White Paper: Towards “Greener” NRENs through the use of eCO2meter

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Date: 13 October 2014

The research leading to these results has received funding from the European Community’s Seventh Framework Programme (FP7 2007–2013) under Grant Agreement No. 605243 (GN3plus).

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1 Introduction

Rising energy consumption of the networking and computing equipment that supports or accesses the Internet will be one of the main challenges that National Research and Educational Networks (NRENs) will have to address to promote a sustainable environment. The amount of data transported over our networks will continue to rise and energy consumption will rise with it. As the cloud and mobile devices become more important in our daily lives, the mobile, access and core networks required to support these services do too. Where energy consumption of networks currently is not regarded as a high priority, this will change in the near future in a business-as-usual scenario due to these trends related to massive increase in network activities. It should be noted that achieving increased energy efficiency is not only good for the environment, but has also positive impact from a business continuity perspective.

Thus, a set of energy efficient practices, techniques and policies has to be adopted by NRENs for handling these challenges along with the specification of short and long term targets for reduction in the overall energy consumption and the adoption of environmental friendly techniques (e.g. integration of renewable energy sources in various parts of the IT infrastructure). However, adoption of energy efficient practices in setup, management, support and decommissioning of our networks has to be combined with the use of ICT technology to measure the success of reducing the energy consumption in various sectors. In order to progress towards this direction and given the lack of robust policies to address climate change – as stated in the GeSI's SMARTer2020 report [1] – NRENs can provide specific guidance to policy makers based on the conduction of detailed national studies of the GreenHouse Gas (GHG) abatement potential in a set of countries.

Based on this fact, the "GÉANT Environmental Green team" has undertaken the initiative for the design and development of an online tool -called eCO_2meter- for the collection of data calculating the yearly energy consumption and GHG emissions of NRENs. The main objectives for the development of eCO_2meter included the creation of an international database with energy consumption and GHG emissions data in NRENs. This will cover a wide geographical area, with the provision of statistics demonstrating the energy consumption of the IT equipment in various networks and associated computing infrastructures' parts. eCO_2meter allows network managers to deduce useful conclusions regarding the more energy-hungry parts of the NRENs infrastructure. In addition, it can be used to help measure the environmental impact when applying energy efficiency techniques (e.g. energy efficiency achieved through virtualization techniques, reduction in energy consumption based on behavioral analytics approaches).

In this paper, a short description of eCO_2meter is provided focusing on the main functionalities provided as well as the interconnection of the tool with the overall work realized within the "GÉANT Environmental Green team". The following structure is followed: in section two, the categories included in the realization of GHG emission reports are described along with the process followed by each NREN for successfully realizing a report; in section three, the eCO_2meter tool is described in detail focusing on the tool's architecture and the provided functionalities; in section four, issues related with exploitation of the collected data towards the design of energy efficient policies and the interaction with interested parties are detailed while section five provides an overall positioning of the eCO_2meter within the working axes of the "GÉANT Environmental Green team".

2 GHG Reports: Categories and Online Process

The requirements for the realization of yearly GHG emission reports from the NRENs based on the ISO 14064 standard have been taken into account, in the design of the online tool. For NRENs, GHG emissions can be consolidated into four categories (Figure 1): the office, the data centers, the network and the transportation. Each one of them is measured in a controlled and documented manner. Office emissions derive from the electricity usage for the offices where the NREN houses its staff (lighting, heating, air conditioning and ventilation, lifts, security etc). For the network equipment, energy consumption values result from real time measurements or available documentation regarding the networking equipment in each of the Points of Presence (PoP) of the NREN. In the data centers, the total energy consumption of the IT storage, computing and networking equipment is measured along with the energy consumption caused by the supportive infrastructure (e.g. air-conditioning, lighting, security). In the latter category, GHG emissions result from personnel's daily transportation and from travels on mission as part of one's duties to the NREN.

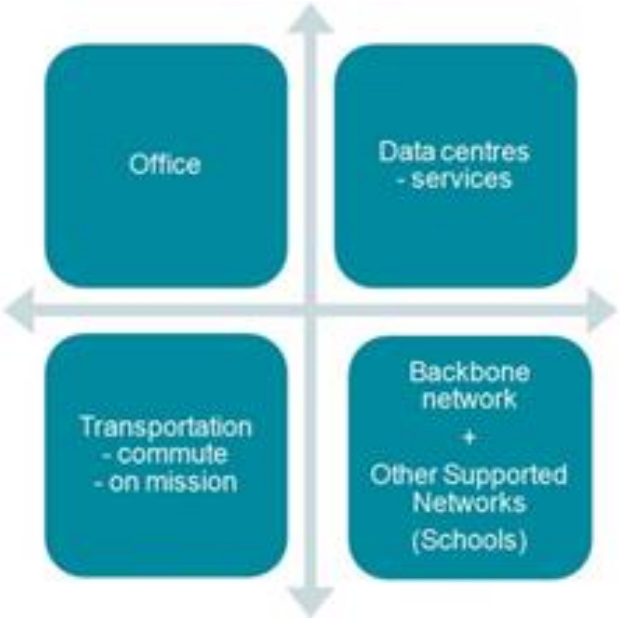


Figure 1: Categories of NRENs' GHG emissions

Having developed a structured framework to record what are the GHG emissions that result from the daily activities of NRENs, the next practical step was to develop the eCO_2meter to partial automate the production of GHG-emission reports of the NRENs participating in the "GÉANT Environmental Green team". The design of the eCO_2meter was based on the process followed up to now for the preparation of the reports, however, some modifications and adjustments were made aiming at reducing the complexity and the administration overhead.

