26-05-2011

Deliverable DN3.5.2: Study of Environmental Impact

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Contractual Date:	31-03-2011
Actual Date:	26-05-2011
Grant Agreement No.:	238875
Activity:	NA3
Task Item:	T5
Nature of Deliverable:	R (Report)
Dissemination Level:	PU (Public)
Lead Partner:	HEAnet
Document Code:	GN3-11-075
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The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7 2007–2013) under Grant Agreement No. 238875 (GÉANT).

Abstract

This deliverable 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. It also draws recommendations from 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. The areas covered are environmental policy, green network management systems, Power Usage Efficiency (PUE), virtualisation, energy-aware traffic engineering, videoconferencing, distance working, Green Public Purchasing (GPP), and purchasing green electricity. It also draws recommendations – pertinent to the GN3 project, the NREN community, their users, and the ICT sector – from the partners' work.

Operational institutions like data centres and networks have traditionally focused on creating the best possible solutions for their clients, with little or no thought for the environment. During the last few years, however, there has been a noticeable increase in awareness, and NA3 T5 – also known as the "Green GÉANT" team – is an example of the developments that such raised awareness has brought about. The research and case studies described in this document follow on from the establishment of externally verified climate accounts in Year 1, which are briefly analysed in Section 2.

Having an environmental policy provides a framework for action, for setting objectives and targets, and sends a clear signal from management to stakeholders and employees. Having a structured management system, such as a network management system enhanced with green networking measures, while not a precondition for identifying improvement possibilities, can help to evaluate, report and improve an organisation's environmental performance. An operational approach to green network management typically includes the following areas: power management for unused computers, using more energy-efficient computers first, trying to optimise load distribution between servers, optimising or replacing sub-optimal computers and software, eliminating underutilised network devices, and reacting to abnormal energy consumptions. As an example of the improvements that are achievable, the Green GÉANT team's findings indicate that simple power management for unused computers can reduce power consumption for each PC from 482 kWh/year for always-on PCs to 86 kWh/year for PCs that are off at night and power-managed.

Power consumption at data centres is a main source of emission of greenhouse gases (GHG). The more effective the utilisation of incoming energy, the smaller the emissions from the production of electricity. Energy efficiency is commonly measured and reported as the Power Usage Effectivenes (PUE). UNI-C, the operator for one of the partners in NORDUNet, has reduced its PUE by at least 10% over 4 years, mainly due to an improved cooling system. The potential savings in GHG emissions from using the most efficient cooling solutions at one of GRNET's data centres have been roughly estimated to be 1450 ton CO_2 equivalents/year.

Virtualisation combines or divides resources to present one or many operating environments. The team's research covered server and network virtualisation, and, as an example of potential environmental benefits, indicates that the live migration technology made possible by server virtualisation can produce desktop energy savings of up to 74% compared to the 32% achievable through traditional power management.

Energy-aware traffic engineering adds the energy consumption of a network to the traditional traffic-engineering objectives of user performance and use of network resources. The three design areas that affect energy consumption are system, network and protocol. For example, findings suggest that Energy Proportional Networking (EPN) can produce energy savings of up to 42%.

Videoconferencing is a vital tool for the research community, and NRENs have for many years featured videoconferencing as a service layered on their network infrastructure. In addition to its advantages for collaboration between distributed communities, a case study at HEAnet showed that videoconferencing saved 66% of the total GHG emissions caused by travelling, with the absolute value of the saving being between 397 kg of GHG emission and 1,535 kg of GHG emission depending on the form of transport.

Distance working – paid work that is done outside the actual workplace – has become more and more common as ICT has developed and possibilities for its use, including at home, have increased. One of the main advantages of distance working is that commuting is avoided, thereby saving a significant amount of GHG emissions. A case study of 30 people at UNI-C, the operator for one of the partners in NORDUNet, showed that distance working saved 309 kg of CO_2 emissions, corresponding to 3 tons when scaled to a full year.

Green Public Purchasing (GPP) is "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" [COM400]. This document outlines the core EC GPP guidelines on office IT equipment and the broader purchasing guidelines for public authorities and private companies developed by the Danish authorities.

Green electricity is electricity whose production involves lower GHG emissions than power produced by traditional methods. The market for green electricity is complex, because electricity production and GHG emissions are influenced by political decisions, state subsidies and targets. This document presents the most common types of green electricity offered and their possible effect on increasing the renewable energy supply and reducing GHG emissions.

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 4 GN3 partner NRENs are reported to have environmental policies in place, of which only 2 have published their policy on their website.)
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 if you want to make environmental improvements, as the achievements of the Green GÉANT partners demonstrate.

4. Production of IT equipment is demanding for the environment, so ensuring a long lifetime with high-quality, needs-based functionality is crucial.
5. The savings envisioned in the SMART 2020 report require that stakeholders at all levels are aware of the mitigation possibilities provided by high-performance data centres and networks.
6. There is scope for sharing information, collaboration and collective action among NRENs, with the GN3 project and TERENA providing enabling forums.
7. NRENs are potentially well placed to take a lead in industry initiatives to promote sustainable policies.

The deliverable concludes that the 2009–2010 audit of carbon footprint stimulated ideas for GHG reduction and for smart use of the GÉANT network and its layered services. This helped to drive the second phase, in which the Green GÉANT partners developed case studies to show what NRENs could do to mitigate GHG emissions in the extended communities they serve, where possible applying metrics to any savings made, and comparing these with recognised projections, such as those of the SMART 2020 report. Environmental activities are not confined to the five members of the Green GÉANT team: serious initiatives are under way in other NRENs and in their client institutions, and learning from these is part of our remit. The outlook as we enter the third year of the GN3 project is that much remains to be done in raising awareness and in helping each other in the common task of reducing the likelihood of increased GHG emissions. There is a real need to mainstream this project activity, and to make it as sustainable as the high-end network services for our users. Just as GÉANT and its members have developed world-class e-infrastructure for research and education, so we can also show the way in harnessing smart networking to combat climate change.

1 Introduction

The often repeated statement that the Information and Communications Technology (ICT) industry accounts for about 2% of the global emissions of greenhouse gases (GHG), while ICT solutions may reduce current emissions by 15%, is becoming a mantra to many types of stakeholders, not least politicians and other decision-makers.

Whether the statement is true is uncertain. The emissions related to ICT activities can be accounted for with reasonable precision, but determination of the savings potential would require a very good crystal ball. One of these has been used in the report *"SMART 2020: Enabling the low carbon economy in the information age"* [SMART2020], which calculates the reductions potential of a number of future, but realistic, ICT solutions as implemented on a large geographic scale. In this way, the SMART 2020 report motivates actors and helps define targets at all levels of the industry.

The estimated 2% contribution to GHG emissions by the ICT sector is serious enough, however. It compares with the contribution from the airline industry, but it has its own dynamics and is increasing at a far greater rate. The ICT sector contributes to atmospheric and environmental pollution at all parts of the cycle. This includes the use of rare and often toxic products in the manufacture of electronic devices; the amount of packaging that goes into products which are marketed aggressively and with unrealistic replacement times; and the consumption of electricity generated by fossil fuels in networks, data centres, and from the use of end-user devices in the home, the office and on the move.

Marginal reductions in consumption of electricity will not be enough to counteract the growth of the Internet and of ICT generally. In router technology, for instance, there is a monotonic link between speed of routing and power consumed. There is no sign of a tail-off in this trend as we achieve greater and greater throughputs. In any event, savings made in this way will often be offset by more usage, so we are back to square one.

The only way out of this spiral of increasing emissions is to break the link between power generation and GHG emissions, that is, to move to a more sustainable position, with energy from renewable sources being used, and with adaptability being used to allow the network to use the right generation mechanism as appropriate.

These are issues of concern to National Research and Education Networks (NRENs) as to all others in ICT. The solutions needed extend beyond the industry, however, so NRENs must influence stakeholders not only in ICT but also in government, other sectors and the research community.

It must be acknowledged that the environment is taken into consideration only to a very modest extent by many organisations. Also, operational institutions like data centres and networks (national and regional) have traditionally focused on creating the best possible solutions for their clients, with little or no thought for the environment. That said, during the last few years there has been a noticeable increase in awareness, and the "Green GÉANT" team – the name given to GN3 Networking Activity 3 (Status and Trends), Task 5 (Study of Environmental Impact) (NA3 T5) – is an example of the initiatives that such raised awareness has brought about.

The research and case studies described in the current report constitute the second initiative undertaken by the Green GÉANT team. The first was the establishment of climate accounts, according to the requirements in ISO 14064-1 [ISO14064-1], for four National Research and Education Networks (NRENs) as well as for the GÉANT network itself. The climate accounts were verified by a third party, FORCE Technology in Denmark [FORCE], and as such they provide each of the partners with a "climate change baseline" against which future development and new initiatives can be measured. The climate accounts for the four NRENs have been published on the GÉANT website [GEANTEnvImpact], giving the opportunity for interested parties to dig a bit deeper into quantified information about "typical" NRENs.

Besides giving a brief analysis of this climate account information, the current report describes a wide range of environmental initiatives undertaken by the partners in the Green GÉANT team. It also points to less strong aspects of the overall GÉANT network, as it stands today, in relation to environmental awareness and activity. Most notably, only 4 out of 35 GÉANT partner NRENs are reported to have environmental policies in place, of which only 2 have published their policy on their website [TERENACompenium2010]. Formulating a written environmental policy is a step that most experts consider to be a very important first initiative on the way to making environmental improvements. Describing and implementing a network management system enhanced with green networking measures is strongly recommended as the second step towards environmental improvements. Nevertheless, only one of the NRENs is known to have such a system in place. The report gives an overview of its elements, their importance, and how they can be integrated into an operational system. It also shows that simple measures may produce significant reductions, while complex interactions between elements necessitate a greater amount of analytical work before real-life benefits are ensured.

Even without a "green" management system, the partners in Green GÉANT have introduced and completed initiatives aimed at reducing environmental impacts in general and emission of GHG in particular. The following areas have been chosen for inclusion in the report:

- **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. 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 in respect of reductions in energy consumption and GHG emissions.
- **Virtualisation** (Section 6) also is becoming more and more interesting from an environmental point of view, on the national, regional and global level. The report gives an introduction to the subject and describes some of the partners' ongoing initiatives. No efforts are devoted to quantification of the possibilities at this stage of development.
- **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 as the energy-oblivious approaches at a lower overall energy cost. GRNET participates in the ECONET project [ECONET], which aims at rethinking and redesigning wired

network equipment and infrastructures as well as developing energy-aware traffic engineering mechanisms towards 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 otherwise would require short or long transportation, often by demanding means such as airplanes. The report 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 at the level of NRENs hosting videoconferences.
- **Distance working** (Section 9) is made possible through ICT solutions, thereby avoiding transportation to work and home again. It is a well-known fact that transportation in total accounts for a large share of society's GHG emissions, but how important is it for an institution with 20+ employees? The report presents an example of what was achieved in a single campaign, including the finding that most employees give a high priority to 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 impacts. The section introduces the EU guidelines for GPP and Danish green IT guidelines which have a somewhat broader perspective.
- **Purchasing "green electricity"** – 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 impacts 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. Partners in the Green GÉANT team, and other NRENs and organisations, are researching methods of dynamically allocating network resources to maximise the use of renewable energy. The report presents a short overview of the most commonly discussed possibilities, authored by FORCE Technology, who have also been technical editors of the report.

While this report does not allow for firm conclusions. a few basic recommendations can be extracted from the work of Green GÉANT partners. These are presented in Section 12, together with a summary of the status of the Green GÉANT team's work, and the outlook for Year 3.

2 NREN GHG Audit Results

Green GÉANT's first deliverable, DN3.5.1, was based on a GHG audit of the GÉANT network, using the ISO 14064 standard to determine scope, methodology and validation. At the same time, the team conducted similar audits of their own NRENs, also using ISO 14064, and using a common carbon accounting tool. The findings make for interesting comparisons, as shown in Table 2.1 below.

