GÉANT
ASSOCIATION
Networking • Services • People

GÉANT Association
COMPENDIUM
of National Research and
Education Networks in Europe

2014 Edition

compendium.terena.org

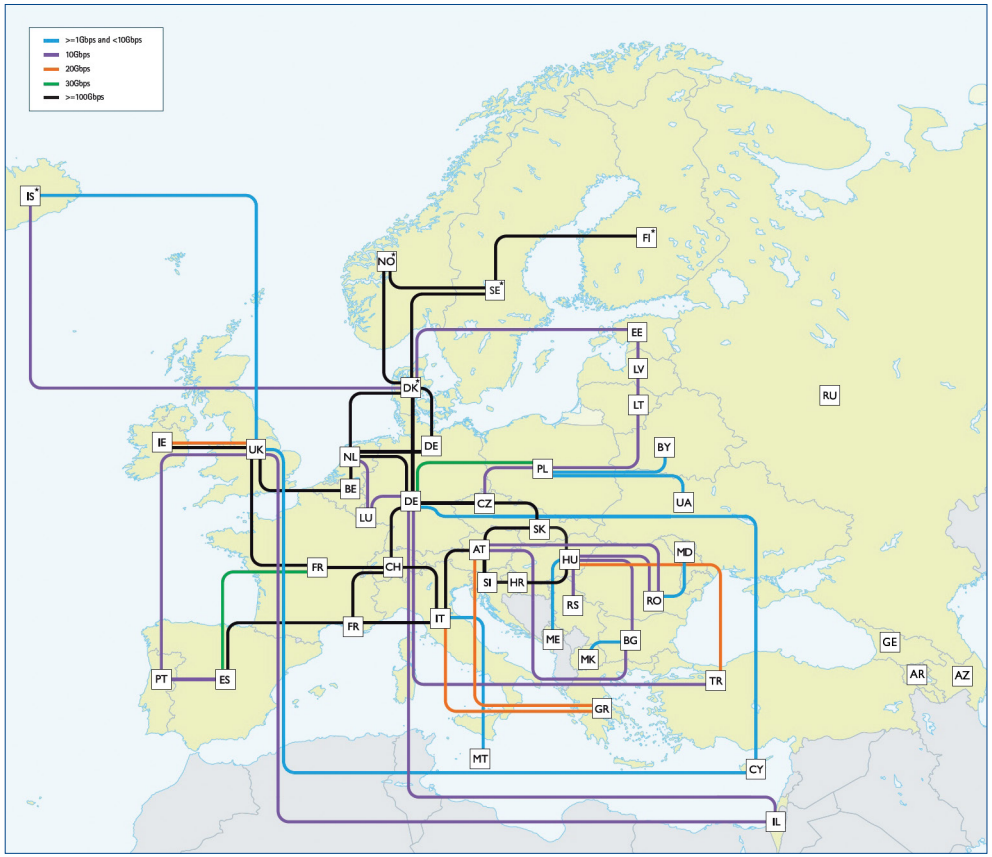
What is the GÉANT project?

The GÉANT network is the pan-European research and education network that interconnects Europe's National Research and Education Networks (NRENs). Together, these networks connect over 50 million users at 10 000 institutions across Europe, delivering a range of networking services for institutions, projects and researchers.

The GÉANT network, associated services and innovation programme comprise the GÉANT project (currently administratively known as GN3plus). Co-funded by the European Commission and Europe's NRENs, the GÉANT project lies at the heart of the EU's e-Infrastructure strategy. It seeks to promote the free, unimpeded movement of scientific data and knowledge, by connecting and empowering research and education communities within Europe and other world regions.

The GÉANT project is a collaboration between 39 partners: 37 European NRENs, the GÉANT Association's Cambridge office (formerly DANTE) and Amsterdam office (formerly TERENA), NORDUnet (representing the 5 Nordic countries). Open calls allow participation by more partners. The project is managed and run by the GÉANT Association on behalf of the partners.

GÉANT backbone topology as at January 2014.



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The GÉANT Association is solely responsible for this publication, which does not represent the opinion of the European Union, nor is the European Union responsible for any use that may be made of the data appearing herein.

CONTENTS

INTRODUCTION

In the more than ten years since its inception, the *Compendium* has grown into a much sought-after and authoritative reference source for researchers and organisations that are interested in the development of research and education networking. With each successive edition, the information included in the *Compendium* has become increasingly varied and dependable, although, as always, the data should be interpreted with the necessary caution. This year's edition of the *Compendium* – the fourteenth in the series – is produced by the GÉANT Association, which resulted from DANTE and TERENA joining forces in October 2014.[1]

As in previous years, this edition of the *Compendium* is part of the GÉANT (GN3plus) project. It has been enhanced with input from activity leaders working within the scope of that project. Most of the tables and graphs included below present information compiled from input provided by all GÉANT partner NRENs. As in previous years, we have examined and attempted to explain multi-year (i.e. 'longitudinal') trends. Each section of the *Compendium* starts with an overview, which summarises and analyses the most important information presented in that section. The section on **key findings**, which follows this introduction, provides a more general analysis of recent developments in research and education networking.

This year, for the second time, the *Compendium* survey was based on a Common NREN Information Model, which was developed in a joint effort by a worldwide team of experts: Markus Buchhorn (APAN), Salem Alagtash (ASREN), Thomas Tam (Canarie), Helmut Sverenyák (CESNET), Marcela Larenas and Florencio Utreras (RedCLARA), Claudio Allocchio (GARR), Mirjam Kühne (RIPE NCC), Thomas Lenggenhager (SWITCH), Katrina Sataki (SigmaNet), Tiwonge Banda (UbuntuNet) and Omo Oaiya (WACREN).

The GÉANT Association hopes that it will be possible to continue this global collaboration in future years and that this effort will lead to other regional publications of this type and even to a joint global compendium publication.

Non-European NRENs – except those in Latin America – were invited to submit their data for inclusion in this edition of the *Compendium*. Information on Latin American NRENs is available on the RedCLARA website (**www.redclara.net**). Overall, this year's responses came from a total of 61 NRENs operating in the same number of countries (49 in Europe and the Mediterranean region; 12 in other parts of the world). All the NRENs were asked to double-check their responses and ensure that the information was up to date.

Collecting such data requires contributions from, and careful checking by, several staff members of each NREN. The GÉANT Association would like to thank all those in the NREN community who gathered, submitted, clarified and checked the data included in this publication. Where possible, we have also included data from other sources, such as that on GÉANT traffic, eduroam and the TERENA Certificate Service.

In general, this edition of the *Compendium* looks back five years, comparing 2014/2013 with 2010/2009. The *Compendium* consists of two parts: the entire body of information submitted by the individual NRENs (published online at **compendium.terena.org**) and this printed publication. Over the past year, a new interface has been developed, allowing better comparison of data from several years and more on-line reporting options than was previously possible. A number of tables and maps that, in earlier editions, were available in printed format have been moved to the online publication and are now only available there.

Most of the tables and graphs included below first list all responses from the GÉANT partner NRENs and then those from other countries. In most cases, the data are presented in alphabetical order, sorted on the English name of each country. All the European NRENs included in this *Compendium* are listed in **Section 1.1**. The respondent NRENs in all other regions of the world (except Latin America) are listed in **Section 1.2**. In several tables, the responses received from the NRENs are edited and abridged. The full responses are always available online at **compendium.terena.org.**

[1] See inside cover for further information.

Please note that, unless otherwise specified, all data indicate the situation on or around 31 January 2014.

We hope that this fourteenth edition of the *Compendium* will prove to be at least as valuable as the previous ones. You are warmly invited to give feedback, which is the key to the *Compendium's* future development!

Bert van Pinxteren, GÉANT Association.

KEY FINDINGS: A BRIEF OVERVIEW

'Connected Communities'

Through the GÉANT network, more than 100 countries around the world are now interconnected with high-speed links, which are dedicated to research and education. 'Connected Communities' is the theme chosen for the 2015 TNC[1]. It reflects not only the opportunities that are now open to National Research and Education Networks (NRENs) but also the challenges that are in sight.

As in 2013, this 2014 edition of the *Compendium* is the product of a global collaboration effort that has led to an NREN Common Information Model, which is now being used by regional NREN associations around the world. Policymakers, funders, NRENs and their users all need to know where the opportunities and challenges lie and what the trends are. The *Compendium* seeks to meet this need by documenting the work currently being done by NRENs, examining the different contexts in which they operate and explaining important trends in research and education networking that concern them.

The primary focus of all NRENs is to connect universities and research institutes. However, many NRENs go beyond this by also connecting institutes of further education, as well as libraries and museums. Such connections are generally of very high quality: for universities[2] within the GÉANT region, the typical connection capacity is now above 1 Gb/s — a tremendous increase compared with the situation a few years ago. All other categories of users have significantly lower capacities. Based on the data provided by NRENs themselves and our own conservative assumptions, we estimate that the NRENs in the GÉANT region provide services to approximately 82% of all university-level students in the countries involved; that is, a total of 24 million students.

NRENs offer national backbones and international connectivity of exceptional quality. In most GÉANT partner countries, the typical core capacity is now 10 Gb/s, though some NRENs have reached 100 Gb/s. Germany is planning to upgrade to Terabit capacity. Some NRENs deploy several paths in their backbone, effectively increasing the capacity even further. For the first time since the

[1] The TNC (formerly: TERENA Networking Conference) is the largest annual European research networking conference.
[2] See Appendix 2 for a definition of the term 'university'.

inception of the *Compendium*, NRENs have reported that users are experiencing no congestion at the backbone level.

Connections to the GÉANT backbone are the largest category for GÉANT NRENs. Connections to GÉANT, to commercial providers, to neighbouring countries via cross-border fibre and to Internet exchanges together account for 85% of these NRENs' external capacity.

Within Europe there are still substantial differences: NREN traffic per inhabitant in Armenia, Azerbaijan, Belarus, Bulgaria, Cyprus, Latvia, Macedonia, Moldova, Montenegro and Ukraine remains below 15% of the European average level.

In the past few years, traffic growth seems to have slowed down. However, we believe this is because, increasingly, traffic from very large users is now routed via separate lambda or other point-to-point connections, over which traffic is not measured.

Twenty-one GÉANT partner NRENs now provide dedicated wavelengths (lambdas) to their customers. Per NREN, the number of static point-to-point fixed-bandwidth connections provisioned in January 2014 varies between three and 511 (HEAnet of Ireland). Within GÉANT, nearly 1300 wavelength circuits are now in use (up from 875 in the year 2012 and 1200 in 2013). Five NRENs are currently using dynamic lambdas, which can be set up and taken down by the NREN or its clients for short-term requirements.

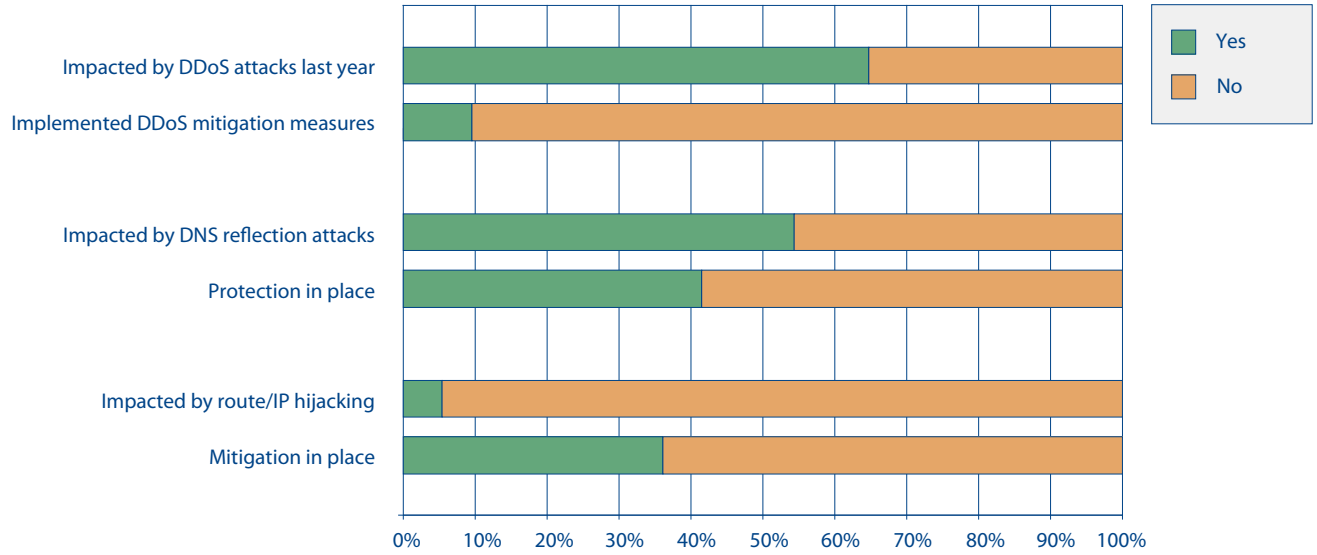
Growth in services

Authentication and Authorisation Infrastructures (AAIs) are key to giving users access to services independently of the physical location of both user and service. All but four of the 42 GÉANT NRENs currently offer, or are planning to offer, an AAI service. This has enabled the introduction of new services and the development of collaborative platforms that were previously impossible.

As service access is becoming increasingly independent of the physical location of the user and/or the service, the need for trust – that is, **security services** – is growing.

This edition of the *Compendium* shows that NRENs are aware of possible security risks; indeed, over the past year some of them have been impacted by various types of attacks. Clearly, more can still be done to put mitigation or protection measures in place.

Security risks, GÉANT NRENs



Most of the GÉANT partner NRENs (and a few non-GÉANT NRENs) have joined or are planning to join the **eduGAIN interfederation service** — a development that holds the promise of worldwide service access across federations.

Over the past year, **eduroam** has shown remarkable growth. It is now available not only in all GÉANT countries but also in a growing number of other countries and territories. The number of locations with eduroam availability grew by 25% and the number of authentications more than tripled between January 2013 and January 2014; by September 2014, it was approaching 150 million authentications per month.

Cloud services not procured via a commercial vendor are currently offered by 17 of the GÉANT partner NRENs, and 12 others are planning to offer such services. Eighteen of the GÉANT partner NRENs currently provide an e-learning service, and five others are planning work in this area.

NRENs function as centres of excellence, in service of their clients. This year's *Compendium* survey has identified a number of services being provided by NRENs in the general category of 'brokerage'. This seems to be an area in which NRENs can achieve considerable savings for their customers and where there is potential for expansion. NRENs are also undertaking framework procurements for network and related equipment. Ten GÉANT partner NRENs currently offer some form of support for procurement processes. The majority (21) indicate that they would be interested in benefiting from framework agreements put in place by another purchasing body, for a wide palette of services.

Economic and organisational challenges

Indexed on 2009, the average NREN budget in the GÉANT region rose by 2%, even though average staff size increased by 31%. Although the costs of transmission capacity and equipment have decreased overall, new services have necessitated staff size increases.

Comparing 2014 budget data with those from previous editions of the *Compendium* reveals that, overall, NREN budgets decreased with respect to 2013. At the time of going to press, for some NRENs the budget situation is still unclear because final budget decisions are made in the course of the year. As reported in previous editions of the *Compendium*, the overall trend is that, each year, NRENs are able to deliver more bandwidth and more services for roughly the same amount of money as in the previous year.

Finally, although it is impossible to make general recommendations on NREN funding mechanisms, a model that in some way involves all the various stakeholders in an NREN would seem to provide the best guarantees for its continued success. In their respective fields, many NRENs are engaged in innovations, which are often steered by dedicated funding mechanisms. It is important for NRENs to use such funds to their advantage wherever they exist.

1 ORGANISATIONAL INFORMATION

The GÉANT *Compendium*, funded by the GÉANT project, is an authoritative reference on the development of research and education networking in Europe and beyond. Below, Section 1.1 presents information on the European National Research and Education Networks (NRENs) that responded to the questionnaire distributed in May 2014. Map 1.1.1 shows the European NRENs that responded and a selection of the services that they provide. Section 1.2 includes a comprehensive list of non-European NRENs, indicating which of them submitted responses to the questionnaire. Section 1.3 gives an overview of the legal status of the European NRENs and their relationship with government. Section 1.4 summarises recent major changes in NRENs, their services and/or their users. Section 1.5 overviews NREN environmental policies.

1.1 European NREN respondents

There are 54[1] countries in the main area covered by this 2014 edition of the *Compendium* (that is, Europe, as well as Mediterranean countries in the Middle East and North Africa). In three of those 54 countries (Libya, the Palestinian Territory and Syria) there is either no NREN or we have no knowledge of NREN work there. In two other countries (Albania and Lebanon) there are NREN initiatives but no operational NRENs. Replies or partial responses were received from 49 NRENs or NREN initiatives. In addition, full or partial responses were received from a further 12 NRENs in the same number of countries outside of Europe[2]. Map 1.1.1 and Tables 1.1.1 and 1.2.2 give an overview of the NRENs that submitted responses. Please note that in most of the tables and graphs included in this edition of the *Compendium*, NRENs are identified by abbreviations of their official English names.

Table 1.1.1, which lists the European and Mediterranean NRENs, is divided into two categories: GÉANT partner countries (42 in total) and other countries.

Legend for Table 1.1.1

	Responses received
	No responses received
	NREN planned but not operational
	No NREN or NREN status unknown

Table 1.1.1 - European and Mediterranean NRENs included in this *Compendium*
(GÉANT Association members are shown in **bold**)

Country	NREN	URL
GÉANT partner countries		
Armenia	**ASNET-AM**	www.asnet.am
Azerbaijan[3]	AzRENA	www..azrena.org
Austria	**ACOnet**	www.aco.net
Belgium	**Belnet**	www.belnet.be
Belarus	**BASNET**	www.basnet.by
Bulgaria	**BREN**	www.bren.bg
Croatia	**CARNet**	www.carnet.hr
Cyprus	**CYNET**	www.cynet.ac.cy
Czech Republic	**CESNET**	www.cesnet.cz, www.ces.net
Denmark	**DeIC**[4]	www.deic.dk
Estonia	**EENet**	www.eenet.ee
Finland	**Funet**	www.funet.fi (www.csc.fi/funet)
France	**RENATER**	www.renater.fr
Georgia	GRENA	www.grena.ge
Germany	**DFN**	www.dfn.de
Greece	**GRNET S.A.**	www.grnet.gr
Hungary	**NIIF/HUNGARNET**	www.niif.hu
Iceland	**RHnet**	www.rhnet.is
Ireland	**HEAnet**	www.heanet.ie
Israel	**IUCC**	www.iucc.ac.il
Italy	**GARR**	www.garr.it
Latvia	**SigmaNet**	www.sigmanet.lv
Lithuania	**LITNET**	www.litnet.lt
Luxembourg	**RESTENA**	www.restena.lu

[1] This number excludes Andorra, Kosovo, Liechtenstein, Monaco, San Marino and the Vatican City State, which are not included separately in this *Compendium*.

[2] Several more responses were received from non-European countries after the deadline for the start of our analysis had expired; these are available on the *Compendium* website: compendium.terena.org.

Map 1.1.1 - European NRENs and selected services

Table 1.1.1 - continued

Country	NREN	URL
GÉANT partner countries		
Macedonia, FYRo	**MARNet**	www.marnet.mk
Malta	**UoM/RicerkaNet**	www.um.edu.mt/itservices/about
Moldova	**RENAM**	www.renam.md
Montenegro	**MREN**	www.mren.ac.me
Netherlands	**SURFnet**	www.surfnet.nl
Norway	**UNINETT**	www.uninett.no
Poland	**PIONIER**	www.pionier.net.pl
Portugal	**FCCN**	www.fccn.pt
Romania	**RoEduNet**	www.roedu.net
Serbia	**AMRES**	www.amres.ac.rs
Slovakia	**SANET**	www.sanet.sk
Slovenia	**ARNES**	www.arnes.si
Spain	**RedIRIS**	www.rediris.es & www.red.es
Sweden	**SUNET**	www.sunet.se
Switzerland	**SWITCH**	www.switch.ch
Turkey	**ULAKBIM**	www.ulakbim.gov.tr
Ukraine	URAN	www.uran.ua
United Kingdom	**Janet**	www.ja.net
Other European and Mediterranean countries		
Albania	**ANA**	www.rash.al
Algeria	ARN	www.arn.dz
Azerbaijan	**AzScienceNet**	www.ict.az, www.azsciencenet.az/en
Bosnia/Herzegovina	SARNET[5]	jusarnet.net
Egypt	EUN	www.eun.eg
Jordan	JUNet	www.junet.edu.jo
Lebanon	CNRS	www.cnrs.edu.lb
Libya		
Morocco	MARWAN	www.marwan.ma

[3] In Azerbaijan, there are two NRENs: AzRENA, which is a partner in the GÉANT network, and AzScienceNet, which is not.

Table 1.1.1 - continued

Country	NREN	URL
Other European and Mediterranean countries		
Palestinian Territory		
Russian Federation	e-ARENA	www.e-arena.ru
Syria	HIAST	www.hiast.edu.sy
Tunisia	RNU	www.cck.rnu.tn/?lg=fr&idm=1&id=2
Ukraine	UARNet	www.uar.net/en

1.2 NRENs in other regions and continents

Table 1.2.1 lists sources of information on NRENs in other regions and continents.

Tables 1.2.1 - Information on non-European NRENs

Area	Organisation/project	URL
Arab states	ASREN	www.asrenorg.net
Eastern and Southern Africa	Ubuntunet Alliance	www.ubuntunet.net
West and Central Africa	WACREN	www.wacren.net
Asia/ Pacific	APAN	www.apan.net
Central Asia	CAREN	caren.dante.net
Latin America	CLARA	www.redclara.net
Caribbean	CKLN	www.ckln.org
Canada	CANARIE	www.canarie.ca
USA	Internet2	www.internet2.edu
	ESnet	www.es.net
	National Regional Networks consortium	www.thequilt.net

Several projects that aim to connect research communities around the globe to the GÉANT network are listed at **www.geant.net/Network/GlobalConnectivity**.

[4] The five Nordic NRENs (DeIC, Funet, RHnet, SUNET and UNINETT) are represented in the GÉANT Association through NORDUnet.
[5] SARNET is active only in the Republika Srpska entity of Bosnia/Herzegovina.

Map 1.2.1 - NRENs known to be operating in other countries

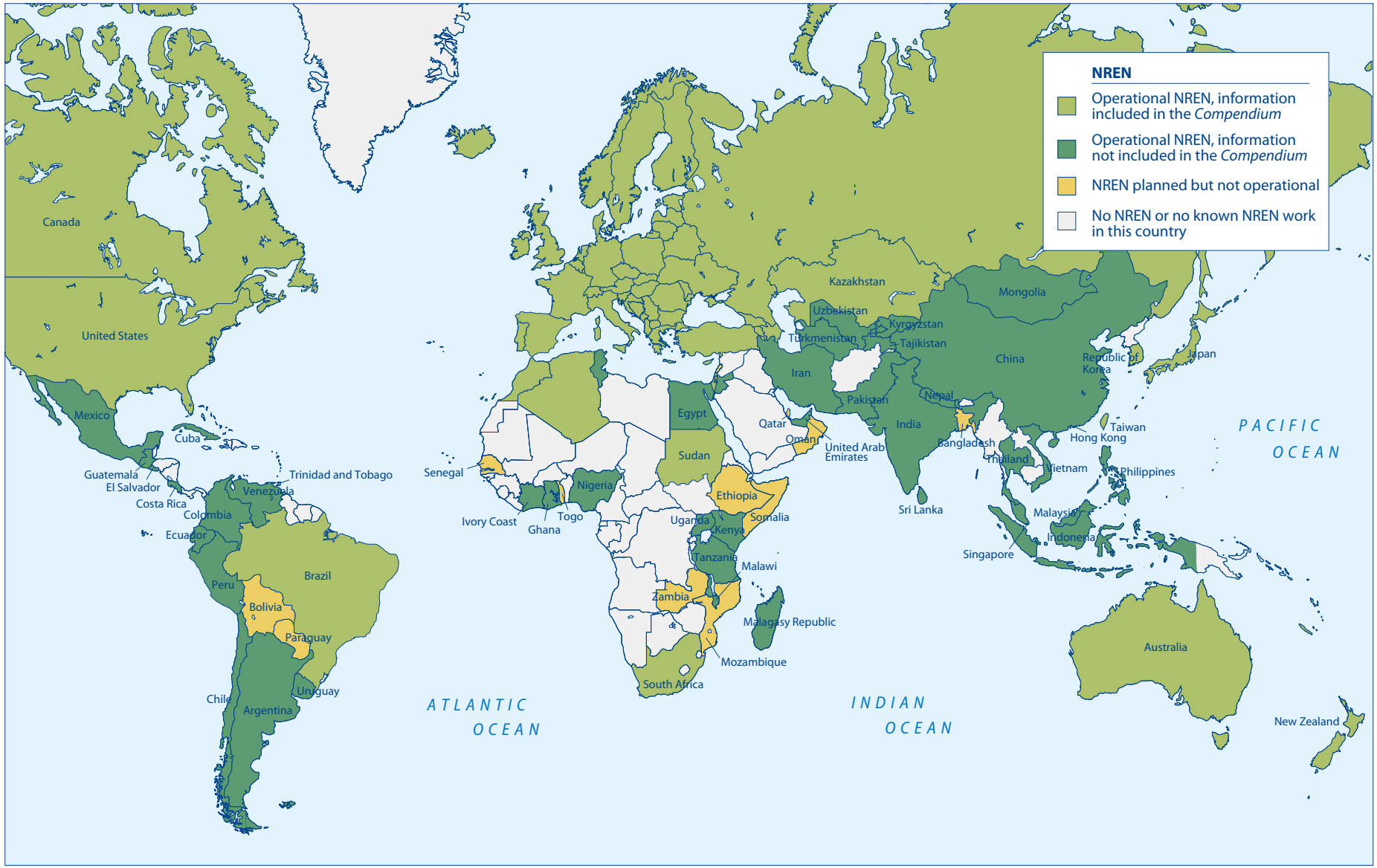


Table 1.2.2 lists those NRENs and NREN initiatives of which GÉANT is currently aware beyond the region covered by this *Compendium*. Note that this list is not comprehensive: there may be other NRENs of which we have no knowledge. Also, in some countries the situation may be subject to rapid change. Twelve NRENs from non-European countries submitted data for this *Compendium*; they are highlighted in green. Their full responses are available at **compendium.terena.org**

Further information on Latin American NRENs is published in the CLARA *Compendium* of Latin American National Research and Education Networks, available at **www.redclara.net/compendio**.

Legend for Table 1.2.2

	Operational NREN, information included in this *Compendium*
	Operational NREN, information not included in this *Compendium*
	NREN planned but not operational
	No NREN or NREN status unknown

Table 1.2.2 - NRENs known to be operating in other countries

Country	NREN	URL
Argentina	INNOVA|RED	www.innova-red.net
Australia	AARNet	www.aarnet.edu.au
Bangladesh	BdREN	www.bdren.net.bd
Bolivia	ADSIB	www.adsib.gob.bo
Brazil	RNP	www.rnp.br
Canada	CANARIE	www.canarie.ca
Chile	REUNA	www.reuna.cl
China	CERNET	www.edu.cn
China	CSTNet	www.cstnet.net.cn
China (Hong Kong)	HARNET	www.harnet.hk
Colombia	RENATA	www.renata.edu.co

Table 1.2.2 - continued

Country	NREN	URL
Costa Rica	CONARE	www.cenat.ac.cr/computacion-avanzada/red-conare
Cuba	RedUNIV	www.reduniv.mes.edu.cu
Ecuador	CEDIA	www.cedia.org.ec
El Salvador	RAICES	www.raices.org.sv
Ethiopia	EthERNet	
Ghana	GARNET	www.garnet.edu.gh
Guatemala	RAGIE	www.ragie.org.gt
India	ERNET	www.eis.ernet.in
Indonesia	INHERENT-DIKTI	www.inherent-dikti.net
Iran	IRANET/IPM	www.iranet.ir
Ivory Coast	RITER	www.riter.ci
Japan	SINET	www.sinet.ad.jp
Japan	NICT	www.jgn.nict.go.jp/english
Kazakhstan	KazRENA	www.kazrena.kz
Kenya	KENET	www.kenet.or.ke
Korea, Republic Of	KOREN	www.koren.kr
Korea, Republic Of	KREONET	www.kreonet.re.kr/en_main
Kyrgyzstan	KRENA-AKNET	www.krena.kg
Malagasy Republic	iRENALA	www.irenala.edu.mg
Malawi	MAREN	www.malico.mw/maren
Malaysia	MYREN	www.myren.net.my
Mexico	CUDI	www.cudi.edu.mx
Mongolia	ErdemNET	www.erdemnet.mn
Mozambique	MoRENet	
Nepal	NREN	www.nren.net.np
New Zealand	REANNZ	www.reannz.co.nz
Nigeria	ngREN	ngren.edu.ng
Oman	OmREN	www.trc.gov.om
Pakistan	PERN	www.pern.edu.pk

Table 1.2.2 - continued

Country	NREN	URL
Paraguay	Arandu	www.arandu.net.py/cms/index.php
Peru	RAAP	www.raap.org.pe
Philippines	PREGINET	www.pregi.net
Qatar	Qatar Foundation	www.qf.qa
Senegal	SnRER	snrer.edu.sn
Singapore	SingAREN	www.singaren.net.sg
Somalia	Somaliren	www.somaliren.org
South Africa	SANReN	www.sanren.ac.za
Sri Lanka	LEARN	www.learn.ac.lk
Sudan	SudREN	www.suin.edu.sd
Taiwan	TWAREN	www.nchc.org.tw/en
Tajikistan	TARENA	www.tarena.tj
Tanzania	TERNET	www.ternet.or.tz
Thailand	ThaiREN	www.thairen.net.th
Thailand	UniNet	www.uni.net.th/UniNet/Eng/index_eng.php
Togo	RNERT	www.togorer.tg
Trinidad and Tobago	TTRENT	www.ttrent.edu.tt
Turkmenistan	TuRENA	www.science.gov.tm/en/turena
Uganda	RENU	www.renu.ac.ug
United Arab Emirates	ANKABUT	www.ankabut.ae
United States	Internet2	www.internet2.edu
Uruguay	RAU	www.rau.edu.uy
Uzbekistan	UzSciNet	www.uzsci.net
Venezuela	REACCIUN	www3.reacciun.ve
Vietnam	NASATI	www.vista.gov.vn
Zambia	ZAMREN	www.zamren.zm

1.3 Legal form of NRENs

NRENs have various legal forms. NREN names and their English translations may be misleading: what is called a 'foundation' in one country may be quite different from a foundation in another country. The same is true of several other designations, including 'association'. This section distinguishes two parameters which, together, help to characterise the legal form of an NREN:

1) Its relationship with government; and
2) Whether it is a separate legal entity.