In order to be feasible to make comparisons among different NRENs, GHG emissions reports have to be created on an annual basis and the process of completing the report is based on a series of web-forms for each section or subsection (a set of figures from the various web forms are depicted in the Appendix). Access to the online tool is based on the support of

authentication/authorization schemes, according to the eduGAIN[1] service. Authenticated and authorized users from each NREN are able to access the eCO$_2$meter, view the existing reports, and edit and finalize new reports. Unauthorized users can only view the finalized reports. Each final report (without the detailed data for the calculation process or the process itself) may be extracted to a pdf format and may be used for verification purposes by external bodies (this is a requirement to report an official ISO 14064 compliant report). Specific guidelines, suggested texts and URLs to existing emission calculators (e.g. calculator for flight emissions) are provided throughout the process of completing the report online. Text areas for describing methodologies, samples, exclusions etc. per form/section and predefined texts are also provided, as well as capacity to upload images and add references to the text in each section.

One page per NREN entitled "NREN Specific Data" is provided for inserting/updating/validating NREN specific data, such as NREN's name, website, environmental policy, country, logo, the base year report and the responsible person and contributors to the report. In each report there is also a "Report Specific Data" page with information regarding the reporting period covered, the preferable metric for distance values, the emission factors for the specific year, documentation files etc. "Documentation files" serves as a "storage area" allocated to each NREN for uploading files used for the realization of the report (e.g. energy consumption bills, reports extracted from energy consumption monitoring tools, etc.).

In addition to the introductory forms, a series of web forms are available for providing input data to each category of GHG emissions of each NREN (indirect and direct emissions). For the indirect emissions, specific sub-pages are available for the office area, the networking infrastructure, the data centers and the transportation sector. Indirect emissions in the office area originate from: electricity usage for the office itself (electricity is used for lighting, air conditioning and ventilation, desktop/laptop computers, coffee machines, displays, beamers, etc.) and electricity for building services. Outside the offices, energy is spent on lifts, lighting and security. Specific fields are available for reporting electricity usage in each area. Direct energy consumption, as well as emissions in office areas, may derive either from a smart meter installed in NRENs' premises or from an overview of the service costs for the NREN's premises (a file with all the power utility operator bills − or whatever is available − for justification purposes may be uploaded).The NREN must add the number of units used per bill for the corresponding year to arrive at the annual amount. Then the total amount is automatically converted to tones of CO_2-eq based on how many kg CO_2-eq correspond to 1 KWh for the NREN's country in a specific year. The procedure is similar for all sources of energy.

Specific web forms are also provided for declaring energy consumption of the networking infrastructure that -as already stated- includes energy consumption in all the PoPs, where network equipment, owned by the NREN, is located. This equipment may consist of (i) optical network equipment consisting of optical amplifiers, (de)multiplex devices, wavelength switches, optical controllers and DWDM equipment, (ii) IP network equipment, consisting of routers and (iii) Layer2 network equipment, consisting of switches. In case the total energy consumption in the PoP, including the networking and the supportive infrastructure, is available (through an energy consumption monitoring infrastructure or the energy bills from the utility

[1] http://www.geant.net/service/eduGAIN/Pages/home.aspx

operator), the corresponding value may be declared and no further calculations need to be done. Otherwise, the NREN must state all of its PoPs and list the network equipment in each PoP, accompanied with the corresponding energy consumption. In the latter case, energy consumption values may result either from real-time monitoring of energy consumption of the device (e.g. in case of existence of a smart power outlet or in case of collection of such data via SNMP) or from the device specifications in the manufacturer's datasheets.

Following, the user is directed on web forms for providing information regarding energy consumption and GHG emissions in data centers. Energy consumption data for each data centre (IT and supportive infrastructure) may be based on real-time measurements (in case that monitoring infrastructure is available) or on typical energy consumption of the hosted equipment, as detailed in the manufacturer's datasheets.

It should be noted that both in the network PoPs and the data centres it is important to provide information for the Power Usage Efficiency (PUE) metric in order to be able to estimate the total energy consumption, given the value of the estimated IT equipment consumption. Furthermore, some extra values are requested for the extraction of meaningful statistics, such as: total network traffic (incoming and outgoing) served by the NREN's network, minimum and maximum values of the real-time energy consumption, number of racks in a DC, etc.

In the latter category, GHG emissions result from personnel's daily transportation and from travels on mission as part of their duties to the NREN. For transport associated with commuting to and from work, all employed staff is able to answer an online questionnaire regarding how they reach the office, based on their area of residence. The approximate distance for each staff member's daily journey may be taken from Google Maps, while the form of transportation may include car, motorbike, subway, bus, tram, etc. Daily kilometers are multiplied by the working days to get the annual figure and then the CO2-eq is automatically calculated.

Given the online completion of the data in the four specified sections, a summary of the overall consumption and emissions is automatically provided in the form of a table in a specific web page.