Network	Office	Data Centre	Core Network	Transport	Total
GÉANT	233	1094	582	124	2033
HEAnet	123	540	1060	43	1766
NIIF	52	729	123	52	956
NORDUnet	30	77	28	93	228
PSNC	62	115	978	37	1192
Total	**500**	**2555**	**2771**	**349**	**6175**
Proportion	**8%**	**41%**	**45%**	**6%**	

Table 2.1: Breakdown of GHG emissions of five RENs, in tons of CO_2 equivalent (2009)

The largest network, in geographical terms at least, is GÉANT and this reports the highest total carbon footprint, of 2033 tons. However, the smallest network is probably that of HEAnet (Ireland) and it reports the second highest, at 1766 tons. NORDUnet has the lowest footprint overall, at 228 tons. This network has only five client connections, in the form of the five Nordic countries, and does not connect institutions within those countries; that is the function of the national network, such as FUnet in Finland and UNI-C in Denmark. Nevertheless, NORDUnet is a large-scale undertaking, with external connections to the rest of Europe, to North America and to the Internet generally. Yet its carbon footprint is only 11% of GÉANT's and 13% of HEAnet's.

This can be understood better if we look at the percentage breakdown of the NRENs' carbon footprints by the four categories: office, data centre, core network and transport.

Network	Office	Data Centre	Core Network	Transport
GÉANT	11%	54%	29%	6%
HEAnet	7%	31%	60%	2%
NIIF	5%	76%	13%	5%
NORDUnet	13%	34%	12%	41%
PSNC	5%	10%	82%	3%

Table 2.2: Relative contribution of each category to the RENs' GHG emissions

In the case of NORDUnet, the biggest single contributor is transport. This is due to secondary emissions arising from travel by staff, either in commuting to and from work, or on work-related travel. The calculations of such secondary emissions for cars and airplanes are quite uniform across all countries, as these forms of transport use common fuels. Travel by train and bus may vary from country to country, depending on the mix of fuels and power sources used. NORDUnet's transport emissions, at 93 tons, are therefore comparable with those of GÉANT, at 124 tons. Both are significantly higher than the transport emissions of the other, smaller networks. In other words, there is a correlation between these emissions and the size of the network, and this is independent of location.

In the other categories, where emissions are almost entirely due to the use of electricity, there is no such correlation. This is because the link between electrical power used and GHG emissions caused is a national conversion factor. This is a measure that is published by the energy regulator in each country. Its value depends on the mix of sustainable and fossil-based electricity generation in a country. If a country relies largely on coal, oil and gas to produce its electricity, then the conversion factor is going to be high. If, on the other hand, the country has a high proportion of renewable sources of power generation, such as hydro, wind, geo-thermal and nuclear power, then its conversion factor is going to be relatively low. This is the case in the Nordic countries, and accounts for the low contributions of NORDUnet's core infrastructure and data centres to their carbon footprint.

In Hungary, there is a high proportion of nuclear power in the national inventory. This helps to explain the relatively low carbon footprint of the Hungarian NREN, NIIF.

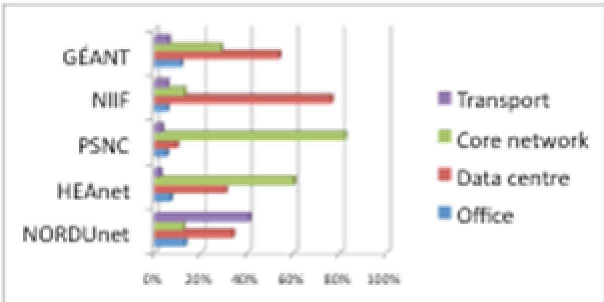


Figure 2.1: Relative contribution of each category to the RENs' GHG emissions

This comparison underlines the need for NRENs and ICT generally to move to sustainable sources of power. Moreover, NRENs can show how smart technology can make best use of renewable energy sources, particularly those that are not constant, such as wind and solar energy.

3 Environmental Policy

An environmental policy is defined in ISO 14001 [ISO14001] as “the overall intentions and direction of an organisation related to its performance as formally expressed by top management”. The environmental policy provides a framework for action and for setting of environmental objectives and environmental targets.

According to the 2010 TERENA Compendium [TERENACompendium2010], in 2009 only 2 partners in GÉANT had an environmental policy. In 2010 the number had risen to 4 (out of 35 GN3 partner NRENs), with only 2 NRENs publishing their policy on their website. It is not known whether the situation is different from that in other sectors, but it is a strong indication that environmental issues have a low priority in most of the partner institutions.

There is no legislation or other formal requirement obliging organisations to have an environmental policy; it is completely voluntary. However, environmental specialists recommend – and environmental standards require – that organisations adopt an environmental policy as an important first step towards environmental improvements. When a company or institution publishes its environmental policy, it shows that the top management is committed to the environment, and 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, that of HEAnet, one of the Green GÉANT partners, can be seen in Figure 3.1 [HEAnetPolicy].

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 3.1: HEAnet environmental policy

A somewhat simpler, but still operational, environmental policy is that published by JANET(UK) [JANETPolicy]:

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 3.2: JANET(UK) environmental policy

Not having an environmental policy does not mean that you cannot respect environmental considerations in your institution. Nor does it mean that the top management is not committed. 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 of making a verified GHG account according to ISO 14064 [ISO14064], 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 formalised programmes (e.g. GRNET's long-standing participation in the ECONET project) aimed at GHG reduction. The sections in this report contain many examples of initiatives that have been taken without a formal policy or management commitment, and the results are probably the same as they would have been had an environmental policy been published.

In this context it is worth noting that publishing an environmental policy is not, on its own, the end of the story. Actions are needed at all levels of the organisation, and dedicating a chapter (or a few pages) in the annual report to describing the initiatives and achievements in the previous year is a strong motivating factor. Still, having an environmental policy ensures continuous focus and commitment from top management, and is therefore a very good way of starting a structured effort towards environmental improvements.

4 Green Network Management Systems

According to ISO, having an environmental policy and establishing 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” [ISO14001].

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 identifying improvement possibilities – or for their implementation. Nevertheless, writing and following a set of procedures is often helpful in the process, especially if you want your colleagues to participate actively.

This section explains the concept of “green IT”, and outlines an operational approach to some of the important elements in a management system focusing on energy reductions in data centres and other institutions with a continuously increasing need for data power and data management. It then briefly introduces a case study of green network management at Poznan Supercomputing and Networking Centre (PSNC). It does not give instructions about specific actions, but should rather be seen as a catalogue of ideas that can be used at almost all levels of ICT use.

4.1 Green IT

IT systems in large organisations such as universities, e-commerce platforms, Internet banks, travel portals and others are complex and typically utilise many elements to provide the service, such as:

1. **Network infrastructure**: Power over Ethernet (PoE) switches, routers, firewalls, load balancers and others.
2. **Servers**: hardware, virtual machines, terminal servers, clusters, database servers and others.
3. **Storage and backup**: Redundant Array of Independent Disks (RAID) arrays, Storage Area Network (SAN) devices, tape storage and others.
4. **Software**: databases, application/web servers, user applications (such as Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), Business Intelligence systems)

5. **Voice infrastructure**: softswitches, phone system, Public Switched Telephone Network (PSTN) gateways and others.

Nowadays, with the growing price of energy and growing awareness regarding sustainability and the “green world”, the power consumption of such infrastructure elements has become an important part of operating expenditure (OPEX).

Organisations trying to find savings in the operational field of their activity, besides the regular hardware renewal cycle, look 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 fits well with the pressure coming from society for every organisation to care about the issues of sustainability and social responsibility, so turning to “green technologies” is worth mentioning as being beneficial for the environment.

So, what is “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.

Globally, tremendous reductions in power consumption can be achieved by a few steps, such as:

- Power management for unused computers.
- Using more energy-efficient computers first.
- Trying to optimise load distribution between servers.
- Replacing sub-optimal computers.
- Optimising or replacing sub-optimal software.
- Eliminating underutilised network devices.
- Reacting to abnormal energy consumptions.

The following paragraphs describe an operational approach, starting with straightforward initiatives and ending with more complex measures. A more technical description of some potential solutions is given in Section 6 Virtualisation on page 24. Please also refer to Section 5 *Power Usage Effectiveness (PUE)* on page 19, which is dedicated to one of the most important elements in achieving an energy-efficient ICT environment.

4.2 An Operational Approach to Green Network Management

With simple **power management for unused computers** one can achieve significant savings. Moreover, this does not require any sophisticated mechanism, just the use of simple built-in power-management features. Switching off or hibernating workstations and monitors when they are unused, and turning to standby mode when inactive, give reduction in power consumption as shown in Figure 4.1 below.

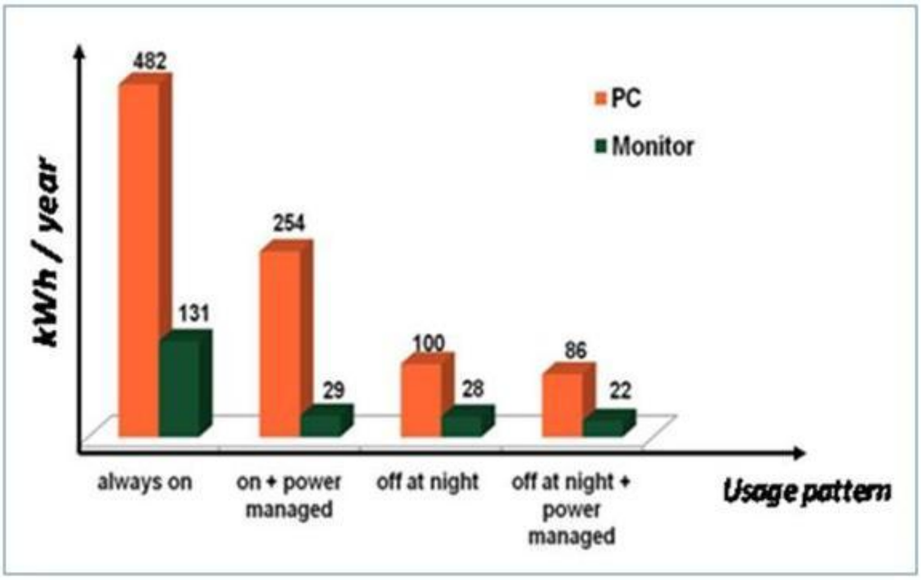
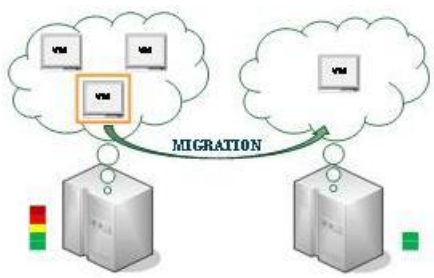


Figure 4.1: PC and monitor power consumption at different levels of energy management

Similar considerations can be given to servers: based on current usage, usage record and planned/forecast usage, switch active servers on, put ones ready to be used in standby and switch off all the rest. However, when deciding which servers should be activated or deactivated first, one should use more **energy efficient servers** first.

The next step is to analyse load distribution between servers. Because overloaded servers might not be energy efficient, it is worth considering moving some virtual machines to other, underutilised servers, of course taking into account current, historical and planned resource utilisation as well as energy consumption aspects. Such **optimisation of load distribution** could also be a source of power-consumption savings.



Replacing sub-optimal computers requires more effort, because simulation is needed to examine the impact on overall energy consumption. The general rule is to replace the least energy-efficient computer – if it pays off. 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 scientific institute), its planned usage and the required capacity. Any mistake in the analysis can potentially lead to an increase of overall power consumption because we will have new and energy-efficient, but underutilised computers at our disposal.

A similar analysis can be done, using special software, to monitor the energy consumption on the software level. Different applications cause different computer loads and this of course leads to various power-consumption levels (Figure 4.2).

