers and others wanting to find and promote environmentally preferable products. This is 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.

Also referenced earlier in this document was the EU’s *2012 Best Practices for the EU Code of Conduct on Data Centres,* ” which is the third iteration of this document since 2008. [EUCODE] In its section on selection and deployment of new IT equipment, it has a link to the EnergyStar or SPECPower [PPGUIDELINES], which is the first industry-standard 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.

10.6 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, which is the global register for Greener Electronics**.

11 Green Electricity and Energy Source Choices

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 greenhouse gas (GHG) emissions. Depending on the fossil fuels used, some methods of generating electricity generate more emissions in production of electricity. A major contribution to NRENs' GHG emissions may be totally outside of their control, depending on how electricity is generated in their country, such as in Poland, which has huge natural resources of coal. A natural gas power station generates less GHG in the production of electricity than would a coal-fired generation station.

All energy sources cause environmental concerns whether in the extraction, processing, usage or disposal of the energy source. Countries that have availability of energy sources usually base their electricity generation on such availability so countries that are not fortunate enough to have much renewable energy resources, will have high a 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 market for generating and trading all types of electricity is complex, especially as these markets have been de-regulated to stimulate more competition. Even the generation sources and the power grids to which they supply the electrical power into have been decoupled to actively encourage more competition in this market. This has led to new trading environments in which negotiations for electrical power are short-term in nature, and which are much linked to matching the supply of electricity with the consumer demand for this energy.

The setup of electricity generation facilities is a major, long-term investment, which must be paid back with income generated in short-term bursts, often in negotiated, 15-minute intervals. National grids impose practical limits on the distribution of electricity, which cannot be stored, so must be used or distributed to other countries' power grids for immediate use. NRENs, like all electricity users, cannot influence these business practices but they do have to live with the outcome of such business practices. 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 even more complex, because such electricity production and GHG emissions are influenced by political decisions and targets. There are several green electricity products on the market and as the political scene is constantly changing, their actual effect on global GHG emissions cannot be determined precisely. Consumers have the possibility to choose their electricity supplier, thereby choosing 'green electricity'.

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 of the de-carbonisation of the energy supply and reduction in greenhouses gases emissions. They also contribute to energy security, being, for the most part, an indigenous energy source. In a period of increasing and volatile energy costs renewables can also contribute to cost competitiveness by reducing dependence on imported fossil fuels. There is the potential for Ireland to become a net exporter of renewable energy and technology. The ambition is for Ireland to become a globally recognised centre of expertise in the development and integration of renewable energy technologies.