3 eCO$_2$meter Architecture

3.1 Architecture

The design of eCO$_2$meter is following a Model–View–Controller (MVC) architecture at the client and the server side. Communication among the client and the server is standardized via RESTFul API in order to provide an easy integration workflow for the future needs of the tool. Python and the Django Framework was chosen as the platform for backend development, since it contains a robust object relational mapper and provides through Django REST Framework all the necessary automation for creating a web browseable RESTful API. On the frontend, backbone.js (http://backbonejs.org/ - a library that facilitates the design of MVC applications and provides communication interfaces via REST) provides basic model representation in Javascript, Bootstrap and JQuery take care of the presentation layer and for PDF creation XHTML2PDF was used. The design of the eCO$_2$meter architecture ensures the support of flexibility within the platform but mainly the proper assignment of tasks in multiple end

users. Documentation of the used API is automatically generated and may be provided to developers for the design of specific extensions or interconnection of eCO2meter with other tools/services.

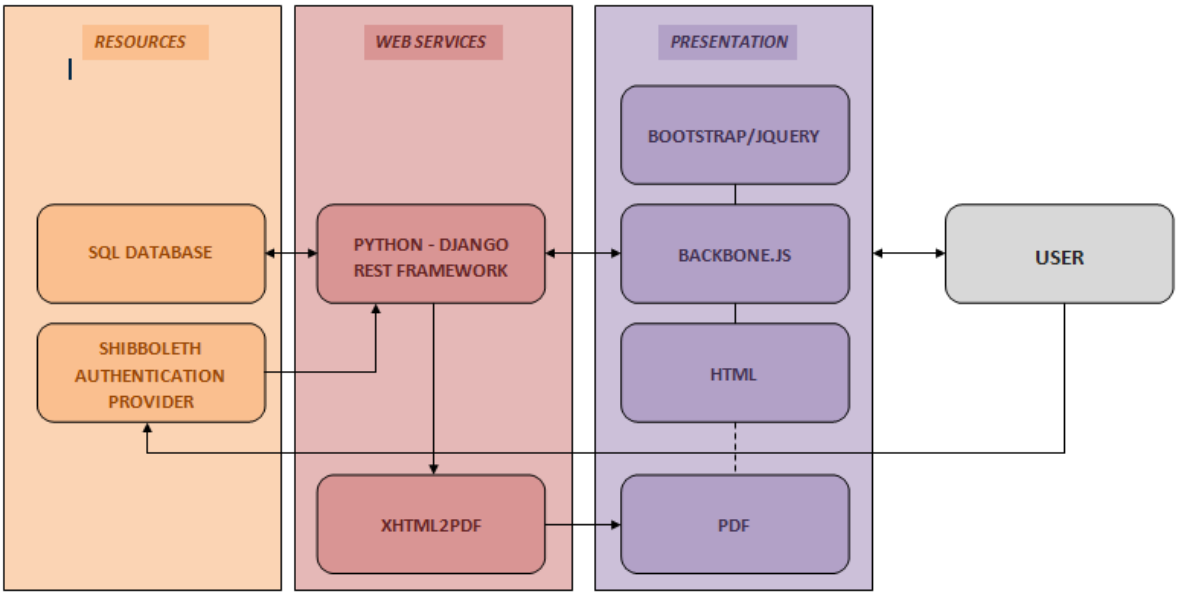


Figure 2: eCO2Meter Architecture

3.2 Functionalities

A set of functionalities are provided through the eCO2meter targeting mainly at the easy and with low complexity editing and completion of GHG emission reports from NRENs. The main functionalities include accounting and authorization services (eduGAIN service is supported, for the trustworthy exchange of information related to identity and authentication), advanced editing functionalities (integration of user friendly editors, ability to add figures and references), provision of storage space per report for uploading the required documentation, provision of indications and guidelines/tips to end users per type of the required information, access to previous reports for automatic cloning of text (e.g. in case of creating a new report with minor differences from the previous ones) and automatic loading of existing PoPs, datacenters, networking, computing and storage equipment based on the already filled in information.

Furthermore, further functionalities are provided, such as the automatic creation of the final reports based on the input provided (these reports can be used for verification by an external body, which is a requirement for an official ISO 14064-compliant report), the automatic estimation of data based on predefined values (e.g. CO_2 emission factors per country, tones of emissions per passenger-mile in international flights), the provision of advanced statistics with useful (longitudinal) comparisons based on a diverse set of criteria (e.g. geographical area,

energy consumption per sector of the NREN's infrastructure, GHG emissions per number of PoPs) and the comparisons among the NRENs.

4 Energy Consumption Data Management

As stated in the previous sections, a wide set of energy consumption data is envisaged to be collected within eCO2meter based on existing, in progress as well as future GHG emission reports from NRENs. These data will constitute the basis for the design and application of a set of environmental friendly actions, given the potential for increasing energy efficiency in diverse parts of the NRENs' infrastructure (Figure 3).