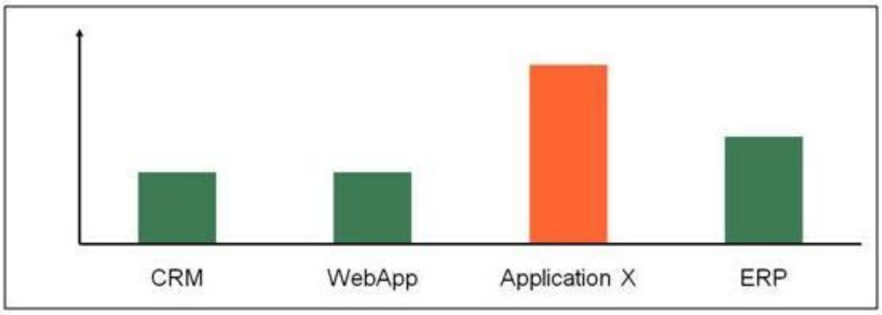


Figure 4.2: Relative energy consumption in different software

Having such measurements we are able to identify bottlenecks and then we can consider trying to **optimise** the code of the application or even to **replace sub-optimal software**.

The next elements to analyse are **network devices**. We should monitor network devices' utilisation and related energy consumption, as in Figure 4.3 below, which shows an example analysis of utilisation and energy consumption by country and device per country (the details are purely illustrative and are fictitious). 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)
France	11	237	115	48	131	46	3.6	36
Germany	20	623	72	42	531	88	1.1	18.5

Devices for Germany

Device no.	Device name	Description	Ports	Unused ports	Unused ports %	Device power (W)	Power per used port (W)
1	Berlin_Switch_1	2KO-32	100	50	50.1	400	33.33
2	Hannover_Switch_3	SWW-123	6	0	0	120	20
etc							

Figure 4.3: Example of information on energy consumption at national and device level

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, we could find some 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.

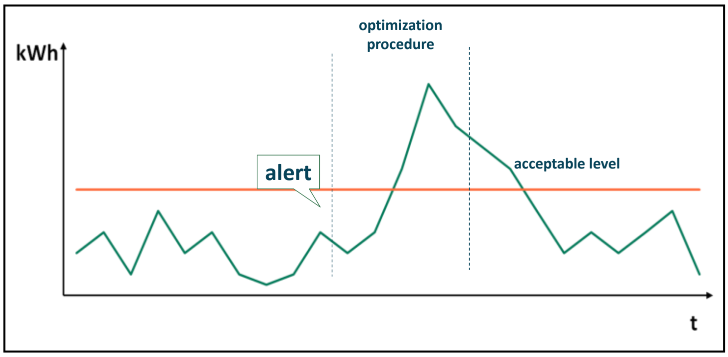


Figure 4.4: Continuous monitoring of overall power consumption

All the steps described above are simple when considered individually and each of the steps will lead to a reduction in overall energy consumption, because most of the individual hardware elements provide us with some kind of energy-savings mechanism. Likewise, applications can be optimised or replaced, but it must be acknowledged that all of the elements presented here are interconnected and influence each other in the delivery of services to the users.

Trying to manage energy consumption on the service level can lead to more energy savings, but it is a complex holistic approach. A typical scenario under such an approach might look as follows: *"If the number of active sessions drops below a certain threshold, move one of the virtual machines from server X to server Y, as this will produce more energy-efficient load distribution"*. It is even more complex when we require that it should be done automatically.

As can be seen from the examples above, in order to execute even such a simple scenario, complex interaction between hardware, software and the network is required.

Such interaction can be seen as a decision-making process 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, historical data and rules, special 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.).

4.3 Case Study: Green Network Management at Poznan Supercomputing and Networking Centre (PSNC)

Poznan Supercomputing and Networking Centre (PSNC) are collaborating in the field of "green" network management systems (NMSs) with locally based Verax Systems [Verax]. With the PSNC Network Operations Centre (NOC), which monitors and manages Poland's national network. Verax have enhanced their NMS with all the green networking measures mentioned above. Although the system is currently still in the testing phase, it manages part of the networking equipment in PIONIER, the Polish NREN.

An NMS is the ideal vehicle for implementing service power management where human involvement is reduced to a minimum:

- An NMS already provides sensor functionality: probes and performance counters.
- Probe and performance-counter data are typically persistent and contains aggregated historical data.
- Commercial NMS systems (Verax NMS is one example of the systems widely available) also contain effectors, allowing configuration actions on network element management.

However, in order to provide service power management, a typical NMS would have to be extended with a rules-based engine which would communicate with NMS core internals. Such an extension was made to the standard Verax NMS solution. With this extension, Verax's green NMS monitors and controls the energy consumption of individual devices and allows custom-defined energy-management policies:

- Remote hibernation for workstations.
- Switch to standby mode or off for servers.
- Use more energy-efficient servers first.
- Optimise load distribution between devices.
- Replace least energy-efficient computers and other devices.
- Replace sub-optimal software.
- React to abnormal power consumption.

The execution of these policies does not normally disrupt the operation of the network. Typically, the NMS generates alarms that are then subject to automatic system analysis; in addition, automated rules can be defined to ensure non-disruptive behaviour.

A built-in predictive analytical module allows:

- Non-intrusive (i.e. meter-less) measurements of momentary power consumption of each managed element.
- Analytical module for a visual presentation of energy consumption per logical block of a data centre. The analytical module helps operators to determine the most power-critical elements of their IT service (e.g. databases, network infrastructure, web static content servers, etc.).
- Detection of abnormal power consumption and generation of power-related alarms based on historical data.

Such implementation is an innovative, next-generation product designed to enforce energy-consumption control and implement cost-effective energy policies, giving benefits for the organisation as well as for the environment.

The route taken by PSNC, while innovative, is not necessarily unique. Similar strategies have been developed in other organisations. Nonetheless, PSNC have shown how real benefits can accrue to NRENs by using a green network management system.

5 Power Usage Effectiveness (PUE)

Power consumption at data centres is a main source of emission of greenhouse gases. As for any other type of consumption, the effective utilisation of incoming energy is important: the more effective it is, the smaller are the emissions from the production of electricity.

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

Determining the total amount of power entering a data centre is often very straightforward, e.g. from invoices. 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 *"PUE/DCiE Detailed Analysis"* [GreenGrid_PUE/DCiE], measurements are made at three levels with an increasing amount of detail and precision: Uninterruptible Power Supply (UPS) level (basic); Power Distribution Unit (PDU) level (intermediate); and server level (advanced) [Haas]. 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	Server
Total facility power consumption	Data centre input power	Data centre input power less shared Heating, Ventilation, Air-Conditioning (HVAC)	Data centre input power less shared HVAC plus building lighting, security
Minimum measurement interval	Monthly/weekly	Daily	Continuous

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

According to the Uptime Institute [Uptime], measurements at PDU level are the most common, but in practice the measurements must be made on the best-suited meter, here defined as the meter closest to the IT equipment, and then 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 (i.e. the normal maximum amount) is used for the calculations. According to the Uptime Institute, many planners use 70% of nameplate effect for their calculations, but measurements made by one of the Green GÉANT partners (GRNET) show that the average real-time consumption of their network routers in general is less than 40% of the nameplate specifications (see Table 5.3 on page 22).

Determining the PUE of a data centre is thus far from being an exact science. The individual topology and function of a data centre, together with the inherent possibilities for making qualified measurements, mean that PUE comparisons with other data centres should not be made without knowing that exactly the same elements are being calculated. 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 describes some of the initiatives undertaken by the Green GÉANT partners and indicates 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 referenced in [Haas]. The suggested approach means that the procedure can be certified and the results verified, if so desired. It is acknowledged all over the world, but it is not known to what extent it is actually used.

The partners in Green GÉANT do not yet make PUE estimations that have been certified or verified. In general, measurements are made at the basic level (see Table 5.1 on page 19) and the case study from UNI-C below is a good example of how consistent calculations of PUE can be used to demonstrate environmental improvements.

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 *input* from the utility, only one watt is delivered *out* to the IT equipment. The Uptime Institute also estimates that most facilities could achieve 1.6 PUE using the most efficient equipment and best practices. Anecdotal reports have shown PUEs below 1.0, but such figures are useless and probably indicate that the reporting institutions do not understand the estimating process.

As a part of the GN3 Networking Activity 3 (Status and Trends) Task 5 (Study of Environmental Impact) work, the partners have measured or estimated PUEs in several contexts. It is outside the scope of this report to go into technical details regarding the measurements, but the key findings and their background are reported in the next paragraphs.

5.2 Case Study: UNI-C

UNI-C – the operator for one of the partners in NORDUNet – have for the past four years monitored the energy consumption at their main location at the Danish Technical University in Lyngby, Denmark. The information is subsequently used to calculate the PUE, using the basic requirements in the Green Grid white paper. Table 5.2 shows the energy consumption distributed to relevant elements for the four-year period. Please note that the UPS figures in the table refer to the consumption (loss) of the UPS units themselves and not to the total power being measured at the UPS level. The latter is the sum of the equipment value and the UPS value.

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

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

It appears from Table 5.2 that the PUE has decreased by at least 10% from 2007–2010. The drop in UNI-C's PUE values from 2007 (1.89) to 2009 (1.65) is mainly due to putting a free cooling system into use in 2008. The system was established by improving an already existing cooling unit on the roof with new cooling surfaces and installing a valve allowing the cooling water to be piped through the open air unit instead of the compressor units. 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 7–8 degrees Celsius outdoor temperature, but tuning is still ongoing.

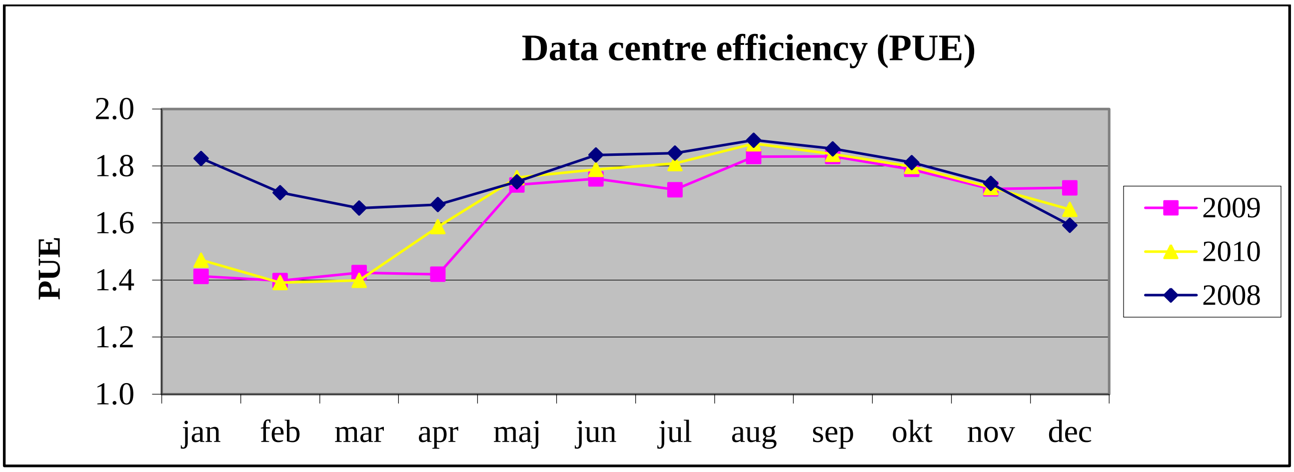


Figure 5.1: Monthly calculations of PUE at UNI-C

Figure 5.1 illustrates clearly the beneficial effect of free cooling on PUE. As soon as the outside temperature drops below 8 degrees Celsius, free cooling is started automatically. Obviously, free cooling gives more benefits when the temperature is even lower, but the time series is indicative of what can be reached in Danish climate conditions. (During April 2010 the switching to free cooling failed, thus causing the PUE for 2010 to be higher than for 2009.)

