GN3 Study of Environmental Impact Inventory of Greenhouse Gas Emissions and Removals – GRNET

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1. Introduction

1.1 Background

Greek Research and Technology Network S.A. (GRNET) joined the Green GÉANT Team in 2011 motivated by the growing interest on the adoption of energy aware techniques and the need for increasing the energy consumption awareness of the research and academic community in Greece. GRNET's network and infrastructure expansion in the last years made necessary the conduction of a survey for the calculation of the energy consumption footprint and the corresponding GHG emissions.
There are many measures used in calculating and reporting on green audits. In order to establish metrics which can be validated, and which can be replicated at different times and in different organisations, it is important to adhere to recognised standards. In this instance, the ISO standard is the set of documents under ISO 14064 [ISO14064-1, ISO14064-2, ISO14064-3]. These documents are used to guide the form and content of the inventory process.

1.2 Scope

The primary goal of this assessment is to account for the Green House Gas (GHG) emission according to the ISO 14064:2006 part 1 standard. This information can be used for comparison with other NRENs, and for use by GRNET for GHG assessments the following years.

1.3 GRNET: Purpose and Profile

GRNET runs the Greek Research & Technology Network, according to the operating model of corresponding EU Research and Education Networks. It operates both at a national and international level and constitutes the setting for the development of innovative services for the members of the Greek research and academic community. GRNET connects more than 100 institutions, including all universities, technical and research institutes, as well as the public Greek School Network, supporting more than 500.000 users all over the country. Moreover, it provides local interconnection services to the main Greek Internet providers, through the Greek Internet Exchange (http://www.gr-ix.gr/).
GRNET aims at contributing towards our country's Digital Convergence with the EU, by supporting the development of Information and Communication Technologies (ICT), by constituting the ideal setting for scientific research towards future network developments, by developing and offering innovative services and applications to Greek citizens from an early age (e-government, e-learning, e-integration), and by introducing advanced technological tools in everyday activities; tools that will improve their quality of life, will reduce unnecessary transportation and will render them more effective and competitive, equal members of the Digital Greek Community.
GRNET vision is the development of Education and Research in our country along with the equal participation of our organizations in the Pan European society of knowledge with the provision of modern, advanced and reliable Internet services to all Educational and Research Institutions.

1.4 Green GRNET Activities

GRNET has recently been involved in several green activities, targeting at (i) the reduction of the energy consumption in its existing networking infrastructures, (ii) the application of novel energy efficient techniques on the deployment of new data centers and Points of Presence (PoPs), (iii) the promotion of research in the field of evolution of energy-aware techniques in Internet Service Providers (ISPs) networks and (iv) the design and development of novel next generation networking paradigms focusing on the reduction of energy consumption of public sector buildings in Greece.

GRNET participates to the FP7 ECONET (low Energy COnsumption NETworks) IP project that aims at studying and exploiting dynamic adaptive technologies (based on standby and performance scaling capabilities) for wired network devices that allow saving energy when a device (or part of it) is not used. The overall idea is to introduce novel green network-specific paradigms and concepts enabling the reduction of energy requirements of wired network equipment by 50% in the short to mid-term (and by 80% in the long run). To this end, the main challenge is to design, develop and test novel technologies, integrated control criteria and mechanisms for network equipment enabling energy saving by adapting network capacities and resources to current traffic loads and user requirements, while ensuring end-to-end Quality of Service.

Furthermore, GRNET participates to the FP7 GEN6 project that is setting up complementary and interoperable national and cross-border pilots across different EU States, in order to validate and catalyse the deployment of IPv6 in the existing EU government infrastructures, services and applications. In the Greek pilot, a large number of smart energy meters placed in different geographical areas will be interconnected, creating an IPv6 network of Internet connected objects. This pilot will provide a signal to European stakeholders that IPv6 technology can be a “green” enabler.

GRNET also participates to the “Green GÉANT” team in the GN3 project that is committed to promoting energy-saving and ecologically sound applications layered over the GÉANT infrastructure. The “Green GÉANT” team has been established to undertake a study of the environmental impact of the network and is responsible for evaluating how to establish and operate “greener” (more environmentally friendly) networks and services.

Finally, GRNET is planning to install a green data center outdoors in the northwest part of mainland Greece, close to a power-production hydro-electric plant facility and in parallel improve the energy efficiency in the existing data centers.

2. Inventory Design and Development

2.1 Organizational Boundaries

GRNET and its network, computational and cloud services comprise several separate facilities, some owned and controlled by the organization, others shared with separate organizations.

The GHG emissions of GRNET are consolidated into four categories: a. office, b. data centers, c. backbone, and d. transportation. Each one is measured in a controlled and documented manner. In this way, GRNET accounts for all GHG emissions and removals from facilities over which it has financial and operational control.

The ‘operational boundaries’ of GRNET include two offices located in Athens (56 Mesogeion Av. and 63 Mesogeion Av.), the Backbone Network, two Data Centers, six Grid nodes and the transportation incurred as a part of the staff’s work. GRNET also rents two warehouses nearby its premises but they are not included in this inventory since their energy consumption is almost null.