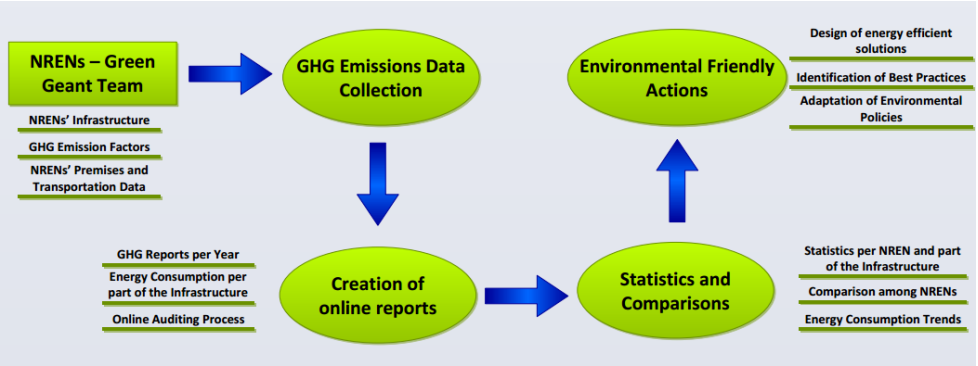


Figure 3: Design of Environmentally Friendly Actions through eCO2Meter

Initially, collected data are going to be used in order to acquire an overall picture of the energy consumption levels in the various parts of the NRENs infrastructure, identify the most energy hungry parts, evaluate the energy efficiency achieved upon the application of energy-aware techniques and proceed to a series of comparative analyses among the reporting periods as well as among NRENs in different geographical areas. Statistics extraction and trends analysis regarding the yearly evolution of the energy consumption of NRENs and monitoring of specific performance metrics (e.g. energy consumed per bit of the overall traffic served, tons of emissions per number of clients) will be periodically produced. Furthermore, forecasting analysis may be realized where appropriate for estimating the impact of the application of specific techniques or energy-aware policies and, thus, facilitate decision makers to proceed or not to their adoption. It could be also claimed that the results extracted from the available data should facilitate the GÉANT community to determine the benefits of any initiative taken towards the reduction of its energy consumption footprint.

In addition to the preparation of statistics and the realization of comparisons, it is envisaged that data available in eCO2meter -given that it regards an international database with energy consumption data- will be used for liaison with international organizations and relevant projects targeting at the exchange of knowledge, dissemination of best practices as well as organization of common activities. For instance, comparison of energy consumption trends of NRENs with relevant trends in commercial ISPs and telecom operators may provide helpful insights on further actions that could be undertaken for moving to greener NRENs.

5 Green GEANT Team: The way forward

The design and deployment of eCO2meter has not to be considered as a stand-alone activity. It is actually fully interconnected with the activities and objectives of the "GÉANT Environmental Green team". Feedback from the data management realized based on eCO2meter data and statistics is going to be provided to various team activities. These activities include -among others- the definition of a unified Environmental or Sustainability policy for NRENs, the definition and evolvement of a Green ICT Maturity Model that allows organizations to carry out a self-scan on their performance of using ICT in an environmentally responsible manner and the identification and dissemination of best practices within the team as well as external stakeholders and interested parties. Followingly, details are provided regarding the interconnection of eCO2meter with each of the mentioned activities.

One of the major focus areas for the "GÉANT Environmental Green team" has been to concentrate on encouraging NRENs to produce their own Environmental or Sustainability policy. These policies are usually concerned with the management of actions in order to conserve resources, reduce waste and generally minimize the impact of any man-made changes on the environment. Translating an environmental policy into operational activities requires long-term strategic thinking from a NRENs management team, as well as an organization following a strategic plan that maps out their activities for a number of years and is endorsed by their stakeholders. Given the issuance of environmental policies from several team members, it has been currently produced an environmental policy template, as well as links to previously published NREN policies. Based on this template, the "GÉANT Environmental Green team" is working hard to help promote environmental sustainability across the R&E community. The goal is to have a large part of the NREN constituency adopt a policy, and use it to define objectives and targets for improving their environmental performance. However, the definition of meaningful and measurable targets and objectives requires the availability of data for the corresponding indexes and performance metrics, activity that is supported by eCO2meter.

In addition to the definition of a common Environmental or Sustainability Policy and in order to benchmark the progress of NRENS or education clients with regards to the adoption of environmental friendly technologies, a Green ICT Maturity Model is designed. This model aims to allow organizations to carry out a self-scan on their performance of using ICT in an environmentally responsible manner. It is designed to be lightweight and allow participants to scan themselves in a quick, inexpensive and independent manner. The purpose of the model is to provide an indicator of an institution's development of green ICT, and it enables organizations to launch an internal dialogue, to gain agreement on the status quo, and to define actions for improvement. Using eCO2meter is considered as one of the Key Performance indicators within the model, since it provides a widely accepted yearly-oriented deterministic measurement regarding the energy consumption and efficiency status of NRENs and contributes to the overall assessment realized via the proposed Green ICT Maturity Model.

The "GÉANT Environmental Green team" is also working on building and continuously updating a collection of best practices for NRENs to adopt to lessen their environmental impact as well as on formulating proposals and recommendations to encourage and guide the policies of NRENs and GÉANT in the pursuance of "greener" performance. Such best practices include -among others- the application of e-waste policies, the application of advanced virtualization and

video-conferencing/tele-working techniques, dematerialization activities, IPv6 enabled smart metering techniques and energy-aware behavioral analytics production. The correlation of eCO$_2$meter with the best practices is twofold. On one hand, short and long-term evaluation of part of the best practices is going to be realized via the data available in the yearly reports. On the other hand, anomalies detected within the energy consumption in various parts of the NRENs' infrastructure may lead to the identification of needs for design or replication of best practices, leading to increase in the energy efficiency achieved.