It is noted that the efforts to improve the efficiency of the data centre are inspired by the EU Code of Conduct initiative, although UNI-C are 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 DKR 200,000, already saving in the first year about 2000 MWh * (1.89-1.73) = 320.000 kWh, thus paying back the investment in less than a year.

The reduction in PUE (and power consumption) of course has 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. (The key figures for electricity consumption have been derived from the European Life Cycle Database (ELCD) core database version II, established and published by the EU Commission through the Joint Research Centre in Ispra, Italy [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 the UNI-C data centre.

More information about the projects at UNI-C can be obtained from Jørgen Moth (jorgen.moth@uni-c.dk).

5.3 Case Study: Energy Consumption Study and Plans at GRNET

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

GRNET Network Router	Vendor/Model	Maximum Power Consumption (Watt)	Average Real-Time Power Consumption (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

The results in Table 5.3 above show that nameplate maximum power consumption is a bad measure in relation to real-time router power consumption. It is therefore not recommended for use, unless the utilisation ratio (= maximum power consumption/real-time power consumption) 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 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 Point of Presence (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 telecom equipment. These racks are fully loaded at a percentage of 60%. For the Grid node, there are 6 racks hosting servers and storage equipment. Average energy consumption for the GÉANT PoP is 63kW; for the Grid node it is 67kW.

The second GRNET data centre is located within the premises of the Greek Ministry of National Education and Religious Affairs in Athens. The data centre is currently equipped with 28 racks for installing servers and storage equipment. Currently, 4 racks are hosting servers and 2 racks storage equipment, but GRNET plan to load 18 extra racks in the coming months. The average energy consumption of the equipment hosted at this data centre is currently around 60kW but it is estimated to increase considerably in the upcoming period and reach 500kW. This data centre has been designed and implemented following high standards regarding the cooling efficiency and the exact Power Usage Effectiveness (PUE) is about to be accurately determined.

An indication of the potential savings in GHG emissions from using the most efficient cooling solutions can be estimated by assuming that a PUE of 1.9 will be found in “conventional” solutions, while a PUE of 1.6 can be achieved through high standards in cooling. With an energy uptake of 500 kW (excluding cooling) of the 18+ racks in the second data centre, the annual savings in GHG emissions can be calculated as:

$$(500\text{kW}*24*365) * (1.9-1.6) * 1.104 \text{ kg } CO_2 \text{ equivalents/kWh} = 1450 \text{ ton } CO_2 \text{ equivalents/year}$$

It must be acknowledged that the calculations are based on crude assumptions. However, as for the UNI-C case study, it demonstrates the order of magnitude of the savings that can be achieved by data centres.

In the slightly longer term, GRNET plan to install a green data centre outdoors in the northwest part of mainland Greece, close to a power-production hydro-electric plant facility. Water from the nearby river will be used to cool the equipment within the data centre, while for this purpose water-cooled racks will be utilised. 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 ones. The reason for selecting water cooling is that it provides greater effects regarding power usage efficiency than the use of air cooling, which is the traditional data centre cooling and refrigeration technology. To this end, large-scale data centres have started to develop water-cooled refrigeration systems since 2006 [Zhang]. However, since water-cooling systems release the heat into the water (in the case of air cooling, the heat is released into the air), environmental concerns for water heat pollution have to be taken into account. The use of water from a river or sea water is recommended in order to minimise the effects on the water temperature.

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

6 Virtualisation

Virtualisation is the technology that combines or divides resources to present one or many operating environments [VMware1, VMware2, Abels]. Examples of virtualisation include the creation of virtual versions of operating systems, servers, storage devices or network resources. Within the GN3 project, virtualisation is being investigated by Joint Research Activity 1 (Future Networks) Task 4 (Current and Potential Uses of Virtualisation). This section considers server and network virtualisation, and presents examples of their use by UNI-C, the FEDERICA project, and by the GreenStar Network and Mantychore project.

6.1 Server Virtualisation

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

1. Reduced hardware maintenance costs from retaining a lower number of physical servers.
2. Efficient utilisation of hardware resources. Reduced total cost of ownership (TCO) and faster return on investment (ROI).
3. Reduced administrative costs when different applications/services run isolated in their own virtual servers as one application is prevented from impacting another when upgrades or changes are made.
4. High diversity of Operating Systems (OSs) hosted on a single platform.
5. Reduced server deployment by having a standard virtual server build that can be easily duplicated.
6. Increased flexibility/agility, exploiting the fact that virtual machines may easily migrate to another host server to achieve reliability, quality of service or other business strategies (such as strategies to reduce required operating energy cost).
7. Increased space utilisation efficiency in the data centre.
8. Highly reduced energy consumption coming from operating fewer physical servers, consequently 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.

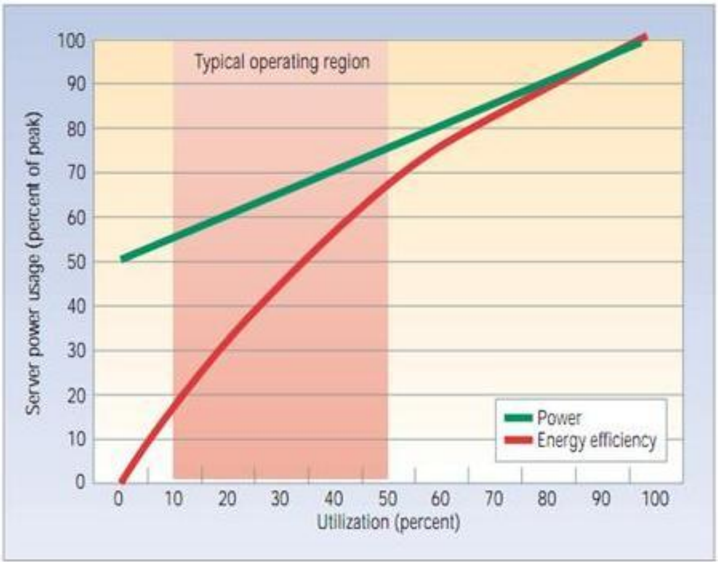


Figure 6.1: Server power usage and energy efficiency at varying utilisation levels, from idle to peak performance [Barroso]

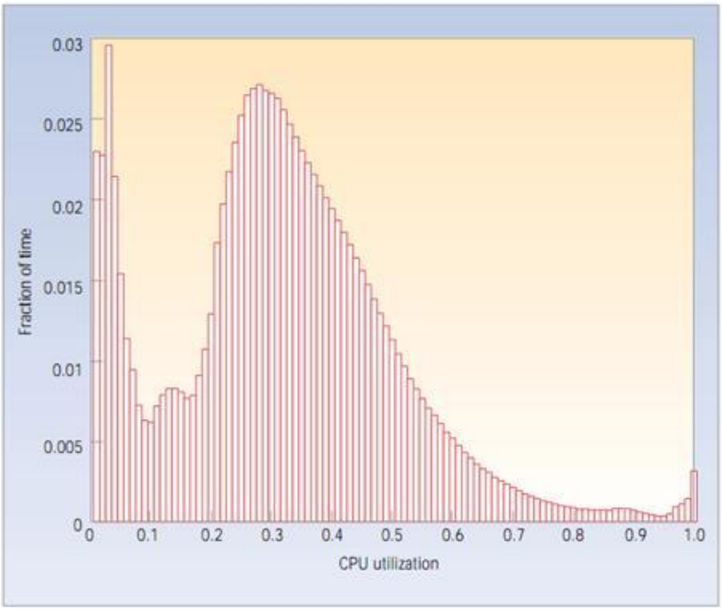


Figure 6.2: Average CPU utilisation of more than 5000 servers during a six-month period [Barroso]

Besides the energy consumption of the servers, further energy is required for cooling (see Section 5 Power Usage Effectiveness (PUE) on page 19). This means that direct reductions in server energy consumption actually pay 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 $MtCO_2e$ 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 usually structured so that the person paying for the IT equipment is not the one paying for the energy consumption of that equipment.

6.1.2 Live Migration

Virtualisation of servers allows for a more efficient use of the servers 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 running multiple services.

An example of this is LiteGreen, which saves desktop energy by migrating the idle desktops in enterprise environments to a central server [Das]. Thus, the user's desktop environment is "always on", maintaining its network presence fully even when the user's physical desktop machine is switched off and thereby saving energy (see Figure 6.3). 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.

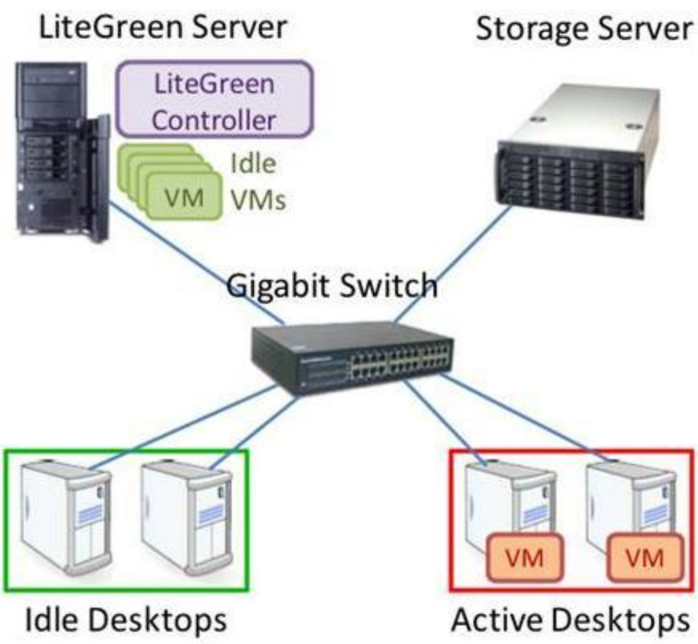


Figure 6.3: LiteGreen architecture [Das]

Another example is the SleepServer technology, in which lightweight virtual images of sleeping PCs are created; these pared-down images maintain connectivity and respond to applications, such as Voice over IP 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 connect remotely into 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 SleepServer deployment in a medium-scale enterprise with a sample set of thirty machines, it is shown that significant energy savings (ranging from 60% to 80%) may be achieved for PCs depending on their use pattern.