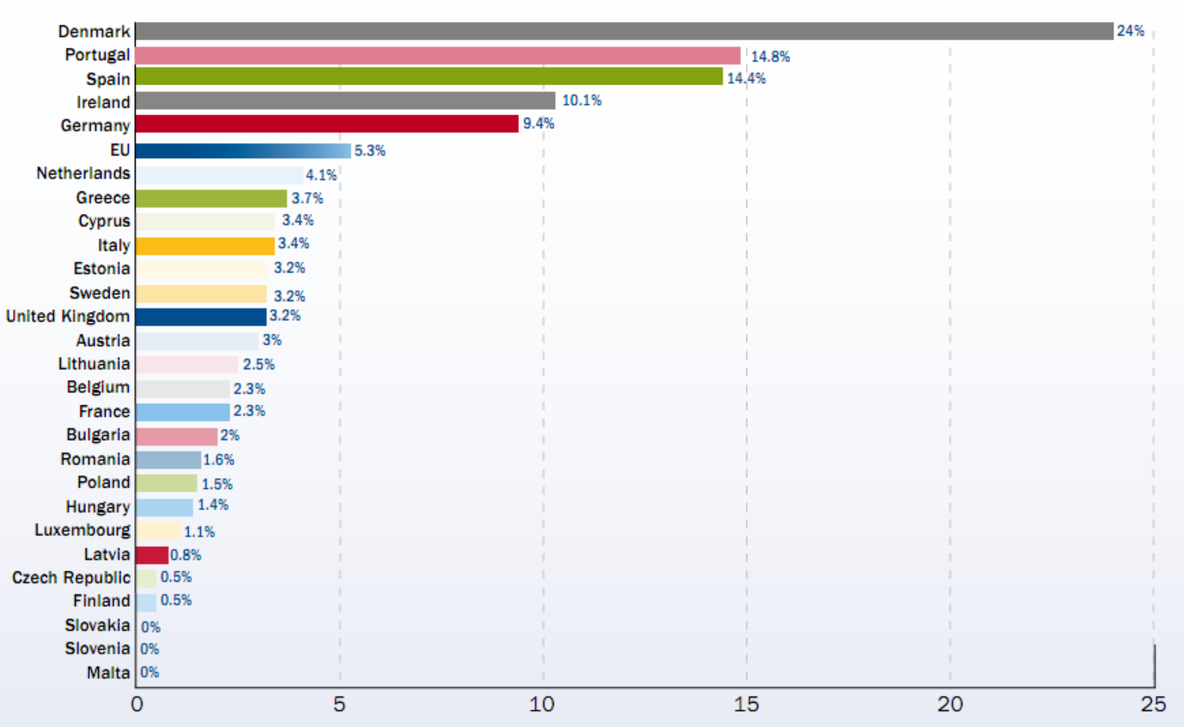

Figure 11.1: Wind share of Total Electricity Consumption in 2010 [DUDURYCH]

However, such a radical change will also introduce challenges for NRENs based in certain countries such as Ireland and Greece. In 2010, Ireland produced 10% and Greece produced 3.7% of its energy from wind turbines. At present, the target for these two countries is to use 37% and 25% 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 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. Even at Ireland's 10% current wind generation potential, the frequency rises that occur are starting to cause concern and the grid supplier, EirGrid, is continually looking at new advanced technologies and measurement techniques.

Country	2020 Gross consumption of electricity (TWh)	2020 Electricity production from renewable energy (TWh)	2020 Electricity production from wind energy (TWh)	2020 Percentage of electricity production from wind
Ireland	32.7	13.9	11.9	36%
Denmark	37.8	19.6	11.7	31%
Greece	68.5	27.3	16.8	25%
Netherlands	135.8	50.3	32.4	24%

Country	2020 Gross consumption of electricity (TWh)	2020 Electricity production from renewable energy (TWh)	2020 Electricity production from wind energy (TWh)	2020 Percentage of electricity production from wind
Portugal	64.5	35.6	14.6	23%
Spain	375.2	150	78.2	21%
UK	376.7	117	78.3	21%
Germany	561.8	216.9	104.4	19%
Estonia	10.9	1.9	1.5	14%
Romania	73.7	31.4	8.4	11%
France	545.5	148	57.9	11%
Latvia	8.7	5.2	0.9	10%
Belgium	110.8	23.1	10.5	9%
Lithuania	13.9	3	1.3	9%
Poland	169.8	32.4	15.2	9%
Sweden	154.6	97.2	12.5	8%
Cyprus	7.4	1.2	0.5	7%
Austria	74.2	52.4	4.8	6%
Malta	3.1	0.4	0.2	6%
Bulgaria	36.6	7.5	2.3	6%
Finland	101.6	33.4	6.1	6%
Italy	374.7	98.9	20	5%
Hungary	51.4	5.6	1.6	3%
Luxembourg	6.6	0.8	0.2	3%
Slovakia	33.3	8	0.6	2%
Czech Rep	84.1	12.1	1.5	2%
Slovenia	15.6	6.1	0.2	1%
EU 27	**3529.4**	**1199**	**494.7**	14%

Table 11.1: Electricity production in 2020, sorted by quantity of renewable energy (Source: EWEA analysis) [EWEA]

While NRENs want to promote greater use of renewable energy to power the data centres housing their equipment, and even power that 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. As mentioned, demand from the grid varies by season and by day. There is less demand for power in summer than in winter. Industry and homes use less power at night, even in hot climates. The grid provider has to have capacity to generate power to match times of peak demand, as well as draw upon access to other grids' supply, in case enough power cannot be generated to meet this demand.

If the grid cannot supply power to all regions, there could be power dips in certain areas, further away from the generation stations. This is called a 'brown out'. Using renewable energy, however, means that 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 that what can be dissipated in the grid, at the same time as demand dramatically lagging the supply.

In such a situation, regions could have excess power in certain section of their grid, which cannot be dissipated fast enough, that will trip out the power in these regions if the excess cannot be consumed or transported to other grids. NREN clients in these regions could lose total connectivity, without power on campus or at the regional PoPs to support them, not 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 to other grids that have a need these energy supplies. HVDC Grid [AHMED] offers the capability to instantaneously switch such loads, but other grids have to be able to absorb and use this capacity. This is still a new technology, and in many situations, it is easier and quicker to build large, renewable energy source locations such as wind farms or solar PV arrays than it is to plan and install power interconnectors between different power grids in different countries.