2.2 Responsible party

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2.3 Reporting Period Covered

The period covered by this inventory is the year from January 2010 to December 2010, both inclusive.

2.4 Base Years

This is the first GHG inventory for GRNET, covering the year January 2010 to December 2010. This period will serve as historical base year as well as base year for this inventory.

2.5 Base Year Changes and Recalculations

This section explains any change to the base year or other historical GHG data, and any recalculation of the base year or other historical GHG inventory. The current report is the first GHG report of GRNET and thus no changes are applicable.
The most relevant changes are to be expected from the growth of the GRNET network itself. It is very unlikely that GRNET will change its type of business, and start other services. GRNET maintains a database in which all GRNET equipment is registered. The purpose of the database, besides serving as authoritative source of information for the GHG emissions report, is to be the central repository to record company assets. It is the company's policy to keep the database updated with new acquisitions, disposals and movement of equipment. By having this company policy in relation to the database, the accuracy of the information used for the purpose of the GHG emission report is ensured.

2.6 Compliance Statement

This section confirms that the GHG report has been prepared in accordance with the appropriate part of ISO-14064. This GHG inventory has been prepared in accordance with ISO 14064-1.

2.7 Verification Statement

This section describes whether the GHG inventory, report or assertion has been verified, including the type. This report was submitted for independent validation by “FORCE TECHNOLOGY S.A” to assure that the report is in accordance with ISO 14064. This resulted in a positive evaluation statement on 29th of February 2012.

3. Calculating GHG emissions

3.1 Greenhouse gasses and CO_2-eq definition

The greenhouse gasses (GHGs) are:

- Carbon dioxide (CO_2).
- Methane (CH_4).
- Nitrous Oxide (N_2O).
- Hydrofluorocarbons (HFCs).
- Perfluorocarbons (PFCs).
- Sulphur Hexafluoride (SF_6).

When GHG emissions are calculated, the impact of each GHG is transformed to a CO_2 equivalent. This is done by multiplying the emissions of a GHG by a factor that represents the effect of the GHG on climate change. These effects are based on the IPCC GWP100 factors. The effect of CO_2 is 1, since by definition effect of CO_2 is 1 CO2-eq.

3.2 Data used for calculating GHG emissions

In order to calculate the GHG emissions, different data sources are used. Specifically, energy consumption in GRNET premises is calculated based on the power utility operator bills as well as the total oil consumption for heating purposes. For the network equipment, energy consumption values result from existing documentation as well as real time measurements. Total energy consumption in data centers is recorded based on existing monitoring infrastructure while energy consumption in Grid nodes arises from the assumption that they operate at the 70% of their maximum capacity.

As mentioned earlier, GRNET maintains a database where all the network equipment in the GRNET PoPs is registered. This database contains information for each item of equipment, including the type, the manufacturer, the model number, the supported modules and cards, the physical location etc. Information in the database is updated in a regular basis.

Regarding the emission factors, specific values are used in our report based on information available by the Public Power Corporation S.A in Greece as well as carbon footprint calculators worldwide. Based on the report "PPC - Corporate Social Responsibility and Sustainability Report 2010.pdf" (page 81) published by Public Power Corporation S.A (PPC), the average CO2-eq caused by 1 kWh of electricity in Greece is 1,021 kgr in 2010. Based on the file "billing catalog.pdf" published by PPC the cost of 1kWh for residential buildings in 2010 is 0,054 Euros. For the GHG emission of heating with a gasoil boiler, the average EU-27 emission of 1 liter of gasoil 3,0595 kg CO2 is used (http://www.nef.org.uk/greencompany/co2calculator.htm).

GHG emissions for transportation result from flights for business purposes and from GRNET personnel's daily transportation. For transport associated with commuting to and from work, all employed staff answered a questionnaire ("03.01.01.01 – Questionnaire.xls"). The approximate distance for each staff member's daily journey is taken from http://maps.google.com and categorized by walk/cycle, train, metro, bus, motorbike, taxi, car. It is assumed that each employee completes a round-trip on the days it commutes to the office. It is also assumed that there are 220 working days per year. Daily kilometres per category are calculated and are multiplied by 220 days to get the annual figure.

The corresponding emissions derive from:

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

In the case of transport used while on mission a log is kept of all flights taken by staff for travel to and from meetings, conferences etc.
GRNET has developed an information system for the approval and the cost statement "**Travel Expenses**" (http://travelexpenses.admin.grnet.gr/) where all flights are registered and managed. Based on the collected data from "Travel Expenses", the approximate emission of each flight is calculated from: http://www2.icao.int/en/carbonoffset/Pages/default.aspx