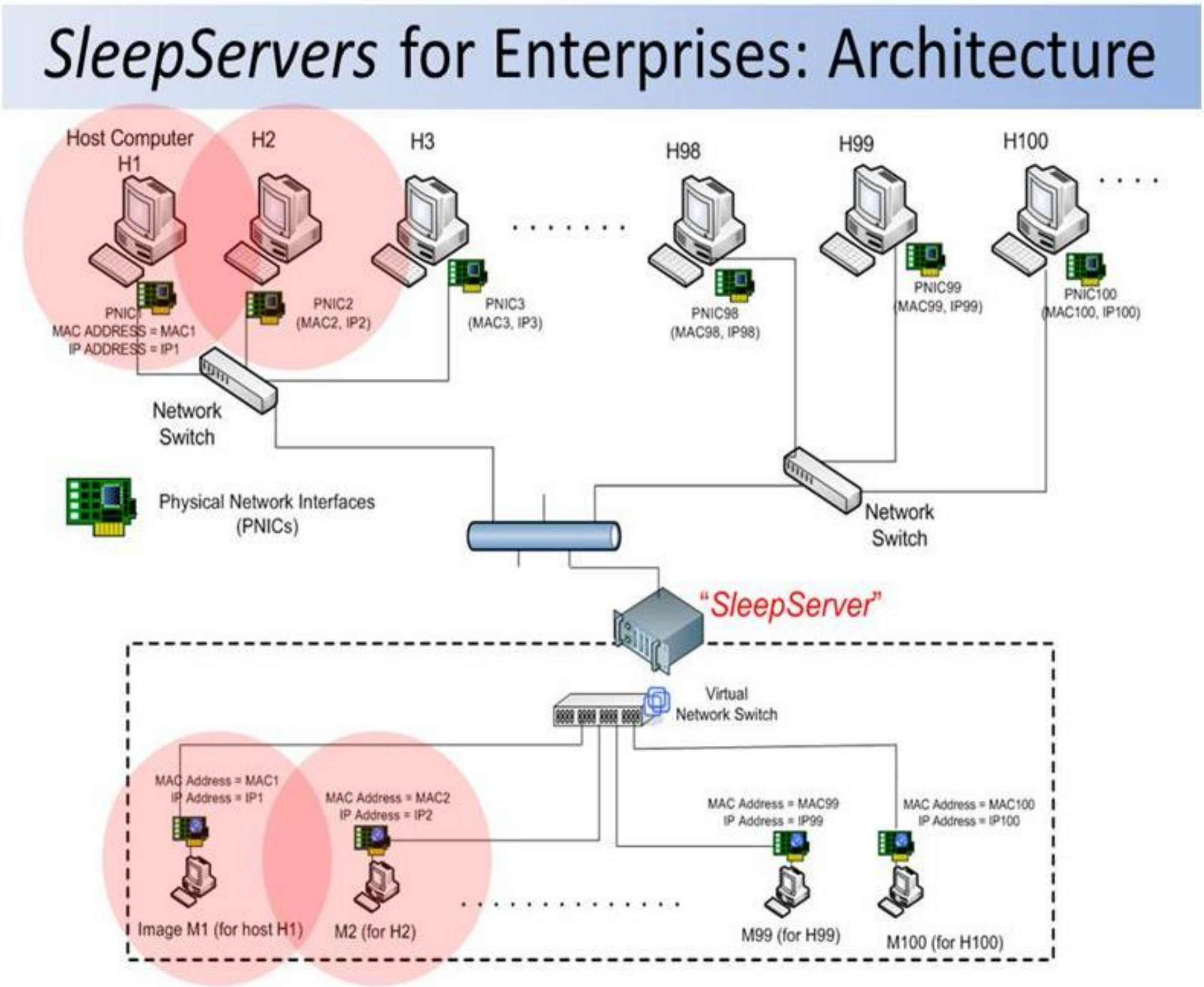


Figure 6.4: SleepServer architecture [Agarwal]

A critical factor for both LiteGreen and SleepServer, and for similar approaches, is the time required to wake up the original working PC and make it functional (time to resume). Both approaches, in the average case, require about 20 seconds to resume the original working environment, leaving room for optimisation. Both technologies go one step further compared to previous proposals, such as SleepProxy [Reich], by not only putting physical machines into sleep mode, but also retaining their network connection.

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].

6.1.3 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.

The virtualisation project also revealed that some servers were still running, although they had been decommissioned for many months or even years. Turning off and physically removing these outdated servers of course also contributed to curbing the power consumption of the data centre. 2011 will better demonstrate the effect of virtualisation alone.

6.2 Network Virtualisation

Network virtualisation refers to the virtualisation of the elements that build 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 as 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]. In Table 6.1 presents a comparison of the characteristics of the two architectures.

Category	Hardware-Isolated Virtual Router	Software-Isolated Virtual Router
Control plane resources (CPU, memory)	Dedicated	Shared
Data plane resources (forwarding engine, queues)	Dedicated	Shared

Category	Hardware-Isolated Virtual Router	Software-Isolated Virtual Router
Chassis resources (power supplies, blowers, fabric)	Shared	Shared
Management, configuration	Dedicated	Typically shared, but varies depending on degree of virtualisation
Connections between virtualised routing entities	Typically external	Typically internal, but possibly external
Per-chassis scalabililty (routing adjacencies, prefixes)	Increased with additional logical routers	Unaffected by additional virtual routers

Table 6.1: Comparison of virtualised routing architectures [Cisco]

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 [Juniper1]. 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 [Qureshi, Juniper2].

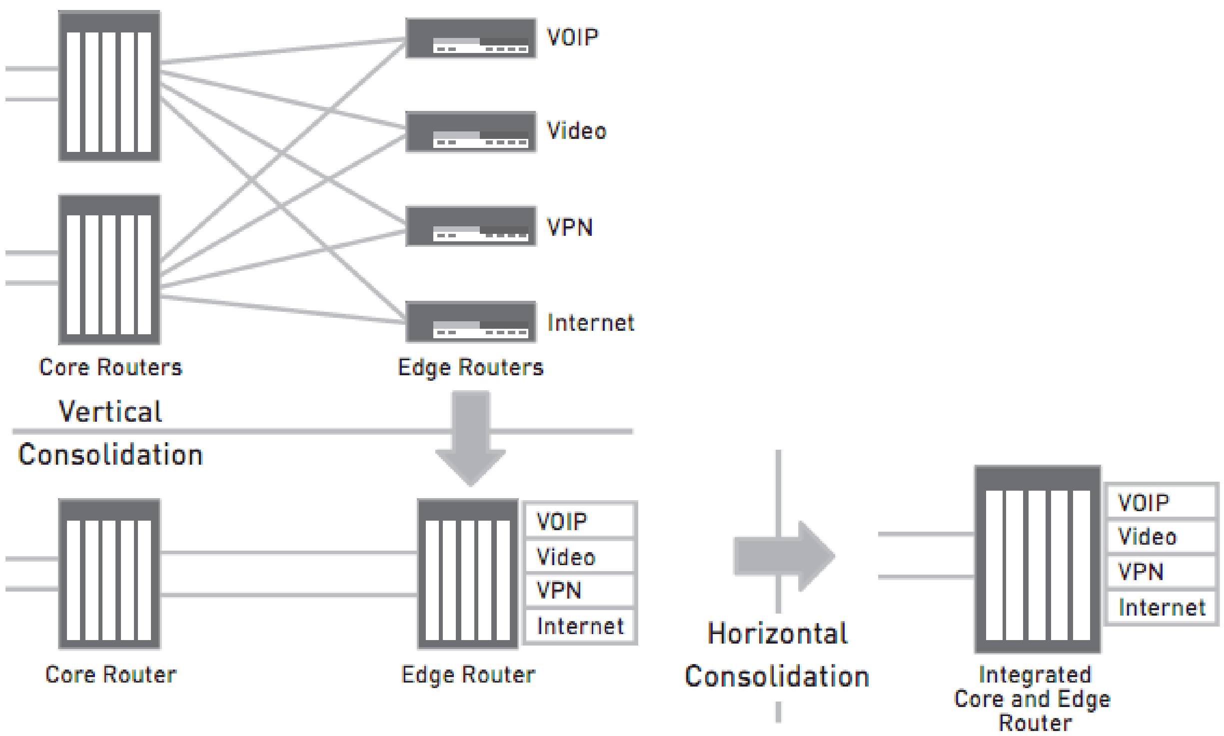


Figure 6.5: Horizontal and vertical consolidation [Juniper1]

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 next paragraphs.

6.2.1 Network Virtualisation: FEDERICA Project

The European project FEDERICA exploits virtualisation technology to offer virtualised infrastructures to researchers experimenting on future Internet technologies. The infrastructure is based on the multi-domain European NRENs and the GÉANT 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 quite 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.

The next section shows that 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. It describes how protocols are being developed to make routing decisions based on green and economic factors.

6.3 Server and Network Virtualisation: GreenStar Network and Mantychore FP7 Project

The GreenStar Network (GSN) project [GreenStar] is one of the first worldwide initiatives aimed at providing ICT services based entirely on renewable energy sources such as solar, wind and hydro-electricity across Canada and around the world. The network can transport user service applications to be processed in data centres built in the proximity of green energy sources, reducing GHG emissions of ICT equipment to a minimum.

In order to move virtualised data centres towards network nodes powered by green energy sources distributed in such a multi-domain network, particularly between Europe and North America domains, the GSN is based on a flexible routing platform provided by the Mantychore FP7 project [Mantychore]. The main objective of the GSN/Mantychore liaison is to create a pilot and a testbed environment from which to derive best practices and guidelines to follow when building low-carbon networks.

Management and technical policies will be developed to leverage virtualisation, which helps the migration of virtual infrastructure resources from one site to another, based on (green) power availability. This will facilitate use of renewable energy within the GSN, providing an Infrastructure as a Service (IaaS) management tool.

Integrating connectivity to parts of the NREN infrastructures with the GSN network develops competencies for understanding how a set of green nodes (where ideally each one is powered by a different renewable energy source) could be integrated into an everyday network.

The migration of virtual data centres over network nodes is indeed a result of a convergence of server and network virtualisations as virtual infrastructure management. Resources are allocated according to user requirements, hence high utilisation and optimisation levels can be achieved. During the service, the users monitor and control resources as if they were the owner, allowing the users to run their applications in a virtual infrastructure powered by green energy sources.

The Mantychore FP7 project [Mantychore] has evolved from the previous research projects MANTICORE and MANTICORE II. The initial MANTICORE project goal was to implement a proof of concept based on the idea that routers and an IP network can be set up as a service, which is exploited in the FEDERICA project. MANTICORE II continued in the steps of its predecessor to implement stable and robust software while running trials on a range of network equipment.

7 Energy-Aware Traffic Engineering

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

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

1. **Power-aware system design** refers to energy-related improvements in network equipment design. According to Juniper [Juniper2], at the highest level they can be classified as organic and engineered. Organic efficiency improvements are commensurate with Dennard's scaling law: every new generation of network silicon packs more performance in 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 discussed in Section 6.
3. **Power-aware protocol design** refers to mechanisms for reducing the energy consumption of network components by changing their operating state (possibly at the expense of performance) or even putting them (wholly or partially) to sleep, according to their usage.

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

Energy-aware traffic engineering is targeted to allow networks themselves to become energy proportional to the traffic served. Networks are designed with two strategic core principles in mind, namely, 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 do 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. The core idea is to adapt the power consumption of a network dynamically by carefully selecting the minimal subset of network elements that satisfies the current traffic demand. In this approach, one would need to collect information about the current traffic conditions and compute the minimal set of network elements that can accommodate the current traffic, while letting 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 [Vasic2], Energy Proportional Networking (EPN) is proposed. EPN is targeted to achieve both optimisation and responsiveness by considering 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. A 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%).

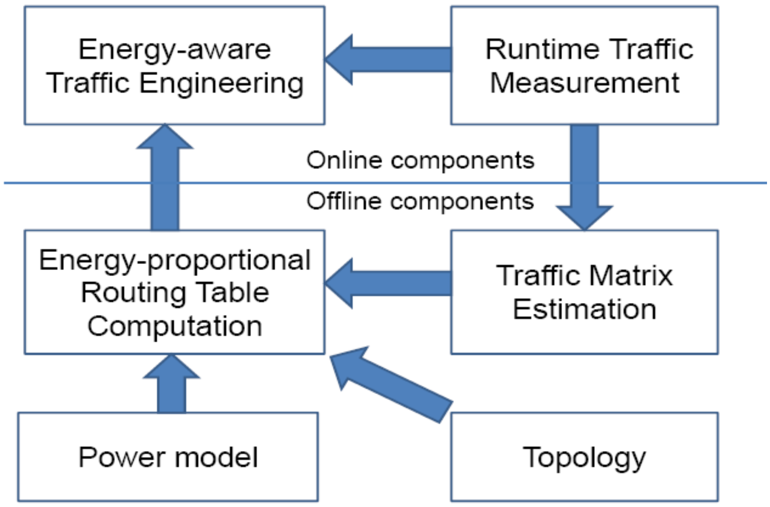


Figure 7.1: An energy-aware traffic engineering approach [Vasic2]

Gupta and Singh [Gupta] quantify some of the savings that are possible due to inter-packet gaps (i.e., packets not continuously arriving at full speed). 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], 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. According to the presented results, proposed algorithms may even halve energy consumption for lightly utilised networks (10%–20%).

7.1 GRNET and the ECONET Project

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

The GRNET network is a next-generation optical fibre network based on Wavelength Division Multiplexing (WDM) technology at Gigabit speeds (1 Gbps – 10 Gbps). All the nodes are based on routers of multi-Gigabit speeds that are interconnected with a network of 2.5 Gbps speeds over Dense Wavelength Division Multiplexing (DWDM) technology with leased wavelengths. Since 2008, the GRNET dark fibre network extends all over Greece, with a total dark fibre length of more than 8500km and optical equipment that may support speeds up to 21 x 10 Gbps. IP and Layer 2 views of the GRNET network topology are shown in Figure 7.2.