Most of the non-renewable-energy generating stations do not have the ability to turn down capacity at short notice, so part of a longer-term solution will need to consider the scenario of over capacity, so 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. The latter is a safety factor controlled locally by the turbine, but may need to be controlled from a central facility in the future. In a volatile market with energy being purchased in small finite time windows, management of excess power generation will also require complex policies to control and sustain accessibility to these resources when needed.

HEAnet investigated the possibility for using a renewable energy source to power a regional PoP, which would house two racks of equipment, with a total load of 6kw.

- A 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.
- There is not a large selection of commercial wind turbines available in this power rating range currently available. This presents risks in terms of product quality and customer support.
- Prospective sites for a wind turbine should involve a wind resource assessment of wind speed distribution and direction at the intended hub height the turbine.

- Stand-alone system require an accurate assessment of the PoP-load profiles, wind resource and turbine size as there is no grid to export excess power to or supply deficit power.
- Battery storage is a feature of standalone systems and should be sized according to autonomy required, which is site dependent.
- A 6kW continuous load in the stand alone case will likely result in a very large storage requirement, therefore back up generation/grid connection on economic grounds should be considered.

NRENs do not wish to own parts of real estate, with most sharing communication room facilities at campuses they serve or co-locating with third-party service providers. The setup up of a wind turbine generation facility would require an area of 40m by 40m, as the wind turbine would be positioned on a 15-metre-high mast and have 3-metre turbine blades. Legislation in Ireland dictates that space must be provided for the mast and the turbine blade radius, and a safety margin, should the whole structure fall in any direction. There are also specifications about distances from other buildings and proximity to roads and noise generation to which the wind turbine must comply.

Alternatively, NREN clients with the large campuses could setup 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 its dispersed campus which 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.

The following sections present the EU energy policy, the most common types of green electricity, and their possible effect on increasing the renewable energy supply and reducing GHG emissions. It is mainly inspired by the publication *Climate Friendly Energy Solutions* [ECOCOUNCIL], published by The Ecological Council, a Danish NGO. It is based on Danish conditions, but the considerations and recommendations are valid for most of the EU Member States. NRENs have to consider the political background to energy monitoring at a macro level, which includes policies to trade Carbon Credits and other European Community and Global initiatives to generate Green Electricity.

11.1 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. In Europe, these 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.

Apart from setting overall targets for reduction at the member state level, the ETS system allocates emission “permits” or “allowances” to companies, power plants, etc., which can be traded on the market.

Such a mechanism is to allow for 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.

11.2 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 this 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 type of solutions seem a natural balancing act to neutralise the carbon emissions we produce, they are far from simple in many different business arenas 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 such 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.

This 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.

11.3 Initiatives to Achieve Green Electricity

11.3.1 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. RECs are independent of the electricity grid, meaning that it is possible to buy RECs from a company other than the usual electricity supplier. In Europe, 16 countries have implemented a standardised certificate system.[1]

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.

11.3.2 Investing in New, Renewable Electricity

An obvious solution to reduce 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 will definitely bring more renewable energy on 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 if 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.

11.3.3 Securing Greener Electricity Production Outside the UN

The mechanisms of the Kyoto Protocol allows for 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 Mechanisms (CDM) projects is to help developing countries securing natural resources and ecosystems and obtaining 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 in 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 the recent years, many projects have been criticised for not being sustainable or

[1] Note also that some countries such as the UK and Poland have specific national legislation on RECs and the somewhat similar Guarantee of Origin.
[2] Unless national governments have decided that private initiatives are not included, which is allowed according to the EU directive on renewable energy.

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.

11.3.4 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. For the time being, cancelling permits does not have an immediate effect, but as the global economy is slowly recovering it may again become an attractive way of reducing GHG emissions.

11.4 Recommendations on Green Power Purchasing

As evident from the above descriptions, 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.

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.

Another recommendation is to be very careful when buying certified renewable electricity, and make sure that the real effects of this are sufficiently documented.