3.3 Impact of Uncertainties on the Accuracy of the Data

This section describes the impact of uncertainties on the accuracy of the GHG emissions and removals data. GRNET has just started, in 2010, to measure and report on GHG emissions. The approach is to begin with the simplest methods available, which include invoiced amounts of power consumed, systematic sampling and projection of equipment power consumption. Having reported through this baseline inventory and having engaged senior management in the process of implementing the environmental policy of the organization, more accurate procedures and systems to measure energy consumed will be used. Nonetheless, the methodologies used in conducting this inventory have been discussed and agreed by the team responsible. We believe that they give a reasonably accurate indication of the level of GHG emissions by the organization in the reporting period.
As detailed in the previous subsection, the emission factors used in our calculations are based on existing reports. Whenever possible, official reports are used and referenced. However, some uncertainties exist in the estimations of emissions that are due to transportation, since the accurate and updated emission factors per type of transportation were not available. Thus, emission factors are based on existing carbon footprint calculators. These factors are taking into account the local conditions in means of transportation in Greece and, thus, the reported factors can be considered as close to the real ones (with uncertainty up to 15%). Furthermore, for the emissions related to transportation of the GRNET staff (excluding flights), uncertainties in the calculations are reduced since information is based on individual responses to a detailed questionnaire. Flight carbon emissions are calculated based on the data available by the International Civil Aviation Organization, while energy consumption calculation in GRNET offices is based on the measurements of the Public Power Corporation S.A (PPC) in Greece. No uncertainties apply for these categories.
Regarding the energy consumption in the GRNET network and data centers, uncertainties exist due to the estimation of data in cases where real time monitoring of energy consumption of the computational, storage and networking equipment was not available. Energy consumption in GRNET routers is based on real time measurements while energy consumption in GRNET network switches is based on their typical energy consumption, as detailed in the manufacturer's datasheets. In the latter case, deviations up to 20% may be present between the estimated and the real energy consumption of the switches. Energy consumption of the optical networking equipment is based on the typical values of the manufacturers' datasheets and is considered stable during the time with low uncertainty in its estimation (up to 5%).
Estimated energy consumption in the GRNET datacenters is based on real time monitoring of energy consumption of the infrastructure in 2011. Since there was not any major upgrade in the networking and computational as well as the cooling infrastructure during 2011, energy consumption during 2010 is based on these measurements. In the forthcoming GHG reports in the following years this uncertainty will not be present since the real time monitoring infrastructure is currently available.

Energy consumption in the HellasGrid infrastructure is based on data collected from the Grid Node in NHRF where energy consumption monitoring infrastructure is available. It is measured that the energy consumption in the Grid Node in NHRF is 70% of the maximum one that is calculated from the corresponding values in the manufacturers' equipment datasheets. This ratio is assumed for the rest Grid nodes where energy consumption monitoring infrastructure is not available in order to minimize the uncertainties in the estimation of the HellasGrid energy consumption.

Finally, an uncertainty with minor impact to the total tons of CO_2 emitted by GRNET has to do with energy consumption from the electricity used by the offices for the building services (lifts, security, lighting) in communal places. In these types of bills it is not stated the exact amount of KWhs spent and the energy consumption is estimated based on the cost for the provision of such services from the PPC. Actually, the cost is divided by 0,054 that is the lowest cost of 1kWh. However, the cost of 1kWh is increasing with the increase of the energy consumption and also the total cost includes some "irrelative" costs regarding cover charge, municipal fees, public television fees etc. In our case, we have chosen to use the conservative low cost of 0,054 euros for 1kWh since it was considered the most reliable approach for estimating the energy consumption in communal places.

4. Scope 1: Direct GHG Emissions

Direct (Scope 1) GHG emissions are defined as emissions caused by the combustion of fuels by GRNET or direct emissions of GHGs. These emissions are characterized as Scope 1 according to ISO 14064.

- GRNET does not own any car or other form of motorized transport which causes direct or combustion related emissions of the GHGs listed.
- GRNET makes use of approximately 45 locations varying in size from a small computer room (a few square meters) to locations with more than 120 square meters.

Typically the larger DataCenters make use of oil powered generators as a backup for mains electricity. The use of those oil powered generators is generally restricted to outages and interruptions of mains electricity and periodic operational testing. Therefore it was decided to not take into account the emissions related to the use of these generators.

4.1 GHG Removals

GRNET is not responsible for any GHG removals.

4.2 Exclusions

As described in the introduction of this section, the oil powered backup generators are excluded from this inventory. The underlying reason is that use of these generators is restricted to outages and interruptions of mains electricity and operational testing.
Furthermore, as described in the "organizational boundaries" of this section, two warehouses are excluded from this inventory. The underlying reason is that use of these warehouses is restricted to limited times per year.

4.3 Direct CO_2 Emissions from the Combustion of Biomass

GRNET is not responsible for any combustion of biomass.

4.4 Total CO_2-eq under Scope 1

The total Scope 1 CO_2-eq emission is **0** tons.

5. Scope 2: Indirect GHG Emissions

This section covers the methodology used to quantify energy-indirect GHG emissions, by sector, within GRNET boundaries. Indirect GHG emissions are caused by using energy produced by others (e.g. electricity or heat). This section provides the Scope 2 GHG emissions for the GRNET offices (Scope2 - subsection 02.01), the GRNET data centers (Scope2 - subsection 02.02) and the GRNET backbone network (Scope2 - subsection 02.03).