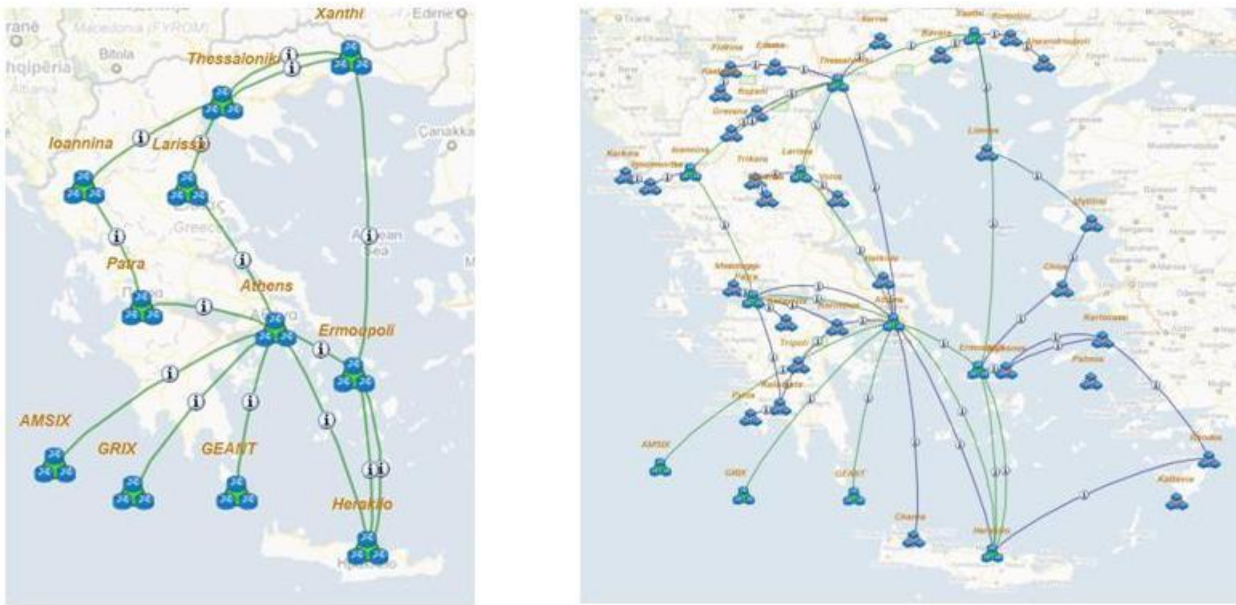


Figure 7.2: GRNET IP network topology (left) and physical network topology (right)

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, already existing and newly developed dynamic adaptive technologies for network devices, capable of reducing their power consumption either by scaling down performance or turning them into standby when underutilised or not used at all respectively.

A detailed profile of the current traffic, as well as a prediction of 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 the absence of a unified method for collecting data-flow statistics in GRNET's network, traffic matrix estimation methodologies are applied, having as input the distinct link loads, in order 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. Figure 7.3 shows the daily, weekly and monthly variations from the core network equipment.

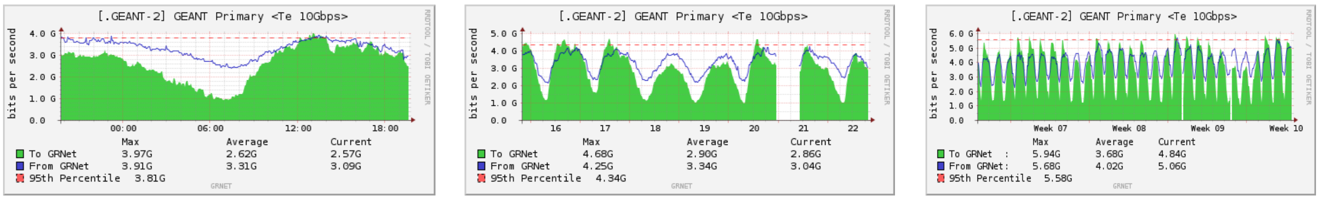


Figure 7.3: Traffic profile of core GRNET network router (peering with GÉANT). Left: daily, center: weekly; right: monthly

Similar information is available for network routers (Figure 7.4) as well as access networks and GRNET power users (Figure 7.5).

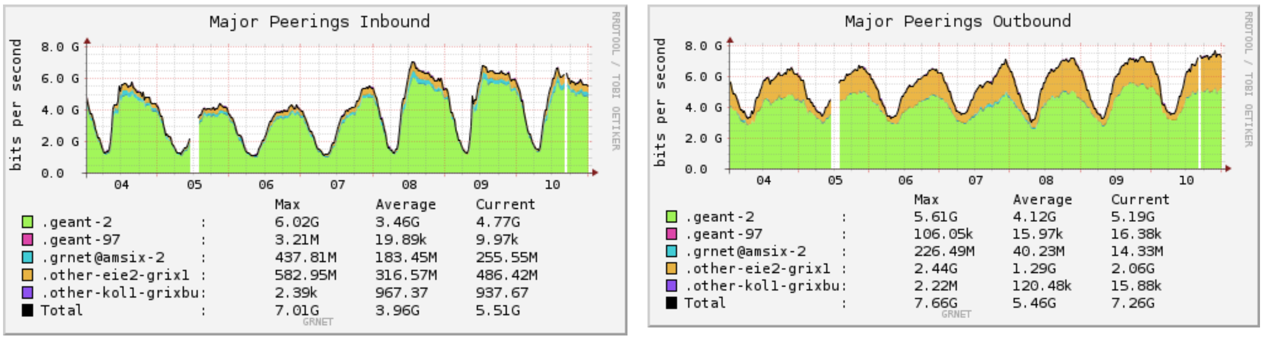


Figure 7.4: Daily traffic profile of core GRNET network router (Incoming (left) and outgoing (right) traffic)

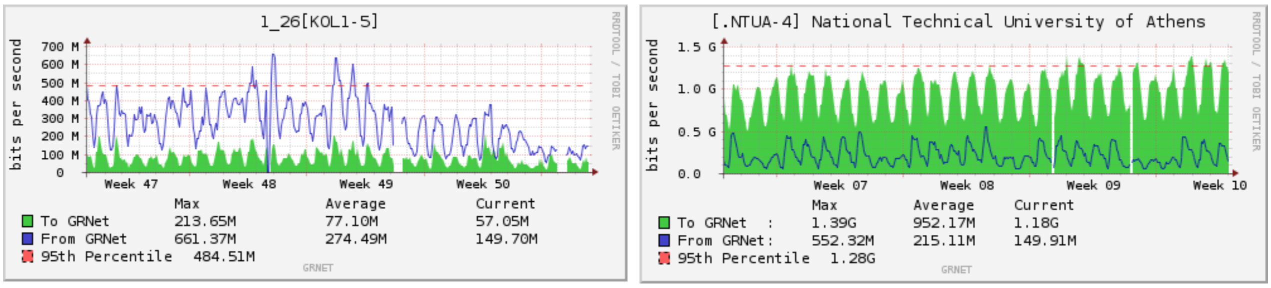


Figure 7.5: Daily traffic profile of access network switch (left) and a GRNET power user (client connected at 10 Gbps) (right)

Based on the collected statistics and diagrams (as shown above), 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 such as those outlined earlier in this section and thus improve the energy-efficiency of the network. As mentioned above, GRNET is studying and evaluating those strategies – including techniques for energy-aware traffic engineering, combined with the support of future energy-aware technologies in network equipment such as sleeping/smart-standby mechanisms and dynamic adaptation mechanisms (e.g. power scaling) – in a small scale testbed in GRNET, within the framework of the ECONET project.

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

8 Videoconferencing

Videoconferencing is a vital tool for the research community, enabling communication between teams located in different centres within a country or around the world. NRENs have for many years featured videoconferencing as a service layered on their network infrastructure.

Videoconferences can have very different formats, from a one-to-one conference between parties situated close or far apart, to 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 like 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, in Africa, in Asia and the 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 throughout the world.

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

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 mitigating effects of videoconferencing is thus not realised by the NRENs alone, but can only be achieved when equipment for high-quality conferencing is available to a broad audience.

A good estimate of the environmental benefits from videoconferencing was made by Guldbrandsson and Malmodin [Guldbrandsson], comparing the use of high-end facilities for videoconferencing to the impacts from air travel. The impacts from the production and use of the VC equipment was distributed evenly over a six-year period with use 4 hours/day and 240 days/year. The VC conferences were assumed to replace 48 trips between Stockholm and Dallas, Texas, during each year. Taking all equipment, data transport, etc. into account, the emission of GHG was estimated to be about 2 kg CO_2 equivalents per hour – or about 1.3 tons of CO_2 equivalents per year. The savings in GHG emissions from avoided transport were much larger, up to 215 tons of CO_2 equivalents per year when indirect emissions are also taken into account.

The following paragraphs describe two selected case studies from Green GÉANT, with very different scopes. The first example quantifies in detail the mitigating effect of videoconferencing caused by a small group of people (10 persons) dispersed in Ireland, using equipment provided by HEAnet to manage the predefined 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. However, 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 of videoconferencing by a closed but geographically dispersed group 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. – 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) [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 associated 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 board meetings. Thus the venue for meetings changes from one institution to another throughout 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, for the past two years, venues for NDLR board meetings have had to 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 high-definition (HD) units in 2009. Its central service includes a multi-conferencing unit (MCU) with HD capability for several concurrent conferences, 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 effect of videoconferencing for the purpose of meetings is to reduce the amount of travel and its concomitant impacts: 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 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 of their 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: Inter-city distances (in km)

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 regular board meetings in the period 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)
7th Nov 2008	NUIG (G)	4xD, 2xG	4xD, 2xL, 1xC	1504	2120
9th Jan 2009	TCD (D)	6xD, 1xM	1xD, 1xC, 1xG, 1xL	48	1156
5th Feb 2009	UL (L)	4xD, 2xL, 1xC	2xD, 1xG, 1xM	1586	1158
2nd Apr 2009	TCD (D)	7xD, 1xC, 1xL, 1xM	1xD, 1xG, 1xL	828	726
18th Jun 2009	UCC (C)	1xC, 1xL	5xD, 1xG, 1xL, 1xM	186	3080
18th 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 a1.6 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 have been 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 saving of people’s time is of real significance to members. Time spent on trains can to a certain extent be used to read reports and perhaps even work online using 3G access. However, time spent travelling by car is considered as dead 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; this is equivalent to two working days a year. Anecdotally, board members remark on the big 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 €100, 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. To run a videoconference involves an MCU, VC equipment at each end point, and network infrastructure to interconnect all the elements. All of these 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. However, an environmental audit of all aspects of the HEAnet network is currently underway, and the results might be used to refine this study.

Production, transportation and disposal of the equipment is not accounted for either, e.g. considering how much GHG emission is involved in the lifecycle 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 a large figure which has not been considered in the SMART 2020 report. The size of the figure indicates that there should be a real need for videoconferencing before investments are made, otherwise the good concept may not prove beneficial to the environment. The need for adequate videoconferencing facilities is obvious in data centres and NRENs, but many research and educational institutions can probably improve their current pattern, e.g. by using environmental arguments when motivating researchers and other users.

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

8.2 Case Study: PSNC

The PLATON – Service Platform for e-Science project is funded by the EU and Polish Ministry of Science funds under the operational programme Innovative Economy 2007–2013, priority 2: R&D Infrastructure. The objective of the 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 towards the innovative economy. The direct goal of the project is to create and implement five innovative ICT 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 Sevices**: 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.