There is therefore scope for individuals and companies to make real contributions, whatever governments and international governments like the EU and the UN do – and suggest doing. For the conscious stakeholder, it is in general a good idea to involve independent counselling, before signing a contract with the energy supplier to fully understand the consequences of choosing a specific type of green electricity.

11.5 Green Electricity and GHG Accounting

It is not very clear how to include purchase of green electricity in GHG accounts, but the Greenhouse Gas Protocol Initiative is in the process of developing a guideline on this specific issue. The guideline is expected to handle the above mentioned dilemmas and will most probably also further define the concept of additionality and – more importantly – how to deal with it in practice. Furthermore, it will take into account the political and market mechanisms of specific regions.

11.6 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 active 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 to increase awareness.

12 Disseminating Green ICT in the Higher Education Community

12.1 Chances for Green ICT in the Higher Education Community

As we have seen in previous chapters, using ICT intelligently can make a big impact on reduction of global carbon emissions. There is not a better place to start a client knowledge dissemination process than in the Higher Education (HE) community. NRENs and HE institutions have a unique relationship as a highly collaborative environment between a service provider and client, to provide opportunities to lead, experiment and set the example for the rest of society.

12.2 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 are proactive in environment awareness activities. SURFnet has given examples where they work with their clients on joint activities in areas described in the report and highlight achievements. HEAnet 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 premise 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 others 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 reducing 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, 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 that could also provide resources to model new approaches.

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

12.3 Greening of 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’.

Between 1999 and 2002, all the Dutch research universities and many universities of applied sciences signed a long-term agreement on energy efficiency with the Ministry of Housing, Spatial Planning and the Environment. This agreement included a commitment from the higher education sector to reduce energy consumption by 30% by 2020, and quickly encourage the remaining applied science university to join the agreement.

From the survey, 22% from 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 relative 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).

12.4 ICT’s Role in Reducing Carbon Emissions in the HE Community

ICT can also be used as an enabler to reduce carbon emissions from other processes, i.e. in the context of teaching, research or management. This involves such things as working at home and videoconferencing rather than travelling. The real challenge regarding sustainability and ICT is to be found in this “enabling” role of ICT. For HE institutions, there are many opportunities in this area, which could not only lead to effective reductions but could also increase flexibility for students, teachers and researchers and increased total efficiency.

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 only for teachers), 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.

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.

12.5 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, which 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. Even if they would want to make some changes, they do not get a return on investment because the rewards of reducing the electricity bill are collected by others, usually the facility department.

So the biggest challenge 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 won't 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.

12.6 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]).

Although inspiring, statements such as “the energy efficiency of our ICT has much improved since last year”, “we’ve come closer to reaching our targets on energy efficiency” or “we’re doing a lot better on ICT energy efficiency than most other higher education institutes” are not very helpful in making proper comparisons, nor are they helpful for making decisions whether it is worthwhile to implement particular energy efficiency measures.

In fact, some people would go as far as classifying such statements as ‘twaddle’. David JC MacKay, chief scientific adviser to the UK Department of Energy and Climate Change (DECC), writes “twaddle emissions are high at the moment because people get emotional (for example about wind farms or nuclear power) and no-one talks about numbers. Or, if they do mention numbers, they select them to sound big, to make an impression and to score points in arguments, rather than to aid thoughtful discussion.” In short, in his excellent book *Sustainable Energy Without the Hot Air* [NOHOTAIR], he argues: “we need numbers, not adjectives.” MacKay carefully crafts kilowatt-hour per person per day (kWh/p/d) as a metric that can be used in sensible discussions about sustainable energy and for discussing energy plans that add up.

12.7 Best Practices for the Higher Education Community

Since ICT is not the core business of HE institutions, there is often plenty of room for improvement; the low-hanging fruit hasn’t been picked yet. In addition, it is hard to quantify ‘greening by ICT’ solutions, even for sustainability experts, thus making such solutions expressed in terms of carbon emission reductions, rather scarce. Therefore, this section focuses mainly on the greening of ICT.

12.7.1 Data Centres

As previously mentioned, the SURFnet / NL Agency survey also looked at reductions in data centres at HE institutions. The study was done with the aid of the Open DCME model (Data Centre Measure of Efficiency) [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) is 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 is 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.

The second reason for this low electricity efficiency is the 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 means that the energy consumption of the air-conditioning is not ideal.

The third and final major reason is the long economic life of ICT hardware. A write-off period of 4.5 years is (too) long; older equipment is less energy- efficient than new equipment. Especially server equipment, 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.