In some countries, there is a distinction between the name of the physical network (e.g. PIONIER in Poland or Funet in Finland) and the name of the organisation that runs it. Thus, Funet is run by an operational unit within CSC, an organisation that performs several other functions within Finland, such as high-performance computing. Although the two parameters cited above can usefully characterise the legal form of an NREN, the classification is not always straightforward.

Relationship with government

In this *Compendium*, we distinguish three situations:

a) A NREN that is under direct government control. Such is the case if an NREN is a government agency or parastatal, or a part thereof.
b) A NREN operating independently of government to a certain extent; for example, those that are separate legal entities with governing boards at least half of whose members are government-appointed. Also, some NRENs that are government agencies enjoy a certain degree of autonomy comparable to that of NRENs that are separate legal entities.
c) A NREN having no direct government ties, even though, typically, the majority of their client institutions are largely government-funded.

Separate legal entity

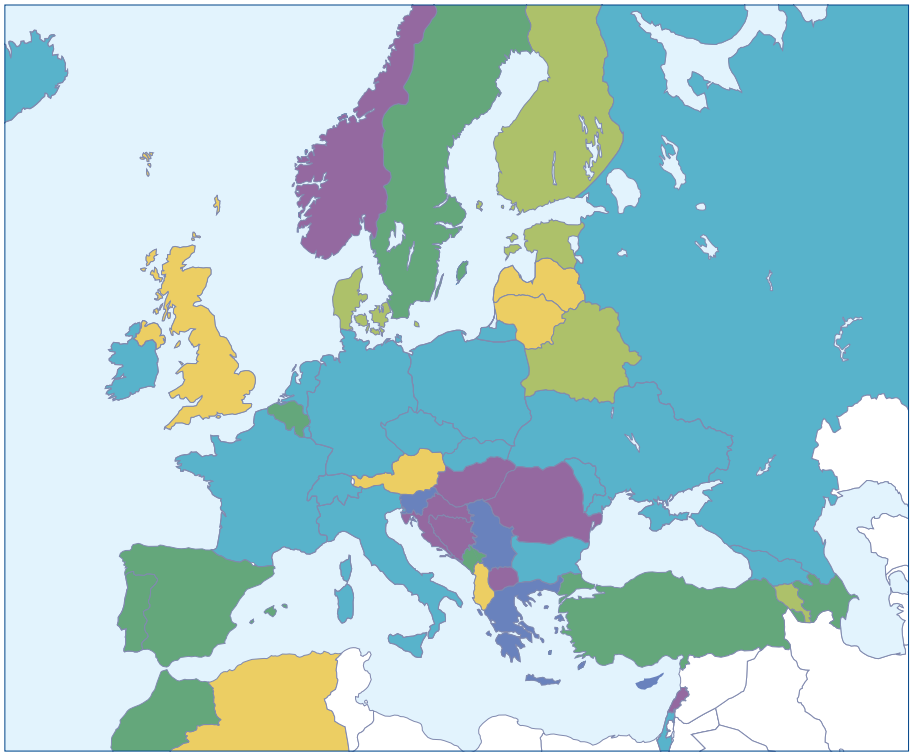
Many NRENs operate as separate legal entities.

A combination of the two parameters leads to six categories, as shown in Map 1.3.1:

Legend for Table 1.3.1

Legal entity? / Level of government control	Separate legal entity	Not separate legal entity
Not under direct government control		
Largely government-controlled		
Entirely government-controlled		

Map 1.3.1 - Legal form of NRENs



In Portugal, FCCN has recently merged with FCT, bringing it under closer government control.

It seems self-evident that for an NREN to develop, the commitment of all its major stakeholders – including funders and users – is required. A governing model that allows all such stakeholders to participate would seem to be the most appropriate; such a situation can be achieved in various ways.

NRENs that can operate with a certain degree of independence from their respective governments may have distinct advantages, such as easier decision-making processes and the ability to recruit and retain suitably qualified staff, partly by setting salaries at competitive levels. This may partially explain why this model is more common in countries where, after many years of development, research and education networking is well-established.

1.4 Major changes in NRENs

All the NRENs covered by this 2014 edition of the *Compendium* were requested to briefly describe any major changes in their mandate or remit, user-base, or technology and services that occurred in the past year or were expected to occur in the coming year. The full responses are available at **compendium.terena.org/reports/major_changes**.

Several NRENs report that they have further upgraded and extended their networks. Several also mention the development of cloud storage and other services. CARNet of Croatia reports a great expansion of its services to the secondary education sector. In Hungary and Ireland, secondary schools were integrated into the NREN network.

1.5 NREN environmental policies

Environmental issues started to feature on NREN agendas a few years ago. NRENs and their users began to realise that it is important to address such issues, for example by measuring and reducing energy consumption, and by promoting green uses of network technology in order to reduce greenhouse gas (GHG) emissions. Various NRENs have made progress on environmental issues.

As part of the GN3plus project, five NRENs (AMRES, GRNET, HEAnet, NIIF/HUNGARNET and SURFnet) have audited their GHG emissions. The full report is available at: **www.geant.net/Resources/Media_Library/Documents/D3-3_DN3-3-1_Environmental-Impact-Report-2014.pdf**.

This report shows that although the quantity of emissions differs considerably from country to country, the overall trend seems to be upward. One explanation for the differences is that GRNET of Greece has a large data centre which has expanded over the years, whereas the other NRENs do not. In the case of SURFnet of the Netherlands, differences can be explained by changes in the underlying measurement methods, which are still under development. In the cases of Ireland and Hungary, savings in some areas were more than offset by expanded networks and activities in other areas, such as storage and computing. The GÉANT project team aims to develop metrics that are independent of such developments, such as energy/bit.

Eight GÉANT NRENs (Belgium, Greece, Hungary, Ireland, Netherlands, Portugal, UK and Ukraine) report that they have an environmental policy in place, whereas only four did in 2012. Now that the GÉANT project has developed a template for such policies[7], a further increase is expected. The Irish and UK policies are available at the respective NREN websites:
www.heanet.ie/about/environmental_policy
www.ja.net/about-janet/environmental-policy

[7] Available at www.geant.net/Network/Environmental-Impact/Pages/Policy.aspx

2 CLIENT INSTITUTIONS

Section 2.2 indicates the 'market shares'; that is, how many institutions in various categories are actually connected to the NREN; Section 2.3 estimates the numbers of connected users that correspond to these market shares; an expanded Section 2.4 documents typical bandwidths; Section 2.5 focuses on dark fibre connections to client institutions. Finally, Section 2.6 examines connectivity to for-profit organisations and international (virtual) research organisations.

2.1 Overview

As indicated in previous editions of the *Compendium*, all the NRENs covered by this publication are allowed to connect universities and research institutes. Nearly all may also connect institutes of further education, as well as libraries and museums. Information on connection policies is not repeated in this year's edition: even though NRENs differ greatly in this respect, there have been no significant changes in the past year.

Even if an NREN is allowed to connect a certain institution, it does not necessarily do so. In the university sector, NRENs obviously have very high market shares. Based on data provided by NRENs themselves and our own conservative assumptions, we estimate that the NRENs in the GÉANT region provide services to approximately 82% of all university-level students in the countries involved; that is, a total of 24 million students.

For universities[1] within the GÉANT region, the typical connection capacity is now above 1 Gb/s — a tremendous increase compared with the situation a few years ago. All other categories of users have significantly lower capacities. As documented in Section 2.4, differences in bandwidth exist not only between but also within countries.

Only a handful of NRENs connect for-profit organisations and/or international (virtual) research organisations. In such cases, the number of organisations connected is very limited; in most cases these connections are made specifically to access services provided by the research and education sector.

2.2 Approximate market shares

Table 2.2.1 gives an overview of the number of institutions in each user-category and indicates the percentage of users that are serviced by each NREN. Note that *Compendium* respondents submitted only approximate percentages.

Many NRENs operating in a strong hierarchy of Metropolitan or Regional Area Networks (MAN/RAN) were unable to provide connection figures but did indicate that they service high percentages of their respective communities. For additional information on individual NRENs, see the *Compendium* website: **compendium.terena.org**.

For this year's edition of the *Compendium*, we asked NRENs to use the new (2011) ISCED classification[2] of educational institutions. More clearly than the previous scheme, this new classification differentiates tertiary institutions offering courses below Bachelor level from those offering Bachelor- and higher-level courses (that is, at ISCED levels 6, 7 and 8). We asked NRENs to provide combined data for all tertiary education institutions in the latter category. In some countries, including Ireland, only institutions offering education up to level 8 (the doctoral level) are considered to be true universities. In the Netherlands, for example, a distinction is made between universities of applied sciences and other universities. Unfortunately, because of this new ISCED classification, for universities and other institutions at ISCED levels 6, 7 and 8 the figures for 2014 are not directly comparable with those for previous years. In France, a number of secondary and primary schools are connected, but indirectly and therefore the numbers connected are not known. Similar situations may exist in other countries as well.

[1] See Appendix 2 for a definition of the term 'university'.

[2] www.uis.unesco.org/Education/Pages/international-standard-classification-of-education.aspx

In the past, almost all NRENs responded that they connected all or nearly all the universities in their country. However, since 2013, several NRENs have reported for the first time that they connect a significantly lower percentage of the universities in their country. Apparently, this is not because the number of connected universities has decreased but because newer institutions providing education at ISCED level 6 in these countries are not connected to the Internet via the NREN.

Legend for Table 2.2.1

Legend	NREN-connected institutions
	> 80%
	60 - 80%
	40 - 60%
	20 - 40%
	< 20%
	Unknown or not applicable
	No answer provided

Table 2.2.1 – Approximate market shares

Country	Universities	Institutes of further education	Research institutes	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
GÉANT partner countries								
Armenia	3		35			4		2
Austria	48		27			12	5	23
Belarus	10		59			17	5	8
Belgium	63	5	37	5	0	15	20	48
Bulgaria	22		42					
Croatia	318	20	62	424	1670	70	36	134
Cyprus	8	3	4					
Czech Republic	35	23	32	77	12	40	43	34
Denmark	8	7	22	0	0	5	0	0
Estonia	22	14	20	43	8	58	0	9
Finland	48		10			7		8
France	409	340	377			19	7	19
Georgia	9	19	4	3		3	1	3
Germany								
Greece	40		15					
Hungary	25	28	73	1580	3050	560	5	4
Iceland	7	2	8	1				1
Ireland	27	10	12	800	3200	0	0	13

Table 2.2.1 – continued

Country	Universities	Institutes of further education	Research institutes	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
GÉANT partner countries								
Israel	12	0	4	0	0	1	0	0
Italy	99	0	329	104	19	39	56	3
Latvia	11	2	8	3	0	3	0	0
Lithuania	42	53	32	540	37	29	4	31
Luxembourg	7	0	21	61	226	14	0	15
Macedonia	1	1	1	0	0	0	0	0
Malta	1		3					
Moldova	7	2	36	1	0	10	10	1
Montenegro	19	1	2			2		1
Netherlands	46	32	33			20	4	
Norway	37	20	74	2	4	17	0	0
Poland	199	20	199	244		64	47	157
Portugal	48	0	11	0	0	1	0	9
Romania	50	10	56	350	140	40		30
Serbia	87	9	43	13	5	21	6	2
Slovakia								
Slovenia	4	17	53	154	546	212	0	24
Spain	93	6	199			48	57	32
Sweden								
Switzerland	44	2	11	2	0	1	0	6
Turkey	162		16			1		13
UK	167	428	36			8		6
Ukraine	80	10	7					3
Other countries								
Albania								
Algeria	58	36	15			0		6
Australia	58	16	28	61	80	8	6	8

Table 2.2.1 – continued

Country	Universities	Institutes of further education	Research institutes	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
Other countries								
Brazil	826	3	167	11		154	53	77
Canada	190				2000	24	62	127
Japan								
Kazakhstan								
Korea	51	0	70	1	0	70	0	16
Lebanon	0	0	5	0	0	0	0	0
Morocco	94	9	5			0	0	2
Russian Federation	250		140					
South Africa	25	5	26		0	2	0	0
Taiwan	90	5	5	1000	1000	5	1	5
USA								

2.3 Numbers of users

In the questionnaire for this edition of the *Compendium*, NRENs were asked to estimate the numbers of university students they serve. This information has been combined with enrolment figures derived from UNESCO statistics[3] to produce Graphs 2.3.1 and 2.3.2, showing estimated numbers of university students served by GÉANT NRENs. Note that, in those cases where NRENs were unable to give such an estimate, we have made conservative assumptions. For example, PIONEER in Poland is structured as a network connecting the country's regional networks, which, in turn, connect all or nearly all of the Polish universities. We have therefore assumed that 90% of students in Poland benefit from PIONEER's services.

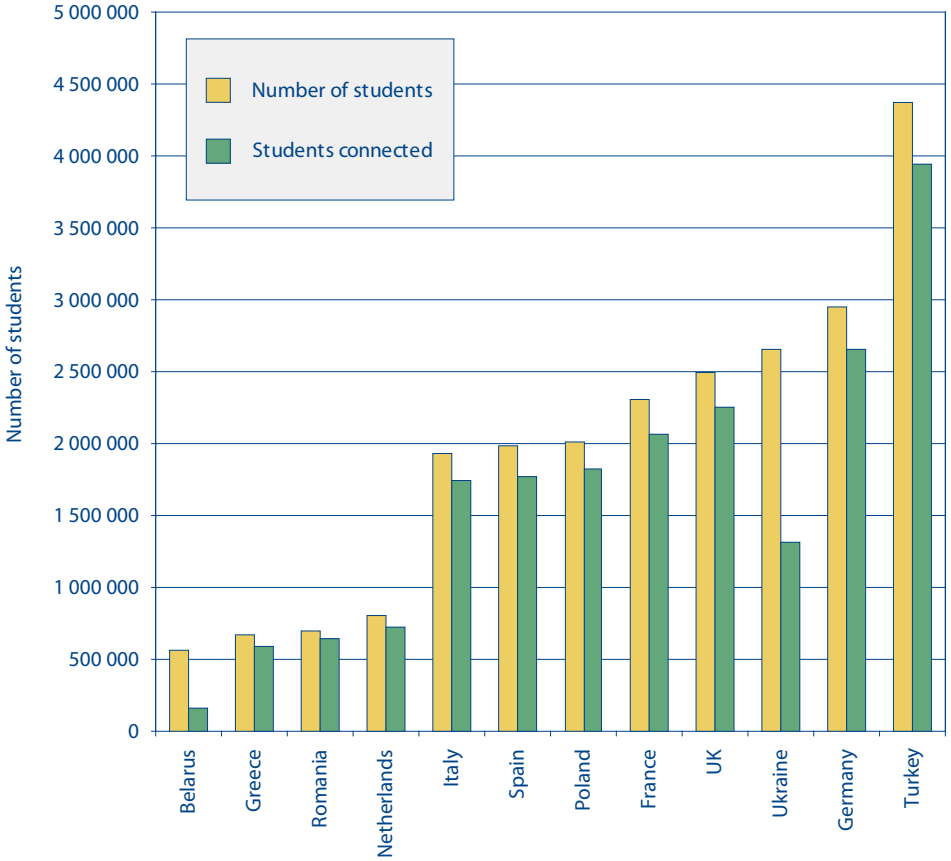
Based on the data received and the assumptions explained above, we estimate that NRENs in the GÉANT region (except Azerbaijan) provide services to approximately 82% of all university-level students in those 41 countries; that is, a total of 24 million students[4].

The data above also suggest that (as was the case in 2013) approximately five million students in the GÉANT region are not serviced by an NREN, the largest numbers being in the Ukraine and Belarus.

Of course, not only whether a student receives NREN services but also the quality of service provided must be taken into account for an accurate impression of the present situation. Map 2.4.3, which indicates the spread of bandwidth between the universities within each country, shows that for a number of countries the typical university connection capacity is less than 1 Gb/s.

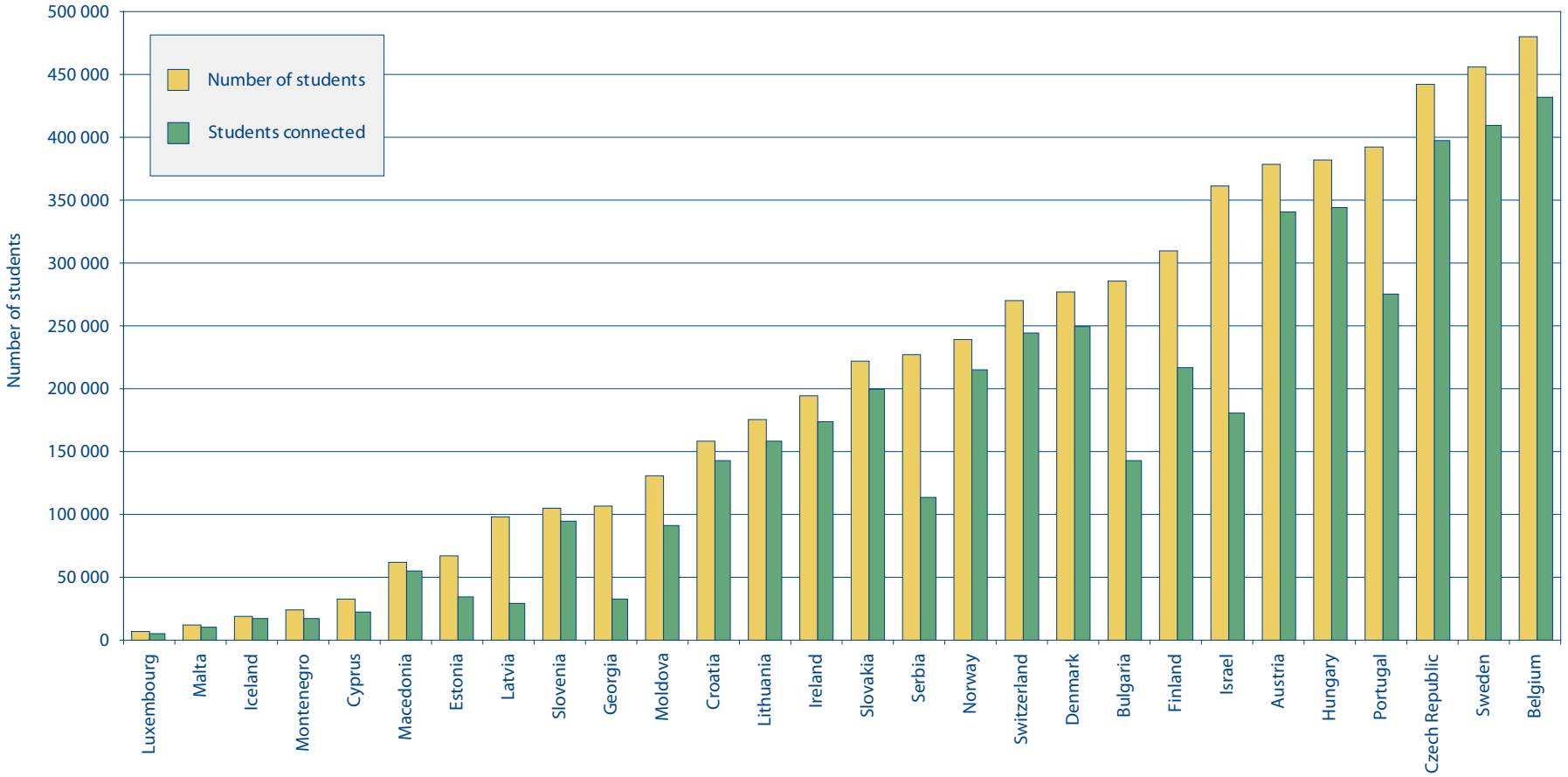
Section 4.4 provides another indicator, showing much higher traffic per inhabitant for the UK than for Turkey, for example.

Graph 2.3.1 – Number of students serviced by an NREN, GÉANT region, for countries with > 500 000 students



[3] In a few cases, Eurostat data were used.
[4] In 2012, the GÉANT region was smaller: 36 countries, whose market share was approximately 88%, a total of around 20.5 million students.

Graph 2.3.2 – Number of students serviced by an NREN, GÉANT region, for countries with < 500 000 students



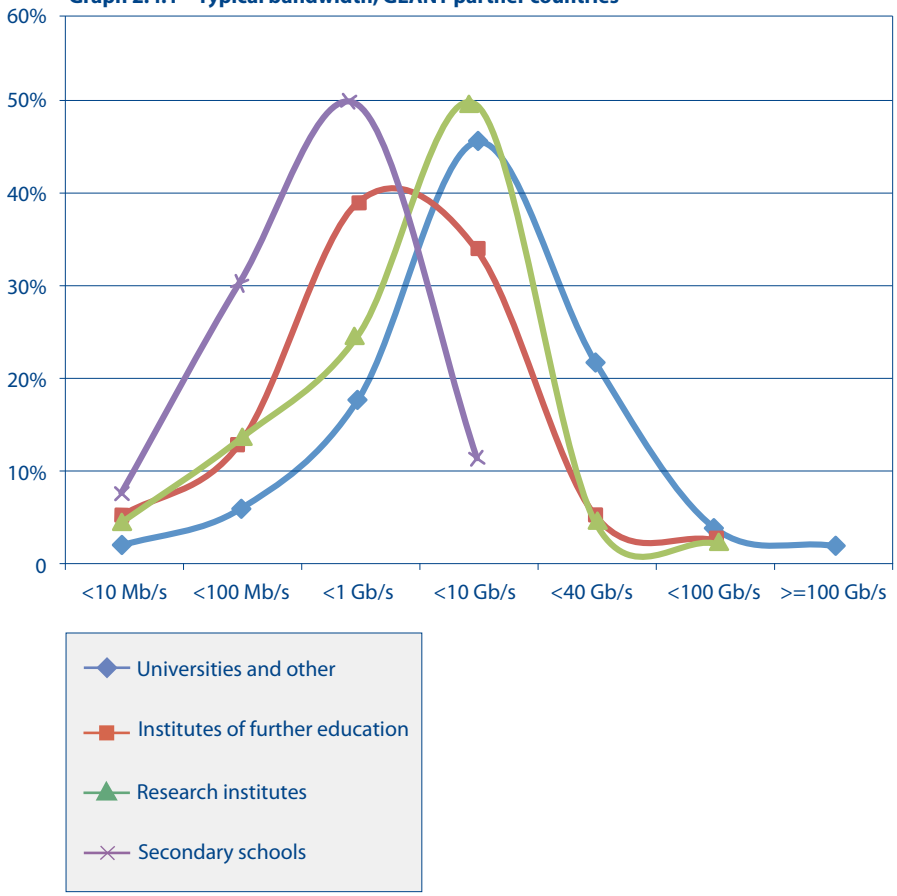
2.4 Bandwidths

The 2008 edition of the *Compendium* stated that:

> *In 2003, the 'average' university was connected at Megabit capacity; by 2008, that had changed to Gigabit capacity.*

The typical capacity for universities in GÉANT partner countries now exceeds 1 Gb/s. All other user-categories have lower capacities, although research institutions are generally close to 1 Gb/s.

Graph 2.4.1 – Typical bandwidth, GÉANT partner countries



Graph 2.4.1 gives an overview of the spread of bandwidths available to NREN users. Note that not all NRENs provided information relevant to this overview, so the set of countries is not exactly the same in each user-category.
Table 2.4.2 shows the information received from non-GÉANT countries.

Table 2.4.2 - Typical bandwidth, non-GÉANT countries

Legend	
	<40 Gb/s
	<10 Gb/s
	<1 Gb/s
	<100 Mb/s
	<10 Mb/s

A	Universities and other
B	Institutes of further education
C	Research institutes
D	Secondary schools
E	Primary schools
F	Libraries, museums, archives, cultural institutions
G	Hospitals (other than university hospitals)
H	Government departments (national, regional, local)

Country	A	B	C	D	E	F	G	H
Albania								
Algeria								
Australia								
Brazil								
Canada								
Hong Kong								
Japan								
Kazakhstan								
Korea								
Kyrgyzstan								
Lebanon								
Morocco								
New Zealand								
Russian Federation								
South Africa								
Taiwan								

We have also considered the spread within individual countries. It should be noted that in some countries all or most institutions in a particular category are connected at similar capacities, whereas in other countries there may be large capacity differences at national level.

To give an impression of the spread of bandwidths among universities within individual countries, we have categorised NRENs according to the spread between the lowest and highest connection categories, using the seven categories indicated in Table 2.4.2. Those countries with no more than one category difference between lowest and highest have been designated as being 'even', those with two or three categories difference as having 'moderate spread', and those with a larger difference as being 'differentiated'. Each category is subdivided into those countries with a typical university capacity of less than 1 Gb/s and those with a typical capacity of 1 Gb/s or more.

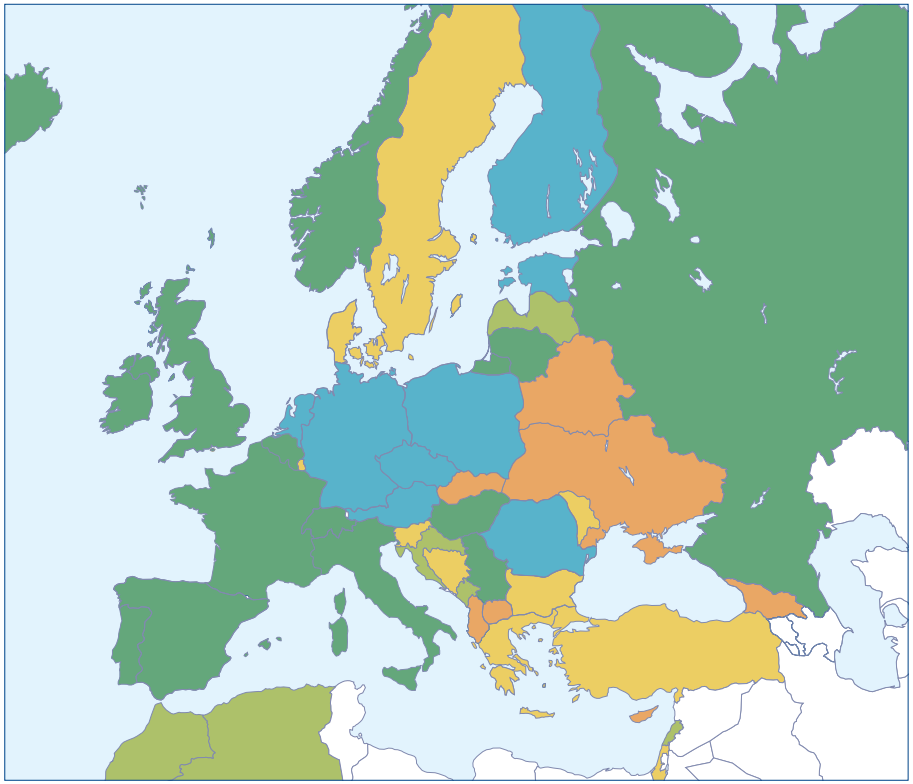
The result is shown in Map 2.4.3. The NRENs with the lowest-capacity connections are Albania, Belarus, Georgia, Macedonia and Ukraine.

We have examined the technological aspect in greater detail by asking NRENs what connectivity services they provide to their client institutions that are connected with dark fibre. The replies are summarised online at **compendium.terena.org/reports/non_ip_connectivity**. With a dark fibre infrastructure, NRENs can offer virtual private networks (VPNs) as a service, often marketed as LAN extensions. In this way, a single university campus and its LAN can extend across multiple separate sites, which can bring significant savings in service and support costs for university IT departments.

Legend for Map 2.4.3

	Even (typical bandwidth < 1 Gb/s)
	Even (typical bandwidth) ≥1 Gb/s)
	Moderate spread (typical bandwidth < 1 Gb/s)
	Moderate spread (typical bandwidth ≥ 1 Gb/s)
	Differentiated (typical bandwidth ≥ 1 Gb/s)

Map 2.4.3 – Spread of bandwidth among universities within countries



2.5 For-profit organisations and international (virtual) research organisations

We asked the NRENs whether they connect commercial, for-profit organisations. Several do so, though in most cases this is specifically to access services provided by the research and education sector. In all cases, the reported number is quite limited, the highest being 31 (for Croatia).

We also asked NRENs whether they connect international (virtual) research organisations. In contrast to 2013, many NRENs reported that they do this, though the numbers of connected organisations are no higher than five (for the UK). Note that all NRENs have an Acceptable Use Policy, to which all their clients must adhere.