5.1 Quantification Methodologies

In this inventory, only recurrent emissions are considered. The embedded energy and consequent GHG emissions from building and production of facilities and equipment are not included. GRNET does not produce any GHGs by direct emission. Indirect emissions are calculated from activities in four main areas:

1. The office: the leased premises at 56 Mesogeion Av, Athens and at 63 Mesogeion Av, Athens where all staff are employed.
   Indirect emissions in this area originate from:
   - Electricity usage for the office itself. Electricity is used for lighting, air conditioning and ventilation, desktop/laptop computers (not the network), coffee machines, displays, beamers, etc.
   - Electricity for building services. The GRNET offices are located in a multi-tenant building. Outside the office energy is spent in lifts, lighting and security.
   - The GRNET office hosts a small part within the building that is used as computer room. In the computer room, there are hosted servers as well as network components needed for the daily operation of GRNET offices. Air conditioning for this room is also included. In order to avoid double counting of energy consumption, the consumed energy of small part of the GRNET offices network is included in the office electricity usage.
2. Backbone Network: The network (or backbone) includes all the PoPs where network equipment, owned by GRNET, is located. This equipment consists of:
   - Optical network equipment consisting of optical amplifiers, (de)multiplex devices, wavelength switches, optical controllers and DWDM equipment.
   - IP network equipment consisting of routers
   - Layer2 network equipment consisting of switches

Part of the nodes of the Greek School Network (GSN) is also co-hosted with GRNET nodes. In these cases, GRNET shares the same facilities with GSN. Otherwise, school network nodes are operated by GSN and, thus, these emissions are excluded from the calculations.

3. Data centers: GRNET owns two data centers where high-density computational and storage equipment is installed. The first data center is hosted in the National Hellenic Research Foundation (NHRF). This data center hosts the GÉANT Point of Presence (PoP) in Athens as well as a HellasGrid site (Grid node). The second GRNET data center is located within the premises of the Greek Ministry of National Education and Religious Affairs in Athens (GMNERA). GRNET operates also the HellasGrid, which is the Greek infrastructure of computing grid and is consisted of six computing and storage nodes in Greece (Athens (3), Thessalonica, Patrai, Heraklio).

5.2 Reasons for Selection of Inventory Sectors

The three sectors (Office, Network, Data Centers) were selected so as to facilitate the allocation of the inventory task to all members of the Environment Working Group, in a fair and sensible manner. The chosen sectors are distinct (with no overlap between them) and comprehensive (no emissions from the GHG profile of the organization). Within each sector, consistent and reproducible methods of quantifying GHG emissions are described below.

5.3 The Office

Direct emissions were derived from an overview of the service costs for the GRNET premises (appended file "02.01.01.02 - 2010 - Mesogeion 63 & Arkadias 31.pdf" and appended file "02.01.01.01 - 2010 - Mesogeion 56.pdf").
The calculation available in appended file "02.01.01 - Total PPC bills.xlsx" estimates that **139.604 KWh** are attributed to GRNET (137.440 KWh for Mesogeion 56 and 2.164 KWh for Arkadias 31).
This corresponds to **142,54 tons CO_2-eq** (based on 1,021 kg CO2-eq per KWh[1]).
The calculation available in appended file "02.01.02 - Total Oil Bills.xlsx" estimates **that 1.346 ltr of oil** are attributed to GRNET. This corresponds to **4,1 tons CO_2-eq** (based on 3,0595 kg CO2-eq per oil litre[2]).

5.3.1 Facilities

The only office facility accounted for is the electricity used by the offices as the amount of electricity used for building services (lifts, security, lighting) in communal places outside the office (appended file "02.01.03.01 – Communal Bills Mesogeion.pdf" and "02.01.03.02 – Communal Bills Arkadias.pdf"). In these type of bills it is not stated the exact amount of KWh, so we have added the cost for these services and then divided by 0,054 since 0,054 euro is the cost of 1 KWh.
The calculation available in appended file "02.01.03 - Total Communal bills.xlsx" estimates that **81.992,3 KWh** are attributed to GRNET (78.119,3,7 KWh for Mesogeion 56 and 3.873 KWh for Arkadias 31).
This corresponds to **83,71 tons CO_2-eq** (based on 1,021 kg CO2-eq per KWh[3]).

5.3.2 Exclusions

No exclusions are applied.

5.3.3 Measurement Method

All GHG emissions are indirect, resulting from the consumption of electricity for power, lighting, heating and cooling from both buildings and from the consumption of oil for heating the Mesogeion Av. 63 & Arkadias 31 building.
Electricity is supplied by the Public Power Corporation (PPC). The PPC billing periods do not correspond to yearly quarters or monthly periods. We add the number of units used per bill for the year 2010. We add all relevant portions of PPC bills together to arrive at the yearly amount. The unit used by the PPC is the kilowatt hour: 1 unit = 1 kWh.
Especially for the Mesogeion 63& Arkadias building there are indirect emissions resulting from the consumption of oil for heating the building. Litres of oil spent; result from the "oil bill". Billing periods do not correspond to yearly quarters or monthly periods. We have added all relevant portions of oil bills together to arrive at the yearly amount. The unit used is the litre: 1 unit = 1 lt.
Additionally, it is calculated the electricity for building services. Outside the offices, energy is spent in lifts, lighting and security. Electricity spent results from the "communal bill". We have added all relevant portions of communal bills -related to the usage of communal places- together to arrive at the yearly amount. The unit used is the kilowatt hour: 1 unit = 1 kWh.