12.7.2 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 also usually do not have any “switch-off” policy. 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. An enormous amount can therefore be gained by turning PCs off when they are not being used. Account should also be taken of energy consumption when purchasing workstation equipment.

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 experience shutdowns initiated by PowerDown. Even with only this many computers participating, they save **over 1,000,000 hours** per month. A lot of the pointless uptime comes from the student PCs. The typical student PC is in a building, which 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 pointless 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.

12.7.3 Cloud Computing

The following approach was used to discuss cloud computing as part of SURFNET initiatives with Higher Education schools. In principle, cloud computing offers an increase in scale environment, leading to an increase in energy efficiency. Of course cloud computing also offers other benefits to institutions such as flexibility in use (on demand), which means that more and more institutions move their ICT services off premises and into 'the cloud'. It is therefore worth looking at the greenness of cloud solutions.

Focussing on "Infrastructure-as-a-Service" clouds – i.e. clouds in which storage and processing capacity is made available as a service – what determines the answer of the question "When is a cloud green?" "Green" in this context is constitutes both energy consumption as well as the associated CO_2 emissions.

The energy consumption of a cloud depends mainly on the *efficiency*: Is all ICT equipment 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 turning resources 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 is 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 that storage and processing take place at a location where energy – i.e. locally generated energy – is cheapest (including the transport costs) and greenest.

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.

Level	Description
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 12.1: The CO_2 Performance Ladder (skao.nl)

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 (Table 12.1). 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.

12.7.4 The Most Important Features of Cloud Computing

A cloud provider is greener if:

- The servers are fully utilised: the number of servers that are switched on but are not doing any useful work has been minimised (efficiency); techniques that can be used to this purpose are e.g. virtualisation, scheduling and provisioning and energy-efficient hardware;
- The energy that the data centre consumes is mainly consumed by the servers; in reverse: only a minimum of energy is necessary for cooling, lighting, and other systems (effectiveness); frameworks and metrics that can be used to measure effectiveness include frameworks such as OpenDCME, BREEAM, LEED and metrics such as Green Grid;
- The energy consumed leads to the minimum possible emissions; in other words, it has been generated sustainably;
- The data centre is not too far away from the users so that transporting the data consumes less energy;
- The energy is generated at a location close to the data centre so as to minimise transport losses.

Cloud service customers should take the following into account:

- Provider assessment by means of a framework such as the CO_2 Performance Ladder;
- Inclusion of energy efficiency (or another sustainability metric) in their own management systems and management reports;
- Allow for the energy efficiency of ICT use in the internal pricing for services;
- Encourage efficient use, e.g. by encouraging that computationally intensive but non-interactive tasks (that cause little network traffic) are processed within the cloud.

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.

12.8 Case study: SURFnet and the Dutch Community

After completing a survey in 2010, SURF hosted a symposium to present the results focusing on topics in this area which were of most interest to this community. [SURFNET_2] One hundred participants attended the event, all eager to learn about and do more with Green ICT which encouraged SURF to create a Special Interest Group SIG on Green ICT and Sustainability which marked the start of the Green ICT HE community in the Netherlands.

SURF then started a LinkedIn group [LINKEDIN] to provide for a place where members of the SIG could meet and discuss various topics. Two years later, the group has grown to well over 300 members in 2012, to stimulate sharing of such knowledge and experiences. The role of the SURF as an NREN has been here is thus 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 SURF showed that the average institution could easily save tens of thousands of euros by implementing PC power management software. [SURFSITES]

While SURF does put some effort in generating knowledge, the end goal is to create an active community, which 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 provided funding for innovative sustainability projects. [SURFSITES] These projects should somehow reduce carbon emissions, be it direct or indirect, and the results should be 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:

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 12.2: SURFNET interaction plan 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. SURF is of course happy to share the lessons learned with other NRENs who want to set up similar communities.

12.9 Case Study HEAnet's Liaison with the Green Campus Programme

HEAnet also started to investigate some outreach activity to be held with their client, Universities and Higher Education Institutes and quickly found that most of these clients were actively involved in the programme called "Green Campus" run by An Taisce. HEAnet found that 25% of An Taisce's full client list were actively involved in the programme. Three institutions had achieved full certification being award a Green Campus Flag. One of these clients, University College Cork are now registered as an ISO50001 campus and made savings of over EUR.5 million because of initiatives taken by students and staff.