Table 2.5.1 – Connections to for-profit and to international research organisations

Country	Connects for-profit organisations?	Connects international (virtual) research organisations?	Activity related to virtual research communities?	Brief description:
GÉANT partner countries				
Armenia	No	Yes	Yes	ATLAS, ALICE, ENVIROGRIDS
Belarus	No	Yes	Yes	
Belgium	No	Yes	Yes	* Flemish Supercomputer Center (www.vscentrum.be): supercomputers of five universities are interconnected/clustered over our backbone via 10 GE lightpaths for shared use by researchers (further information: https://vscentrum.be/nl/en). A similar initiative has started in the Walloon region (further information: http://www.ceci-hpc.be/)
Bulgaria	Specifically to access services provided by the research and education sector	Yes	No	
Croatia	Specifically for offering services to the research and education sector	Yes	No	
Cyprus	Specifically for offering services to the research and education sector	Yes	No	
Czech Republic	No	Yes	Yes	Auger observatory, EGI, ELIXIR, XiFi
Denmark	On the same basis as R&E organisations	Yes	Yes	Connection between CERN and Niels Bohr Institute, Copenhagen.
Finland	Specifically for offering services to the research and education sector	Yes	Yes	NeIC (http://neic.nordforsk.org/) operates the Nordic WLCG Tier-1 center; ELIXIR
France	On the same basis as R&E organisations	Yes	Yes	We collaborate with communities including LHC and PRACE to understand their needs and adapt the network infrastructure
Georgia	No	Yes	Yes	On Grid site several VOs are registered
Germany	Specifically for offering services to the research and education sector	Yes	Yes	We provide network services (IP, Lambda), security services (PKI, CA) and participate in testbeds

Table 2.5.1 – continued

Country	Connects for-profit organisations?	Connects international (virtual) research organisations?	Activity related to virtual research communities?	Brief description:
GÉANT partner countries				
Greece	No	Yes	Yes	GRNET participates in EGI.eu and coordinates the HP-SEE (http://www.hp-see.eu) project. It serves several Virtual Research Communities including Life Sciences, Biomed, Computational Chemistry and Computational Physics. GRNET will also participate as computational infrastructure provider in the Greek national CLARIN center (CLARIN-EL project)
Hungary	Under certain circumstances	Yes	Yes	Advanced videoconferencing facilities and service, extended basic investigations in VRE (Virtual Research Environments) and VRC (Virtual Research Communities), including eduCONF and WebRTC
Iceland	Specifically for offering services to the research and education sector	Yes	No	We host a Mantycore node
Ireland	Specifically for offering services to the research and education sector	Yes	Yes	[1] HEAnet client ICHEC is very active in the PRACE project: http://www.ichec.ie/research/prace_proto.php [2] HEAnet client Marine Institute is involved in the Smartbay project: http://www.marine.ie/home/research/ProjectsDatabase/CurrentProjects/SmartBay [3] HEAnet clients WIT and TSSG are involved in the Finessey and XiFi projects [4] Many Irish Researchers take part in FP7, ESFRI, PRACE, BBMRI, ECRIN, EUROBIOIMAGING, ISBE, DARIAH, ESS, SHARE, EMSO and EPOS projects using IP connectivity including: Tyndall, CTVR and Clarity
Israel	No	Yes	Yes	
Italy	Under certain circumstances	Yes	No	
Latvia	No	Yes	Yes	We participate in the National Grid Initiative and the European Grid Initiative
Lithuania	Specifically for offering services to the research and education sector	Yes	No	
Luxembourg	Specifically for offering services to the research and education sector	No	No	
Macedonia	No	Don't know	No	2 clusters are included in EGI-InSPIRE (http://www.egi.eu/about/egi-inspire/), HP-SEE (http://www.hp-see.eu/)
Malta	Specifically for offering services to the research and education sector	Yes	No	
Moldova	Under certain circumstances	Yes	Yes	We provide connectivity to support various VRCs that are using resources of the National Grid Infrastructure; we also provide access to VRCs that use regional SEE HPC infrastructure
Netherlands	Under certain circumstances	Yes	Yes	Community support, outreach programme, cloud services, middleware support, pilots
Norway	No	Yes	Yes	Connected to the worldwide LHC Computing Grid
Poland	Specifically for offering services to the research and education sector	Yes	Yes	For users including AstroGrid-PL, HEPGrid, QosCosGrid, LHCONE, VLBI
Portugal	Under certain circumstances	Yes	Yes	We manage the datacentre that houses the Portuguese Tier-2 node for CERN

Table 2.5.1 – continued

Country	Connects for-profit organisations?	Connects international (virtual) research organisations?	Activity related to virtual research communities?	Brief description:
GÉANT partner countries				
Romania	No	Yes	No	
Russian Federation	Under certain circumstances	Yes	Yes	LHC Computing GRID, IVOA
Serbia	No	Yes	No	
Slovakia	Specifically for offering services to the research and education sector	No	No	
Slovenia	No	Yes	Yes	Cluster supports Atlas VO, IPv6 testing, CVMFS testing
Spain	Specifically for offering services to the research and education sector	Yes	Yes	For-profit organisation connections only for R+D departments of companies participating in research projects and only for the duration of the project. Virtual research communities: LHC and DEISA. We are members of the Spanish Grid Initiative and participate in the EGI-InSPIRE project.
Sweden	Specifically for offering services to the research and education sector	Yes	Yes	DEISA, LHC
Switzerland	Specifically for offering services to the research and education sector	Yes	Yes	Member of the Swiss NGI
Turkey	No	Yes	Yes	Atlas, CMS, BIOMED, SEE, BELLEII, EUMED and 4 national VOs (TRGRIDA, TRGRIDB, TRGRIDD, TRGRIDE)
UK	Specifically for offering services to the research and education sector	Yes	No	
Ukraine	Specifically for offering services to the research and education sector	Yes	No	
Other countries				
Albania	Specifically for offering services to the research and education sector	No		
Algeria	No	Yes	Yes	We participate in EUMEDGRID infrastructure with EUMED VO use for some of our researchers
Australia	Specifically for offering services to the research and education sector	Yes	No	
Brazil	Under certain circumstances	Yes	No	
Canada	Specifically for offering services to the research and education sector	Yes	Yes	We provide connectivity to advanced computing consortia and fund development of middleware to serve VRCs
Japan	Specifically for offering services to the research and education sector	Yes	Yes	APAN
Kazakhstan	No	Yes	No	

Table 2.5.1 – continued

Country	Connects for-profit organisations?	Connects international (virtual) research organisations?	Activity related to virtual research communities?	Brief description:
GÉANT partner countries				
Korea	Specifically for offering services to the research and education sector	Yes	Yes	LHC Computing Grid, GLIF, GLORIAD, PRAGMA, CINEGRID, APAN
Kyrgyzstan	No	Yes	Yes	www.KyrgyzstanVSL.org
Lebanon	Specifically for offering services to the research and education sector	Yes	No	
Morocco	No	Yes	Yes	Morocco is a member of the ATLAS collaboration (LHC).
New Zealand	Specifically for offering services to the research and education sector	Yes	No	
South Africa	No	Yes	Yes	Via SAGRID we enable: biomed - life sciences, enmr.eu - structural biology, ATLAS collaboration production, ALICE collaboration production, GEANT4 collaboration, EELA - Latin America Catch-All VO, sagrid.ac.za - South African Catch-All VO, EUMED - North-African Catch-All VO
Taiwan	No	Yes	Yes	We have a direct lightpath connection to the iGENI platform and run OpenFlow collaboration on top of it.
USA	Yes	Yes		

3 NETWORK AND CONNECTIVITY SERVICES

This section provides insights into several important network characteristics. Section 3.2 presents information on core capacity on the routed network. Section 3.3 examines the capacity of NREN external connections. Section 3.4 documents recent developments in dark fibre, and Section 3.5 focuses on cross-border dark-fibre links. Section 3.6 examines network topologies. Section 3.7 includes an overview of expected major developments in research and education networking. Sections 3.8 and 3.9 look at Software-Defined Networking (SDN) and Network as a Service (NaaS), respectively.

3.1 Overview

In most GÉANT partner countries, the typical core capacity is now 10 Gb/s, though some NRENs have reached 100 Gb/s. Because many NRENs in the GÉANT region have access to dark fibre (see Section 3.4), which is potentially able to handle high capacities, they can increase capacity easily and economically whenever required. Some NRENs allow several paths in their backbone, effectively increasing the capacity even further.

In other OECD countries, the trend is similar. Australia and the USA, for example, have both introduced 100 Gb/s capacities.

In several cases, the NREN's network is structured as a mesh, having redundant core and access links. Thus, SURFnet indicates that its core capacity is 200 Gb/s, even though the capacity of the individual links is 100 Gb/s.

In general, connections not only to the European academic backbone network (i.e. GÉANT) but also to the general Internet are crucial to NRENs. Connections to the GÉANT backbone are the largest category for GÉANT NRENs. Connections to GÉANT, to commercial providers, to neighbouring countries via cross-border fibre and to Internet exchanges together account for 85% of these NRENs' external capacity

For the purposes of the *Compendium*, we have been monitoring the uptake of dark fibre by NRENs since 2005. At that time, only a few networks used dark fibre in their backbones, and GÉANT was just starting to use dark fibre and light it for transnational trunks.

This year (2014), the aggregate length of dark fibre used internally by NRENs in the GÉANT region exceeds 139 000 km, approximately the same as in 2013.

Within an NREN there are many ways to use dark fibre cost-effectively, all of which are focused on enhanced services to clients and users. NRENs, as a result of moving from managed network links to their own transmission infrastructure, have been able to develop new features and services at various levels.

Another continuing development is the implementation of cross-border dark-fibre links between NRENs. Section 3.5 presents information on new links implemented since January 2013.

In the past, the logical and physical structures of a network were roughly the same. This is no longer always the case, for it has become possible to define logical routes in a network independently of the physical routes. This presents advantages including lower latency and the possibility of creating logical links of greater capacity than that of the largest individual link. Section 3.6 gives an example of this.

Six GÉANT partner NRENs currently have a testbed for Software-Defined Networking (SDN). This enables the creation of virtual networks using the underlying infrastructure, though with varying characteristics and topologies, adapted to user needs. Ten NRENs have plans in this area.

Network as a Service (NaaS) is currently being considered in three countries; several more have plans in this area.

Major expected network developments reported by NRENs include:

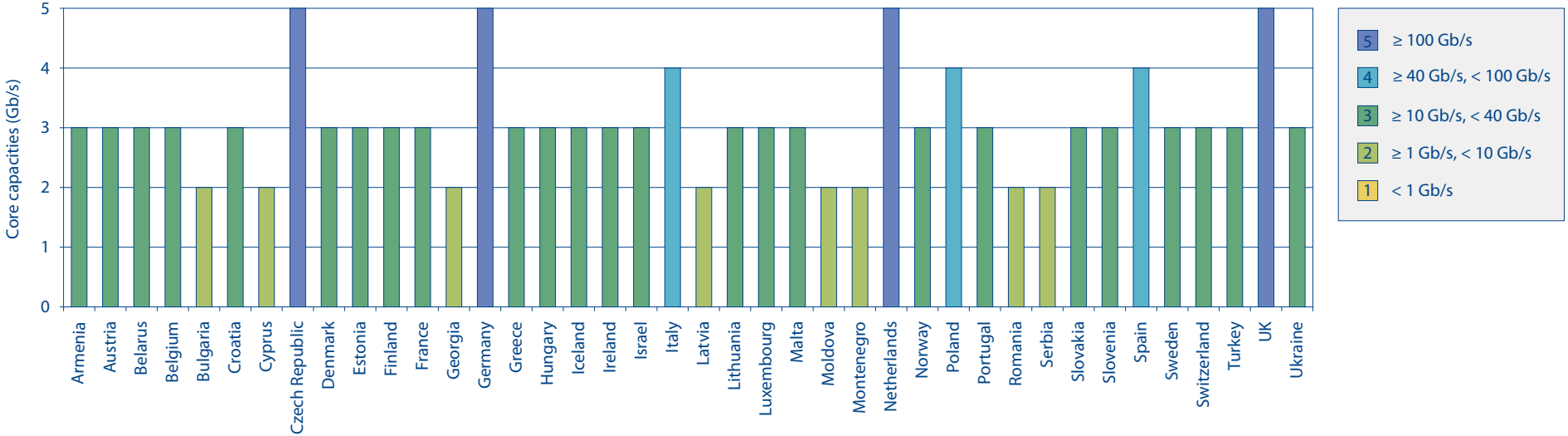
- In the OECD countries, dark-fibre networks are already in place and being upgraded and extended. Several NRENs are preparing for 100 Gb/s or even multiples thereof; Germany is planning an upgrade to Terabit capacity.
- Many NRENs also report that they have expanded the types of services they offer to clients.

3.2 Core capacity on the routed network

The term 'core usable backbone capacity' means the typical core capacity of the linked nodes in the core. Some NRENs have dark fibre with a very high theoretical capacity; in such cases, we requested data on the usable IP capacity.

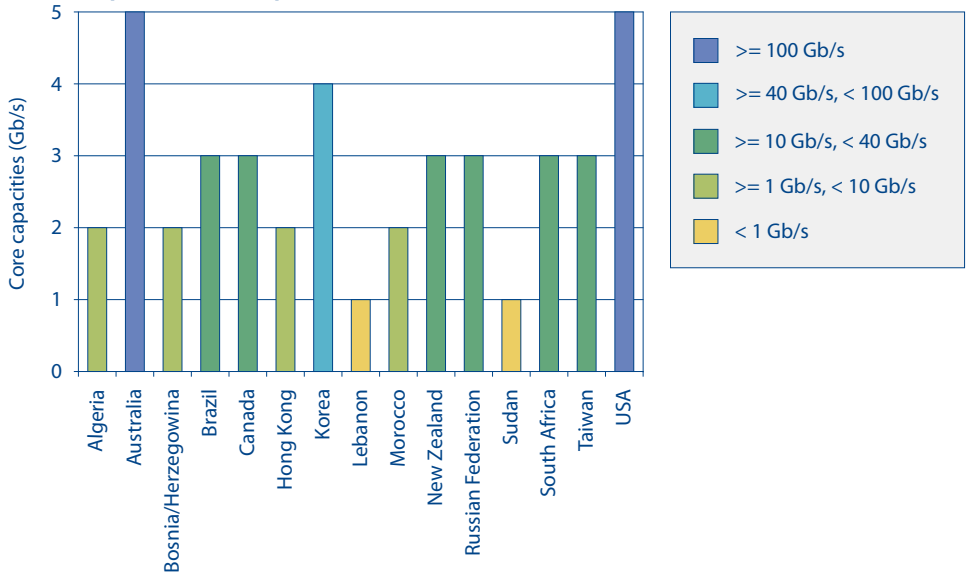
In most GÉANT partner countries, the typical core capacity is now 10 Gb/s, though some NRENs have reached 100 Gb/s. The trend is similar in non-GÉANT countries that submitted data for this year's *Compendium* survey. Both Australia and the USA have introduced capacities of at least 100 Gb/s. Graphs 3.2.1 and 3.2.2. present the data for the individual countries.

Graph 3.2.1 – Core capacities, GÉANT partner NRENs



As many NRENs in the GÉANT region have access to dark fibre (see Section 3.4), which is potentially able to handle high capacities, they can increase capacity easily and economically whenever required. In addition, as indicated in Section 3.4, many NRENs now have several point-to-point circuits and lightpaths, which offer additional capacity that is not usually included in normal traffic statistics.

Graph 3.2.2 – Core capacities, other NRENs



Knowing the typical capacity of the links is no longer sufficient. In several cases, the NREN's network is structured as a mesh, having redundant core and access links. For example, GARR (Italy) allows load-balanced traffic between two points using multiple paths through the mesh, which means that the GARR network's effective core capacity is not 60 Gb/s (the typical link capacity) but 600 Gb/s (the capacity of the mesh as such). Similarly, SURFnet indicates that its core capacity is 200 Gb/s, even though the capacity of the individual links is 100 Gb/s. SUNET finds it impossible to state a figure for its core capacity, because it has a "redundant star-shaped backbone".

It should be noted that network capacity grows stepwise rather than linearly.

3.3 External connectivity: total external links

The NRENs covered by this edition of the *Compendium* were asked to list all their external connections as of January 2014.

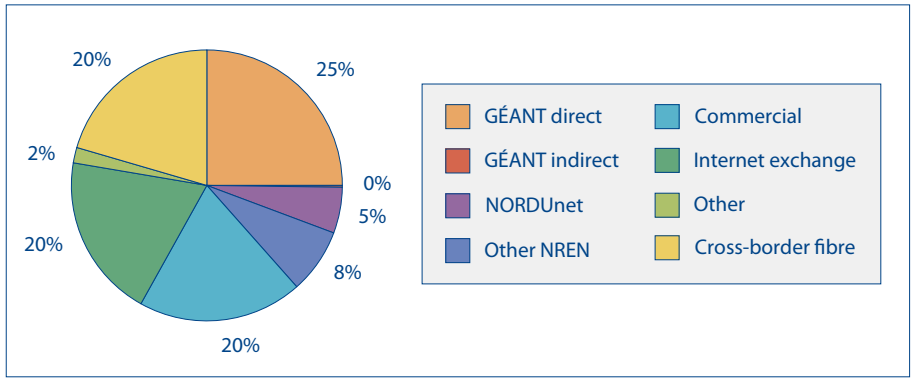
It should be noted that the Nordic NRENs (DeIC of Denmark, Funet of Finland, RHnet of Iceland, SUNET of Sweden and UNINETT of Norway) share their external connections through NORDUnet.

In general, connections to GÉANT and to other NRENs carry research and education traffic, whereas peerings and other connections convey traffic to and from the general Internet. Research and education traffic may consist of highly specialised data and is often transmitted in huge volumes within very short time-frames; for example, real-time observational data from a radio telescope, which must be transmitted over large distances for pre-processing and storage. As high traffic peaks can be expected on such links, they must be dimensioned to accommodate them; it is not unusual to see a flow of 1 Gb/s generated by a single high-end researcher. Thus, the average volume of traffic is not a reliable indicator of the required capacity of the link.

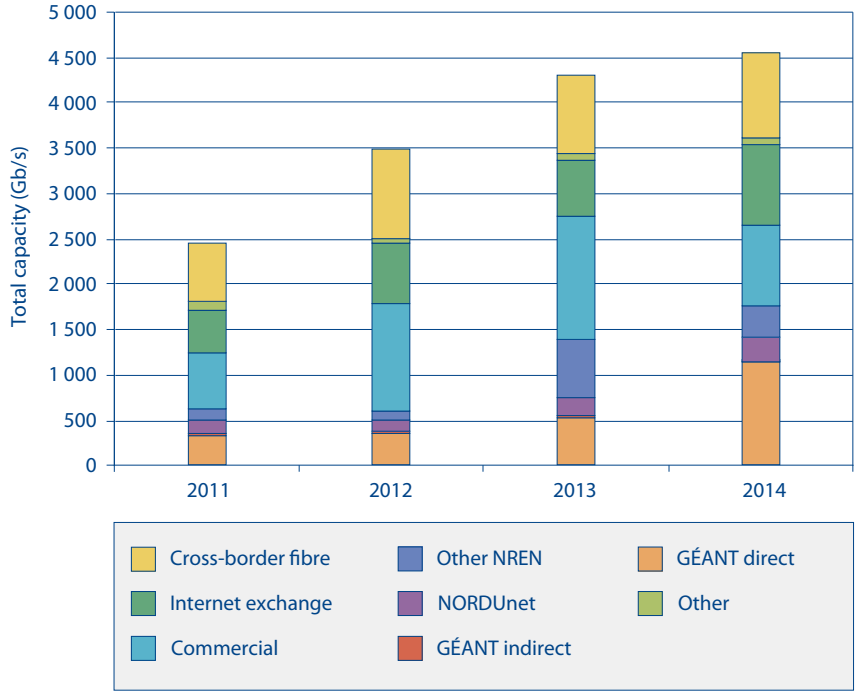
In contrast, traffic to and from the general Internet tends to be aggregated and smoothly varying. It comprises a large number of small-to-medium data flows, which combine to produce a fairly predictable traffic pattern. Therefore, the required capacity of the link can be reliably related to the average flow of data. Note that in Graph 3.3.1, which represents the average situation for all GÉANT partner NRENs, these two distinct categories of connections are combined.

In general, connections not only to the European academic backbone network (i.e. GÉANT) but also to the general Internet are crucially important to NRENs. As Graph 3.1.1 illustrates, connections to the GÉANT backbone are the largest category for GÉANT NRENs. Connections to GÉANT, to commercial providers, to neighbouring countries via cross-border fibre and to Internet exchanges together account for 85% of these NRENs' external capacity. Compared to 2013, total capacity shows continued growth, though the capacity to commercial ISPs now is smaller (percentage-wise) than last year.

Graph 3.3.1 – Capacity of NREN external connections, GÉANT partner countries, 2014



Graph 3.3.2 – Capacity of NREN external connections, GÉANT partner countries, 2011 – 2014



3.4 Dark fibre[1]

As some NRENs either own, lease or have indefeasible rights of use (IRUs)[2] to dark fibre, they can decide what technology and speeds to use on it. The NRENs covered by this edition of the *Compendium* were asked whether they currently own or have IRUs to dark fibre, or plan to acquire it within the coming two years. The NRENs were also asked to state approximately what percentage of their backbone is accounted for by dark fibre.

The *Compendium* has been monitoring the uptake of dark fibre in NRENs since 2005. At that time, only a few networks used dark fibre in their backbones, and GÉANT was just beginning to use dark fibre and light it for transnational trunks.

This year (2014), the aggregate length of dark fibre used internally by NRENs in the GÉANT region exceeds 139 000 km, approximately the same as in 2013. Cross-border fibres are also an important feature, and in some cases these bi-lateral links are being integrated into the GÉANT pan-European infrastructure.

Within an NREN there are many ways to use dark fibre cost-effectively, all of them focused on enhanced services to clients and users. NRENS, as a result of moving from managed network links to their own transmission infrastructure, have been able to develop new features and services at various levels, including:

- Network engineering;
- Campus networks at regional and national levels;
- Premium IP networks;
- Hybrid and multi-protocol networks;
- Wavelength or Lambda services;
- Dynamic Lambdas.

Dark fibre can be used to engineer 'future-proof' networks, which are sustainable against the inevitable demand for greater bandwidth at reduced unit cost. Although budgets generally have not increased much since 2009 (see Section 7

[1] Analysis provided by Mike Norris, formerly of HEAnet.

on funding and staffing), NRENs have been able to scale up their capacity from multi-megabit to multi-gigabit per second. A major advantage of using dark fibre is that clients can upgrade their access capacity quickly and relatively cheaply.

Lambdas (also referred to as 'lightpaths') are an advanced service that has become available due to the move to dark fibre and is provided nationally by several NRENs. It is important to distinguish this service from the NRENs' use of wavelengths to engineer their networks and to provide different layers for switched and routed services. The use of lightpaths, unlike the use of wavelengths, arises from user requirements for specific circuits to interconnect resources. The responses to this year's *Compendium* questionnaire indicate that 21 European NRENs (the same number as in the past two years) are offering lambdas as a service. Two more are planning to introduce this. For further information, see Section 4.7.

At the European level, GÉANT provides a lambda service – analogous to the NRENs' national-level services – which can be extended to its peer networks in North America. The use cases, though not plentiful, include some of the most cutting-edge research areas.

In 2013, dark-fibre network expansions of at least 15% occurred in the Czech Republic and Estonia. Outside Europe, Australia is the country with by far the largest dark fibre network.

See also the map at **compendium.terena.org/reports/darkfibre**.

Table 3.4.1 – Dark fibre on NREN backbones, 2014

Country	Total length of dark fibre (km)	Proportion of total network length (%)	Percentage of dark fibre length added	Percentage of dark fibre length decommissioned
GÉANT partner countries				
Armenia	70	80		
Austria	4500	100		
Azerbaijan	65	20		
Belgium	2068	100	0.1	0
Croatia	131	100	0.011	0.0036
Czech Republic	6000	100	16.3	0
Denmark	2591	54	10.3	0
Estonia	1400	80	22	0
Finland	4290	91	1.2	0
France	13800	92		
Georgia	50	10		
Germany	10547	99		
Greece	9000	100		
Hungary	3200	85		
Iceland	190	19		
Ireland	2600	94		
Israel	770	100		
Italy	9500	85	9.1	1.1
Lithuania	1350	54	8	0
Luxembourg	480	80	0.14	0
Macedonia	20	95	50	
Moldova	165	78	7	0
Montenegro	10.4	5	0	0
Netherlands	11000	100	0.01	0.01
Poland	6479.3	89.46	0	2.56
Portugal	1000	25		
Romania	5350	98	1	6

[2] Effective long-term leasing (temporary ownership) of a portion of the cable's capacity. The distinction between an IRU and a lease is becoming less clear; therefore, in this section these two categories have been combined.

Table 3.4.1 – continued

Country	Total length of dark fibre (km)	Proportion of total network length (%)	Percentage of dark fibre length added	Percentage of dark fibre length decommissioned
GÉANT partner countries				
Serbia	4000	95		
Slovakia	2360	100	2.6	0
Slovenia	1660	100	0.72	0
Spain	13750	97	0.75	0
Sweden	8000	95		
Switzerland	2969	100	13.4	1
Turkey	200	0.3	0.08	0
UK	9500	70		
Ukraine	350	10		
Other countries				
Australia	91000	93	0.04	0
Bosnia/Herzegovina	722	100	0	0
Brazil	1461	5.03	0.32	0
Canada	4900	50	0	
Hong Kong	~300*			
Kazakhstan	59			
Korea	1842	47.5	47.5	0
New Zealand	2205	68		
Russian Federation	650	4.4	8	0
Sudan	0			
USA	25294	86		

** Via managed optical network services with usable lambda.*

3.5 Cross-border dark fibre

Most European NRENs have already installed or are planning to install cross-border dark-fibre links to neighbouring NRENs. Cross-border dark fibre is an (optical) network connection between two NRENs / R&E networks, crossing national borders and / or going outside the usual service area or country of the network. There has been considerable development in this area over the past five years, as was documented in the 2013 edition of the *Compendium*.

In 2013, the following links were added:

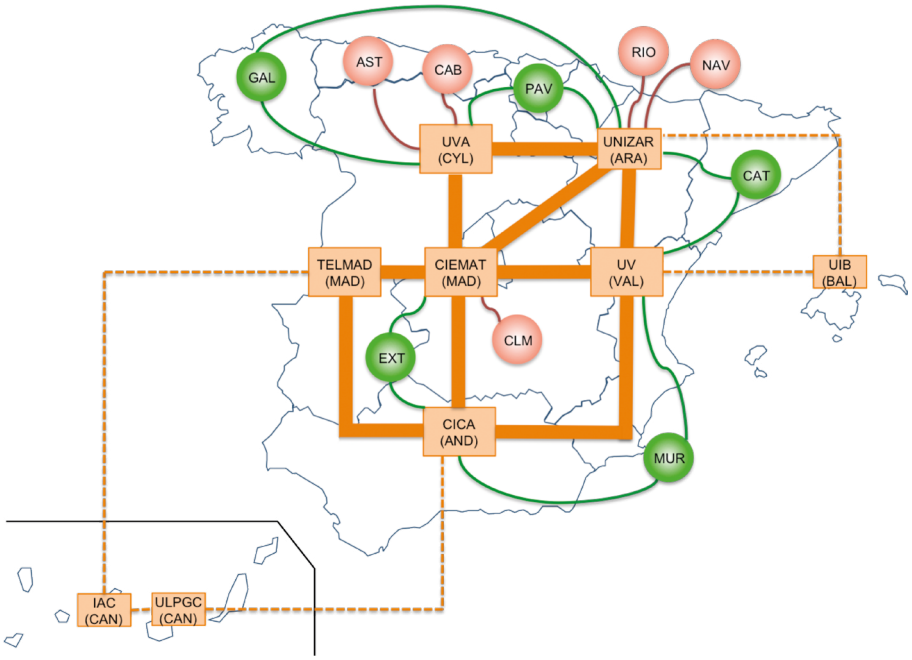
- EEnet – CSC/Funet: a 10 Gb/s lambda between Estonia and Finland;
- LITNET – PIONIER: a 40 Gb/s connection between Kaunas University in Lithuania and PIONIER of Poland.

3.6 Network topologies

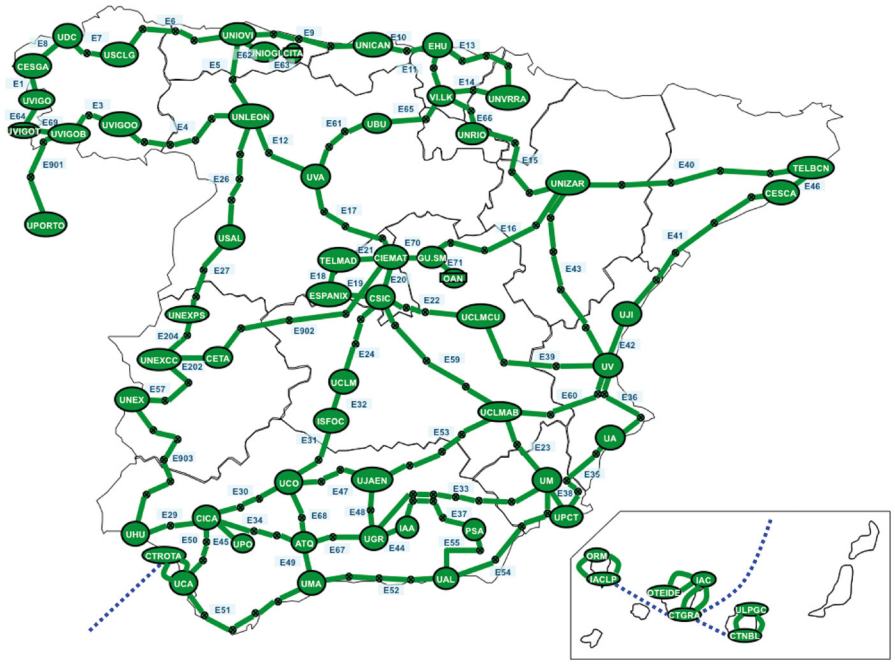
In the early days of the Internet, the logical and physical structures of a network were roughly the same. In other words, the path the bits and bytes took through the copper wires corresponded to the logical geographical path between two systems. In modern network designs, the physical backbone structure, which is based on dark fibres, has a high degree of redundancy. This means that there are several geographical paths between two systems. The IP network (on layer 3) is usually simpler – often more centralised – with fewer nodes than the physical network. This may simplify network management and reduce operational costs. In addition, it is possible to create logical links that simultaneously use several physical connections. Such point-to-point shortcuts can reduce the latency and create a capacity greater than that of the largest individual link. In theory, that capacity could equal the sum of the capacities of all the links to a specific node. Furthermore, a modern physical layer with optical switching increases the stability and flexibility of an IP network.

We asked NRENs to provide us with (hyperlinks to) their network maps of the physical and the logical layers. The maps of RedIRIS (Spain) nicely demonstrate the differences. Map 3.6.1 shows the logical structure of the RedIRIS IP network. For example, there is a direct logical connection between CICA, the regional computer network of Andalusia, and the University of Valencia (UV on the map). Map 3.6.2 shows the physical network, in which there are multiple paths between CICA and UV, each with several intermediate nodes.