8.2.1 The Technological Service

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

Figure 8.2: Intended PIONIER network beneficiaries of PLATON project videoconference services

Communication is established using videoconference rooms specially designed and set up for the purpose in order to obtain the best quality of video and audio broadcast. However, it is also possible to move the terminal to other facilities (laboratories, lecture halls, etc.). It is also possible to carry out simultaneous videoconferences between all the MAN centres, as well as many concurrent videoconferences in smaller groups. The conference is archived, with the possibility of playing it back on a later occasion.

The videoconference system solution is flexible and allows other potential applications, 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 a 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 option of remembering frequently used settings. As well as the main camera and microphone, it is possible to connect an additional PC, second camera, DVD player, etc.

Devices that control the coordination of the connections are located in two PIONIER network nodes. One node acts as a primary server and the second as a backup. Since the two nodes are identically equipped, and since both nodes are active, it is possible to use both servers simultaneously for a larger load.

A web portal makes easy VC reservation possible for network users and allows advanced resources administration. Additionally, users can obtain information about active resources, statistics and device monitoring.

8.2.2 Use Pattern

Typical usages of the videoconferencing infrastructure are:

- Scientific discussions.
- Virtual science conferences.
- Tele-mentoring (i.e. remote access in surgical operations).
- E-learning (remote interactive learning).

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

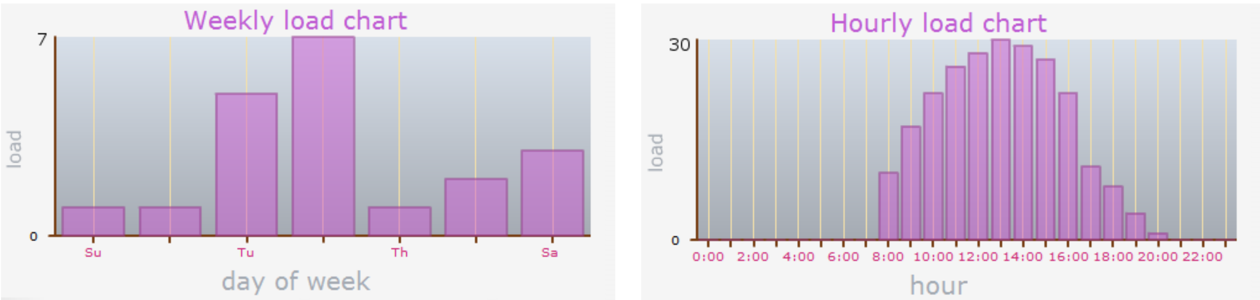


Figure 8.3: Average number of VCs on each day of the week (left), and total number number of VCs during the observed period, indicating “rush hours” for VCs (right)

8.2.3 A Real-Life Example of Tele-Medicine and E-Learning

A **real-life example** of tele-medicine and e-learning 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 the delegates are able to question doctors via moderators. The project also demonstrates the idea of connecting new technologies with education and creates archive material that can be used by students of medical sciences and reference material for use by other doctors.

The LION Foundation was created in 2006 as a non-profit organisation. It is dedicated to promoting high-quality medical and surgical continuing education programs. LION was conceived in order to improve the knowledge, skills and discipline of current otolaryngologists, while introducing innovative programs designed to provide worldwide education, including developing countries.

The aim of LION is to create a permanent interactive worldwide high-speed network for continuing education in otolaryngology (i.e. ear, nose and throat (ENT) medicine), and to promote distance learning using innovative videoconferencing technologies. The project is focused on otology-neurotology, but it will grow in the future to include other fields of ENT medicine. The project provide a focus for training as well as an enhanced professional experience using data-communications infrastructure and an interactive videoconferencing system essential to the development of the global otolaryngological community, known as the global videoconference network for otolaryngology.

8.2.4 LION Network Configuration

The LION network is an international videoconferencing network dedicated to otolaryngology, which links hospitals for medical events enabling surgeons and other healthcare professionals specialising in ENT from all over the world to share their knowledge and view surgical techniques performed in real time by leaders in their respective fields at distant hospitals.

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 performs live surgery, gives a lecture, leads a conference or participates in a panel discussion.
- A Distant site is any conference room or computer worldwide from which delegates follow the LION session and interact with the faculty.

The central point connecting Faculty and Distant sites is Eurohub, the MCU provided by SURFnet, the Dutch educational ISP, located in Utrecht. An overview of the infrastructure of LION is given in Figure 8.4.

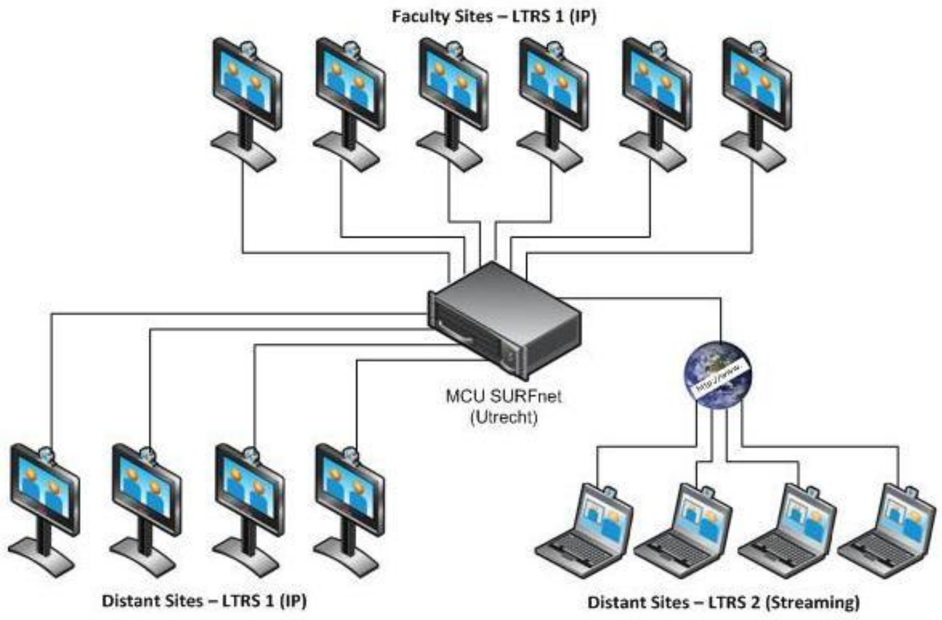


Figure 8.4: Basic infrastructure of LION

SURFnet's MCU is used to interconnect all sites during each multi-centre session of LION. The Eurohub moderators are located at the SurfNET MCU. There is a LION Technical Requirements Standard (LTRS) levels 1 and 2:

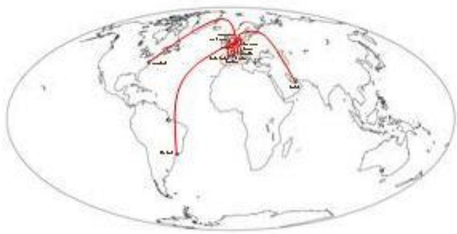
- **LTRS level 1 – IP connection**: this configuration is mandatory for all Faculty sites and is also recommended for all Distant sites to offer real-time interaction between faculty and the delegates in the conference room facilities. LTRS1 requires the use of professional videoconference equipment.

- **LTRS level 2 – live Internet streaming**: this is powered by SURFnet and offers high audio-visual quality. Direct questions to the faculty cannot be asked from Distant sites using LTRS level 2. Interaction with the faculty is possible by email or by using a chat room via the moderators located at the MCU. LTRS2 does not require the use of professional videoconference equipment.

8.2.5 Example of a LION Event

The 5th Global Otology-Neurotology Live Surgical Broadcast took place on 27 May 2010. The event was attended by the Department of Otolaryngology of Poznań University of Medical Sciences. Professor Szyfter performed cochlear implant surgery and stapedotomy surgery, which allows the treatment of otosclerosis, in front of audiences in countries all over the world. In all, on just one day, using video conferencing, thirteen doctors from countries including France, Germany, Netherlands, Spain, Turkey, USA, United Arab Emirates and Brazil performed more than twenty operations covering various surgical situations and demonstrating many different practical techniques of both middle ear and skull base surgery.

The LION workshop linked ten operating rooms and seven conference rooms across Europe, plus an additional two conference facilities in Mexico City and in Pretoria, South Africa. There were also 310 visitors watching the streaming video.



Technical assistance for the part of the project held in Poznań was provided by PSNC, which provides audio, HD video conferencing equipment and a dedicated broadband link to the PIONIER optical network. Because of the crucial importance of image quality during the medical operation, the video signal was broadcast in HD quality. Two channels of videoconferencing were available for the participants.

9 Distance Working

Distance work refers to paid work that is done outside the actual workplace – such as at home, from holiday accommodation, or when travelling on the train – and that has been agreed with the employer. Distance work generally involves use of information technology and has become more and more common as ICT has developed and possibilities for its use, including at home, have increased.

One of the main advantages of distance working is that commuting is avoided, thereby saving a significant amount of GHG emissions, especially if personal cars are used for the transportation. Furthermore, many employees see distance working as potentially allowing more flexible and integrated planning of work and leisure time. However, a drawback mentioned by many is that the social contact with colleagues diminishes as a result of days working away from the organisation workplace.

In the SMART 2020 report [SMRT2020, p. 30], it is claimed that “currently the largest opportunity identified within dematerialisation is teleworking – where people work from home rather than commute into an office”. The report estimates this saving to account for 0.26 $GtCO_2$ out of the total anticipated “business as usual” emission of 51.9 $GtCO_2$ in year 2020, or about 0.5%.

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

UNI-C has undertaken a study of the mitigating effects that ICT, through the provision of distance working, can have on the environmental impacts of commuting. The primary goal of the study was to evaluate the claim in the SMART 2020 report referred to above 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 2010 to 28 February 2010. During this period, 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 in 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"* [NORDUnetGHGAudit] were used, i.e. 42 g/km for transport by regional train, 175 g/km for private cars, 90 g/km for buses and 16 g/km for S-tog or Metro. Walking and cycling are 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. Nor does the study 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 3 tons when scaled proportionally to the full 52 weeks of a year. In round 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 on 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" for 2020.

Employee	Commuting pattern (in kilometres)						# Days at home	CO_2-saving (kg)
	Walk	Bicycle	Car	Bus	Train	S-tog and Metro		
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

Employee	Commuting pattern (in kilometres)						# Days at home	CO_2-saving (kg)
	Walk	Bicycle	Car	Bus	Train	S-tog and Metro		
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, # of days working at home and CO_2 savings

It is noted that one employee (No. 23) alone accounts for 10% of the reduction achieved in the study period – and that the 10% was reached by working at home for just one day. Theoretically, a similar reduction could almost 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.

9.1.2 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, as for the HEAnet videoconferencing case study (see Section 8.1), the saving of travelling time is of real significance to people. Time spent on trains can to a certain extent be used to read reports and perhaps even work online using Internet access. However, time spent travelling by car is considered as dead time.

The amount of time and money saved by the use of distance working was not assessed directly in the study. Estimating that 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.

9.2 Case Study: Reducing the Impacts of Commuting at UNEP in France

The United Nations Environmental Programme (UNEP) has investigated the potential savings that can be achieved at the Paris office of its Division of Technology, Industry and Economics (DTIE) [UNEP]. A number of theoretical scenarios were investigated, as shown in Table 9.2.

Number of days per week working away from office	Percentage of staff enrolled in regular distance work		
	10%	30%	50%
1 day	A	B	C
2 days	D	E	F

Table 9.2: Scenarios investigated in the UNEP study on distance work

The result of the scenario calculations are shown in Table 9.3.

Scenarios	A	B	C	D	E	F
Estimated operational costs reductions (%)	0.86%	2.68%	4.50%	1.72%	5.36%	9.01%
Estimated emissions reductions (tC02eq)	1.57	4.90	8.22	3.14	9.79	16.45

Table 9.3: Results of the scenarios in the UNEP study

It is obvious from the results that larger benefits (both economically and environmentally) are achieved with an increasing amount of distance work being conducted. Unfortunately, the reference does not include information about the number of employees and it is therefore not possible to look more deeply into the results, e.g. by comparing them to the SMART 2020 estimates and the real-life calculations made at UNI-C.