This Green-Campus initiative is based on the success of the Green-Schools Programme. 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. 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: establishing a Green-Campus committee incorporating student and staff representatives, undertaking an environmental review, implementing an action plan, monitoring and evaluating actions carried out, linking the programme to curriculum work, informing and involving the campus and wider community, and developing a green charter.

12.9.1 Green-Campus Programme Structure

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.

The Programme primarily aims to ensure that members of a campus community can engage in a meaningful way to enhance sustainability on their campus. The Green-Campus Programme is an evolution and adaptation of the International Eco-Schools Programme.

As stated earlier, the Environmental Education Unit at 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 has 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 which is independent of local campus 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 which as part of FEE.

12.10 Recommendations

Sustainability is all about 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 the nature of NRENs and the collaborative environment they work in, NRENs with their community have excellent opportunities to do this and set the example for the rest of society to follow.

- Plan for **dissemination activity with clients** in all areas of experience.
- Be open to **show best-case 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 program sponsors and local client teams.

Note that many environmental awareness programs may have a broader focus than what may be practiced at NRENs, so there is opportunity to gain knowledge and best-practice ideas in different areas of experience.

13 Conclusion

In conclusion, we look back at a phased programme of engagement with the environmental aspects of Research and Education networking. Put simply, we began with a benchmark measurement or audit of carbon footprint. The ISO 14064 standard was adopted for this purpose, which provided a level of quality assurance, as well as the ability to assert, compare and reduce levels of greenhouse gas emission.

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 HG 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 three years of the GN3 task duration, the team has 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.

As we enter 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. Our work plan includes submission of a proposal to setup a GÉANT Taskforce to focus on Green ICT & Sustainability, and this document is almost complete. There is a real need to mainstream this project activity, however, and to make it as sustainable as the high-end network services for our users. The team has 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).

(a) Some larger aspects of the task that the Environmental Team has to resolve is 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.

(b) If the reduction of CHG 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 enormity 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 our the amount of technology deployed or to use it in a more productive manner, which reduces the carbon footprint of such a network.

(c) 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.

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.

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Glossary

ACPI	Advanced Configuration and Power Interface
BMS	Building Management System
BoD	Bandwidth on Demand
BSS	Business Support System
CCTV	Closed-Circuit Television
CO_2	Carbon dioxide
CRM	Customer Relationship Management
DCIE	Data Center Infrastructure Efficiency
DWDM	Dense Wavelength Division Multiplexing
EMAS	EU Management and Audit Scheme single line, as this line should demonstrate
ERP	Enterprise Resource Planning
ETS	Emmisions Trading Scheme
FINSENY	Future Internet for Smart Energy
GeSI	Global e-Sustainability Initiative
GHG	GreenHouse Gas
GiCOMP	Green IT Control and Management Platform
GPP	Green (Public) Purchasing
GRE	Generic Routing Encapsulation
GSM	Green Star Network
ITU	International Telecommunication Union
HE	Higher Education
HVAC	Heating, Ventilation, and Air Conditioning
HVR	Hardware-Isolated Virtual Router
IaaS	Infrastructure as a Service
IEEE	Institute of Electrical and Electronics Engineers
LED	Light-Emitting Diode
MCU	Multi-Conferencing Unit
MPLS	Multi-Protocol Label Switching
NMS	Network Management System
NOC	Network Operations Centre
NREN	National Research and Education Network
OS	Operating System
OSPF	Open Shortest Path First
PDU	Power Distribution Unit
PoE	Power over Ethernet

PoP	Point of Presence
PSNC	Poznan Supercomputing and Networking Center
PSTN	Public Switched Telephone Network
PSU	Power Supply Units
PUE	Power Usage Efficiency
RAID	Redundant Array of Independent Disks
QoS	Quality of Service
ROADM	Reconfigurable Optical Add-Drop Multiplexer
ROI	Return On Investment
RRP	Enterprise Resource Planning
SAN	Storage Area Network
SSH	Secure Shell
SVR	Software-Isolated Virtual Router
TCD	Trinity College Dublin
TCO	Total Cost of Ownership
TE	Traffic Engineering
VM	Virtual Machine
VNC	Virtual Network Computing
VoIP	Voice over Internet Protocol
WDM	Wavelength Division Multiplexing