Map 3.6.1 – RedIRIS (logical)

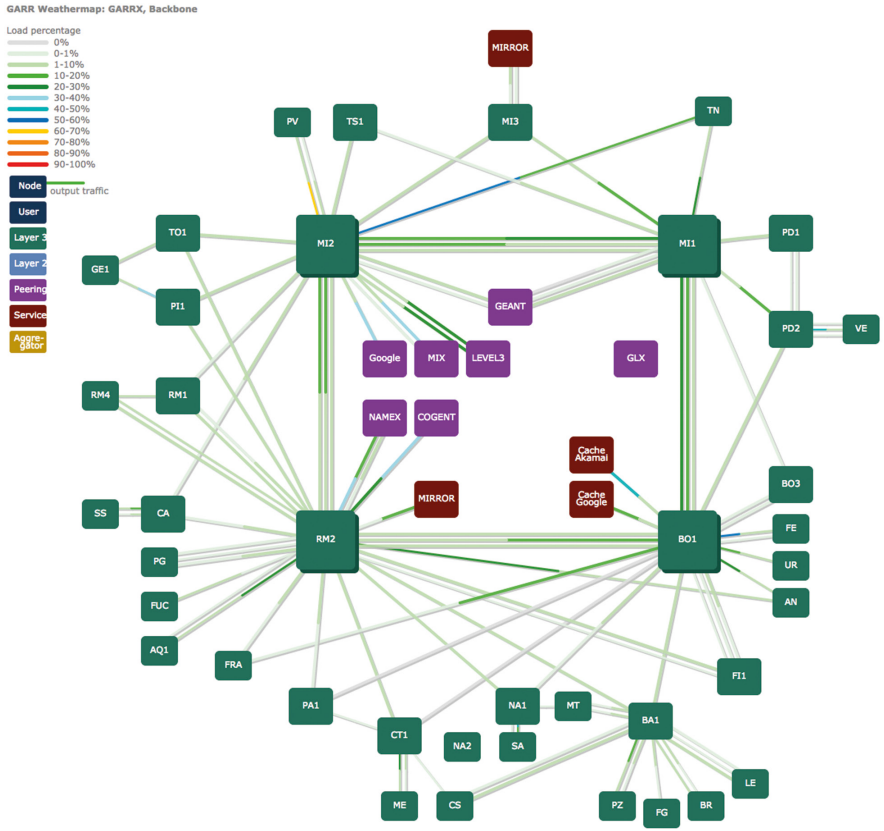


Map 3.6.2 – RedIRIS (physical)

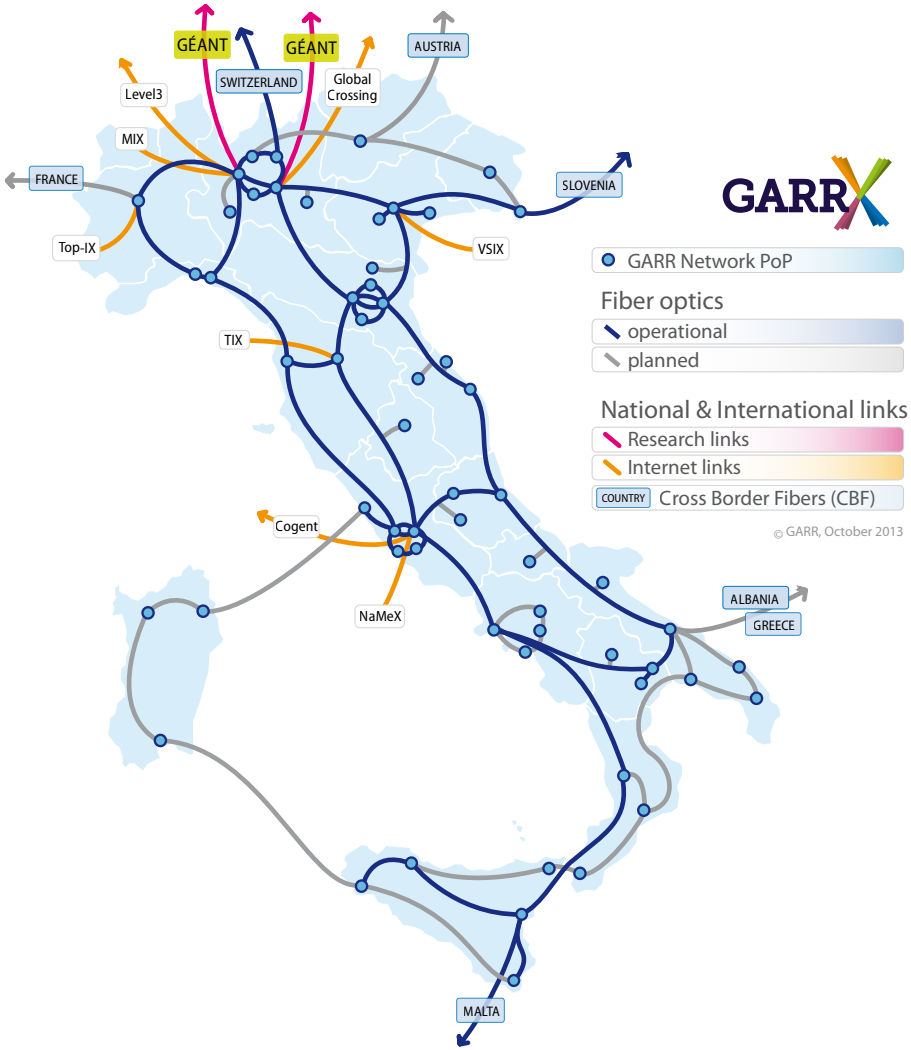


Another illustration, more complicated but conceptually similar, is from GARR in Italy. Map 3.6.3 shows how each of the nodes in the network is connected to several other nodes. This map illustrates how various logical routes from point A to point B on the GARR network are possible. Of course, it is the underlying physical infrastructure, shown in Map 3.6.4, which makes this possible.

Map 3.6.3 – GARR (logical)



Map 3.6.4 – GARR (physical)



3.7 Major expected network developments

The NRENs covered by this edition of the *Compendium* were asked to outline major initiatives related to development of their underlying network that they expect to realise within the next two to five years. Several NRENs that did not respond to this question did provide information on major changes in their organisations (see Appendix 1). Table 3.7.1 provides general insight into major developments in research and education networking that are expected by NRENs in the various countries of Europe and other continents, including:

- In the OECD countries, dark-fibre networks are already in place and being upgraded and extended. Several NRENs are preparing for 100 Gb/s or even multiples thereof; Germany is planning an upgrade to Terabit capacity.
- Many NRENs also report that they have expanded the types of service they offer to clients.

Table 3.7.1 – Major expected network developments

Country	Developments	Timeframe (years)	Confidence
GÉANT partner countries			
Belarus	Increase the capacity of the link to PIONIER to 10 Gb/s	2014-2015	Likely
Belgium	Implementation of a new, state-of-the-art optical network	Mid 2014	Quite certain
	Implementation of a new, state-of-the-art IP network	Mid 2015	Quite certain
	Extension of the Belnet fibre footprint	Continue	Quite certain
	Testing & implementing SDN/NFV technology	2016-2017	Likely
Bulgaria	100 Gbit/s	2-5 year	Likely
Cyprus	Dark fibre deployment	18 months	Quite certain
Denmark	DWDM upgrade	2016	Quite certain
	Faroe Islands connection	2014	Likely
	Greenland connection	2015	Uncertain
Estonia	100G	2016	Likely
Finland	100G upgrade	2 years	Quite certain
	Introduce dynamic lightpath services	2 years	Quite certain
Germany	Upgrade to TB/s	4 years	Likely
Greece	Upgrade of optical transmission equipment	6 months	Quite certain
Hungary	Primary running task is the modernisation of the facilities and services of the school network and improvement of backbone flexibility	until late 2015	Quite certain
Iceland	Replacement of leased capacity from other providers with fibre	1-3 years	Uncertain
Ireland	Enhanced Optical Resilience	2014	Quite certain
	Replacement of Layer 2 network	2015/2016	Likely
Italy	GARR-X Progress aims to strengthen the optical network dedicated to the research and education community in the four regions of convergence, to include, by the end of the project, about 3900 km backbone, 24 Points of Presence (PoP) and over 2200 km of user access links. The transmission and IP/MPLS levels will be implemented with leading-edge equipment, characterized by high degrees of scalability, speed and flexibility, which will deliver capacities in the order of 100 Gb/s and multiples thereof. User access links will also be upgraded, thanks to the implementation of symmetric fibre links with capacities of at least 100 Mb/s. Overall, the project includes a minimum of 120 sites belonging to universities and research institutions (which could increase to 400 as the project progresses), and about 380 secondary schools located in main urban areas, for more than 2000 km of access fibre links to be rolled out by the project.	2014-2015	Quite certain
Latvia	None		Quite certain
Lithuania	WiFi as a service	2016	Likely
	VPN as a service	2016	Likely
	Firewall on demand	2016	Likely
	WiFi for schools	2016	Quite certain
	Cloud services	2017	Quite certain
Luxembourg	Full 10G backbone coverage	1	Quite certain
	Extend DWDM network coverage	2	Quite certain
	Planning IRU contracts replacement	4	Quite certain
Malta	More use of dark fibre 2015-2017	2015-2017	Likely

Table 3.7.1 – continued

Country	Developments	Timeframe (years)	Confidence
GÉANT partner countries			
Moldova	EPIC (EaP@interconnect)	2016	Quite certain
Netherlands	SURFnet8 - renewal service layer	2017	Likely
	SURFnet8 - renewal photonic layer	2017	Likely
Norway	Dark fibre from Longyearbyen to Ny-Ålesund (Spitsbergen)	2014	Quite certain
Poland	Deploy 100G links	2015	Quite certain
Romania	Deploying 100 Gb/s core with new routing equipment	1 year	Quite certain
Serbia	SEELight project - full realization – to connect ~110 new institutions, increase backbone links capacity to 10Gb/s and implementation of DWDM technology on backbone links	3	Likely
	Educational network: plans for connecting ~2900 schools on AMRES network by ADSL and 3G technology	3	Likely
Slovakia	Capacity upgrade	2 - 3 years	Quite certain
	New POPs installation	Future	Likely
Slovenia	Additional CBF between Nova Gorica, Slovenia and Gorizia, Italy	Q4/2014	Quite certain
Spain	New fibre to Baleares	2015	Quite certain
	Extension of the network (Donana, some technological parks in Seville, Santander and Madrid, etc.)	2015	Quite certain
Sweden	New nationwide backbone	2016	Quite certain
Switzerland	New DWDM system	1 year	Quite certain
	First 100G backbone links	1 month	Quite certain
	First 100G client connection	3 months	Quite certain
UK	Insourcing of regional networks	Within next two years	Quite certain

Table 3.7.1 – continued

Country	Developments	Timeframe (years)	Confidence
Other countries			
Albania	10 Gb/s backbone	Q4, 2014	Quite certain
	1 Gb/s link to most universities and research centres	Q4, 2014	Quite certain
Algeria	Upgrade GEANT link	1	Quite certain
Brazil	Introduction of SDN pilot	1	Quite certain
	Deployment of some 100G links both at national and international levels	2	Quite certain
	Extension of performance monitoring to include user access links	2	Quite certain
Canada	Fibre builds	mid 2015	Quite certain
	100G Core IP Upgrade	end of 2014	Quite certain
	SDN development	2015	Likely
Hong Kong	Enable IPv6 at all participating institution	2-3 years	Likely
	Experiment mutual backup/DR sites within members' campuses	1-2 years	Likely
	Experiment NRENum among participating institutions	1-2 years	Likely
	Cloud Services	2-3 years	Uncertain
Kyrgyzstan	eduroam		
	e-library		
	Hosted LMS services for universities		
Lebanon	Switch to fibre optic	1 year	Quite certain
Morocco	Marwan 4	2015	Quite certain
Russian Federation	Russian Ring 10Gbit/s	2014	Quite certain
	DWDM Moscow - St. Petersburg	2015	Likely
	SDN Testbed	2015	Likely
Sudan	Dark fibre	2016	Uncertain
	Increase bandwidth	2016	Uncertain
	Increase members	2016	Uncertain
South Africa	Backbone upgrade	2015-2017	Quite certain
	International capacity upgrade	2015-2018	Quite certain
	Addition of new sites	2014-2018	Quite certain
	Backbone expansion	2014-2018	Quite certain
Taiwan	Upgrade to 100G backbone	Dec, 2014	Quite certain

3.8 Software-Defined Networking

Software-Defined Networking (SDN) enables the creation of virtual networks using the underlying infrastructure, though with varying characteristics and topologies, adapted to user needs[4].

For this year's *Compendium*, we asked NRENs whether they have an SDN testbed, how it is managed and for what purposes it is being, or will be, used. The responses are shown in Table 3.7.1. Six GÉANT partner NRENs currently have such a testbed, up from four in 2013. Ten more are planning to deploy one. In all cases, the setup is still experimental. The exception is Brazil, which has offered the testbed to researchers.

Table 3.8.1 – Software-defined networking

Countries	Testbed?	How will it be extended in future?	Interest in multi-domain SDN capabilities	Plan to implement an SDN-based testbed	Introducing SDN-based capabilities in the production network?
GÉANT partner countries					
Czech Republic	Planned	First to implement and test it locally, then in cooperation with other partners	Yes	2015	
Denmark	Planned	Add BoD as a service	Yes	We have participated in several projects	
Germany	Yes	Currently prepared in GN3plus/ SA2	Yes		After stabilisation of test services
Greece	Planned		Yes	2014	SDN capabilities are being assessed for the next generation of Data Centers hosting our cloud infrastructure
Hungary	Planned	Provide testbed interface.	Yes	next few years	
Ireland	Yes		Yes		
Italy	Yes	National testbed available for the researchers. Available by 2014 Q3	Don't know	2015 Q2	
Lithuania	Yes		Don't know	During 2013	
Moldova	Planned	Participate in GN3plus & GN4 TaaS activities	Yes	2015-2016	
Netherlands	Planned	Collaboration with other NREN and universities	Yes	2014	2015-2018
Norway	Yes	Add Lambdas	Yes	2013	No
Poland	Yes	Upgrade to higher versions of OpenFlow protocol	Yes	2014	
Russian Federation	Planned		Yes	2015	Yes
Slovenia	Planned		Don't know		
Spain	Planned		Yes	2015/2016	
Switzerland	Planned		Don't know	According to user demand; also, willing to connect sites to GÉANT SDN testbed.	No

[4] For more information, see for example en.wikipedia.org/wiki/Software-defined_networking

Table 3.8.1 – continued

	Testbed?	How will it be extended in future?	Interest in multi-domain SDN capabilities	Plan to implement an SDN-based testbed	Introducing SDN-based capabilities in the production network?
Other countries					
Algeria	Planned			2014 Third quarter	
Australia	Yes	By exploiting the MPLS capability of AARNet4. It is planned to make it compatible with (for example) GENI, with initial international deployments in response to researcher demand, e.g. in NZ, USA and Europe.	Yes		Employing MPLS, e.g. for DaShNet (https://www.rdsi.edu.au/dashnet). A testbed is about to be introduced for researchers needing it, determined by demand for which countries they want to connect to.
Brazil	Yes	The present FIBRE testbed currently reaches 10 institutions in Brazil and 3 in Europe (http://www.fibre.org.br). Extensions are planned by including more institutions in Brazil, and by federating with testbeds in other countries, especially EU and US.	Yes		The main purpose is to implement a virtualized backbone resource in such way that it could be controlled by software and isolated. In this way we can distribute the network resource based in a Business Model.
Canada	Yes	Extending the testbed access to researchers and regional providers.		Current year	
Kazakhstan	Planned			2014/2015	
Korea	Yes	Extension to international domain like Hong Kong, Seattle, Chicago and Daejeon.	Yes		
Morocco	Planned		Yes	2015	No
New Zealand	Planned				
South Africa	Planned		Don't know	2015-2016	
Taiwan	Yes	We plan to connect more universities and commercial companies to facilitate OpenFlow advancement.	Yes		SDN switches are planned to be deployed on the backbone and interconnected by VPLS VPN to provide the SDN testbed services to the researchers.

3.9 Network as a Service

Network as a Service (NaaS) gives cloud users the capacity to reserve bandwidth on the network dynamically[5].

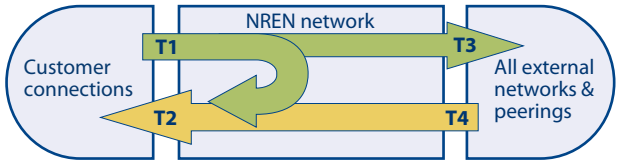
Currently, only three NRENs have deployed such capabilities on their network infrastructure (Israel was the latest country to implement this, following Ireland and the Netherlands last year).Seven GÉANT NRENs have plans in this area; a few non-European NRENs including Brazil and Korea also have such plans. For SURFnet, the purpose is to provide researchers with a flexible Bandwidth-on-Demand (BoD) service. Lithuania would like to serve smaller institutions who do not have the necessary capabilities to construct the network themselves. Italy is planning to use NaaS for inter- and intra-data-centre connectivity for distributed clouds. Brazil aims to dynamically provision a set of services that integrate network (VPN, BoD, VLAN), storage and computer processing.

[5] For more information, see for example en.wikipedia.org/wiki/Network_as_a_service

4 TRAFFIC

As in previous years, the NRENs covered by this edition of the *Compendium* were requested to report their total annual traffic flows at the boundaries of their networks. The four flows they were asked to specify are defined in Diagram 4.0.1.

Diagram 4.0.1 – Types of traffic flow



T1	All IP traffic from customer sites and the NREN.
T2	All IP traffic to customer sites and the NREN.
T3	All IP traffic leaving the NREN
T4	All IP traffic entering the NREN

External traffic = all traffic to the NREN's regional backbone, the commercial Internet, Internet Exchanges, etc. (consisting of T3 + T4 above).

Note: all IP traffic includes both IPv4 and IPv6 traffic.

What this diagram does not show is that, in some cases, the reported traffic may include traffic flowing between separate customers of the NREN. In other cases, such traffic may be confined to separate MANs/RANs and not appear on the NREN backbone.

In certain cases, non-routed traffic within a customer network may be switched via NREN point-to-point circuits but not be reported in traffic statistics, as it does not appear as IP traffic on the NREN network.

Similar distinctions apply to external traffic. IP traffic is exchanged with external networks via neutral exchange points, via peerings with commercial Internet service providers, via GÉANT with other NRENs in Europe and around the world, and in some cases via cross-border fibre with neighbouring NRENs. In addition, some NRENs use direct point-to-point circuits to interconnect, for example, research facilities with their users. Because traffic on such links does not go through the routed IP network, it is not reported here.

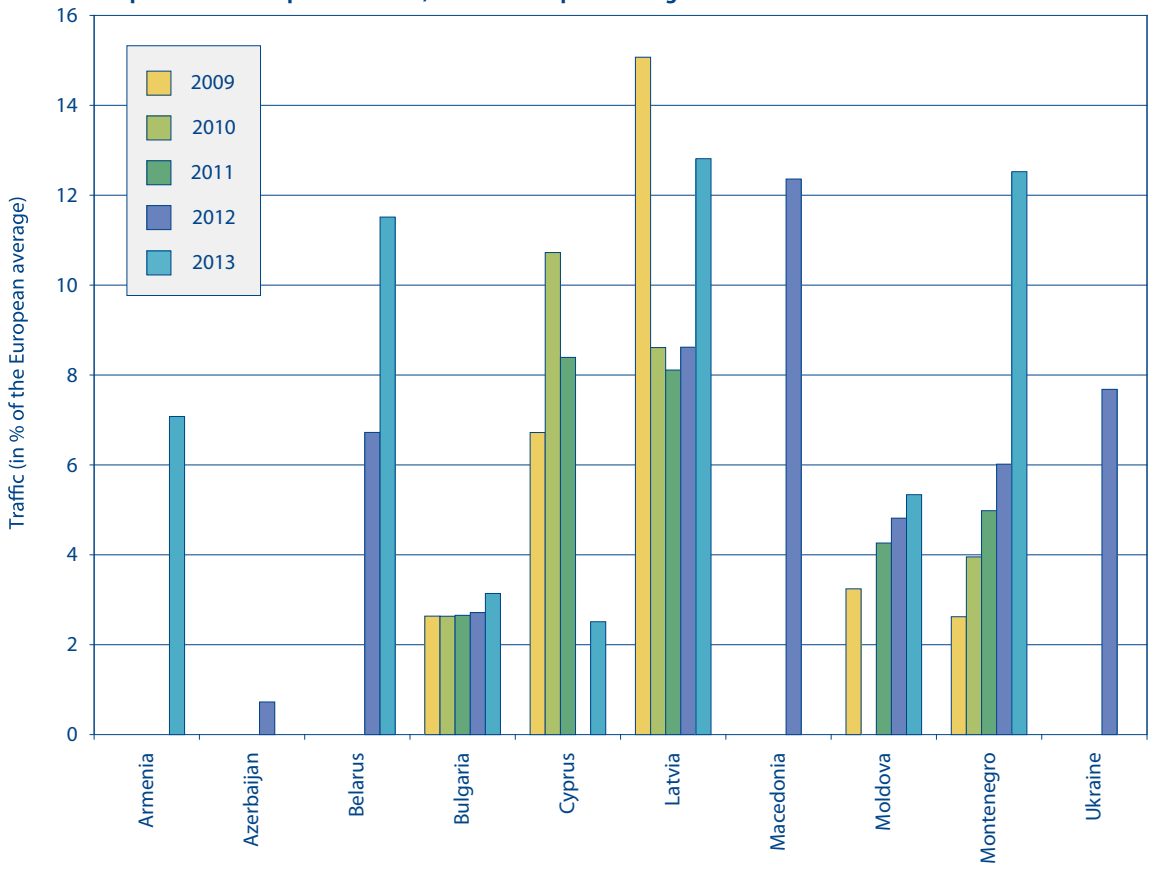
Below, Section 4.1 gives an overview of the NRENs' responses, as well as this year's traffic trends. Section 4.2 considers traffic in 2013, whereas Section 4.3 analyses traffic trends over the past ten years. Section 4.4 gives information on NREN traffic per inhabitant. Section 4.5 considers the issue of congestion. Section 4.6 examines deployment of IPv6. Finally, Section 4.7 focuses on lambda and point-to-point fixed bandwidth traffic.

4.1 Overview

Most of the NRENs that responded to the questionnaire for this 2014 *Compendium* reported annual IP traffic flows at the points where they exchange traffic with external networks (T3 & T4); most NRENs also reported annual traffic flows between their connected sites and their backbone network (T1 & T2). The T3 and T4 traffic levels are relatively easy to measure and record, as there are only a few points on the network to monitor. Below, Graphs 4.2.1 (2013 traffic, T3 > 10 000 TB) and 4.2.2 (2013 traffic, T3 < 10 000 TB) represent all the national responses submitted in 2014. Comparison with data from previous years reveals that IP traffic continues to grow. Over the past ten years, the annual rate of growth has fluctuated around an average of almost 30% (but always remained positive). In recent years, growth seems to have slowed down. Traffic on the GÉANT IP backbone has decreased, likely because increasing volumes of traffic from very large users are now routed via separate lambda connections, over which traffic is not measured.

It should be noted that traffic growth patterns differ from country to country and from year to year.

Graph 4.1.1 – Traffic per inhabitant, <15% of European average



Analysing the available traffic data reveals substantial differences within Europe: NREN traffic per inhabitant in Armenia, Azerbaijan, Belarus, Bulgaria, Cyprus, Latvia, Macedonia, Moldova, Montenegro and Ukraine remains below 15% of the European average level. Compared to 2012, traffic per inhabitant increased in Serbia and Turkey, bringing them above the 15% level. (See Graph 4.4.2.)

For the GÉANT partner countries, average estimated congestion levels have increased at the campus and access-network level but have almost disappeared at the levels of backbone and external connections levels.

The vast majority of NRENs provide some or all of their clients with both IPv4 and IPv6 connectivity. Fourteen of the thirty GÉANT partner NRENs that provided information for this section of the *Compendium* have so far allocated less than 1% of their IPv6 address space to client institutions. NRENs do not generally engage in carrier-grade NAT or other forms of address sharing, though there are a few exceptions.

Traditionally, NRENs have provided connected institutions with both the physical connections and the routing that is necessary to transport IP packets from their place of origin to their destination. Traffic is measured by counting the IP packets that are routed by the NREN. However, with the advent of optical networking, it has become possible to directly interlink high-end users by means of a dedicated physical connection in the form of a wavelength or 'lambda' on an optical fibre cable. In principle, the users that are thus connected decide how to use that wavelength; the routing is no longer the automatic or standard responsibility of the NREN. (In theory, over such a wavelength it is possible to transport data using methods other than standard IP.) Therefore, it is no longer feasible for

4.2 Traffic in 2013

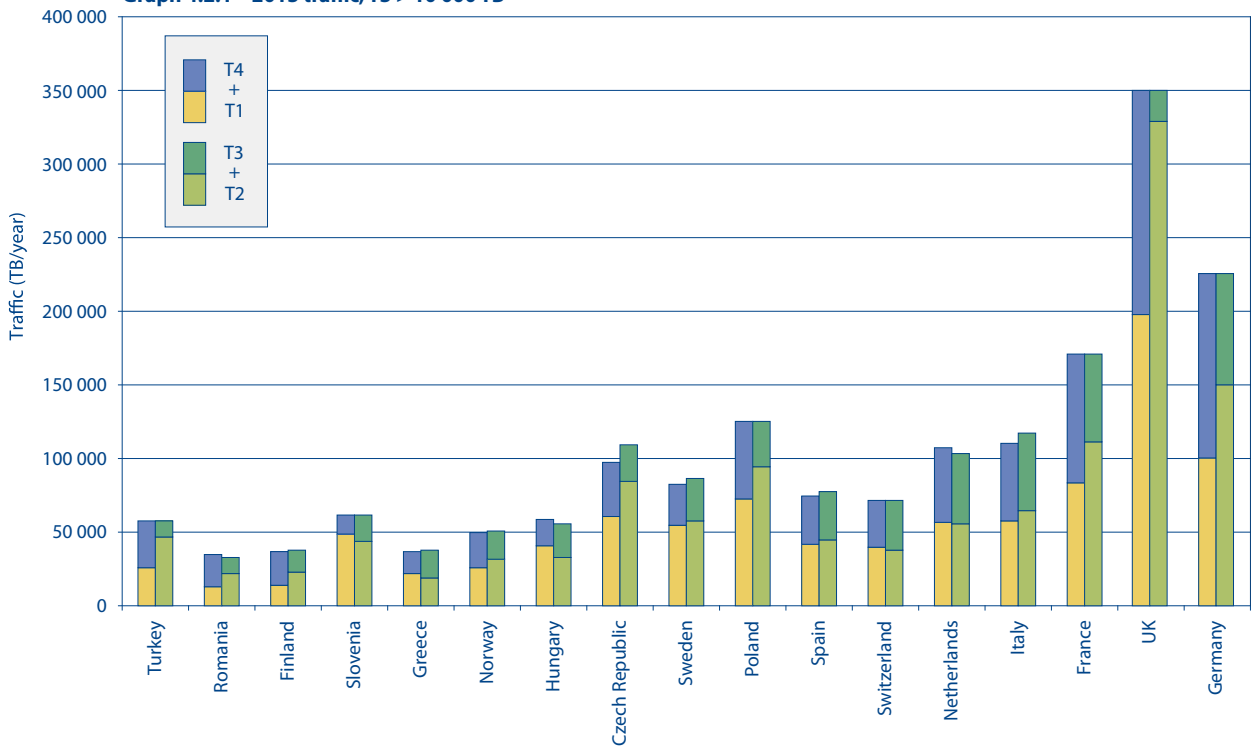
the NREN in question to measure the traffic on such links. Given that such traffic volumes are normally supplied only to high-end users, it is reasonable to assume that they are substantial and growing.

Twenty-one GÉANT partner NRENs now provide dedicated wavelengths (lambdas) to their clients. Per NREN, the number of static point-to-point fixed bandwidth connections provisioned in January 2014 varies between three and 511 (HEAnet of Ireland). At present, the number of circuits seems to be the only measurable parameter that can be used to document the evolution of lambda traffic. Nearly 1300 wavelengths circuits are now in use by the GÉANT NRENs for high-bandwidth, low-jitter transport (up from 1200 in the year 2013 and 875 in 2012). Nearly all lambdas reported by the 21 NRENs concerned are static or fixed. Five NRENs are currently using dynamic lambdas, which can be set up and taken down (by the NREN or its clients) for short-term requirements.

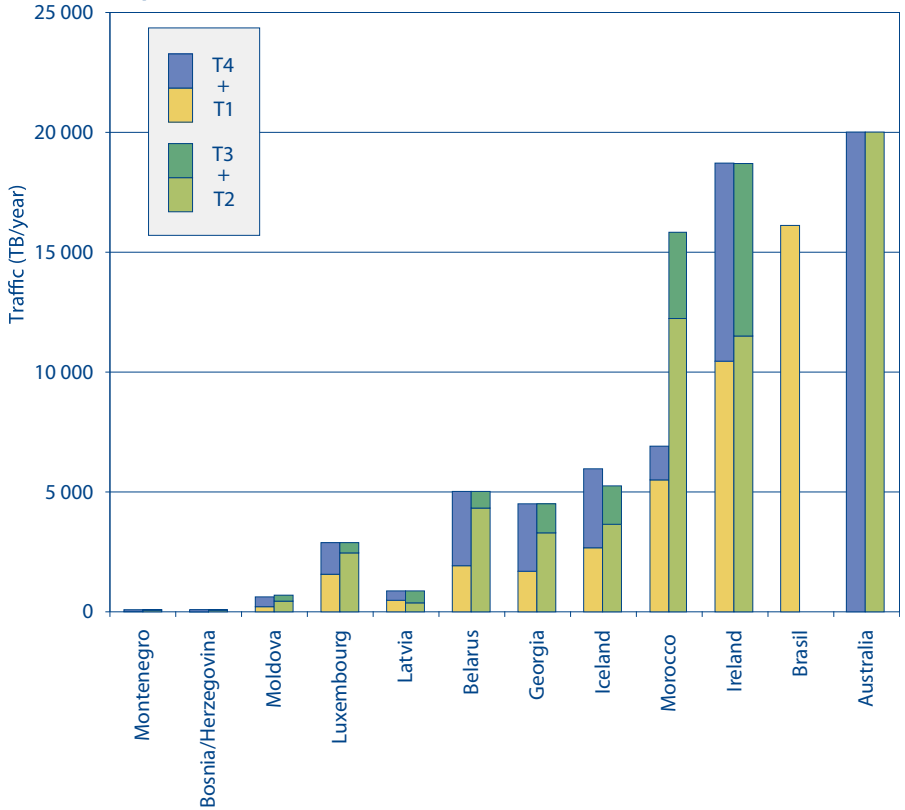
Graph 4.2.1 represents the data submitted by those NRENs whose T3 traffic exceeds 10 000 terabytes per year, whereas Graph 4.2.2 represents the data submitted by NRENs with lower levels of T3 traffic. (In both graphs, the countries have been sorted on the amount of T3 traffic.) These graphs clearly show how the distribution of total traffic between the four categories (T1 to T4) differs from NREN to NREN. Note that not all respondent NRENs provided all four traffic values.

For most NRENs, the reported traffic sent into their backbone (T1+T4) is equal or nearly equal to the reported traffic sent out of their backbone (T2+T3). The few NRENs for which this is not the case cite, as main reasons for the discrepancy, the effects of traffic-monitoring efforts, hosting of Content Delivery Networks such as Akamai, and difficulties in separating out the various traffic types.

Graph 4.2.1 – 2013 traffic, T3 > 10 000 TB



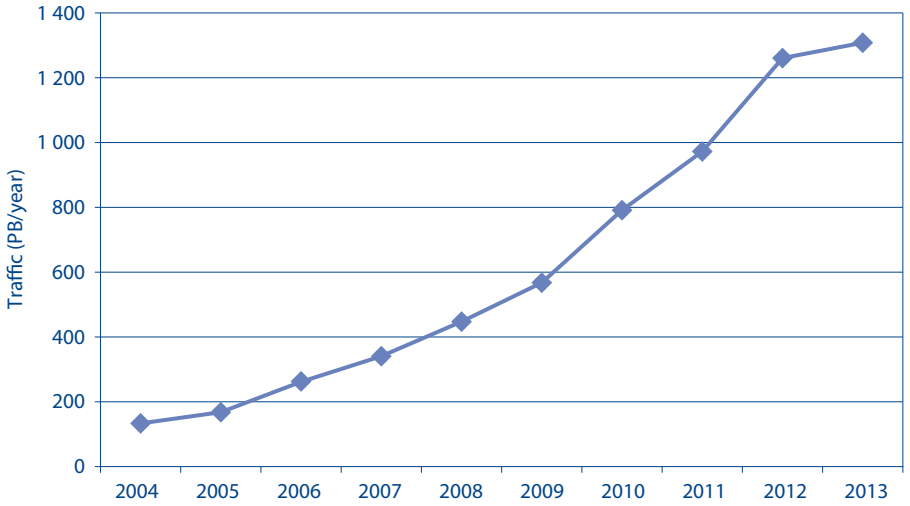
Graph 4.2.2 – 2013 traffic, T3 < 10 000 TB



4.3 Traffic trends, 2004-2013

As in the 2013 edition of the *Compendium*, Graph 4.3.1 shows T3+T4 values for a subset of 23 NRENs that have consistently submitted complete data. Clearly, over this ten-year period (2004-2013) NREN traffic has continued to grow steadily, even though growth in 2012/2013 was lower than in earlier years.