By taking into account the above-mentioned facts, it could be claimed that eCO$_2$meter is directly related with several activities within the "GÉANT Environmental Green team" and that its proper use will provide the potential to estimate the impact of undertaking energy-aware actions and provide valuable feedback to decision-makers and stakeholders. The target is to exploit in an optimal way the available data and proceed to the design and application of environmental friendly activities and actually pave the way towards greener NRENs.

References

[1] GeSI SMARTer2020: The Role of ICT in Driving a Sustainable Future, Available Online: http://gesi.org/SMARTer2020

Appendix

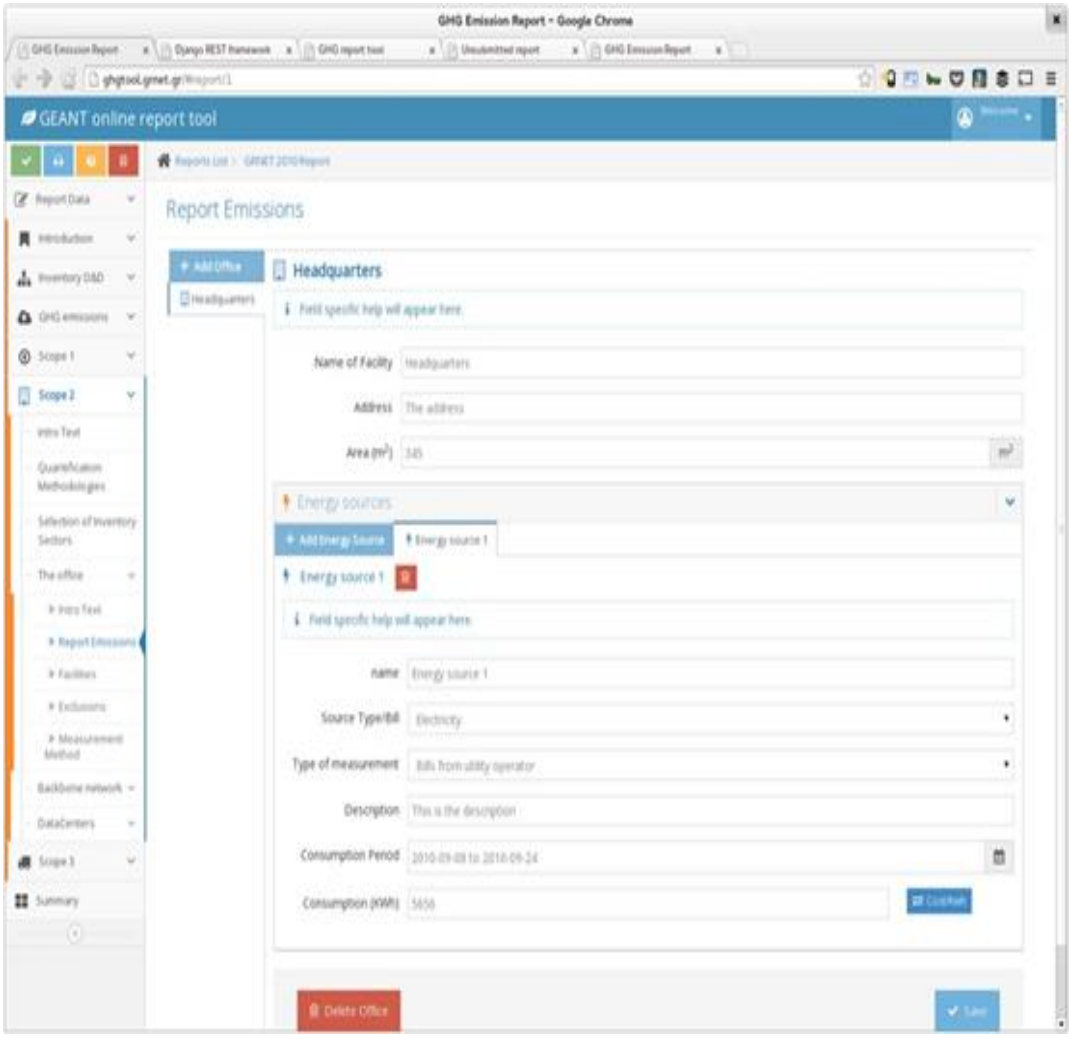


Figure A-1: Data entry for energy usage at a facility headquarters

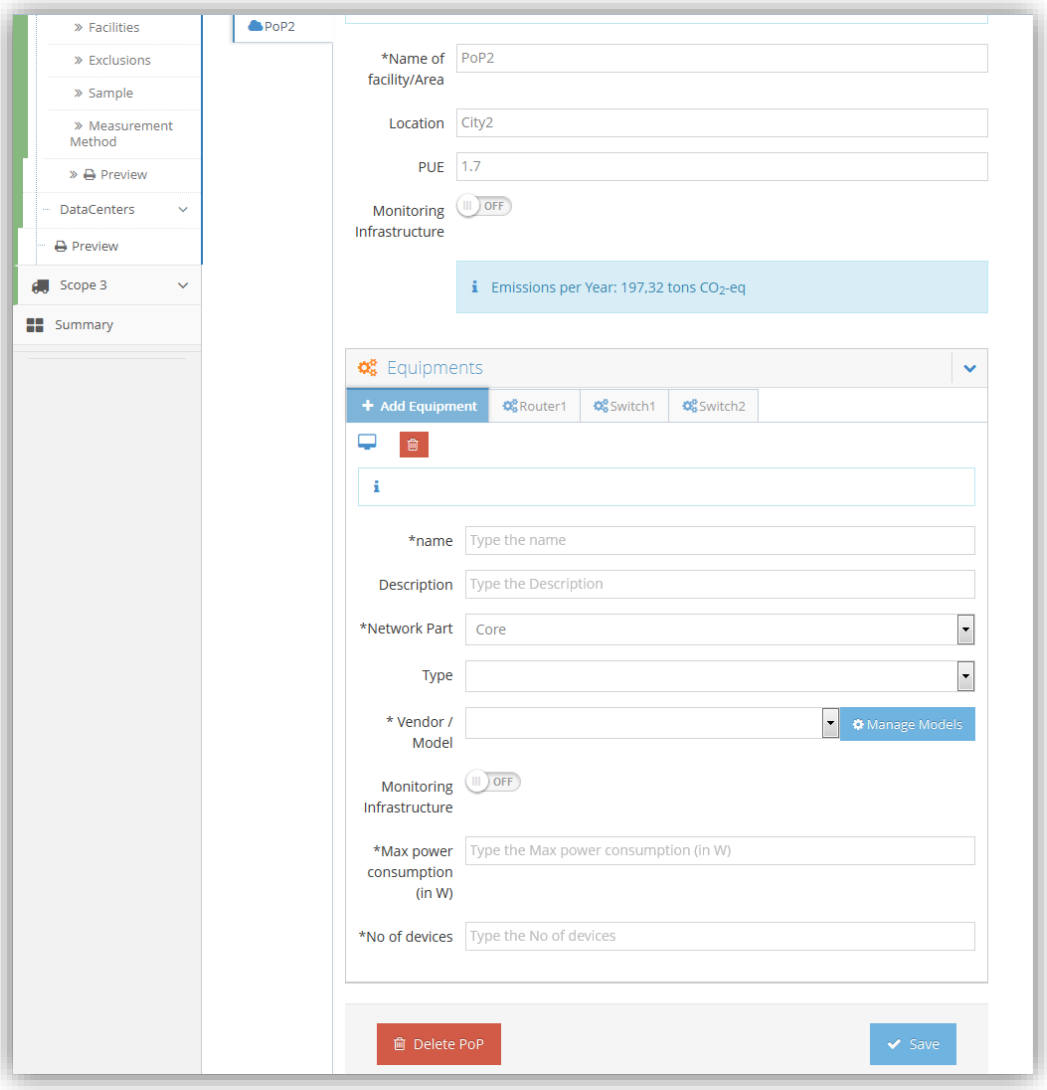


Figure A-2: Data entry for PoP's Equipment

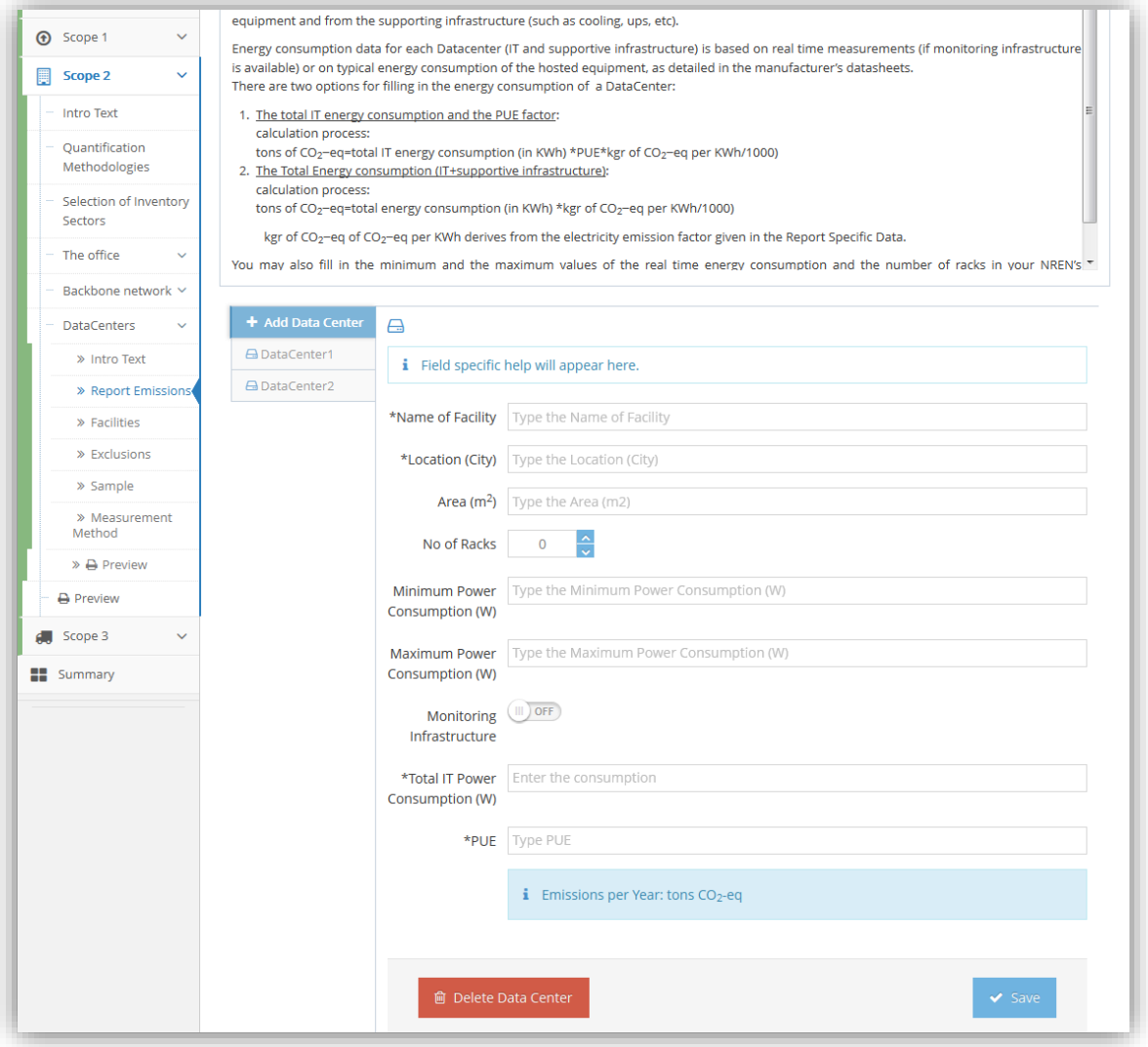


Figure A-3: Data entry for adding a Data Center

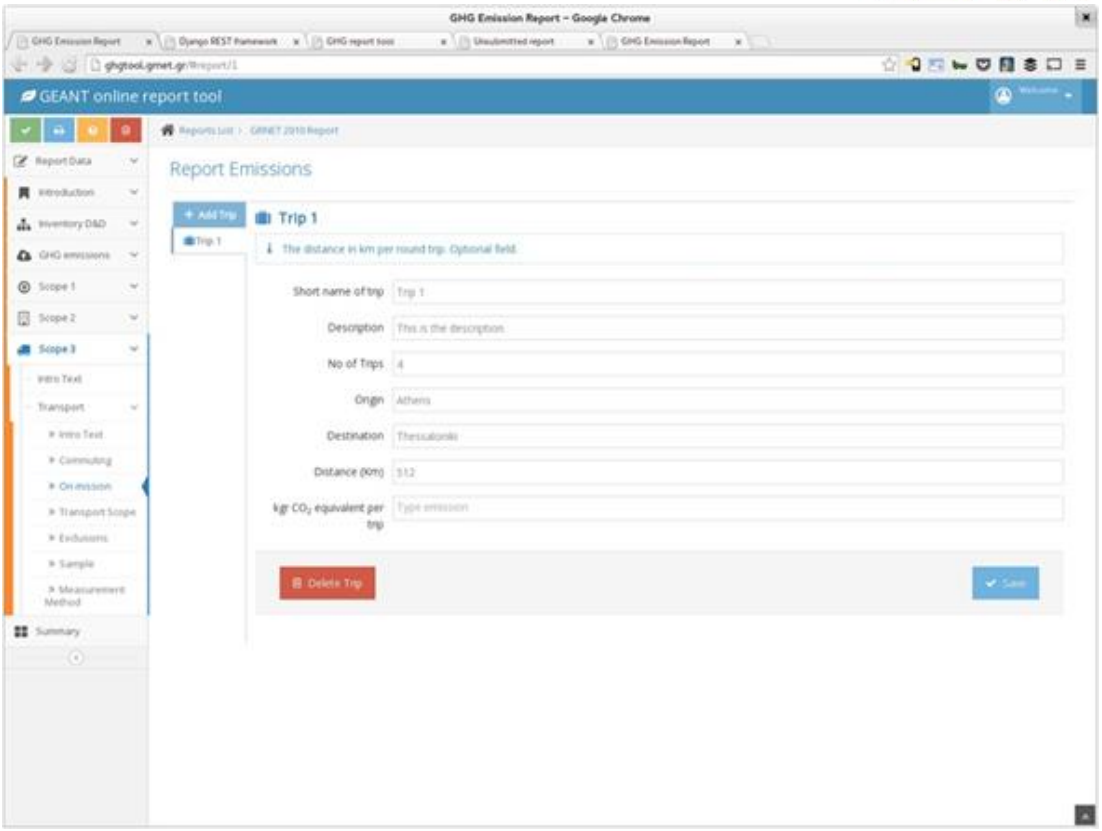
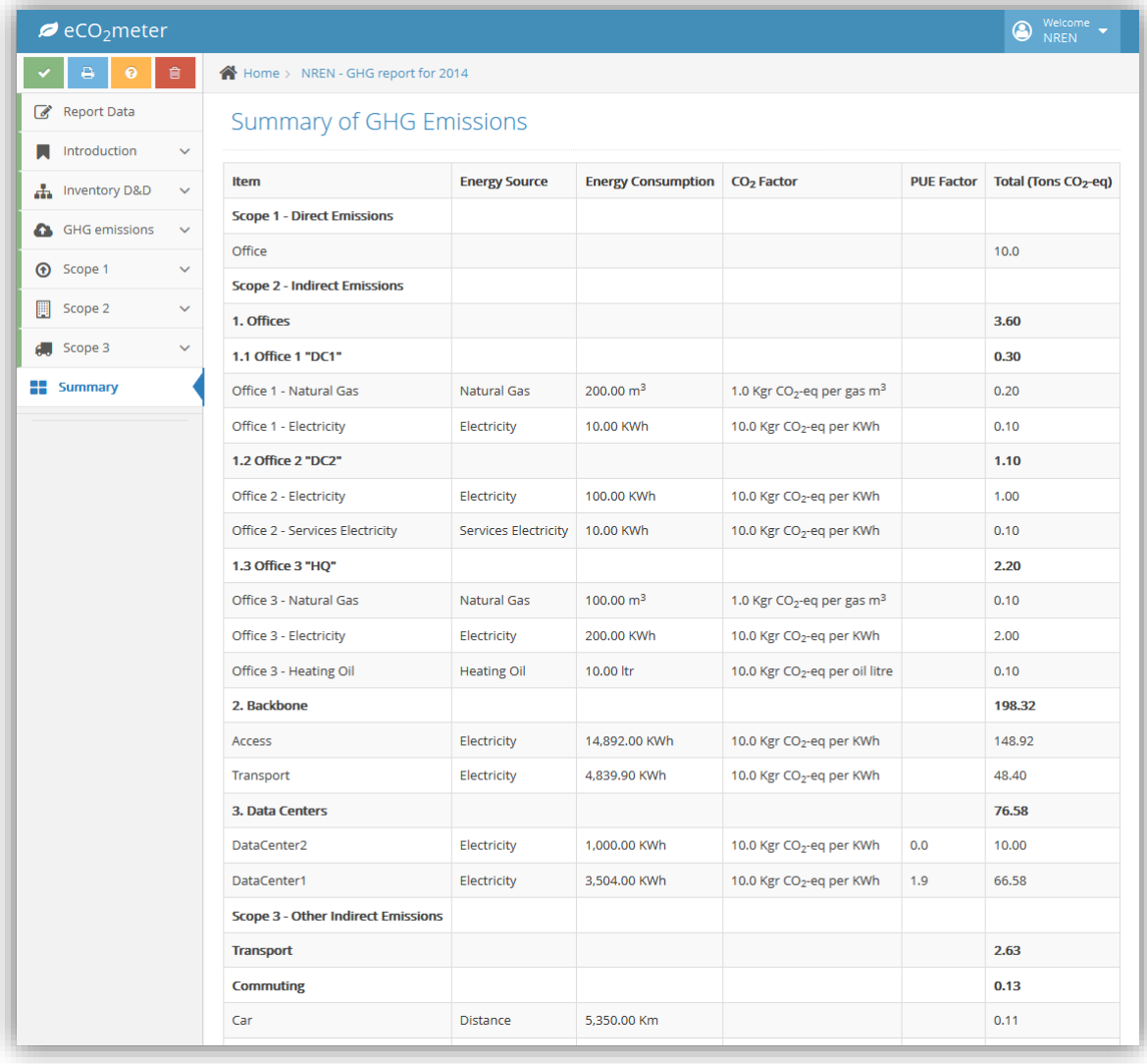