5.4 Backbone network

The GRNET network is a new generation optical fiber network based on Wavelength Division Multiplexing – WDM technology at high speeds (1-10 Gbps). The core network is formed by IP routers that are interconnected with PoS 2.5 Gbps circuits over 10Gbps wavelengths that are implemented via owned DWDM

[1] DEH_CSR_Greek.pdf
[2] http://www.nef.org.uk/greencompany/co2calculator.htm
[3] DEH_CSR_Greek.pdf

equipment. Since 2008, GRNET dark fiber network is extended all over Greece, with total length of dark fiber more than 9000km and optical equipment that may support speeds up to 21x10 Gbps per link.

5.4.1 Facilities

The GRNET IP network topology including the established Layer 2 Ethernet links for the interconnection of GRNET clients is shown in Figure 1. The GRNET network can be divided into core and access network parts. The access network consists of dark fiber pairs between the point of presence (PoP) of GRNET in each major city in Greece and the PoP of the connected university or research institute. Around 100 clients are connected to the GRNET network. Thus, the GRNET network topology can be considered as a flat network topology without large aggregation points. Alternative backup paths are available for the majority of the network nodes while more than one alternative paths exist for the central network nodes.

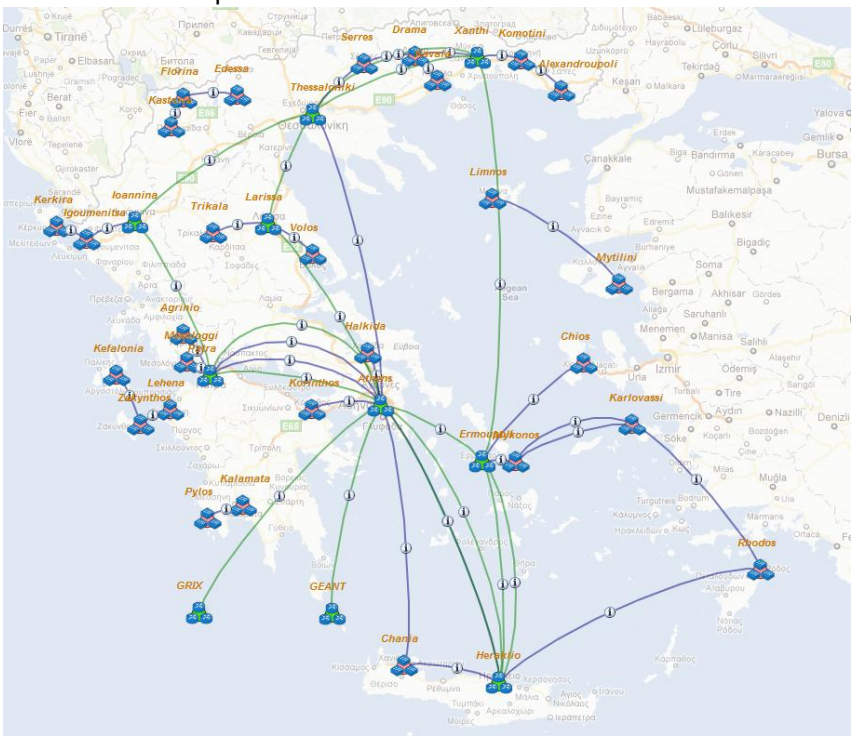

Figure 1: GRNET Network Topology.

5.4.2 Exclusions

No exclusions are applied.

5.4.3 Sample

Real time power consumption is measured at the majority of GRNET core network routers for a period of 3 weeks. The collected results, as depicted in Figure 2, indicate constant values in power consumptions for most of the routers and small variations in the power consumption of a Juniper router. The observed small variations are probably due to the starting and stopping of the device's cooling fans. The average energy consumption for each core network router ranges from 923 W to 2537 W, taking quite lower values compared to their maximum energy consumption.