Graph 4.3.1 – NREN annual traffic flows (T3+T4), 2004-2013, n = 23 NRENs

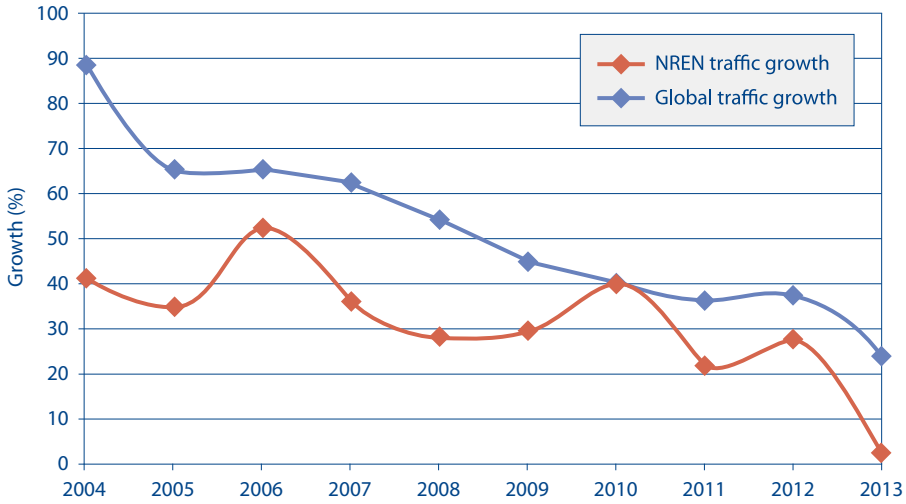


The annual average growth rate was almost 30%. Graph 4.3.2, which shows the growth rate variation over the same period, reveals that, overall, growth has slowed down somewhat in recent years. Figures from Cisco[1] show global IP traffic growth slowing down to 25% in 2013. However, this is still considerably higher than the NREN traffic growth of 3%.

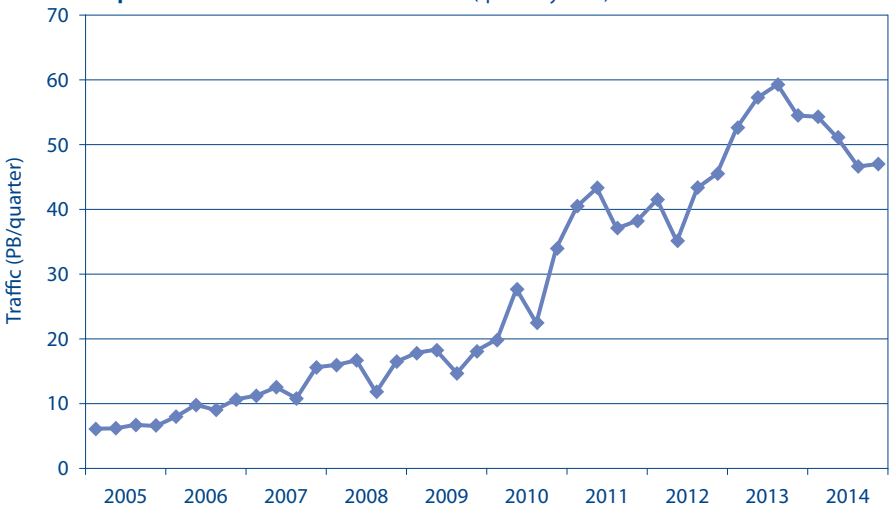
Using data from GÉANT service reports, GÉANT IP traffic growth has been plotted in Graph 4.3.3. This shows a traffic decrease over the past year, probably because traffic flows from very large international users increasingly use dedicated bandwidth services. Traffic on these services, although substantial, is not measured together with normal IP traffic. The effects of this development, which started a few years ago, are starting to become evident on the GÉANT backbone network. (See also Section 4.7.)

[1] See www.cisco.com/web/solutions/sp/vni/vni_forecast_highlights/index.html.

Graph 4.3.2 – Growth rates of NREN and global IP traffic, 2004-2013 (in %, T3+T4)



Graph 4.3.3 – GÉANT IP traffic 2005-2014 (quarterly data)



Note that the traffic growth pattern is somewhat erratic: it differs from country to country and from year to year. Growth is influenced by many factors, such as backbone and access-network capacity upgrades, connections to large users, and changes in policy and charging models.

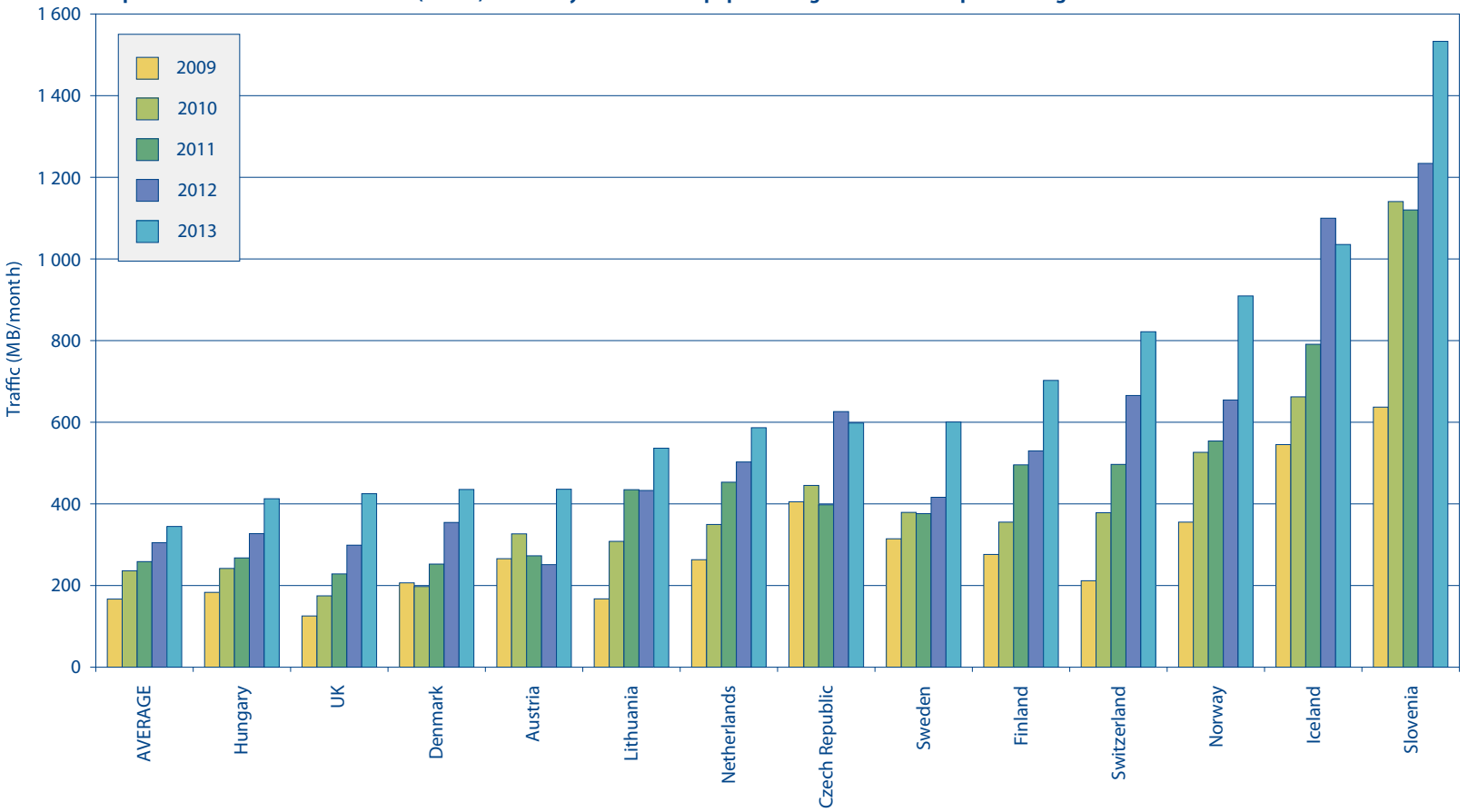
4.4 NREN traffic per inhabitant

In 2009, we attempted to identify an indicator that would enable NRENs to be compared in terms of traffic. After considering several alternatives, the simplest indicator – traffic-per-inhabitant – was found to be the most reliable, because there is a roughly proportional relationship between a country's total population and the size of its education and research community. We have found this relationship to be valid for most countries surveyed and, therefore, no other assumptions or data convolutions need to be made. However, as with other high-level indicators, these statistics should be treated with caution, as large differences between countries do exist and any comparison of this type is a simplification of reality.

Graphs 4.4.1 and 4.4.2 show NREN annual T3+T4 traffic in 34 countries over the period 2009-2013, normalised according to the total national population in each corresponding year. Note that this figure should not be taken as an indicator of the network traffic generated by a typical NREN user.

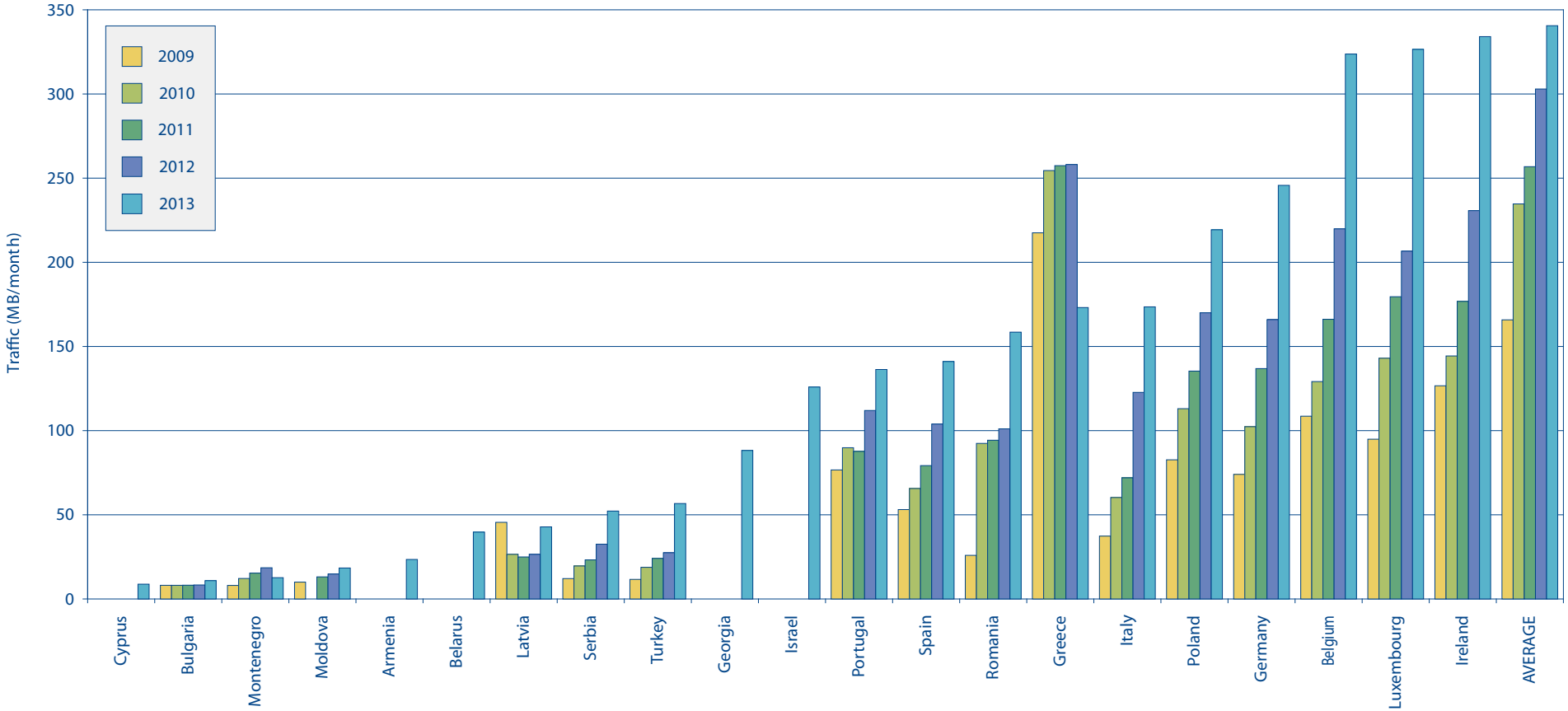
In these 34 countries, the average traffic per inhabitant grew from 166 MB/month in 2009 to 342 MB/month in 2013, with an average annual growth rate of 19.7%.

Graph 4.4.1 – Nominal external traffic (T3+T4) divided by total national population: greater than European average



Slovenia has had consistently high nominal traffic (per inhabitant) over the five-year period (2009-2013). Although Slovenia's population is quite small, the country has a relatively high proportion of traffic generated by primary and secondary schools: indeed, nearly 700 schools and a few universities are connected to the ARNES backbone, and some of the schools are connected with gigabit capacities. Therefore, the proportion of the population that is connected by the NREN is relatively high, and Slovenia's external traffic is higher than that of the other European countries shown.

Graph 4.4.2 – Nominal external traffic (T3+T4) divided by total national population: lower than European average



Note that the vertical scale of Graph 4.4.2 is much smaller than that of Graph 4.4.1. Clearly, there remain substantial differences within Europe: Armenia, Bulgaria, Cyprus, Georgia, Latvia, Montenegro, Moldova, Serbia and Turkey show much lower values than the rest of Europe (despite the traffic growth in Latvia, Serbia and Turkey).

Like Slovenia, many countries with quite a small population have relatively high traffic per inhabitant. Simply having an NREN in itself generates a certain amount of traffic (including mirroring services, news groups and library databases) — at least, once the NREN has attained a certain minimum level of development and connectivity. For larger countries, that 'base-load traffic' does not significantly affect the traffic statistics.

4.5 Congestion

The NRENs covered by this edition of the *Compendium* were asked to estimate the percentage of institutions connected to their networks that experience none-to-little, some-to-moderate, or serious congestion at the various network levels.

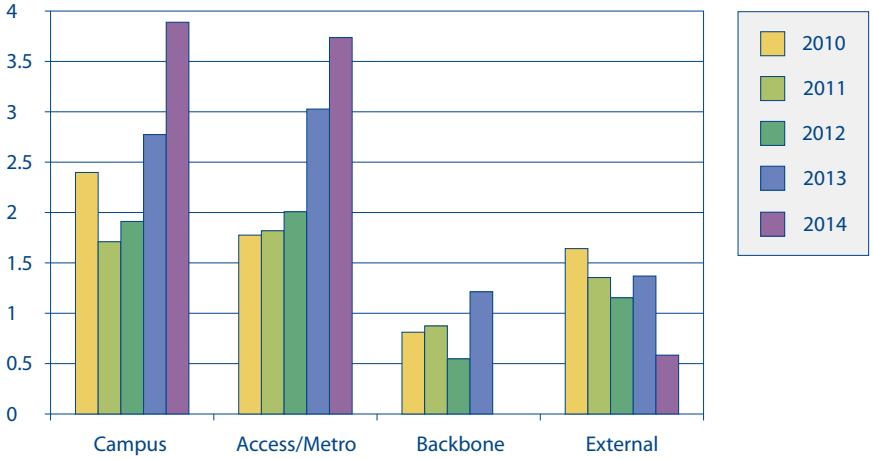
From the subjective levels reported by NRENs, a metric was derived for the level of congestion in each network element, using the following formula[2]:

congestion index = (0.05*little + 0.2*some + 0.5*serious) – 5

Note that the data for MANs and access networks were combined. Applied to all the submitted data on congestion, this formula provides a single uniform metric.

As shown by Graph 4.5.1, for the GÉANT partner countries, the average estimated congestion levels have increased at the campus and access-network levels. For the first time this year, no congestion is reported at the backbone level, whereas at the level of external connections, the congestion has dropped to minimal levels. However, it seems that recent investments in increased capacity at the external and backbone levels are causing some bottlenecks at the access-network level.

Graph 4.5.1 – Congestion index, GÉANT partner countries, n = 31



4.6 IPv6 deployment

There have been numerous reports concerning the impending shortage of IPv4 address space[3] and the need to start deploying IPv6. As indicated in previous editions of the *Compendium*, because most European NRENs have already deployed IPv6 on their backbones, client institutions can start to use this new protocol as and when the need arises. The ratio of IPv6 to IPv4 traffic is currently very low and has not risen much over the last few years.

Nine GÉANT NRENs do not yet provide IPv6 connectivity to any of their clients. However, the vast majority of NRENs do provide some of their clients with both IPv4 and IPv6 connectivity. Four NRENs (one more than in 2013) provide this to all their clients. The GÉANT network itself has been carrying IPv6 traffic, along with IPv4, since 2000.

[2] This index was developed for the *Compendium* by Mike Norris, formerly of HEAnet. The index was modified in 2009 to set the minimum value at 0 rather than 5.

[3] For information on IPv4 exhaustion, see for example: www.ripe.net/internet-coordination/ipv4-exhaustion.

Four of the 30 GÉANT NRENs that provided information for this section of the *Compendium* have not yet allocated any IPv6 address space to their client institutions. Ten have allocated less than 1% (down from 17 last year), eight have allocated more than 1%, and one has allocated 100%.

We asked NRENs if they have taken any measures in response to the growing deployment of carrier-grade NAT or other forms of address sharing. The only NRENs who report doing anything of this kind are those in Bosnia/Herzegovina and Hong Kong. A few more NRENs or NREN customers are deploying carrier-grade NAT themselves. However, most NRENs are not doing this and are discouraging their customers from doing so.

Table 4.6.1 – Carrier-grade NAT deployment

Country	NREN or its customers deploying or considering the use of carrier-grade NAT or similar address sharing technologies?
GÉANT partner countries	
Belgium	Belnet: no. We discourage our customers from doing this.
Greece	Not yet. We had an issue with resource exhaustion in the cloud infrastructure, but we decided not to invest in CGN.
Hungary	Yes
Lithuania	We advise our customers not to do this.
Serbia	There are plans for connecting schools, and we estimate that the entire network will need to use private IPv4 addresses with a carrier grade NAT solution, because of the lack of IPv4 address space.
Sweden	Yes
Other countries	
Australia	AARNet: no; customers: yes
Bosnia/ Herzegovina	Yes
Brazil	Not that we are aware of.
Hong Kong	Yes

4.7 Lambda and point-to-point fixed bandwidth traffic

As in the past two years, 21 of the GÉANT partner NRENs who responded to our questionnaire this year currently offer dedicated wavelengths (lambdas) to their clients. As of 31 January 2014, five NRENs (up from three a year earlier) had dynamic lambdas. Three NRENs offered only one or two ports for this; the Netherlands and Poland offered 35 and 21 ports, respectively.

The number of static point-to-point fixed bandwidth connections that were live at the end of January 2014 ranges from three to 511 (HEAnet in Ireland). The provisioning time ranges from a few minutes to three months. Table 4.7.1 shows that at the end of January 2014 almost 1300 static point-to-point lambdas were live, while there were over 1400 static point-to-point fixed bandwidth connections.

As originally indicated by the 2010 *Compendium*, measurement of the traffic on such lambdas is sometimes complex and not added to the traffic on the rest of the network. Table 4.7.1 gives an overview of the large number number of lambdas provisioned as of 31 January 2014 and it is an indication of the large amount of traffic carried over separate paths.

Many NRENs do not measure this type of traffic at all, whereas others are only able to measure it via their own routers and/or IP-based traffic. An alternative method to measure lambda take-up and traffic still needs to be found. One proposal is to measure the number of circuits, rather than the traffic itself. Table 4.7.1 at least provides an overview of the number of lambdas provisioned as of 31 January 2014.

Table 4.7.1 – Lambda provisioning

Country	Lambdas?	Number static	Static point to-point fixed-bandwidth connections	Number dynamic	Charge?	Provisioning time	Number leaving country or NREN
GÉANT partner countries							
Belgium	Yes	123	132	0	Yes	24 hours	2
Czech Republic	Yes	15	4	1	No, but planned	3 months	5
Denmark	Yes	142	20	2	Yes	3 weeks	We use Bandwidth-on-Demand for this purpose
Estonia	Planned						
Finland	Yes	117	234	0	Yes. For example, fixed yearly price for 1 Gb/s and 10 Gb/s lightpaths.	1 Gb/s: typically 1 week if fibre infrastructure exists. 10 Gb/s: 8-12 weeks.	3
France	Yes	132			No	3 months	8
Germany	Yes	43	43	0	Yes	On average, 10 days	16, Only CBF
Greece	Yes			0	No	2 days to provision a new lambda on existing link	None
Hungary	Yes	70	10	0	No	Depends on availability of transponders or ports	2
Ireland	Yes	64	511	1	Yes, they are charged as per a Normal circuit.	4-6 weeks	0
Italy	Yes	110	30	0	Yes	30 days	5
Lithuania	Yes	13	8	0	No, but in practice users speed up the process by buying their own coloured interfaces.	Aliens add up easily, but we do not possess surplus transponders so new ones should be purchased by means of public procurement	7
Luxembourg	Yes	24	34	0	No	1 month	1
Moldova	Planned						4
Netherlands	Yes	210	242	35	Yes	3 weeks excluding new fibre orders	18
Norway	Yes	3	4	0	Yes	4-8 weeks	0
Poland	Yes	80	0	21	No	1 day	12
Portugal	Yes	25	147	0	Historically no costs were charged, though the official policy states that costs could be charged.	If no purchases are needed, one week. If purchases are needed, one month	3
Slovenia	Yes	3	3	0	No	Approx. one week, excluding all the meetings with the institution and waiting time for the equipment that the institution needs to provide to be delivered	2
Spain	Yes	176			No	Minutes, if hardware (TRBDs) is available on equipment	8

Table 4.7.1 – continued

Country	Lambdas?	Number static	Static point to-point fixed-bandwidth connections	Number dynamic	Charge?	Provisioning time	Number leaving country or NREN
GÉANT partner countries							
Sweden	Yes	Less than 10	Less than 10	0	Yes	Between 10 min and 12 weeks	8
Switzerland	Yes	6	14	0	Yes	1 month	3
UK	Yes	34	0	0	Yes, over 1 Gb	45 working days	17
Other countries							
Brazil	Yes	0	0	0	No	Two days	0
Canada	Yes	10	65	0	No	10 days	14
Hong Kong	Yes						
Japan	Yes				No		Unknown
Korea	Yes	10	30	-	No	Within 1 minute	10
New Zealand	Planned						
Russian Federation	Yes	4	12		Yes	0	4
USA	Yes				Yes	Pre-deployed services, such as pre-placed transceivers, may be turned up within hours but generally require 72 hours notice to ensure proper notification of non-service-affecting maintenance. Due to the diverse and expansive geography of the United States, shipping times may dominate turn-up speed for services that are not pre-deployed.	Several circuits, such as the ANA 100G, exit Internet2, however no lambdas egress and become alien wavelengths in another optical domain.

5 MIDDLEWARE SERVICES

Middleware services provide an essential bridge between the network infrastructure and its uses. Below, Section 5.2 considers key security services, including anti-spam measures and mechanisms for sharing information on security issues. Section 5.3 examines various authentication and mobility services: specifically, identity federations (5.3.1), digital certificates (5.3.2) and eduroam take-up across Europe (5.3.3).

5.1 Overview

Service access is becoming increasingly independent of the physical location either of the user or of the service. As a result, there is a growing need for **security services**, identity federations and certification services; in all these areas, which involve secure access by remote users, developments are rapid.

Important new developments in security include the adoption of structured formats for exchanging information about computer incidents, and the use of network devices for addressing security threats. Many NRENs are also active in the related area of spam filtering.

Twenty-seven GÉANT partner NRENs currently provide an **Authentication and Authorisation Infrastructure** (AAI); eleven are planning to introduce one. In most cases, the web single-sign-on federation is operated by the NREN. Most of the GÉANT partner NRENs (and a few non-GÉANT NRENs) have joined or are planning to join the **eduGAIN interfederation service** — a development that holds the promise of service access across federations.

By 31 December 2014, approximately 150 000 valid outstanding **server certificates** were being used by GÉANT partner NRENs. Of those, around two-thirds had been issued under the TERENA Certificate Service.

eduroam has shown remarkable growth over the past year: the number of locations with eduroam availability grew by 25%. The number of authentications more than tripled. By September 2014, it was approaching 150 million authentications per month.

5.2 Security services

As security services are becoming increasingly important to NRENs, the questionnaire for this year's *Compendium* included several additional questions related to security. The responses are summarized in Graph 5.2.1. In addition, the answers to some of the new questions are shown in Table 5.2.2.

This information shows that 90% of the GÉANT NRENs take measures to reduce spam activities. Although nearly two-thirds of the GÉANT NRENs were impacted by DDoS[1] attacks last year, less than 10% had previously implemented mitigation measures. By contrast, only 5% of the GÉANT NRENs were impacted by route/IP hijacking, whereas 36% had mitigation measures in place. Thirty-nine percent of the NRENs have a Chief Information Security Officer. A similar percentage of NRENs work according to a formal security policy, even though only 14% follow formal security standards (such as ISO 27001). Twenty-five percent of GÉANT NRENs are planning to introduce such standards.

For further information on how NRENs have recently been collaborating in the area of security, see for example the TF-CSIRT[2] web pages at **www.terena.org/activities/tf-csirt**.

[1] Distributed Denial of Service Attack.
[2] TF-CSIRT is the GÉANT Association Task Force on Computer Security Incident Response Teams.

Graph 5.2.1 – Security services, GÉANT NRENs

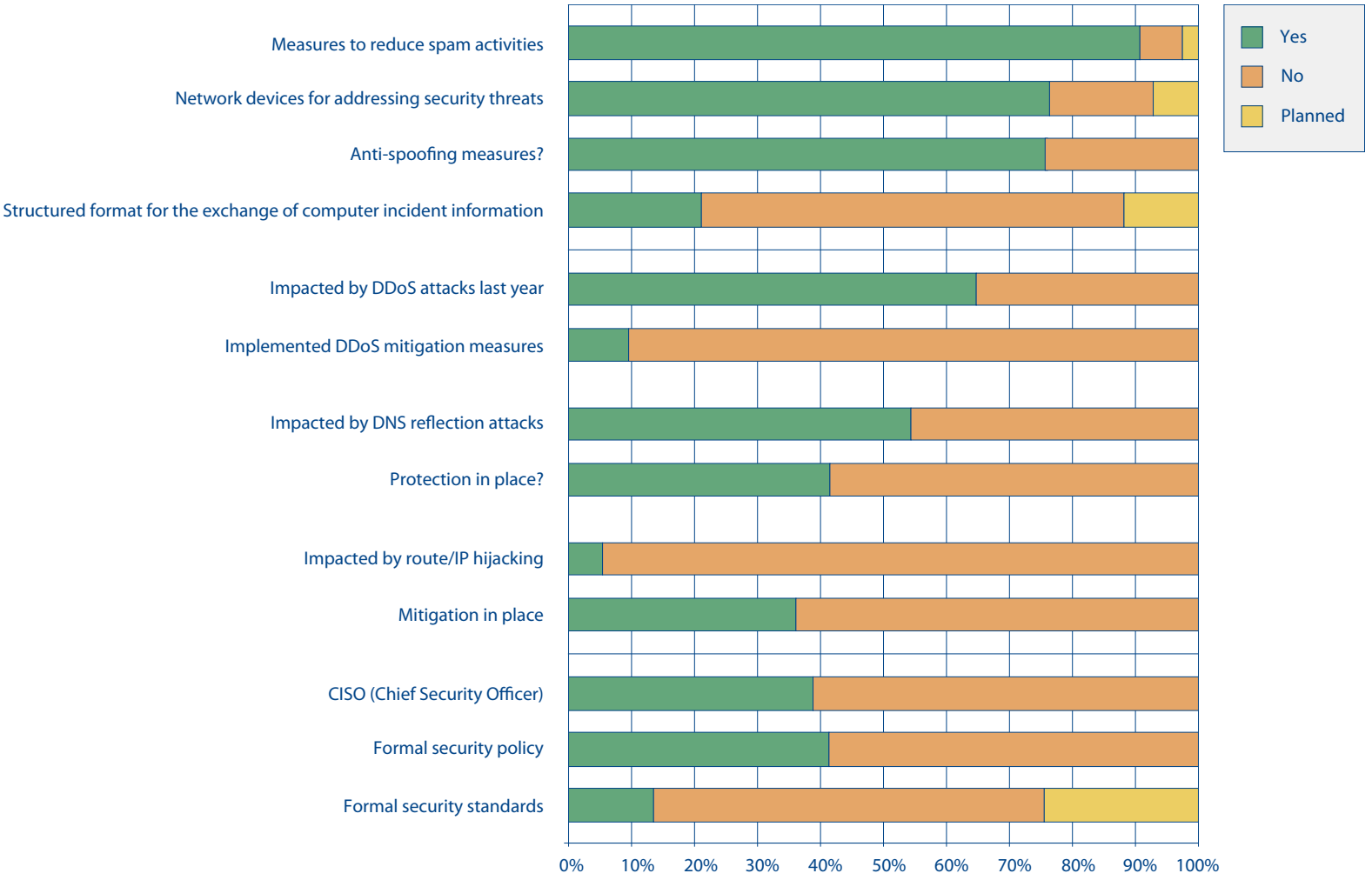


Table 5.2.2 – NREN security services

Country	Negatively impacted by DDoS attacks	DDoS mitigation measures	Negatively impacted by DNS Reflection / Amplification attacks?	Protection in place?	Negatively impacted by route/IP hijacking	Mitigation measures	Designated CISO	Formal security policy	Formal security standards
GÉANT partner countries									
Armenia	Yes	No		Yes	Yes	No	Yes		Yes
Austria	No	NetFlow Data	No	No	No	No	No	No	No
Belarus	Yes	No	No	No	No	Monitor routing changes	No	Yes	No
Belgium	Yes	Filters on the core routers + remote triggered blackhole filtering towards upstream providers	Occasionally additional load on DNS server (but not problematic)	Yes	No	No	No	No	Planned
Bulgaria	No	No	No	Yes	No	No	No	Yes	No
Croatia	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Planned
Cyprus	Yes	No	No	No	No	No	No	No	No
Czech Republic	Yes	NetFlow data.	Yes	Yes	No	Monitoring	No	No	No
Denmark	No	No	No	No	No	No	No	No	Planned
Estonia	Yes	No	Yes	No	No	No	No	No	No
Finland	Yes	We have implemented BGP blackhole communities that can be used to discard traffic to affected hosts. We also have a self-made tool for adding stateless firewall filters on demand. However, both of the tools require manual intervention.	Yes	Yes	No	We use RIPE RIS alert service in order to detect whether someone announces our prefixes or more specifics.	No	Yes	Yes
France	Yes	Blackholing at several levels already in place. DDOS mitigation will be deployed during 2015.	Yes	Yes	No	No	Yes	Planned	Planned
Georgia	Several times	Depends on case	No	No	No	Monitor routing changes	No	Yes	No
Germany	No	NetFlow-Data and SNMP-Data	No	Yes	No	Yes	Yes	Yes	Yes
Greece	Yes	Firewall on Demand service to currently block (could also mitigate) the attack	Yes	Yes	No	No	Yes	No	No