9.3 Additional Remarks

Both studies show that there are significant environmental benefits attached to distance working, but the UNI-C study also shows 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 low-carbon (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.

As another indication of the growing awareness of the possibilities of distance working, the Danish Ministry of Education has proclaimed 2 May to be a national “work-at-home” day. Traffic congestion and supermarket queues can be avoided, but the main argument for proclaiming a national work-at-home day is that it is believed to increase productivity. The Danish Minister, however, also warns against losing the professional and social network at the workplace.

10 Green Public Purchasing (GPP)

Green Public Purchasing is defined in the Communication from the EU Commission *"Public procurement for a better environment"* [COM400] 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".

The concept of GPP is regarded by many authorities and private institutions as a promising way of achieving environmental improvements, and national and supranational guidelines for GPP have been developed for a broad range of product groups, including IT equipment and focusing on office electronics like computers, monitors and printers.

The following paragraphs outline the basic features of the core GPP guidelines on office IT equipment developed by the EU Commission and the Danish *"Green IT guidelines for public authorities"* that have a broader outlook than just purchasing of equipment.

10.1 EU GPP Guidelines

The guidelines developed by the EU for IT office equipment can be found at [ECEnvCriteria], together with a 40-page background report. The first set of criteria focuses on product specifications, e.g. with respect to energy consumption, the possibility of upgrading of memory, etc., content of mercury in LED monitors, ease of disassembly, sound emissions, and substances in plastic parts.

The EU guidelines also describe the actual purchasing process, giving advice on contract performance clauses and establishing award criteria to help choose between different offers. In short, the recommended specifications for IT equipment are similar to the criteria for award of the EU eco-label "The Flower", the Nordic eco-label "The Swan" and the German "Blaue Engel" eco-label for relevant product groups. Reference to relevant criteria documents can be found in the background document [GPPBackground].

10.2 Danish Green IT Guidelines

The Danish National IT and Telecom Agency have developed *"Green IT guidelines for public authorities"* [GreenITGuide] that are more comprehensive insofar as they address not only the actual purchasing process and criteria for green equipment, but also energy-efficient installation and use of the equipment in server rooms as well as 29 proposals for a wide range of awareness raising and other technical and behavioural "green" initiatives, for example:

- Change from stationary computers to thin clients or portable computers.
- Obtain green costs when upgrading software (i.e. its environmentally relevant implications, such as extra power consumption due to the software version requiring additional hardware).
- Install blank panels in sever racks.
- Position the servers in module cabinets with dedicated cooling.
- Virtualise the servers and consolidate capacity/storage space.
- Change to flat screens.
- Regular, but unobtrusive reminders about good green habits.
- Increase use of video and telephone conferencing.

A similar pamphlet has been written for private companies *"Green IT in* your *company – ideas and inspiration for a greener profile"* [GreenITCo]. This pamphlet also includes successful case studies from private companies in many sectors, and it is therefore a strong support for the general, public guidelines.

With their broad outlook, the Danish green IT guidelines are recommended to all persons in the IT sector, not only public authorities. Obviously, it is not realistic to implement all the proposed initiatives, but most actors will find many of the proposals very inspiring and relatively easy to work with.

11 Green Electricity and Choice of Electricity Supplier

In the ICT sector, electricity is by far the most important source of GHG emissions. Energy savings are therefore often the main target to reduce GHG emissions. Another way of reducing the emissions is to lower the emissions from production of electricity. As a consumer, you have the possibility of influencing who you want as an electricity supplier and choosing so-called green electricity.

The market for green electricity is complex, because electricity production and GHG emissions are influenced by political decisions, state subsidies 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.

The text below presents the most common types of green electricity offered 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"* [EnergySolutions], published by the Danish 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.

11.1 Policy Framework – The EU Emission Trading Scheme

With the Kyoto Protocol, specific GHG emission reduction targets were introduced within the UN, and these were implemented by the introduction of the EU Emissions Trading Scheme (ETS). Besides 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.

The idea behind this mechanism is that the emission reductions will 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 flood of allowances on the market, and the price of them has been reduced significantly, 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 not, in the short term, 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

To understand how the purchase of green electricity products actually affects the electricity market and the global GHG emissions, it is necessary to introduce the concept of additionality. In this context, additionality is reductions of GHG emissions that are *in addition to* the reductions already planned or determined to happen due to political target setting.

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.

11.3 Initiatives to Achieve Green Electricity

11.3.1 Buying Certified Renewable Electricity

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) and each certificate represents the generation of 1 MWh of renewable electricity. RECs are independent of the electricity grid, meaning that you can buy RECs from a company other than your electricity supplier. In Europe, 16 countries have implemented a standardised certificate system [RECS]. (Note also that some countries such as the UK and Poland have specific national legislation on RECs and the somewhat similar Guarantee of Origin.)

Buying RECs increases the demand for renewable energy and the extra cost for the consumer is ideally supporting 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. You may buy greener electricity yourself 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.

11.3.2 Investing in New Renewable Electricity

An obvious solution to reducing GHG emission from data centres, etc., is to invest in your own wind turbine, in 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 should definitely bring more renewable energy onto the market. However, this should be seen in the context of the EU 2020 targets.

The EU has set a target that 20% of the energy consumption should be based on renewable energy in 2020. Each Member State has different targets and all activities, no matter if they are introduced by private initiatives or public projects, count (unless national governments have decided that private initiatives are not included, which is allowed according to the EU directive on renewable energy). 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 allow companies to reduce GHG emissions by investment in renewable energy projects in so-called Non-Annex 1 countries as defined in the Kyoto Protocol. The idea behind these projects (called Joint Implementation (JI) or Clean Development Mechanisms (CDM) projects) is to help developing countries secure natural resources and ecosystems and obtain cleaner production technologies or more renewable energy production. From a global perspective, these projects support the mechanism of reducing GHG emission where it is most feasible. At the same time, the projects assist parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments.

Many organisations offer carbon credits resulting from such projects to companies, and the market is full of certification systems. In recent years, many projects have been criticised for not being sustainable or additional, so it is important to select a collaborating organisation carefully. 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 the carbon neutrality of a product or a company is to buy emission permits and cancel them. It means that you make sure 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 to make sure that the real effects of this are documented satisfyingly.

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 Relation to GHG Accounting

It is not very clear how to include the 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 dilemmas mentioned above, and will probably also define further the concept of additionality and – more important – how to deal with it in practice. Furthermore, it will take into account the political and market mechanisms of specific regions. A first draft of the guideline is expected in the first half of 2011.

12 Conclusions: Status, Recommendations and Outlook

12.1 Status

In conclusion, the Green GÉANT team 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, and this 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, in which the partners developed case studies to show what NRENs could do to mitigate GHG emissions in the extended communities they serve. Again, we have – where possible – applied metrics to any savings made, and compared these with recognised projections, such as those of the SMART 2020 report.

Throughout, 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 five members of the NA3 Task 5 team. Serious initiatives are under way in other NRENs and in their client institutions, and learning from these is part of our remit.

12.2 Recommendations

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

1. Having a written environmental policy is a sensible first step towards a raised environmental awareness and reduction in environmental impacts. This statement is universally valid and thus applies to companies and institutions in the ICT sector.
2. Establishing a dedicated green network management system and using it to identify problem areas and potential solutions for network elements and data centre infrastructure is recommended as an

operational second step. The level of ambition does not need to be very high; simple measures can often produce significant improvements at an early stage of implementing the management system.

3. Despite the first two recommendations, there are no formal preconditions if you want to make environmental improvements. If you get a good idea, try to put it into practice as soon as possible. A formal system (such as those discussed in Section 4) may be of great help, but it is also possible to achieve significant benefits without such a system. The report provides a number of examples of what has been done in Green GÉANT, some of which are readily implemented while others require efforts at the system level. More inspiration can be found in the Danish *"Green IT guidelines for public authorities"* [GreenITGuide] and in the pamphlet *"Green IT in* your *company – ideas and inspiration for a greener profile"* [GreenITCo], which contains a wide range of proposals and inspiring case studies.
4. Production of IT equipment is demanding for the environment, so ensuring a long lifetime with high-quality functionality is crucial. Make sure that you purchase equipment that fulfils your needs as far as possible, and also beyond the near future. Also, remember that videoconferences are only beneficial for the environment when they are held: having high-quality equipment at hand does not help the environment if it is not used – rather the opposite.
5. The savings envisioned in the SMART 2020 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 for the strategy of mitigation.
6. There is scope for sharing information, for collaboration and for collective actions among NRENs. The concerted action on the network audits of GHG emissions showed what could be achieved by working together and sharing resources such as the ISO 14064 standard, and the carbon-accounting tool developed by UNI-C. In addition to the collaborative environment provided by GN3, the TERENA organisation provides a forum for NRENs and industrial players, and this 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.
7. NRENs are potentially well placed to take a lead in industry initiatives to promote sustainable policies. With due regard to their neutrality and not-for-profit ethos, they 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 in tackling the global problem.

12.3 Outlook

The outlook as we enter the third year of the GN3 project 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 the delivery of a final report and recommendations. In addition, though, there is a real need to mainstream this project activity, and to make it as sustainable as the high-end network services for our users. Just as GÉANT and its members have developed world-class e-infrastructure for research and education, so we can also show the way in harnessing smart networking to combat climate change.

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Glossary

CDM	Clean Development Mechanisms
CO_2	Carbon Dioxide
CPU	Central Processing Unit
CRM	Customer Relationship Management
DCiE	Data Centre Infrastructure Efficiency
DTIE	Division of Technology, Industry and Economics, UNEP
DWDM	Dense Wavelength Division Multiplexing
ELCD	European Life Cycle Database
EMAS	EU Management and Audit Scheme
ENT	Ear, Nose and Throat
EPN	Energy Proportional Networking
ERP	Enterprise Resource Planning
ETS	Emissions Trading Scheme
GDS	Global Dialling System
GeSI	Global e-Sustainability Initiative
GHG	Greenhouse Gases
GPP	Green Public Purchasing
GSN	GreenStar Network
HD	High Definition
HEA	Higher Education Authority, Ireland
HPCC	High-Performance Computing Centre
HVAC	Heating, Ventilation, Air-Conditioning
HVR	Hardware-Isolated Virtual Router
IaaS	Infrastructure as a Service
ICT	Information and Communications Technology
I/O	Input/Output
ISDN	Integrated Services Digital Network
ISO	International Organisation for Standardisation
ISP	Internet Service Provider
JI	Joint Implementation
LED	Light Emitting Diode
LION	Live International Otolaryngology Network project
LTRS	LION Technical Requirements Standard
MAN	Metropolitan Area Network
MCU	Multi-Conferencing Unit
NA3	GN3 Networking Activity 3 (Status and Trends)

NA3 T5	NA3 Task 5 (Study of Environmental Impact)
NDLR	National Digital Learning Repository, Ireland
NGO	Non-Governmental Organisation
NMS	Network Management System
NOC	Network Operations Centre
NREN	National Research and Education Network
OPEX	Operating Expenditure
OS	Operating System
P	Provider
PDU	Power Distribution Unit
PE	Provider Edge
PoE	Power over Ethernet
PoP	Point of Presence
PSTN	Public Switched Telephone Network
PUE	Power Usage Efficiency
QoS	Quality of Service
REC	Renewable Energy Certificate
RAID	Redundant Array of Independent Disks
ROI	Return on Investment
SAN	Storage Area Network
SMART	Standards, Monitoring, Accounting, Rethink, Transform
SSH	Secure Shell
SVR	Software-Isolated Virtual Router
TE	Traffic Engineering
TCO	Total Cost of Ownership
UNEP	United Nations Environmental Programme
UPS	Uninterruptible Power Supply
VC	Videoconferencing
VM	Virtual Machine
VNC	Virtual Network Computing
WDM	Wavelength Division Multiplexing