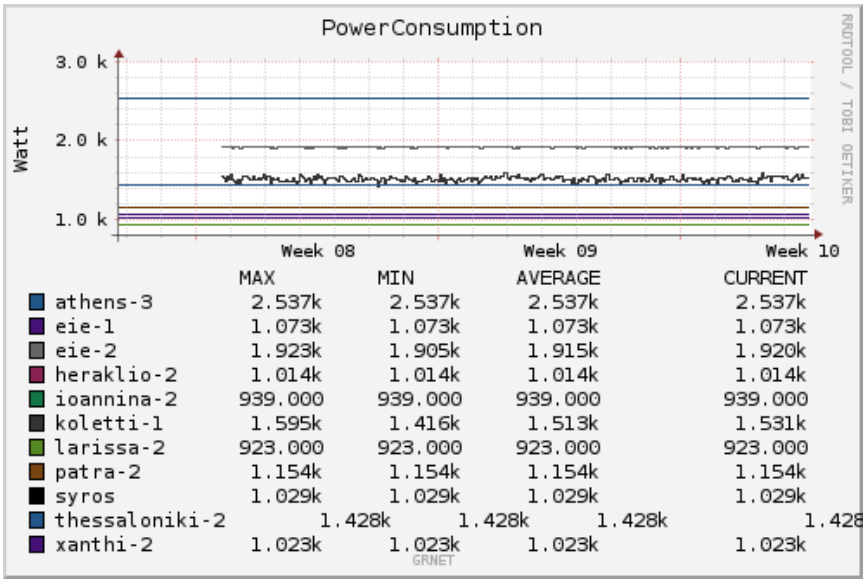

Figure 2: Power consumption in core GRNET routers over a period of 3 weeks.

5.4.4 Measurement Method

GRNET's network is illustrated by IP/Ethernet and optical network equipment. The IP/Ethernet network consists of 11 routers and roughly 45 switches from different vendors. Energy consumption data for all the types of equipment is based either on real time measurements (in cases that it was possible) or in their typical energy consumption, as detailed in the manufacturer's datasheets. Detailed calculations are can be found in the appended file "02.02.01 - Backbone Network.xlsx".
Depending on the considered model, maximum energy consumption in switches varies among 60 W and 659 W, while maximum energy consumption in routers varies among 75 W and 1915 W. Regarding the optical network, the DWDM equipment employed in the core network has a total maximum power consumption of 24.783,5 W.

5.4.5 GHG emission of the GRNET network

The calculation available in appended file "02.02.01 - Backbone Network.xlsx" estimates that **445.340 KWh** are attributed to GRNET (105.873,36 KWh for Routers, 122.363,18 KWh for Switches 217.103,46 KWh for DWDM).
This corresponds to **909,39 tons CO_2-eq** (based on 1,021 kg CO_2-eq per KWh[4] and a PUE = 2).

5.5 Data Centers

5.5.1 Facilities

GRNET owns two data centers, as stated earlier, where high-density computational and storage equipment is installed. The first data center is hosted in the National Hellenic Research Foundation. This data center 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 HellasGrid Node NHRF, there are 6 racks hosting servers and storage equipment. Average energy consumption for the GÉANT PoP is **63 kW**; for the NHRF node it is **67 kW**.

[4] ENVIRONMENT GR.pdf

The second GRNET data center is located within the premises of the Greek Ministry of National Education and Religious Affairs in Athens. The data center 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 plans to load 18 extra racks in the coming months. The average energy consumption of the equipment hosted at this data center is currently around **90 kW** but it is estimated to increase considerably in the upcoming period and reach 450 kW. This data center 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.
Furthermore, GRNET operates the HellasGrid infrastructure that consists of 6 Grid Nodes including the above mentioned one in NHRF. The 5 extra nodes are located in Heraklion (HellasGrid Node Forth), Athens-NKUA (HellasGrid Node IASA), Thessaloniki (HellasGrid Node AUTH), Patra (HellasGrid Node CTI), Athens – NCSR (HellasGrid Node NCSR). Since for these extra nodes there is no energy consumption monitoring infrastructure it is assumed that they operate at the 70% of their maximum energy consumption. This assumption is based on the ratio that is measured in the HellasGrid Node NHRF.
In the slightly longer term, GRNET plans to install a green data center 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 center, while for this purpose water-cooled racks will be utilized. The maximum power for the equipment hosted at this data center 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 better results regarding power usage efficiency than the use of air cooling, which is the traditional data center cooling and refrigeration technology.

5.5.2 Exclusions

No exclusions are applied.

5.5.3 Sample

In the following Figures, samples are depicted for the total power consumption In GRNET data centres. Samples are depicted for 2011 since the monitoring infrastructure was not fully operational in 2010. Figure 3, Figure 4 and Figure 5 depict the average energy consumption for an one-month period for the GÉANT PoP in EIE, the HellasGrid node in EIE and the GRNET data center in the Greek Ministry of National Education and Religious Affairs respectively.