Table 5.2.2 – continued

Country	Negatively impacted by DDoS attacks	DDoS mitigation measures	Negatively impacted by DNS Reflection / Amplification attacks?	Protection in place?	Negatively impacted by route/IP hijacking	Mitigation measures	Designated CISO	Formal security policy	Formal security standards
GÉANT partner countries									
Hungary	Yes	blackholing outside NIIF network after detection of the sources	Yes	Yes	No	No	No	Yes	Yes
Iceland	Yes	Blackhole routing.	Yes	No	No	No	Yes	No	No
Ireland	Yes	Filtering	Yes	Yes	Yes	Monitor routing changes.	Yes	No	No
Israel		No							
Italy	Yes		Yes	No					No
Latvia	Yes	Remote triggered blackhole	Yes	No	No	No	No	No	No
Lithuania	Yes	No. Transition to IPv6 is imminent.	Yes	No	No	No	No	Yes	No
Luxembourg	No	No	No	Yes	No	No	No	No	No
Moldova	No	No		No	No	No	Yes	No	Planned
Montenegro	No	ASA IPF	No	No	No	Yes	No	Yes	Planned
Netherlands	No	Filtering	Yes	Yes	No	RPKI	Yes	Yes	Planned
Norway	Yes	Rate limiting.	Yes	Yes	No	Border filtering and customer filter. In addition, strict filtering on BGP towards customers.	Yes	Yes	Yes
Poland	Yes	Blackholing and more sophisticated methods depending on DDoS targets. DNS servers auditing and patching — implementation of BCP 140. Implementation of BCP 38 was possible.	Yes	Yes	No	No	No	No	No
Portugal	Yes	No	No	No	No	RPKI	Yes	No	No
Romania	Yes	RTBF	Yes	No	No	We're using BGPmon for route changes.	No	Yes	No
Russian Federation	Yes	No	Yes	No	No	No	No	No	Planned

Table 5.2.2 – continued

Country	Negatively impacted by DDoS attacks	DDoS mitigation measures	Negatively impacted by DNS Reflection / Amplification attacks?	Protection in place?	Negatively impacted by route/IP hijacking	Mitigation measures	Designated CISO	Formal security policy	Formal security standards
GÉANT partner countries									
Serbia	No	No	No	No	No	No	Yes	No	No
Slovakia	Not significantly	No	No	No	No	No	No	No	No
Slovenia	No	Routes to blackhole with BGP, rate limiting.	No	No	No	No	No	No	No
Spain	No	Mitigation system at the backbone using BGP.	No	Yes	No	No	No	No	Planned
Sweden	No	No	No		No	Yes	Yes		No
Switzerland	Yes	No	Yes	No	No	No	Yes	No	No
Turkey	Some of our users (universities and research organizations) were affected.		Some of our users (universities and research organizations) were affected.	No	No	No	No	Yes	No
UK	Yes	Filtering of incoming UDP traffic using traffic policing rules at network ingress points.	Yes	No	No	No	Yes	Yes	Planned
Other countries									
Algeria	Yes	IPS for Data Center	No	Yes	No	No	Yes	No	No
Australia	Yes	RTBH, packet filtering via ACLs.	Yes	Yes	Yes	We monitor routing changes (usually post hoc); not using RPKI.	No	Yes	No
Bosnia/ Herzegovina	No	No	No	No	No	No	No	No	No
Brazil	Yes	DDoS mitigation through traffic monitoring using Arbor Peakflow solution. Flowspec (RFC 5575) and a proprietary threat management system.	Yes	Yes	Yes	No	No	Yes	Planned
Canada	No	No	No	No	No	No	No	No	No
Hong Kong	No	No	No	Yes	No	No	No	No	No

Table 5.2.2 – continued

Country	Negatively impacted by DDoS attacks	DDoS mitigation measures	Negatively impacted by DNS Reflection / Amplification attacks?	Protection in place?	Negatively impacted by route/IP hijacking	Mitigation measures	Designated CISO	Formal security policy	Formal security standards
Other countries									
Kazakhstan	No		No	Yes	No	No	No	No	Planned
Korea				No	No	No	Yes	Yes	Planned
Lebanon	No		No	No	No	No	Yes	No	No
Morocco				No	No	No	Yes	No	No
Sudan		No		No	No	No	No	No	No
South Africa	Yes		No	No	No	No	No	No	No
Taiwan	Yes. DDoS attacks originated from outside and inside were both often seen.	No	Yes, mainly originated from the outside.	No	No	No	No	Yes	Yes

5.3 Authentication and mobility services

State-of-the-art services give specific user groups access based on each user's identity and role (faculty, staff, student, etc.) as provided and managed by the users' home institution. As a result, access to services is becoming less dependent on the physical location either of the user or of the service. The research and education community is at the forefront of this development. Security is a key issue in this area: it is essential to know who wants to access a particular service and who is entitled to do what. This means that authentication and mobility services go hand in hand and that the development of these services can either constrain or stimulate the way other services are developed and delivered to users.

A pioneering mobility service is eduroam®[3], which was developed by the European NRENs and has grown into a secure roaming access service for the research and education community internationally. This service is currently offered by all GÉANT partner NRENs except Azerbaijan, Georgia and Ukraine, and by NRENs in a growing number of countries in other regions (for further information, see Section 5.3.3).

eduroam offers general Internet access. Access to more specific services belongs to the domain of identity federations.

5.3.1 Identity federations

An identity federation enables a user registered in the identity management system of his university or home institution to access services provided either by his university or by other institutions participating in the identity federation. Federated authentication across institutional boundaries originated in the NREN community. Like NRENs, federations have a variety of organisational forms (e.g.

[3] A registered trademark of the GÉANT Association.

a project within an NREN, a consortium, a separate entity, a collaboration with primary education, etc.). Most countries have a single federation for higher education and research. NRENs either operate the research and education federation themselves or have close organisational ties with the federation in their country. These federations have implemented data protection in accordance with national and EU Data Protection Acts and actively work to preserve privacy while enabling sharing of user-related information.

Identity federations provide access to a variety of services, which may include:
- library resources;
- catalogue systems and document delivery;
- collaboration tools such as wikis;
- web-conferencing and mailing-list subscription services;
- e-learning tools and web portals.

In addition, there are services such as:
- video- and web-conferencing;
- MCU booking systems;
- streaming video portals;
- software licensing;
- webshops for a range of academic services.

Service providers can use federated access to identify and authorise a particular set of users; for example, students who may be entitled to special terms for travel, mobile phones, etc.

As reported in the *Compendium* since 2006, the number of identity federations has been growing continually. In order to foster collaboration in this area, TERENA has facilitated the formation of REFEDS (Research and Education Federations), in which most federations collaborate. For further information, see **www.refeds.org**.

With the growth of identity federations and federated services, the extra advantages of interfederating them has been recognised. The oldest operational interfederation activity is Kalmar2, which links the Nordic federations. The eduGAIN interfederation service started operating in 2011. For further information on eduGAIN, see **www.eduGAIN.org**. Both eduroam and eduGAIN are supported by the EU through the GN3plus project.

Table 5.3.1.1 shows the current situation. Differences with respect to 2013 are highlighted in colour. Almost all GÉANT partner NRENs provide an AAI or are planning to do so. There are only four exceptions (BREN of Bulgaria, CYNET of Cyprus, SANET of Slovakia and URAN of Ukraine).

Since 2013, five more countries (Austria, Ireland, Israel, Slovenia and the UK) have joined eduGAIN, and more are planning to do so.

Table 5.3.1.1 – AAI (yellow highlights denote differences with respect to 2013)

Country	AAI provided?	Federation	NREN operated?	Interfederate?
GÉANT partner countries				
Armenia	Yes	No		
Austria	Yes	Yes	Yes	Yes: eduGAIN
Azerbaijan	No	No		
Belarus	Yes	No		No
Belgium	Yes	Yes	Yes	Yes: eduGAIN
Bulgaria	No	No	Yes	Yes: eduGAIN
Croatia	Yes	Yes	No	Yes: eduGAIN
Cyprus	No	No	Yes	No
Czech Republic	Yes	Yes	Yes	Yes: eduGAIN
Denmark	Yes	Yes	Yes	Yes: Kalmar, eduGAIN
Estonia	Yes	Yes	Yes	No, but plan for 2014
Finland	Yes	Yes	Yes	Yes: Kalmar, eduGAIN
France	Yes	Yes	Yes	Yes: eduGAIN

Table 5.3.1.1 – continued

Country	AAI provided?	Federation	NREN operated?	Interfederate?
GÉANT partner countries				
Georgia	Plan	No		No
Germany	Yes	Yes	Yes	Yes: eduGAIN
Greece	Yes	Yes	Yes	Yes: eduGAIN
Hungary	Yes	Yes	Yes	Yes: eduGAIN
Iceland	No	No		No
Ireland	Yes	Yes	Yes	Yes: eduGAIN
Israel	Yes	Yes	Yes	Yes: eduGAIN
Italy	Yes	Yes	Yes	Yes: eduGAIN
Latvia	Plan	No		No, but plan
Lithuania	Yes	Yes	Yes	No, but plan for 2014
Luxembourg	Yes	Yes	Yes	No, but plan for 2014
Macedonia	Plan	No		No
Malta	Yes	No	No	No, but plan
Moldova	Plan	No		No
Montenegro	Yes	No		No, but plan
Netherlands	Yes	Yes	Yes	Yes: eduGAIN
Norway	Yes	Yes	Yes	Yes: Kalmar, eduGAIN
Poland	Yes	Yes	Yes	Yes: eduGAIN
Portugal	Yes	Yes	Yes	No, but plan for 2014
Romania	Plan	No		No, but plan
Serbia	Yes	Yes	Yes	No, but plan for 2014
Slovakia	No	No		No
Slovenia	Yes	Yes	Yes	Yes: eduGAIN
Spain	Yes	Yes	Yes	Yes: eduGAIN
Sweden	Yes	Yes	Yes	Yes: eduGAIN
Switzerland	Yes	Yes	Yes	Yes: eduGAIN
Turkey	Yes	Yes	Yes	Plan for 2014
UK	Yes	Yes	Yes	Yes: eduGAIN
Ukraine	No	No		No

Table 5.3.1.1 – continued

Country	AAI provided?	Federation	NREN operated?	Interfederate?
Other countries				
Albania	No	Yes	No	
Algeria	Yes	No		No, but plan
Australia	No	Yes	No	Yes: eduGAIN
Bosnia/ Herzegovina	Plan	No		
Brazil	Yes	Yes	Yes	Yes: eduGAIN
Canada	Yes	Yes	Yes	Yes: eduGAIN
Japan	Plan	No		Yes: other
Lebanon	Plan	No		
Morocco	Yes	Yes	Yes	No, but plan for 2014
Kazakhstan	Yes	Yes	No	Yes: other
Korea	Plan	No		No, but plan
Kyrgyzstan	Plan	No		No, but plan
Hong Kong	No	No		
New Zealand	Plan	Yes	No	Yes: other
South Africa	Plan	No	No	No
Russian Federation	Plan	No		No, but plan
Sudan	Plan	No		No, but plan
Taiwan	No	No		No
US	Yes	Yes	Yes	Yes: other

5.3.2 Digital Certificates

Certification Authorities (CAs) issue digital certificates that certify that servers or users are who they claim to be. As such, they help to establish secure and reliable communication between servers, between users, or between a user and a server. Examples of such use include:

- a user with his browser connecting securely to a web server (server certificate);
- a user authenticating securely with a server (personal and server certificate);
- two users exchanging encrypted emails (personal certificates).

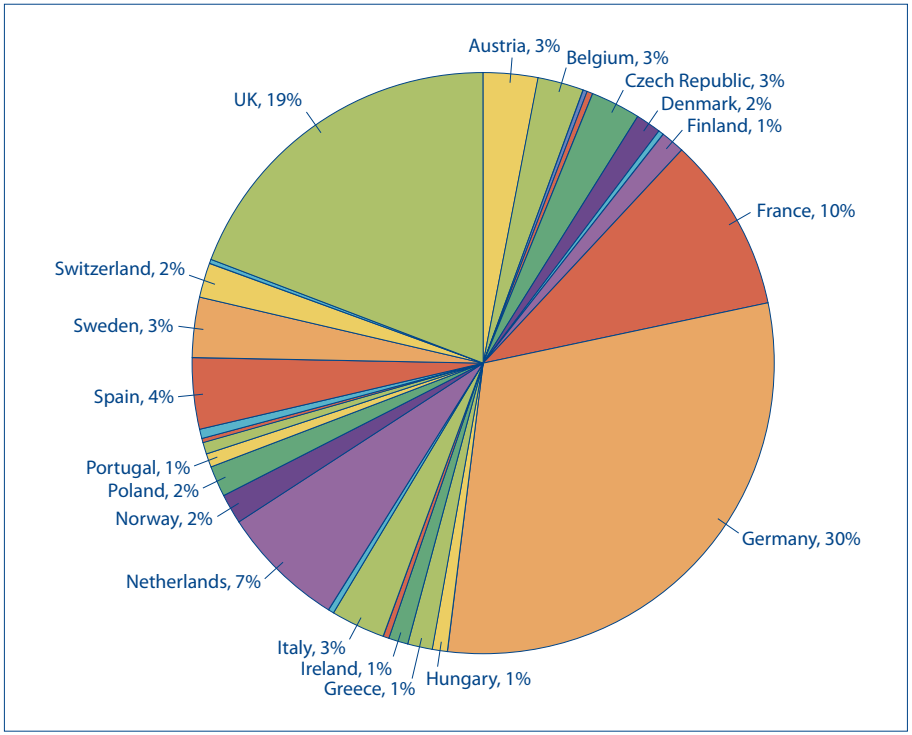
The Grid community requires secure authentication for users to log in to Grid resources; this requirement is met by using personal certificates. At present, server certificates are more widely used than client/personal certificates, as the former are required whenever a secure connection is needed between servers, or between a client and server.

In order to support the user community in deploying services securely (for example, in eScience), many NRENs run a certification authority (CA). However, certificates issued by these authorities are not automatically trusted outside the NREN's own domain. Therefore, a few years ago NRENs requested that TERENA offer what subsequently became known as the TERENA Certificate Service (TCS, see **www.terena.org/activities/tcs**). By December 2013, the TCS supported 28 NRENs for server certificates, 18 for personal certificates and eight for code-signing certificates.

Many NRENs do not rely solely on the TCS for issuing certificates. Currently, 29 GÉANT partner NRENs operate certification authorities in addition to, or independent of, the TCS (six more than last year). By far the largest of these is in Germany. In seventeen cases, the CA is operated by the NREN itself. Twelve NRENs use a commercial certification authority. Beyond the GÉANT area, many NRENs also operate their own CA. These CAs issue server certificates; most issue personal certificates as well. In recent years, several initiatives have been set up to create a trust fabric within the academic community among academic CAs. One example is TACAR (**www.tacar.org**), a repository set up by TERENA for safe storage and distribution of root CA certificates. Another, more far-reaching example is the set of Policy Management Authorities set up within the international Grid community. The European body is the EUGridPMA (**www.eugridpma.org**); worldwide collaboration is realised through the International Grid Trust Federation (IGTF, **www.igtf.net**). Many NREN CAs are affiliated to the IGTF.

Although there were some problems with the underlying dataset, we estimate that, as of 31 December 2013, there were around 150 000 valid outstanding server certificates in the GÉANT region (10 000 more than one year earlier).

Graph 5.3.2.1 – Division of server certificates, GÉANT partner countries



Around two-thirds of these had been issued under the TCS. How the server certificates are divided among the countries is presented approximately in Graph 5.3.2.1.

In addition to server certificates, there are several other categories of certificates. In terms of numbers issued, personal certificates are the second most important category after server certificates. Germany has issued the vast majority of these: almost 400 000 (compared to around 10 000 issued under the TCS).

5.3.3 eduroam

There is a secure, world-wide roaming access service that has been developed for the international research and education community: eduroam®.

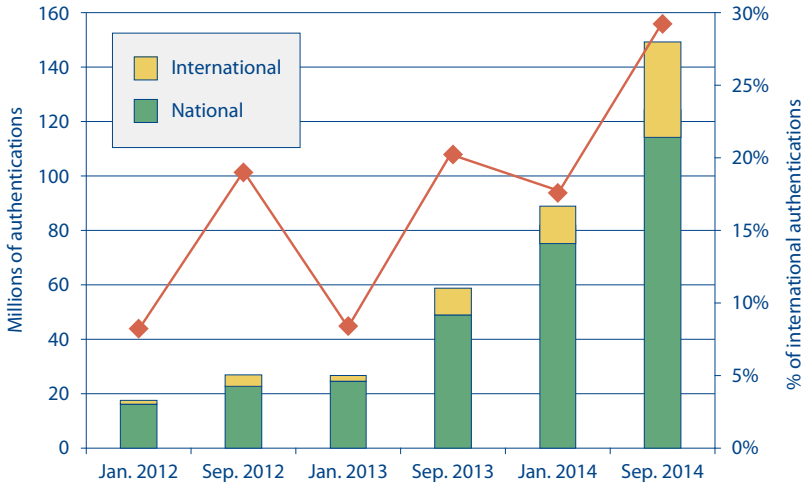
This service allows students, researchers and staff at participating institutions to obtain Internet connectivity campus-wide and when visiting other participating institutions, simply by opening their laptop and connecting to the eduroam WiFi network.

As of June 2014, eduroam is available in 69 countries and territories worldwide, up from 66 in 2013. There are 39 countries in the European eduroam confederation. Up-to-date information on eduroam is available at **www.eduroam.org**.

Even though eduroam may be available in a certain country, that does not mean that all institutions or students in that country have access to it. Of course, the fact that a student has eduroam credentials does not necessarily mean that he or she actually uses the eduroam service; it has to be available at appropriate locations. In October 2014, eduroam was available at more than 10 000 locations[4] in the GÉANT area, 25% more than in 2013; the highest numbers of locations were in the UK and Germany[5].

Take-up of eduroam has grown strongly in recent years, as illustrated by the number of successful authentications in the GÉANT area over the past two years. Between January 2013 and January 2014, the number of authentications more than tripled and is now approaching the 150 million per month. The growth in international authentications slightly outpaced the rate of national growth, as shown in Graph 5.3.3.1.

Graph 5.3.3.1 – Successful eduroam authentications, GÉANT area[6]



[4] 'Location' here means a hotspot, a building or a set of buildings where an eduroam service is offered by a single organisation.

[5] Statistics provided by the eduroam operations team and collated by Miroslav Milinović, SRCE.

[6] Data from the ETRL (European top level radius proxies logs) – not publicly available.

6 COLLABORATION SUPPORT SERVICES

It is becoming easier to introduce collaboration support services, because middleware services (see Section 5) are increasingly widespread. Below, Section 6.1 gives an overview of recent developments. Section 6.2 considers network collaboration tools. Section 6.3 documents NREN involvement in the provision of networked e-Science resources, including cloud resources. Section 6.4 examines e-learning and Section 6.5 interaction with NREN clients. Section 6.6 explores the relatively new areas of broker services and professional development. Finally, Section 6.7 examines the area of software development.

6.1 Overview

Seventeen GÉANT partner NRENs currently offer a multimedia content repository; ten others are planning to establish one.

We asked NRENs to provide information on three related resources in the area of **networked e-Science resources**:

- Grid middleware;
- Computing power;
- Storage facilities.

In some countries, these three related resources are provided by the same institution, but in many other countries the situation is mixed. In most countries, the NREN has some involvement in providing these resources.

Seventeen of the GÉANT partner NRENs currently offer cloud services that are not procured via a commercial vendor, and twelve others are planning to offer such services. NRENs that offer a commercial storage service or that host commercial content on their networks are far less common, though ten of the GÉANT partner NRENs (and several NRENs outside the GÉANT region) already do, or are planning to do, this. This situation has not changed much since last year.

Eighteen of the GÉANT partner NRENs currently provide an e-learning service, and five others are planning work in this area.

Twenty-eight of the GÉANT partner NRENs have separate customer-support departments. Sixteen GÉANT partner NRENs offer some form of best-practice guidance to client institutions, mostly through individual consultation and by publishing technical guides in various areas. Twenty-six GÉANT NRENs have dedicated marketing and communications staff, though in most cases no more than one or two staff members.

NRENs function as centres of excellence, in service of their clients. This year's *Compendium* survey has identified a number of services being provided by NRENs in the general category of 'brokerage'. This seems to be an area in which NRENs can achieve considerable savings for their customers and where there is potential for expansion. NRENs are also undertaking framework procurements for network and related equipment. Ten GÉANT NRENs offer some form of support for procurement processes. The majority (21 NRENs) are interested in benefiting from framework agreements put in place by another purchasing body, for a wide palette of services.

Eleven of the GÉANT NRENs own intellectual property rights to network software. Twenty-one are involved in open-source software development.

6.2 Network collaboration tools

Over the past ten years, NREN collaboration infrastructures and related services have become the cornerstone of European and worldwide collaboration among researchers and higher-education providers. Although collaboration hardware and software has not changed profoundly in the past few years, its significantly increased quality and reduced prices have made network-based virtual meetings

more appealing than ever. In research and education, collaboration technology are playing a key role in making project, research and administration work more effective, by virtually connecting remotely located personnel. Such remote collaboration helps to optimise how time is used, to reduce travel costs and to lower the environmental impacts of travelling.

Four pillars of the NREN collaboration infrastructure are:

1. Numbering schemes and Voice over IP (VoIP) to connect institutional IP telephony deployments or individual end-users.
2. Video- and web-conferencing to provide a high-quality audio/video-based collaboration environment, often enhanced by other tools enabling joint work.

NB: This year's *Compendium* does not report on elements 1 and 2.

3. Group collaboration services: i.e. the bundling of services that allow collaborative groups to form and work together easily, independent of their location.

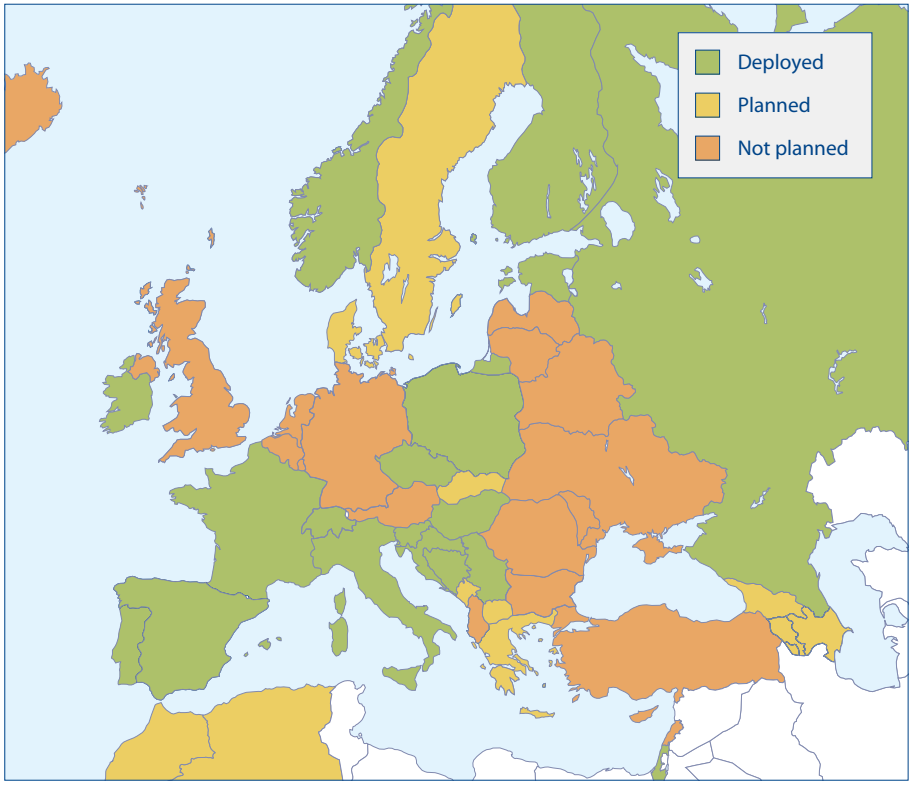
NB: Information on element 3 is available online via the NREN Services map on the *Compendium* website[1].

4. Multimedia content repositories for online presentation of materials recorded by higher education and research organisations to complement remote teaching/learning and science dissemination.

Element 4 is reported on below.

As in previous years, we asked NRENs about their use of multimedia repositories (i.e. audio/video archives) and the streaming services they offer. As shown in Map 6.2.1 , a total of 16 GÉANT partner NRENs currently offer a multimedia content repository, and 10 others are planning to establish one (no change since last year). An online table[1] gives additional information, including links to the various repositories.

Map 6.2.1 – Multimedia content repositories



[1] Available via the services map at compendium.terena.org/reports/nrens_services.

6.3 Networked e-Science resources

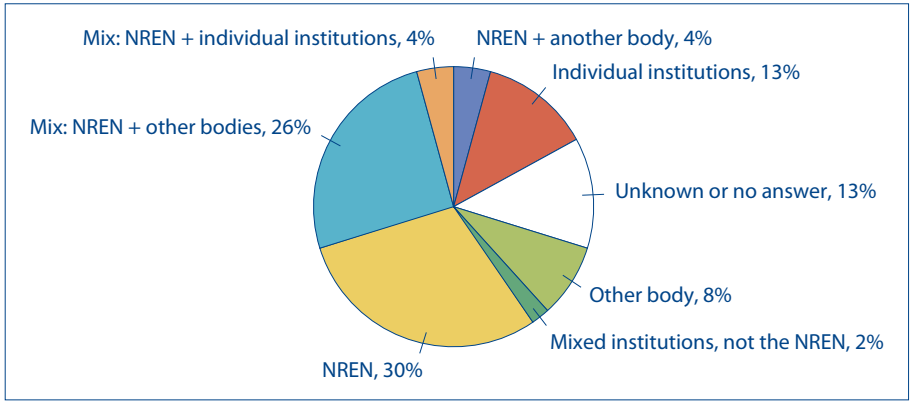
Because resources needed by scientists are increasingly being made available via the Internet, this area has become important for NRENs. In many cases, the NRENs already provide the networking infrastructure for such services and are offering additional services to the Grid community. For this year's *Compendium*, we asked NRENs to provide information on three related resources in this area:

- Grid middleware;
- Computing power;
- Storage facilities.

In some countries, these three related resources are provided by the same institution, but in many other countries the situation is mixed. In most countries, the NREN has some involvement in providing these resources. In some countries, not all of them are available.

Graph 6.3.1 gives an overview of the wide variety of existing models for provision of such resources, in which we were unable to distinguish any geographic pattern.

Graph 6.3.1 – Provision of networked e-Science resources



6.3.1 Cloud services

Seventeen of the GÉANT partner NRENs currently offer cloud services that are not procured via a commercial vendor (up from 16 last year), and twelve others are planning to offer such services. This year, five NRENs brokered agreements with cloud service providers (up from one last year). Several other NRENs are considering doing this. Table 6.3.1.1 gives details for those NRENs that have either existing activities or plans in this area. Changes with respect to 2013 are highlighted.

NRENs offering non-commercial services are far more common than those offering commercial storage services or hosting commercial content on their networks. However, a number of NRENs are already involved, or are planning to become involved, in such commercial activities. Many NRENs, including 19 of the GÉANT partners NRENs (the same number as last year), mirror content from outside the NREN network. Because little has changed in this area since last year, the full information is not repeated in this year's *Compendium*.

Table 6.3.1.1 – Cloud services

Country	Cloud services not obtained through a vendor?	Virtual machines?	Details	Which other services do you offer or are planning to offer?	Does your NREN broker agreements with cloud service providers?
GÉANT countries					
Armenia	Yes	Yes			No
Belarus	Yes	Yes	Standard VMs, small resource pool available.		No
Belgium	Yes	Planned	IaaS	Storage and computing.	No
Cyprus	Planned	Planned		Back-Up MX, Primary DNC, etc.	No
Czech Republic	Yes	Yes	Distributed storage infrastructure with 22 PB raw capacity.	IaaS HPC cloud, PaaS for scientific users planned, SaaS and storage services under discussion.	No
Denmark	Planned	Yes	KVM	Storage and computing.	Yes: IPNETT, BOX: Box.com + XaaS
Estonia	Yes	Yes	VMs	SaaS	No
France	Planned				
Georgia	Planned	Planned			No
Germany	Yes	Planned			Yes DFN-members, non-commercial: storage
Greece	Yes	Yes	We offer two IaaS services addressed to different end-users (i.e. ViMa is offered to NOCs and ~okeanos to end-users). The characteristics of the VMs vary. Maximum allowed values are 4vCPUs, 4GigRAM, 100Gig Disk. More resources may be provided upon request and justification.	Computing and Storage services. ~okeanos (https://okeanos.grnet.gr/home/) is a brand new IaaS Service based on the GRNET cloud computing infrastructure. Cyclades is the Virtual Compute and Network service of ~okeanos. With Cyclades you can build your own virtual machines, always connected to the Internet, manage them, destroy them, connect to them and take a handful of other actions, all from inside your favourite web browser. Pithos+ is the Virtual Storage service of ~okeanos. Pithos+ enables you to store your files online, share them with friends and access them anytime, from anywhere in the world.	No
Hungary	Yes	Yes	KVM-based IaaS cloud, virtual networks, additional geographically distributed huge storage, multi-site deployment.	IaaS virtual machines, virtual interconnects.	No
Ireland	Yes	Planned	EduStorage (Cloud storage).	Planning VMs as a service, planning cloud computing (virtual servers).	Yes: Microsoft, Blackboard, Moodlerooms: storage, computing, LMS
Israel	Planned	Yes			Planned

Table 6.3.1.1 - continued

Country	Cloud services not obtained through a vendor?	Virtual machines?	Details	Which other services do you offer or are planning to offer?	Does your NREN broker agreements with cloud service providers?
GÉANT countries					
Italy	Planned	Yes	Aiming to provide up to a few thousands VMs, with different configurations: from single-CPU to many.	IaaS, Storage-aaS (personal, initially), PaaS (similar to Identity Provider as a Service).	Planned: ownCloud, Google, Box. Integration of commercial and NREN storage provision in a way that is transparent to end-users.
Latvia	Yes	Yes			No
Lithuania	Planned	Planned	Currently in the planning stage.	Backup, storage, webspace, email.	No
Macedonia	Yes			Part of health information system (Ministry of health).	
Moldova	Planned				
Netherlands	Yes	Yes	Commercial (cloud) service agreements are provided via SURFmarket, HPC services via SURFsara. HPC services of SURFsara among others, for an overview see https://surfsara.nl/SURFsara-services.	Overview of all the cloud services from commercial service providers and member institutes is available at http://www.surf.nl/diensten-en-producten/surfconext/op-surfconext-aangesloten-diensten/index.html.	Yes: see http://www.surf.nl/diensten-en-producten/surfconext/op-surfconext-aangesloten-diensten/index.html. Current focus is on Microsoft, IaaS providers, PaaS providers, Identity-as-a-Service providers, global services (and others).
Norway	Planned	Planned		IaaS, PaaS, SaaS.	Yes: Box.com. Personal storage and collaboration
Poland	Yes	Yes	Virtual machines, applications on demand, cloud storage.	On-Demand computing (IaaS, PaaS, SaaS), cloud storage: remote distributed file system (National Data Storage, OpenStack Storage (for several projects).	Planned: Microsoft Office 365.
Portugal	Planned				
Romania	Planned	No	N/A	N/A	No
Slovenia	Yes	Yes	Minimum setup: 4x vCPU, 8GB RAM, 160GB disk.	IaaS	No
Spain	Planned	Planned		We offer cloud spam filtering. We are planning to offer more services – main candidates are mail, VoIP, electronic signature, IaaS and webconferencing.	Planned: Spamina
Sweden	Not planned				Planned, will hopefully be launched end of this year.