Figure A-4: Recording details of a business trip



Summary of GHG Emissions

Item	Energy Source	Energy Consumption	CO_2 Factor	PUE Factor	Total (Tons CO_2-eq)
Scope 1 - Direct Emissions					
Office					10.0
Scope 2 - Indirect Emissions					
1. Offices					**3.60**
1.1 Office 1 "DC1"					**0.30**
Office 1 - Natural Gas	Natural Gas	200.00 m^3	1.0 Kgr CO_2-eq per gas m^3		0.20
Office 1 - Electricity	Electricity	10.00 KWh	10.0 Kgr CO_2-eq per KWh		0.10
1.2 Office 2 "DC2"					**1.10**
Office 2 - Electricity	Electricity	100.00 KWh	10.0 Kgr CO_2-eq per KWh		1.00
Office 2 - Services Electricity	Services Electricity	10.00 KWh	10.0 Kgr CO_2-eq per KWh		0.10
1.3 Office 3 "HQ"					**2.20**
Office 3 - Natural Gas	Natural Gas	100.00 m^3	1.0 Kgr CO_2-eq per gas m^3		0.10
Office 3 - Electricity	Electricity	200.00 KWh	10.0 Kgr CO_2-eq per KWh		2.00
Office 3 - Heating Oil	Heating Oil	10.00 ltr	10.0 Kgr CO_2-eq per oil litre		0.10
2. Backbone					**198.32**
Access	Electricity	14,892.00 KWh	10.0 Kgr CO_2-eq per KWh		148.92
Transport	Electricity	4,839.90 KWh	10.0 Kgr CO_2-eq per KWh		48.40
3. Data Centers					**76.58**
DataCenter2	Electricity	1,000.00 KWh	10.0 Kgr CO_2-eq per KWh	0.0	10.00
DataCenter1	Electricity	3,504.00 KWh	10.0 Kgr CO_2-eq per KWh	1.9	66.58
Scope 3 - Other Indirect Emissions					
Transport					**2.63**
Commuting					**0.13**
Car	Distance	5,350.00 Km			0.11

Figure A-5: Summary Table of GHG emissions