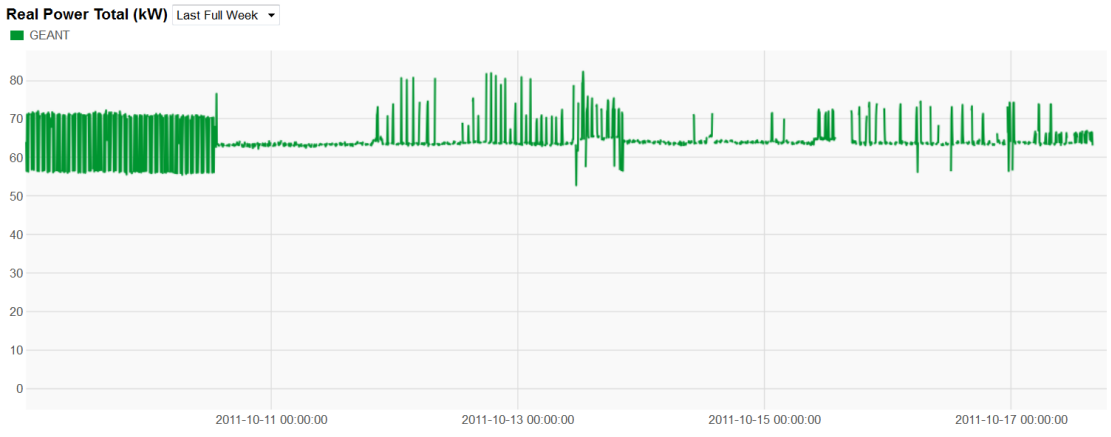

Figure 3: Average energy consumption for the GÉANT PoP.

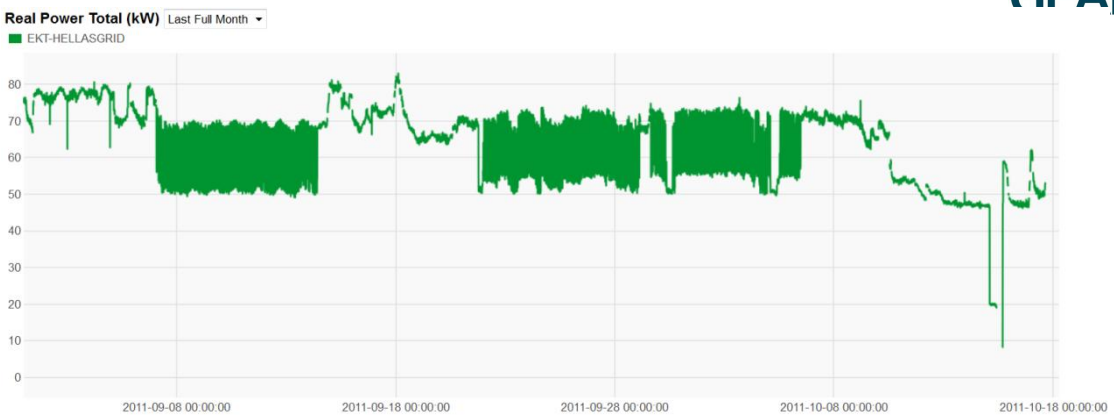

Figure 4: Average energy consumption for HellasGrid node in NHRF.

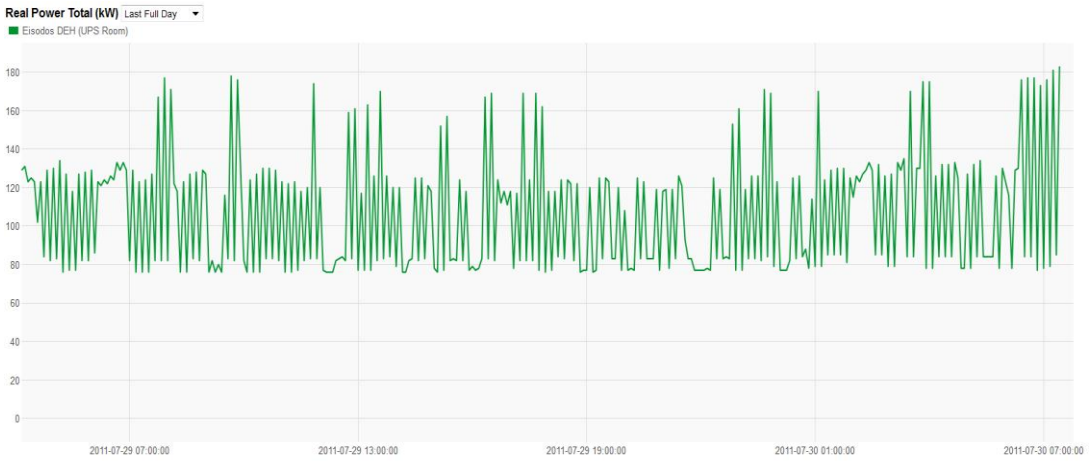

Figure 5: Power Consumption in GRNET data center in the Greek Ministry of National Education and Religious Affairs.

5.5.4 Measurement Method

Monitoring infrastructure is installed in GRNET data centers. This infrastructure provides data for the real time total energy consumption in each data center through specific web interfaces. Indicative figures depicting real time energy consumption in GRNET data centers are shown in Figures 3 to Figure 5.

5.5.5 GHG emission of the GRNET DataCenters

The calculation available in the appended file "02.03.01 - DataCenters.xlsx" estimates that **3.300,33 KWh** is attributed to GRNET DataCenters and Grid Nodes.
This corresponds to **6600,66 tons CO_2-eq** (based on 1,021 kg CO_2-eq per KWh[5] and a PUE = 2).

5.6 Total CO_2-eq under Scope 2

The emissions under Scope2 are **7.657,59 ton CO_2**.