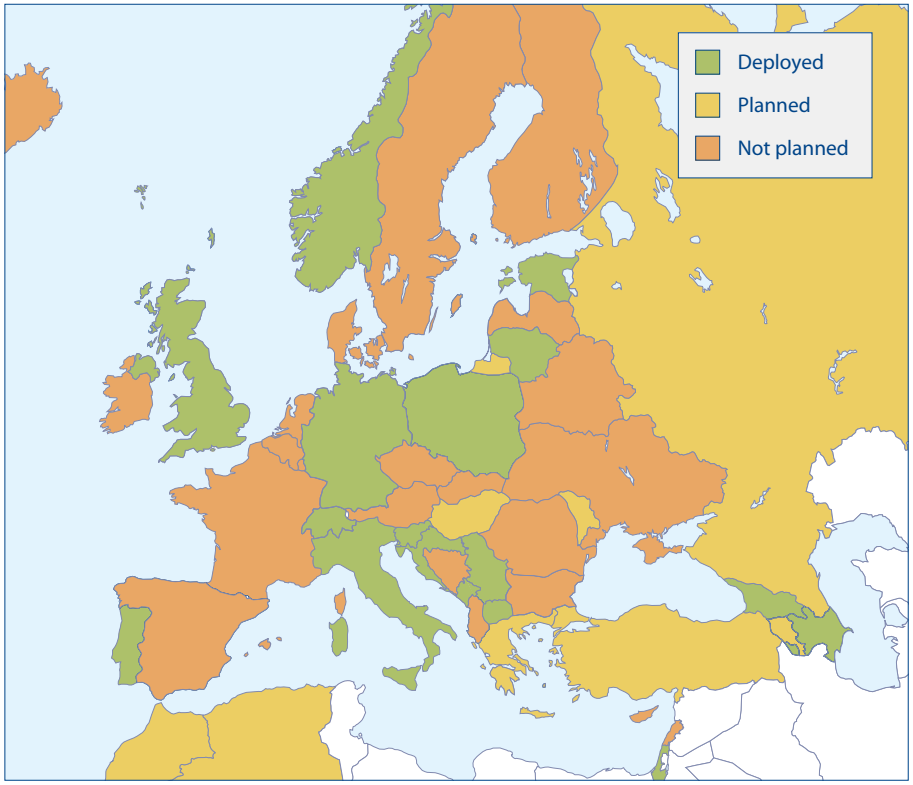
Table 6.3.1.1 - continued

Country	Cloud services not obtained through a vendor?	Virtual machines?	Details	Which other services do you offer or are planning to offer?	Does your NREN broker agreements with cloud service providers?
GÉANT countries					
Switzerland	Yes	Yes	VMs based on OpenStack, offered to all universities who opt in.	SWITCHdrive – ('sync & share') service based on OwnCloud.	No
Turkey	Yes	Yes	OpenStack with KVM.	Production level IaaS and Hadoop services are offered.	No
UK	Not planned		We have framework agreements for File Sync and Share and Telephony.		Yes: Arkiving, Google, Microsoft. Archive tape storage; Google Apps for Education; Microsoft 365.
Ukraine	Yes	Yes			
Other countries					
Algeria	Planned	Yes			No
Australia	Yes	No		Storage, videoconferencing, VPN. AARNet needs to work in harmony with government programmes NeCTAR and RDSI to avoid duplication of cloud and related services.	Yes: Box, Zoom. Cloud storage, videoconferencing.
Bosnia/ Herzegovina	Planned	No			No
Brazil	Planned	Planned	Storage		Planned
Kazakhstan	Planned	No			No
Korea (South)	Planned	Yes	VMWARE	DTN (Data Transfer Node): maximizing data transfer performance.	No
Morocco	Planned				
New Zealand	Yes			Net+ - http://www.internet2.edu/netplus/.	
Russian Federation	Yes	Yes	Cloud services on Openstack + ClasterFS platform.		No
Sudan	Planned	Planned		Web hosting, DNS, Mail.	No

6.4 e-Learning

As shown by Map 6.4.1, 18 of the GÉANT partner NRENs currently provide an e-learning service, up from 17 in 2013. Five others (highlighted in yellow) are planning work in this area, up from four last year. Turkey has started a new e-learning service. In many cases, further information can be found on the NREN websites. Several NRENs beyond the GÉANT region are also active in this area.

Map 6.4.1 – NREN e-Learning services



6.5 Clients interaction, and knowledge dissemination

As in previous years, almost all NRENs provide some form of training courses to their users, and most organise national user-conferences. Compared to previous years, the situation has not changed much. For further information about such activities and the associated resources that NRENs make available to their users, see the separate TF-CPR *Compendium*: **www.terena.org/activities/tf-cpr/compendium**.

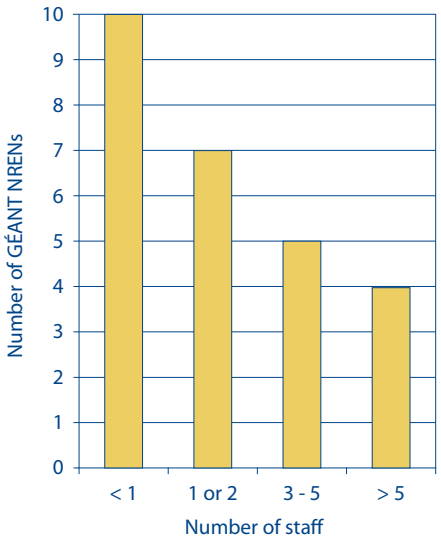
Twenty-eight of the GÉANT partner NRENs have separate customer-support departments. Twenty-seven GÉANT NRENs publish on their website lists of the services they offer. Sixteen GÉANT partner NRENs offer some form of best-practice guidance to client institutions. As clearly shown by Table 6.5.1, such guidance can take many forms; most common are individual consultation with member institutions and publication of technical guides in various areas. In addition, campus best-practice guides are developed through the GN3plus project: more information is available at: **http://services.geant.net/cbp**.

Table 6.5.1 – NREN best-practice guidance

GÉANT partner countries	
Belgium	We offer technical advice (if needed on site, free of charge) for all NREN-related services to our connected institutions and develop best practices for our connected institutions.
Czech Republic	Mainly by means of personal consultations for individual cases.
Estonia	See: http://kuutorvaja.eenet.ee/wiki/Kuutõrvaja.
Finland	Best-practice documents are available in a wiki: https://info.funet.fi.
Germany	Video services, security services , legislation, customer contracts.
Ireland	Security, networking, eduroam, federation.
Lithuania	Consultations and advisory upon request.
Netherlands	Many different areas, including network, collaboration infrastructure, etc. See: http://www.surf.nl.
Norway	We publish UFS (whitepapers on campus best practices) and consultancy on demand.
Romania	On best-effort basis.
Serbia	AMRES is working on best-practice documents for client institutions; the results are available at http://cbp.rcub.bg.ac.rs/.We are also participating in the GEANT CBP task.
Slovenia	Recommendations on network setup and management, as well as IPv6 transition. We also introduce Universities to campus best practice results.
Switzerland	AAI guides.
Turkey	E-mail list, blog, documents, presentations on national user-conference.
Other countries	
Australia	Consultancy services: see http://www.aarnet.edu.au/services/enterprise-services-consulting.
Hong Kong	See: http://www.jucc.edu.hk.
Korea (South)	ScienceDMZ, PerfSONAR, network architecture of campus network, security, etc.
Sudan	Through workshops provided to members, meetings and consulting.

This year, for the first time, we asked the NRENs whether they have dedicated marketing/ communications staff and if so, how many staff members they have in this area. As summarized in Graph 6.5.2, 26 GÉANT NRENs have some staff in this area, although for most of them the staff allocation is no more than two and in many cases less than one staff member. The largest departments, with more than five staff members, are in Belgium, the Netherlands, Switzerland and the UK. Many of the non-GÉANT NRENs also have staff in this area; RNP of Brazil reports the largest staff size.

Graph 6.5.2 – NREN marketing/ communications staff



6.6 Broker and professional services

NRENs function as centres of excellence, in service of their clients. This year's *Compendium* survey has identified a number of services being provided by NRENs in the general category of 'brokerage'; that is, a NREN using its expertise and knowledge to engage with the market on behalf of its clients. A prime example of such brokerage is software licensing, whereby NRENs can negotiate bulk deals at the national level for generic, e-learning and other applications. This seems to be an area in which NRENs can achieve considerable savings for their clients and where there is potential for expansion.

NRENs are also undertaking framework procurements for network and related equipment. Such procurements are often directed primarily at NREN

requirements, though client institutions can use the negotiated terms to their advantage by purchasing equipment for their own networks. Maintenance and support contracts are often part of such frameworks; in some cases, there is a demand for the NRENs to manage these contracts as well.

This year, we asked NRENs whether they provide support for procurement processes or whether they can use a centralised purchasing body. We also asked whether NRENs provide premium professional services or are involved in any e-government public services such as e-voting, e-ID issuing or e-ID related applications. The results, shown in Table 6.6.1, are quite similar to those of 2013.

Legend for Table 6.6.1

	A: Type of procurement process support:	B: Can you make use of the services of a centralised purchasing body?	C: Do you provide premium professional services?
1	Joint procurement of software and software licenses.	Yes, we have to use such a body.	Consultancy services.
2	Joint licensing for digital libraries.	Yes, we are free to use this body if we want to, but only for our own needs.	Security audits.
3	Joint procurement of equipment or negotiation of preferential rates for users or end users.	Yes, and we can also use this for our client institutions.	Support on implementing NREN services (eduroam, IPv6, BoD).
4	Other.		Other services.

Table 6.6.1 – Procurement, broker and professional services

Country	A: Type of procurement process support:	B: Can you make use of the services of a centralised purchasing body?	C: Do you provide premium professional services?	Involvement in e-government services
GÉANT partner countries				
Armenia	3: equipment procurement		1: consultancy	No
Austria	No	1: obligatory	3	No
Belgium	Yes		1: consultancy	Yes
Croatia	No	No	2: security audits	Yes
Cyprus	4: other	1: e-procurement from government	3	No
Czech Republic	1: software procurement	2: optional	1: consultancy	No
Denmark	No	3: also for clients: both state procurement agency and Nordunet	2: security audits	No
Estonia	No	No	1: consultancy	No
Finland	1: software procurement	2: optional	1: consultancy	No
France	No		1: consultancy	No
Georgia	No	No	1: consultancy	No
Germany	No	No	2: security audits	No
Greece	No	No	3	Yes
Hungary	No	No	4: other	No

Table 6.6.1 – continued

Country	A: Type of procurement process support:	B: Can you make use of the services of a centralised purchasing body?	C: Do you provide premium professional services?	Involvement in e-government services
GÉANT partner countries				
Ireland	2: digital libraries, 3: equipment procurement	2: optional	2: security audits	Yes
Israel	1: software procurement	1: obligatory	3	No
Italy	No		2: security audits	No
Latvia	No	2: optional	3	No
Lithuania	No		1: consultancy	Yes
Luxembourg	No	2: optional	3	No
Macedonia	No		3	Yes
Moldova	Planned	3: also for clients	3	No
Montenegro	No	No	3	No
Netherlands	3: equipment procurement	1: obligatory	1: consultancy	Yes
Norway	1: software procurement	3: also for clients	1: consultancy	No
Poland	3: equipment procurement	No	1: consultancy	Yes
Portugal	No		3	Yes
Romania	No	1: obligatory		No
Serbia	No	No	3	No
Slovakia	No	No	3	No
Slovenia	No	No	1: consultancy	No
Spain	Yes: dark fibre networks for regional R&E networks	3: also for clients	No	Yes
Sweden	No	2: optional	No	Yes
Switzerland	1: software procurement	No	3	Yes
Turkey	No	No	1: consultancy	Yes
Ukraine	No	2: optional	3	Yes
Other countries				
Algeria	2: digital libraries		3	No
Australia	Consulting on an ad hoc basis, see: http://www.aarnet.edu.au/services/enterprise-services-consulting	2: optional	1: consultancy	No

Table 6.6.1 – continued

Country	A: Type of procurement process support:	B: Can you make use of the services of a centralised purchasing body?	C: Do you provide premium professional services?	Involvement in e-government services
Other countries				
Brazil	Planned	3: also for clients	3	Yes
Canada	3: equipment procurement		3	No
Hong Kong	1: software procurement		3	No
Korea (South)	No		1: consultancy	No
Lebanon	3: equipment procurement	2: optional	No	No
Morocco	No	No	1: consultancy	No
New Zealand	3: equipment procurement		1: consultancy	No
Russian Federation	Planned	2: optional	Yes, consultancy services	Yes
Sudan	No	No	3	No

We also asked the NRENs whether they are or would be interested in providing services to other NRENs. Five GÉANT partners already do this, and six others are interested in doing so. We also asked the NRENs whether they would be interested in benefiting from framework agreements put in place by another purchasing body. The majority (21) of the GÉANT NRENs is interested in this, for a wide palette of services ranging from communications and equipment to software licenses and library periodicals. The full results are shown in Table 6.6.2.

Table 6.6.2 – NREN to NREN services

Country	Services to other NRENs	Interested in framework agreements put in place by another contracting authority/ centralised purchasing body?
GÉANT partner countries		
Belgium	No, but we are interested in doing this.	Yes, how is not clear yet.
Cyprus	No	Yes: equipment (routers, switches, etc.).
Denmark	No	Yes: infrastructure equipment and cloud vendors.
Finland	No	Yes: cloud services, data security services.
Georgia	No	Yes: would be good to have centralised purchasing for South Caucasus countries for GEANT connectivity channel.
Germany	No	Yes
Greece	No, but we are interested in doing this: cross-border link to enable diversity of physical routes. Cloud services.	Yes
Hungary	No, but we are interested in doing this: any services another NREN can reasonably exploit (and vice versa).	Yes: practically everything related to our e-Infrastructure activities. However, public procurement rules and regulations may be different in the various countries.

Table 6.6.2 – continued

Country	Services to other NRENs	Interested in framework agreements put in place by another contracting authority/ centralised purchasing body?
GÉANT partner countries		
Iceland	No	Yes: comms eq/IRUs
Ireland	Any of our existing services with cost-recovery charging.	Yes: software licensing, information systems, cloud services, data transmission.
Israel	No	Yes
Lithuania	No, but we are interested in doing this: connectivity, transit and expertise. LITNET will provide 10G lambda to GEANT POP, and a peering connection, and fibre to the border with Belarus if BASNET wishes to connect Minks-Vilnius.	
Luxembourg	No	Yes: network equipment.
Malta		Yes: software/support licencing; library periodicals.
Moldova	No, but we are interested in doing this.	Yes: equipment , license to scientific journals.
Netherlands	No, but we are interested in doing this. This subject is too complex to be shortly described (i.e., within the scope of this study) - subject for TF MSP, GEANT etc.).	Yes: pan-European NREN services, supporting international collaboration (international, cross-institutional & cross-sectoral).
Norway	Yes: marketing & communication services via NORDUNet.	Yes: cloud services, software licenses etc.
Poland	Yes: connectivity services for neighbouring NRENs.	Yes
Romania	Yes: RENAM is connected to GEANT Bucharest POP and Internet using our infrastructure.	Yes
Slovakia	Yes: cross border optical connection to AT, CZ and PL.	No
Spain	No	Yes
Switzerland	No	Yes: SW and SaaS products.
UK	Yes: video Conferencing to HEAnet and Belnet.	No
Ukraine		Yes
Other countries		
Australia	No, but we are interested in doing this: advice and guidance (via APAN) – not charged; FileSender & CloudStor+ – not charged; negotiations with vendors (e.g. Box) on behalf of NRENs operating under similar legal frameworks – not charged.	Yes: network hardware & software, cloud services, etc.
Brazil	No, but we are interested in doing this.	Yes: cloud providers, applications, links.
Canada	Yes: wavelength and lightpath services.	Yes: leveraging bulk buying of wavelength services to reduce costs.
Korea (South)	No, but we are interested in doing this.	No
Russian Federation	No, but we are interested in doing this.	No
Sudan	No, but we are interested in doing this: libraries, video conferences, access to network and researches.	

6.7 Software development

Eleven of the GÉANT NRENs (up from nine in 2013) own intellectual property rights to certain software. Twenty-one are involved in open-source software development (up from 19 in 2013). NRENs most frequently cite financial and human resources as obstacles to becoming involved in this area, although for some NRENs software development is not in their remit. Table 6.7.1 provides an overview.

Table 6.7.1 – Open-source software

Country	Owner of IPR for software?	Categories of software products owned	Involved in open-source software development for network services? If not, what are the obstacles?	URL to software repository
GÉANT partner countries				
Armenia	No		Yes	
Belgium	No		No: lack of resources	
Croatia	No		Yes	Microsoft Download Center, http://www.carnet.hr/internet_services/MSDC
Czech Republic	Yes	Monitoring tools, security, multimedia and middleware.	Yes	Redmine (https://homeproj.cesnet.cz/), GIT
Denmark	No		Yes	
Estonia	Yes	Computing resource management, traffic measurement software, server factory.	Yes	
Finland	Yes	Small-scale monitoring and management tools.	Yes	
France	No		Yes	http://www.sympa.org
Georgia	No		No: lack of resources	
Germany	Yes	Intrusion detection (NeMo).	Yes	NeMo
Greece	Yes	All home-grown services are open-source (e.g. virtual machines provision, firewall on demand, e-voting software).	Yes	https://code.grnet.gr/ and https://github.com/grnet/ Mercurial, Git & Subversion (only for backwards compatibility) repositories are supported for hosting code. By default, Git is used and Git repositories are automatically created upon creation of a project, typically after a 2-minute period.
Hungary	No		Yes	Major SW repositories at NIIFI: https://repo.niif.hu/gitweb/ (open) and https://repo.niif.hu/trac (Shibboleth protected/internal usage).
Iceland	No		No: no human resources	
Ireland	No		Yes	We have no public repository. Instead, all software we write is developed under the BSD licence model, and is available for free for others to use.
Italy	Yes	Network Monitoring tools (GINS),Identity Provider in the Cloud.	Yes	Not yet deployed.

Table 6.7.1 – continued

Country	Owner of IPR for software?	Categories of software products owned	Involved in open-source software development for network services? If not, what are the obstacles?	URL to software repository
GÉANT partner countries				
Lithuania	No		Yes	https://github.com/fln/addrwatch, https://github.com/fln/nat64
Luxembourg	No		Yes	http://downloads.geant.net/ -> 'Roaming' -> 'eduroam CAT'
Moldova	No		No: Currently, main network services are implemented by using open-source software, but NREN personnel is only adopting existing open-source products and is not yet involved in developing such products.	
Netherlands	Yes	MediaMosa, OpenConext (middleware and applications), Tiqr, FileSender, Apache RAVE, Mujina and APIS (most of these open source software is available via Github) .	Yes	Github (several)
Norway	Yes	Tools for Network Monitoring (http://software.uninett.no/).	Yes	http://software.uninett.no/, http://www.filesender.org, https://nav.uninett.no/
Poland	Yes	Digital libraries, network management, HD video.	Yes	No repository yet.
Portugal	No		No: lack of resources.	
Romania	No		No: no human resources.	
Serbia	No		No: AMRES has no software development department.	
Slovakia	No		Yes	
Slovenia	Yes	VoD portal, Portal for Adobe Connect, MCU portal.	Yes	Filesender: https://filesender.arnes.si/
Spain	No		No	https://forja.rediris.es/
Switzerland	Yes	AAI middleware, video management.	Yes	
Turkey	No		Yes	https://github.com/ULAKBIM/NfQuery
Ukraine	No		No: not in current remit.	
Other countries				
Australia	Yes	FileSender (co-owned with UNINETT, HEANet and SURFnet); CloudStor+ based on ownCloud. See: http://www.aarnet.edu.au/services/netplus/catalogue.	Yes	http://www.filesender.org
Bosnia/Herzegovina	No		No: no human resources.	

Table 6.7.1 – continued

Country	Owner of IPR for software?	Categories of software products owned	Involved in open-source software development for network services? If not, what are the obstacles?	URL to software repository
Other countries				
Brazil	Yes	Hardware Security Module (HSM)	Yes	https://github.com/
Canada	No		No: we don't do software development.	
Korea (South)	Yes		Yes	
Lebanon	No		Yes	OpenStack
Morocco	No		Yes	
New Zealand	No		Yes	

7 FUNDING AND STAFFING

Some NRENs provide services only to their country's research and/or education community. Others also provide services beyond this community; for example, they administer the country-code top-level domain, or they connect companies and/or institutions outside the research or education community. To enable comparison, we asked the NRENs covered by this 2014 edition of the *Compendium* to provide information only about their activities for national research and/or education communities. We refer to such activities simply as 'NREN activities'.

Section 7.1 gives an overview of recent developments in funding and staffing. Section 7.2 details the considerable differences in the number and types of staff that NRENs employ and attempts to explain some of these differences. Section 7.3 provides information on, and explains the variety of, NREN budgets. Sections 7.4 and 7.5 give further information on income sources and expenditure categories, respectively. Finally, Section 7.6 details NREN expenditure by network level.

7.1 Overview

It is no easy task to compare NRENs by staff or budget size, because their budgets are variously structured, depending on their tasks, while their funding also differs greatly. Compared to 2009, overall budgets in the GÉANT area have risen by 2%, while staff size has increased by 31%. Transmission capacity and equipment costs have decreased, but new services have necessitated staff size increases.

Comparing 2014 budget data with those from previous editions of the *Compendium* reveals that, generally, NREN budgets decreased with respect to 2013, though this is not necessarily the case for individual NRENs. For some NRENs, the budget situation is unclear because final budget decisions are made in the course of the year. Obviously, this is not to be recommended, as it makes forward planning very difficult for the NRENs in question. The general trend is that, each year, NRENs are able to deliver more bandwidth and more services for roughly the same amount of money as in the previous year. The Czech Republic, Estonia, Lithuania and Serbia all suffered budget cuts of more than 15%.

Over the past few years, infrastructural investments have led to savings in transmission costs. In addition, the resulting infrastructural improvements, coupled with innovations in the area of authentication and authorisation, have enabled a new generation of networked services, which have required some increases in staff size.

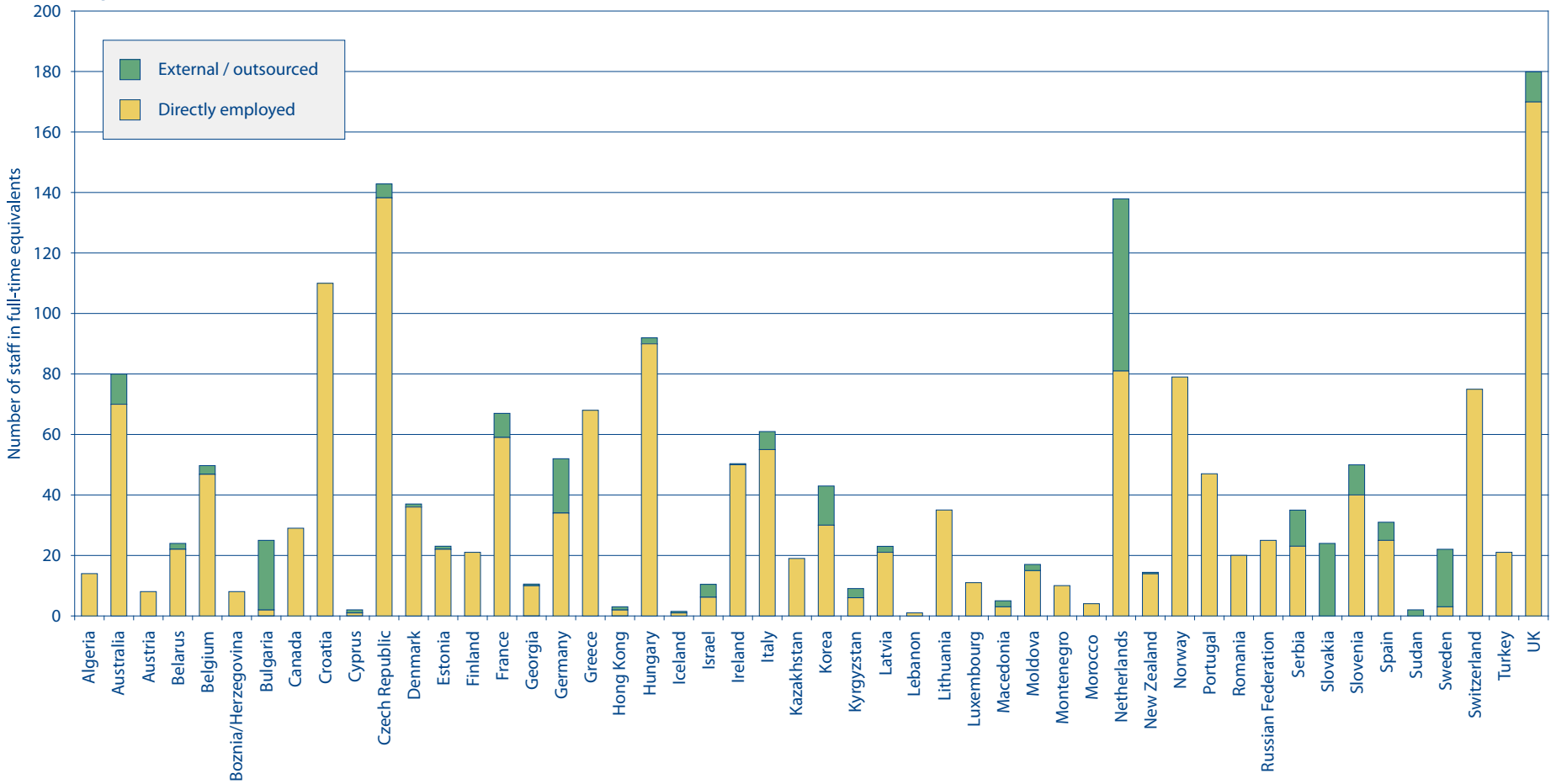
Although it is impossible to make general recommendations on NREN funding mechanisms, a model that in some way involves all the various stakeholders in an NREN would seem to provide the best guarantees for its continued success. In their respective fields, many NRENs are engaged in innovations, which are often steered by dedicated funding mechanisms. It is important for NRENs to use such funds to their advantage wherever they exist.

7.2 Staffing

Graph 7.2.1 gives an overview of all the staff who are directly employed in NREN activities, as well as subcontracted staff, in full-time equivalents (FTE). Graph 7.2.2 provides similar information specifically for technical staff. The data is presented in this way because many NRENs use subcontractors; as a result, staff size alone is not a reliable indicator of the total person-power available to an NREN.

As in previous years, considerable differences from NREN to NREN are evident, not only in the number of staff employed but also in their set of skills. One explanation for these differences is that, in some NRENs, the research network is a service provided by a parent organisation; therefore, it is not possible for all such NRENs to specifically estimate the non-technical staff time (e.g. in accounting and human resources, etc.) allocated to NREN activities. This partially explains why some NRENs have a higher ratio of technical to total staff than others.

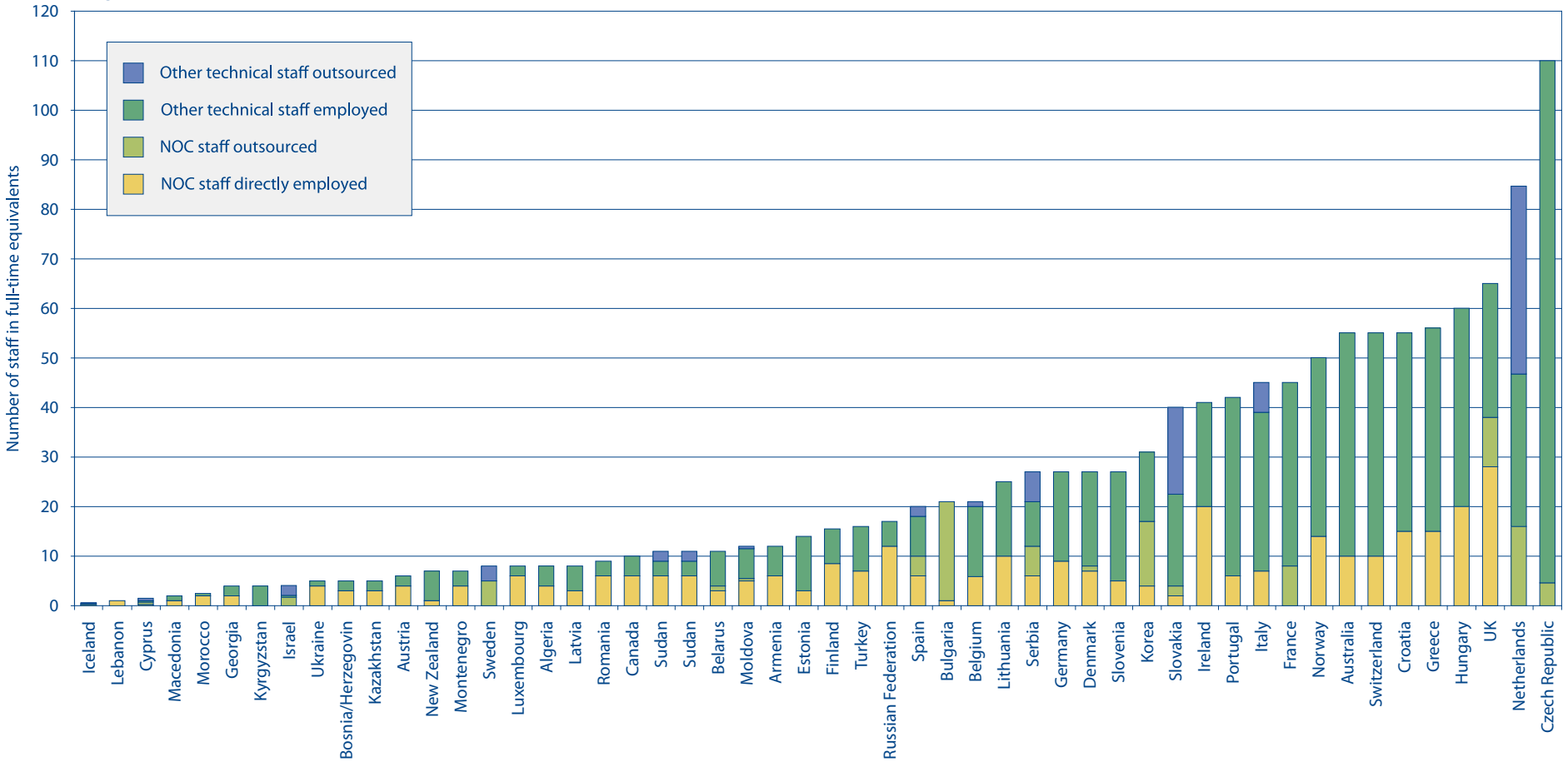
Graph 7.2.1 – Total NREN staff in FTE



NRENs differ considerably in the tasks they perform: for example, some provide connections to metropolitan area networks (MANs) or to access networks, which in turn connect institutions. Other NRENs connect institutions directly, and some manage MANs themselves. The connection policies of NRENs also differ with respect to secondary and primary schools, for example. This affects the remit of the NRENs and explains some of the differences in staff numbers that are apparent in Graphs 7.2.1 and 7.2.2.