[5] ENVIRONMENT GR.pdf

6. Scope 3: Other indirect GHG emissions

Transport is necessitated for GRNET staff in commuting to and from work, and in the normal course of work. Transport "on mission", for instance, is involved in attending projects' meetings, or in carrying out on-site maintenance at a network PoP. Such travel involves the use of transport which consumes fuel and so, either directly or indirectly, is responsible for GHG emissions.
None of the vehicles involved belongs to the company, so these emissions are categorized as "other indirect".
The sources of these emissions arise from the following sources:

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

6.1 Transport

6.1.1 Scope of Transport

In this section, GHG emissions due to forms of transport are considered in two categories, concerning all employees of GRNET: commuting to and from work, and travel "on mission" as part of one's duties to GRNET.

6.1.2 Exclusions

There are no exclusions from either category of transport.

6.1.3 Sample

6.1.4 Measurement Method

For transport associated with commuting to and from work, all employed staff answered a questionnaire "03.01.01.01 – Questionnaire.xlsx" regarding how they reach office based on the area where each employee lives. The approximate distance for each staff member's daily journey is taken from http://maps.google.com and categorized by walk/cycle, train, metro, bus, motorbike, taxi, car.
We assume that each employee completes a round-trip on the days they commute to the office. We assume 220 working days per year. Daily kilometers per category are calculated and are multiplied by 220 days to get the annual figure.
The corresponding emissions derive from:

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

The calculation available in appended file "03.01.01.02 - Questionnaires' Results.xlsx" estimates that **31,14 tons CO_2-eq** are emitted due to personnel commuting.
In the case of transport used while on mission a log is kept of all flights taken by staff for travel to and from meetings, conferences etc. GRNET has developed an information system for the approval and the cost statement "Travel Expenses" where all flights are registered and managed.
The approximate emission of each flight is calculated from http://www2.icao.int/en/carbonoffset/Pages/default.aspx
The calculation available in appended file "03.01.02.01 - On mission.xlsx" estimates that **93,7 tons CO_2-eq** are emitted due to personnel flights.

7. Summary of GHG Emissions

The emission of GHGs caused by GRNET calculated within this report is as follows.

- The emissions under scope/tier 1 are 0 ton CO_2-eq.
- The emissions under scope/tier 2 are 7740,44 ton CO_2-eq, mainly caused by the GRNET Data Centers.
- The emissions under scope/tier 3 are 124,81 ton CO_2-eq.
- The final figure for GHG emissions by GRNET the year 2010 is **7.865,25 tons** of CO_2 equivalent

GRNET GHG AUDIT
JANUARY 2010 – DECEMBER 2010

Item	Energy source	Energy consumption	CO2 Factor	PUE factor	Total (tons CO2-eq)
Scope 1 - Direct Emissions					
Office					0
Scope 2 - Indirect Emissions					
1. Offices					
Office 1 – electricity	Electricity	137.440 KWh	1,021 kg CO2-eq per KWh		140,33
Office 2 – electricity	Electricity	2.164 KWh	1,021 kg CO2-eq per KWh		2,21
Network excluded in the Office	Electricity		1,021 kg CO2-eq per KWh		
Office1 – service	Electricity	81.992,3 KWh	1,021 kg CO2-eq per KWh		83,71
Office2 – service	Electricity	41,8 KWh	1,021 kg CO2-eq per KWh		0,04
Office2 – Heating	Oil	1.346 lt	3,0595 kg CO2-eq per oil lt		4,1
2. DataCenters					
DataCenter NHRF - GEANT PoP	Electricity	551.880 KWh	1,021 kg CO2-eq per KWh	2	1.126,94
HellasGrid Node NHRF	Electricity	586.920 KWh	1,021 kg CO2-eq per KWh	2	1.198,49
DataCenter GMNERA	Electricity	788.400 KWh	1,021 kg CO2-eq per KWh	2	1.609,91
HellasGrid Node Forth	Electricity	209.806 KWh	1,021 kg CO2-eq per KWh	2	428,42
HellasGrid Node IASA	Electricity	313.783 KWh	1,021 kg CO2-eq per KWh	2	640,74
HellasGrid Node AUTH	Electricity	349.217 KWh	1,021 kg CO2-eq per KWh	2	713,10
HellasGrid Node CTI	Electricity	293.941 KWh	1,021 kg CO2-eq per KWh	2	600,23
HellasGrid Node NCSR	Electricity	138.504 KWh	1,021 kg CO2-eq per KWh	2	282,83
3. Backbone Network					
Routers	Electricity	105.873,36 KWh	1,021 kg CO2-eq per KWh	2	216,19
Switches	Electricity	122.363,18 KWh	1,021 kg CO2-eq per KWh	2	249,87
DWDM	Electricity	217.103,46 KWh	1,021 kg CO2-eq per KWh	2	443,33
Scope 3 - Other Indirect Emissions					

Transport					
Commuting					
Private Cars	149.910 km				24,21
Metro	29.615,2 km				2,18
Bus	6104,8 km				0,91
Motorbikes	30.604 km				3,81
On mission					
Flights					93,70
Total CO2 - eq					**7.865,25**