Finally, some NRENs provide extensive support to individual end-users at institutions, some provide limited customer support, and many have service levels that are somewhere in between. This factor can have a significant effect on staff levels.

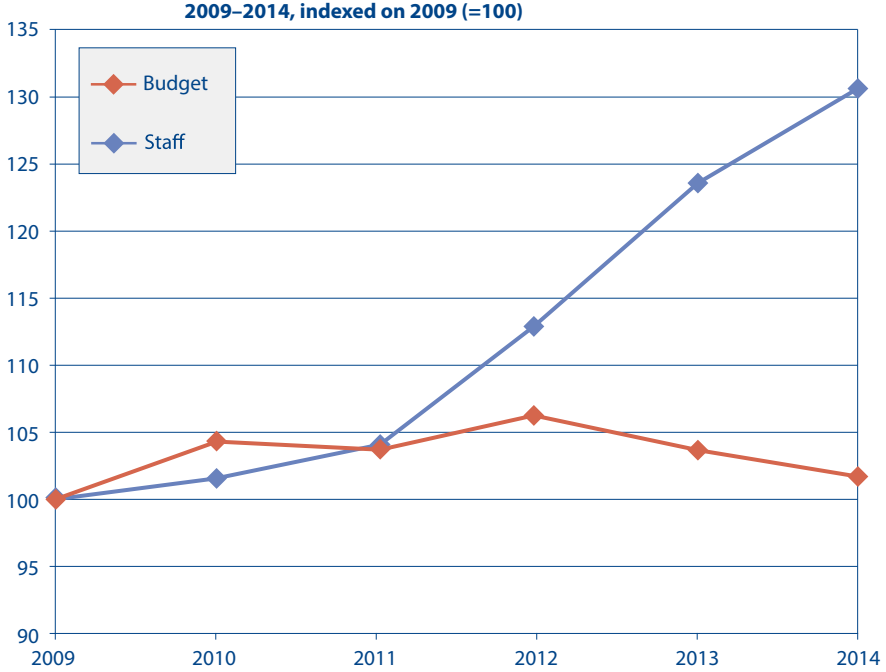
Graph 7.2.2 – NREN technical staff in FTE



RNP of Brazil has more staff than any European NREN: in June 2014, it had 240 employees and 182 outsourced staff.

Graph 7.2.3, which compares budget with staff size for the entire GÉANT region, indexed on 2009 (=100), illustrates the key points made above in this section. Clearly, budgets grew only moderately until 2012, decreasing again afterwards. Nevertheless, staff size has grown considerably over the entire period. As documented in Section 7.5, the costs of transmission capacity and hardware have decreased. Over the same period, improvements in infrastructure, coupled with innovations in authentication and authorisation, have enabled a new generation of networked services, and where these services are administered by NRENs, they require more staff.

Graph 7.2.3 – Total NREN budget and staff size in the GÉANT partner countries, 2009–2014, indexed on 2009 (=100)



7.3 Total budgets, 2009-2011 and 2012-2014

NREN budgets may fluctuate as investment levels vary from year to year. In order to filter out as much of this effect as possible, in Graphs 7.3.2 and 7.3.3 we have compared the total NREN budgets averaged over two three-year periods: 2009-2011 and 2012-2014. Note that for Janet (UK), the financial year is from August to July; therefore, its 2014 budget is actually its 2013/2014 figure.

How total annual budgets have varied over the period 2009 to 2014 is shown in Graph 7.3.4, together with the growth in GÉANT traffic[1].

For some NRENs, the budget situation is unclear because funders make their final budget decisions in the course of the year rather than at the beginning. Obviously, for the NRENs in this category this makes forward planning more difficult, if not virtually impossible. This year, we asked the NRENs that face such budget uncertainties to give greater details of them than in previous years. The responses are shown in Table 7.3.1.

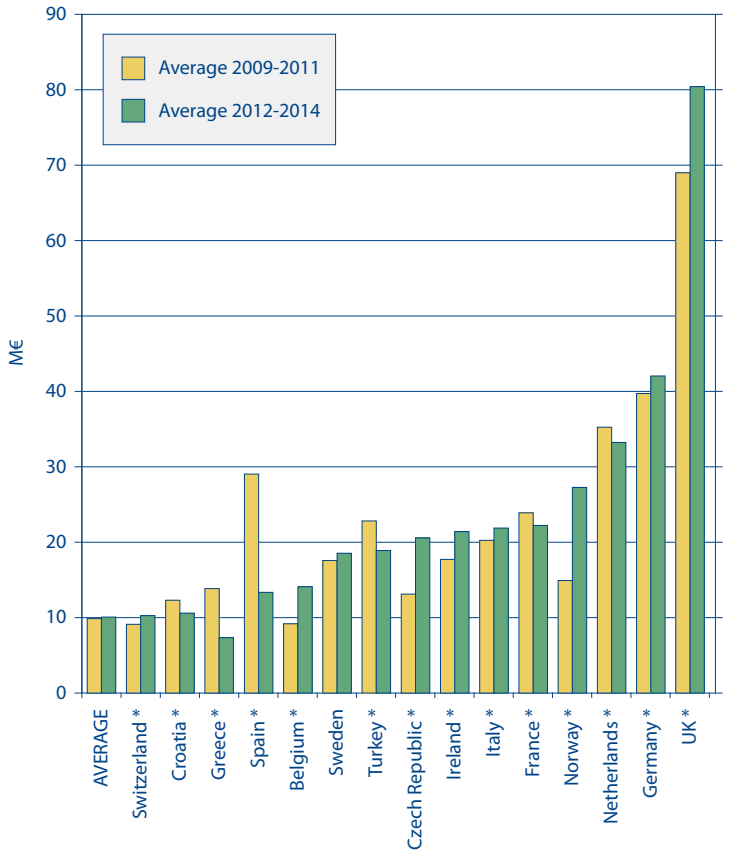
[1] Note, though, that traffic through the GÉANT network is only one of many components of a NREN's traffic.

Table 7.3.1 – Budget uncertainties

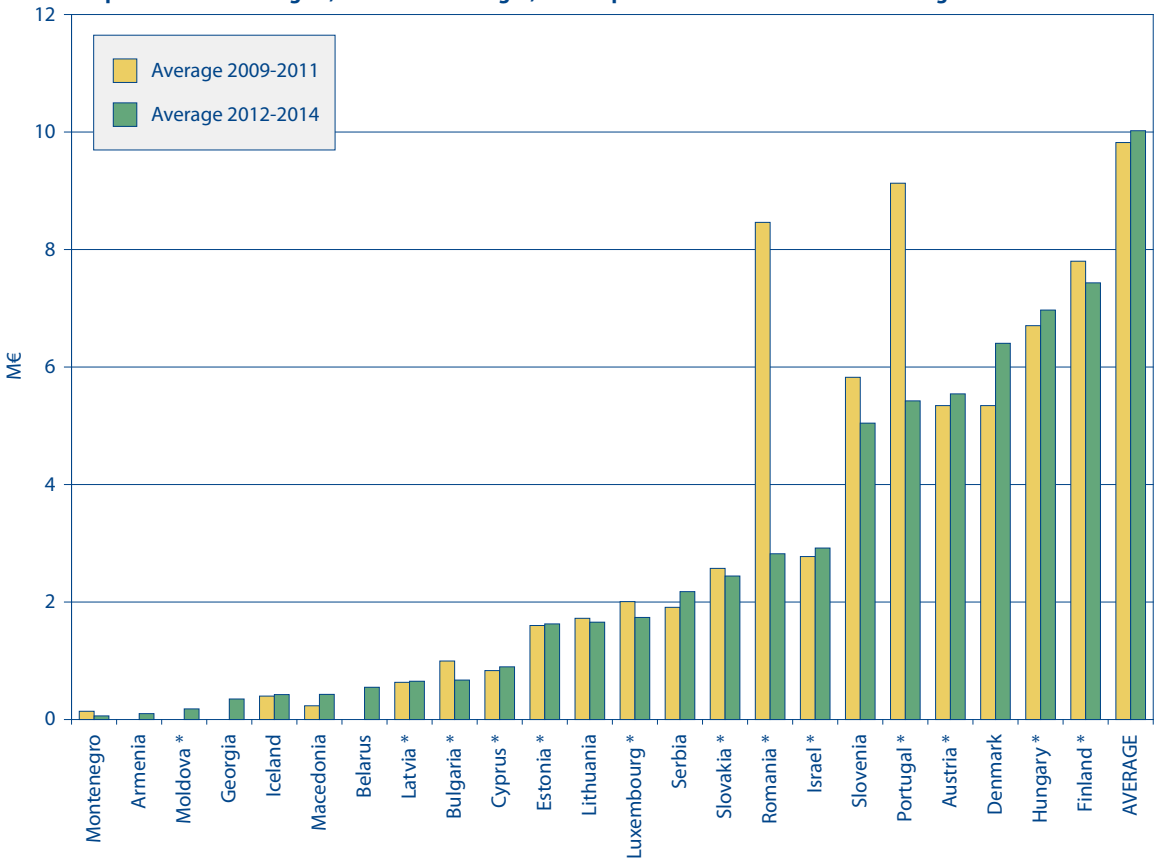
Country	Uncertainties
GÉANT partner countries	
Belgium	The standard process is as follows: 1. Initial budget provided at the beginning of summer of the previous year ; 2. Budget adjustment occurs at the end of the first quarter of the current year. Several other budget adjustments may also be made at the Government's discretion.
Croatia	Our budget falls under the state budget and is corrected during the year.
Cyprus	Due to the unstable financial situation and the freeze on Government funding, CYNET has difficulties implementing projects/services that are essential to the members. Therefore, discussions with members on co-funding are ongoing.
Georgia	Our budget depends on payments from users and projects.
Hungary	Every year there is some uncertainty in the budget, and 2014 seems to be very similar to 2013 in this sense.
Macedonia	MARnet financing is covered partially by the state budget. It is usually determined at the end of the previous year for the next year. Other internal sources should also be estimated as part of the predefined budget, together with the state budget.
Moldova	We have already indicated the 2014 budget estimate. We can only recalculate the real sum at the end of the reporting year.
Slovakia	The basic budget of SANET running cost is included in the chapter 'Education and Research Infrastructure' of the budget set by the Ministry of Education and Research of Slovakia, according to the law.
Turkey	An additional budget will be requested for 2014.
UK	The budget supplied is based on the current prediction; however, this level of funding has yet to be finalised. In addition, we may secure further grants for projects in 2014/15 which we are currently not aware of. Our income is partially government funding and partially from sales to the sector. Therefore, our expenditure is dependent on achieving the forecast sales level.
Ukraine	A great number of payments have been delayed or cancelled. Territories were annexed or invaded.
Other countries	
Bosnia/ Herzegovina	Our budget is set according to the Law on Budget Execution, but the actual financial situation may lead to a certain decrease.
Brazil	The majority of expected revenue is confirmed during the year and is subject to negotiation of Addenda to the multi-annual Management Contract.
Morocco	Our NREN is in this category. Our budget comes from the Ministry of Higher Education and we have to renegotiate it each year.
Sudan	SudREN falls into this category.

For several reasons (see bulleted list) it remains difficult to directly compare budgets. We asked the NRENs whether their submitted budget figures include the EU grant for GÉANT activity. For some NRENs, this is the case; for others, this grant is shown not as part of the budget but as a reduced cost. In Graphs 7.3.2 and 7.3.3, the NRENs that include the GÉANT subsidy in their budget figure are marked with an asterisk*. As shown in Section 7.4, the proportion of funds received from the EU (though not always exclusively for GÉANT) differs considerably. There are other reasons why comparison is difficult:

Graph 7.3.2 – Total budgets, 2009-2014 averages, GÉANT partner countries with annual budgets > 10 M€



Graph 7.3.3 – Total budgets, 2009-2014 averages, GÉANT partner countries with annual budgets < 10 M€



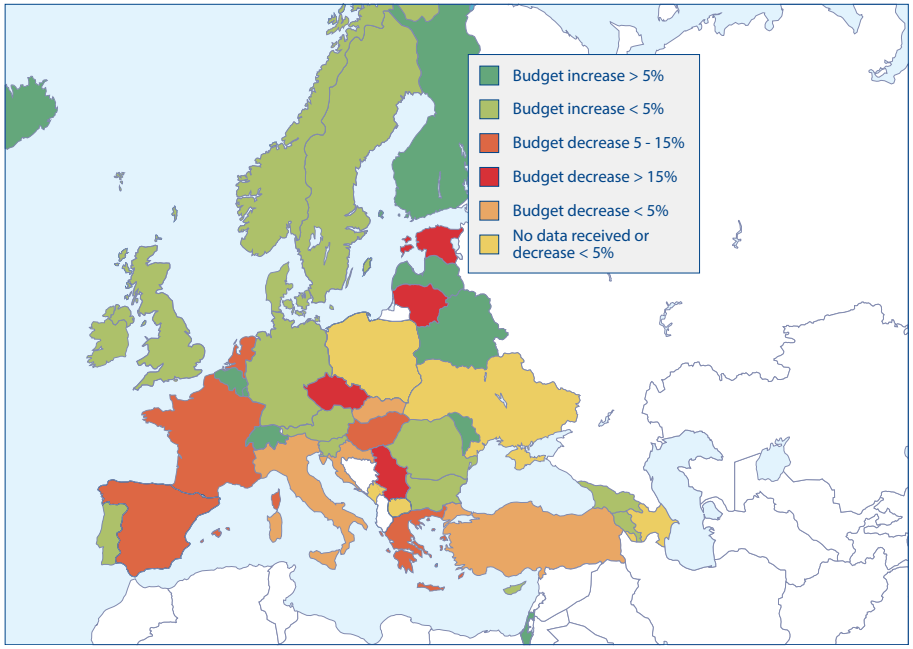
- Regional and/or metropolitan area networks (RANs/MANs) are funded differently in different countries;
- In some countries, clients pay for their link to the nearest NREN point of presence; in others, the NREN pays for this;
- Some NRENs spend a large part of their budget on connecting primary and secondary schools; others do not or may take this separately into account;
- There are large differences in how staff are paid. In the GÉANT area, one NREN spends only 2% of its budget on staff, whereas another spends 59% of its budget on this aspect. In this context, it should be noted that some NRENs have staff who are not paid from the NREN budget. Similar differences also exist in other expenditure categories.

A few NRENs, including GRENA of Georgia, do not have budget certainty until quite late in the year. This may be because there is uncertainty about projects, payments from client institutions or government funding. In some cases, salary payments to NREN staff are relatively stable, whereas additional budgeting for investments is only known later in the year. Obviously, a NREN that is to be at the forefront of Internet developments in its country requires reliable budgeting.

Graphs 7.3.2 and 7.3.3 show a mixed situation: some NREN budgets have increased, others have decreased, but the overall average has remained virtually unchanged. Comparing the three-year averages reveals quite large budget decreases in Bulgaria, Romania, Portugal, Spain and Greece. In part, these can be explained by investments in network upgrades in the earlier period that led to savings in the later period. Budgets increased in Belgium, the Czech Republic and Norway.

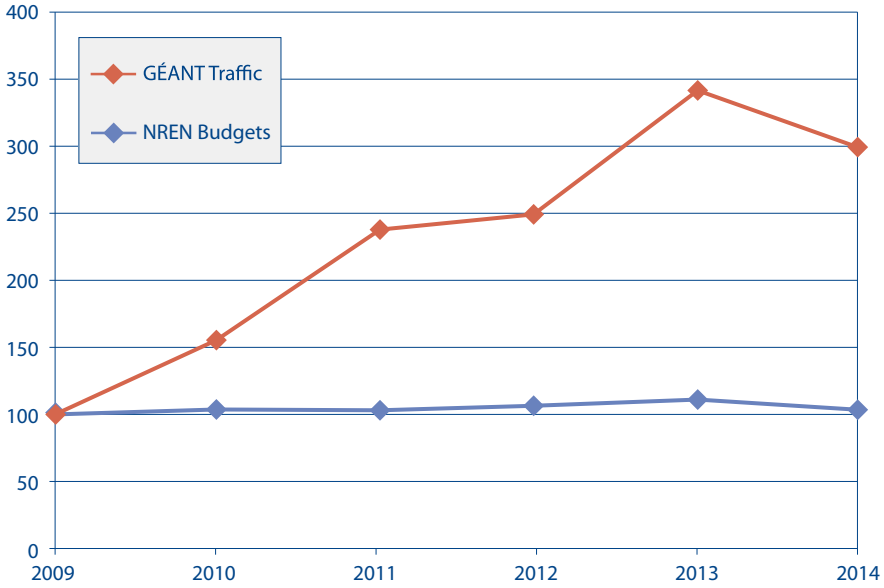
Map 7.3.3, which compares 2013 and 2014, reveals the relatively large budget decreases in the Czech Republic, Estonia, Lithuania and Serbia. For Lithuania, this was the second budget decrease in two consecutive years. There were relatively large budget increases in Belarus, Belgium, Finland, Israel, Latvia, Luxembourg, Moldova and Switzerland. The reasons for these changes are different for every NREN.

Map 7.3.3 – Budget increases and decreases in the GÉANT area, from 2013 to 2014



Traffic has more than tripled since 2009, as illustrated by the figures for traffic on the GÉANT backbone, which are plotted in Graph 7.3.4[3]:

Graph 7.3.4 – Total NREN budgets and traffic, 2009-2014, GÉANT partner countries (indexed on 2009 = 100)



As Graph 7.3.4 shows, the investments in infrastructure upgrades that many countries have made in recent years have enabled steady traffic growth for roughly the same amounts of money each year (see also Section 4.3). This has also enabled growth in both diversity and number of services offered on the network.

The data obtained from the non-GÉANT countries are not sufficiently time-consistent to allow them to be presented in the same form as those from the GÉANT partner countries.

The current funding levels of several of the non-GÉANT countries that provided information in the survey are unlikely to be sufficient for them to reach the standards now common in the GÉANT area, despite the falling prices of connectivity in recent years.

[3] The 2014 traffic data are an estimate, based on extrapolating the figures for the first six months of 2014. Note that this excludes traffic on lightpaths (lambdas) that are not monitored by GÉANT.

7.4 Income sources

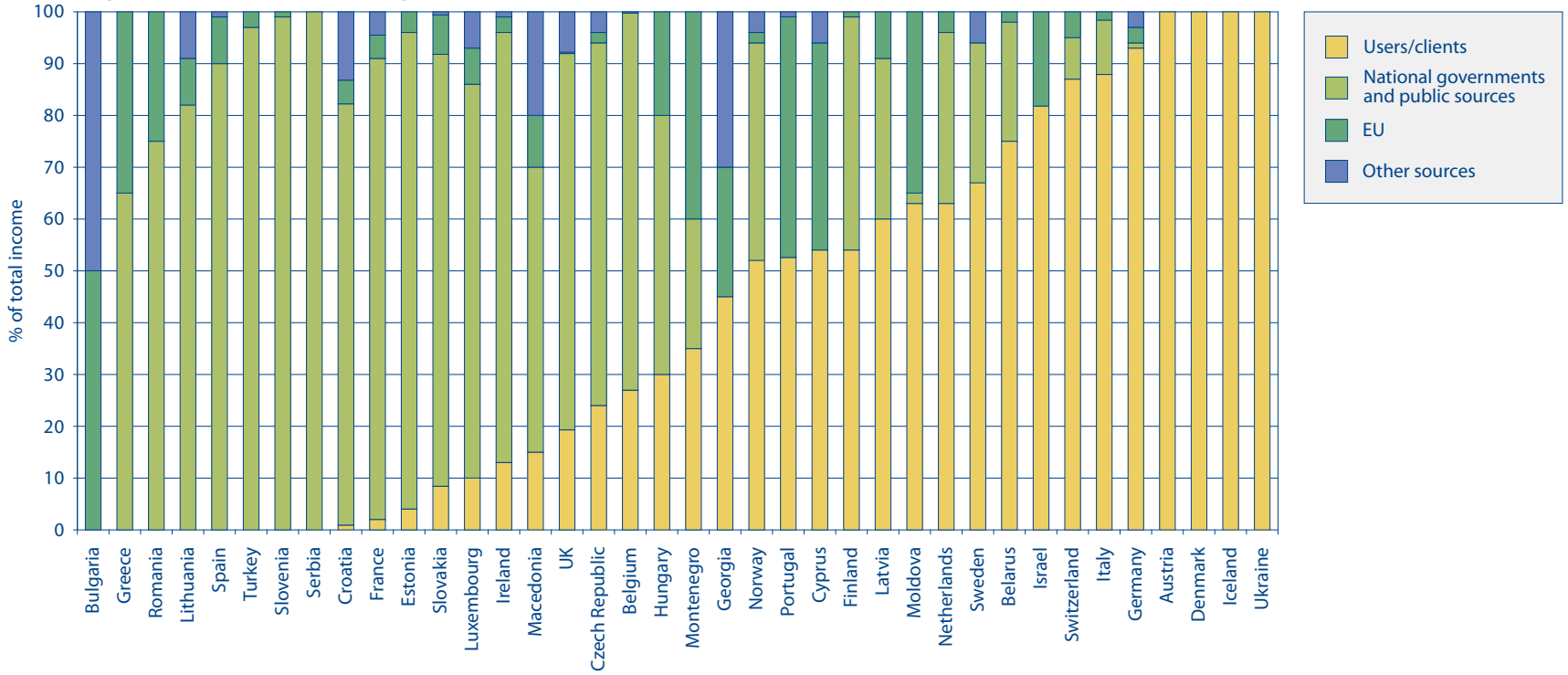
NRENs are funded in various ways: some receive all their funding directly from national government; others are funded entirely by their users (who may, in turn, be government-funded to some extent). Between those extremes there are many variants. Graphs 7.4.1 and 7.4.2 indicate what percentage of NREN funding comes from which source. Note that in many cases (see also Graphs 7.3.2 and 7.3.3) the amount of funding received from the EU is not included.

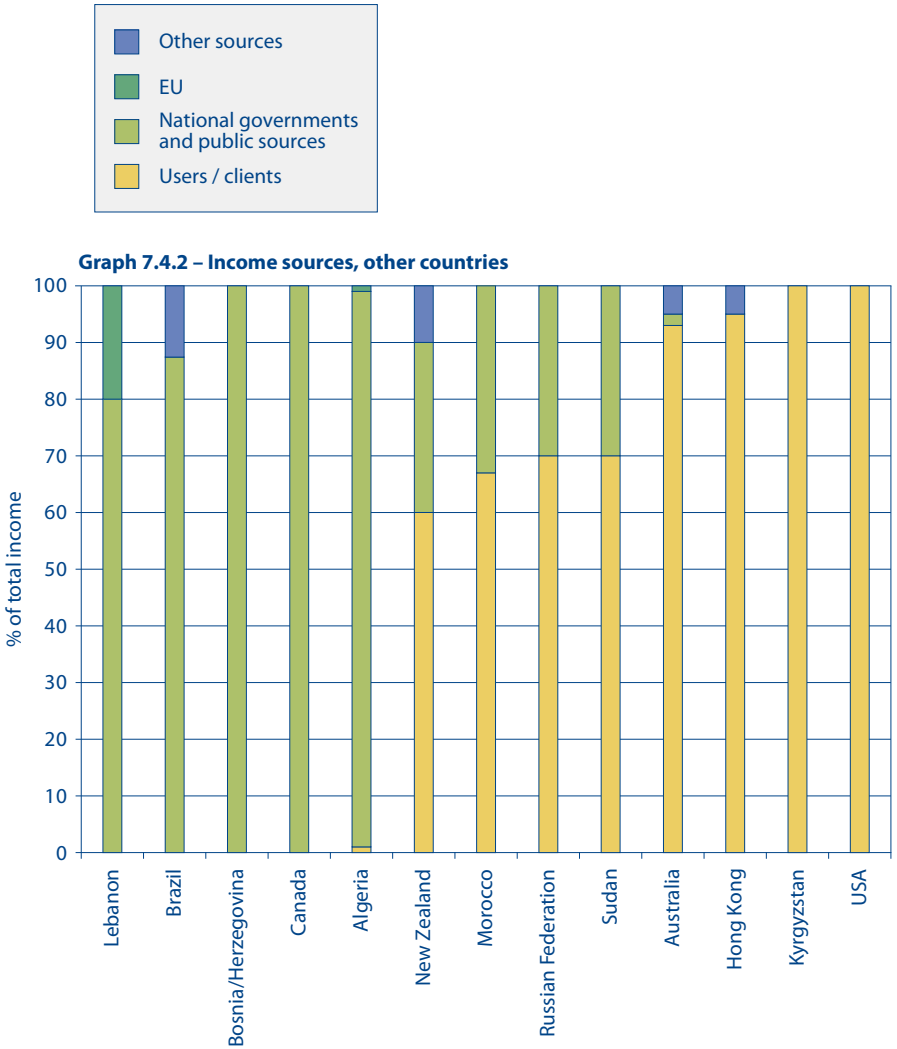
Although it is impossible to make general recommendations on NREN funding mechanisms, a model that in some way involves the various stakeholders in an NREN would seem to provide the best guarantees for its continued success.

It should be noted that, in their respective fields, many NRENs are engaged in innovations, which are often steered by dedicated funding mechanisms. NRENs may consider applying for such funds wherever they are available.

As in previous years, NRENs were asked whether they can make use of multi-annual budgeting. Of the GÉANT partner NRENs, 45% (up from 39% last year) confirmed that they can use such budgeting.

Graph 7.4.1 – Income sources, GÉANT partner countries



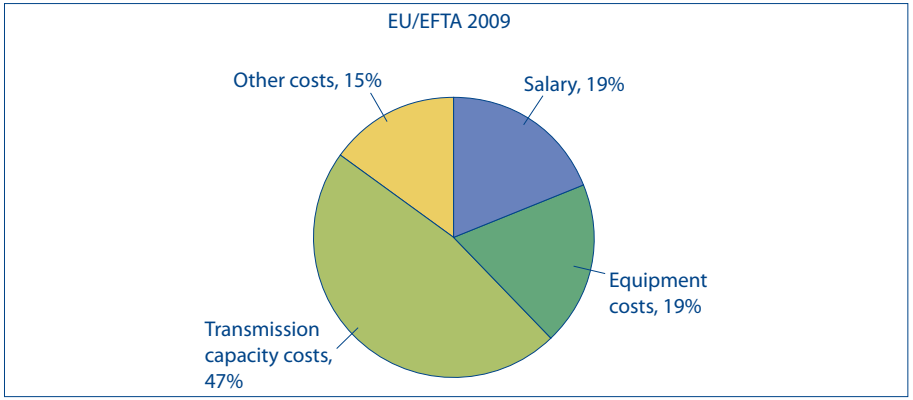


Graph 7.4.2 – Income sources, other countries

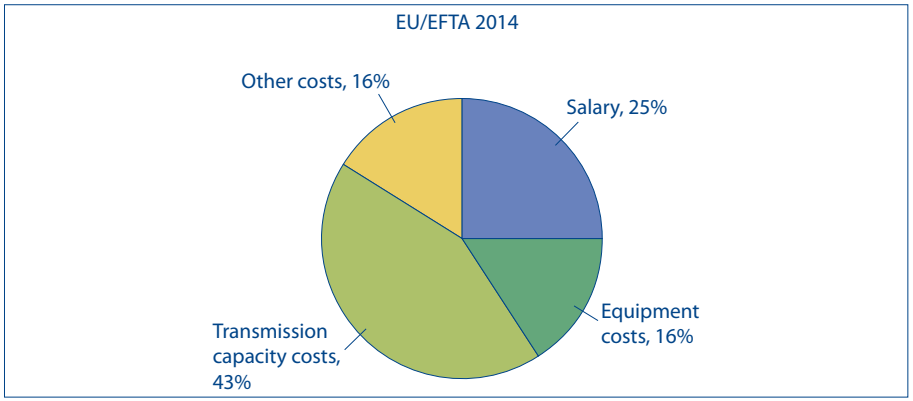
7.5 Expenditure by category

Graphs 7.5.1 and 7.5.2 show the average percentage of NREN income spent on various cost categories. To enable comparison, the graphs show the situation in the same set of (current) EU/EFTA countries for 2009 and 2014[4].

Graph 7.5.1 – Expenditure by category, EU/EFTA countries, 2009



Graph 7.5.2 – Expenditure by category, EU/EFTA countries, 2014



Since 2009, the proportion of transmission capacity costs in the EU/EFTA countries has decreased from 47% of total expenditure to 43%. The proportion of salary costs has increased (in line with the rise in the number of staff, as documented in Section 7.2) from 19 to 25%. The proportion of equipment costs has declined slightly.

[4] This includes those of the current 28 EU countries that submitted data, plus Iceland, Norway and Switzerland.

7.6 Expenditure by network level

GÉANT partner NRENs differ widely in terms of which network levels they specifically fund from their budget and how they account for those levels. This makes it difficult to effectively compare NREN budgets.

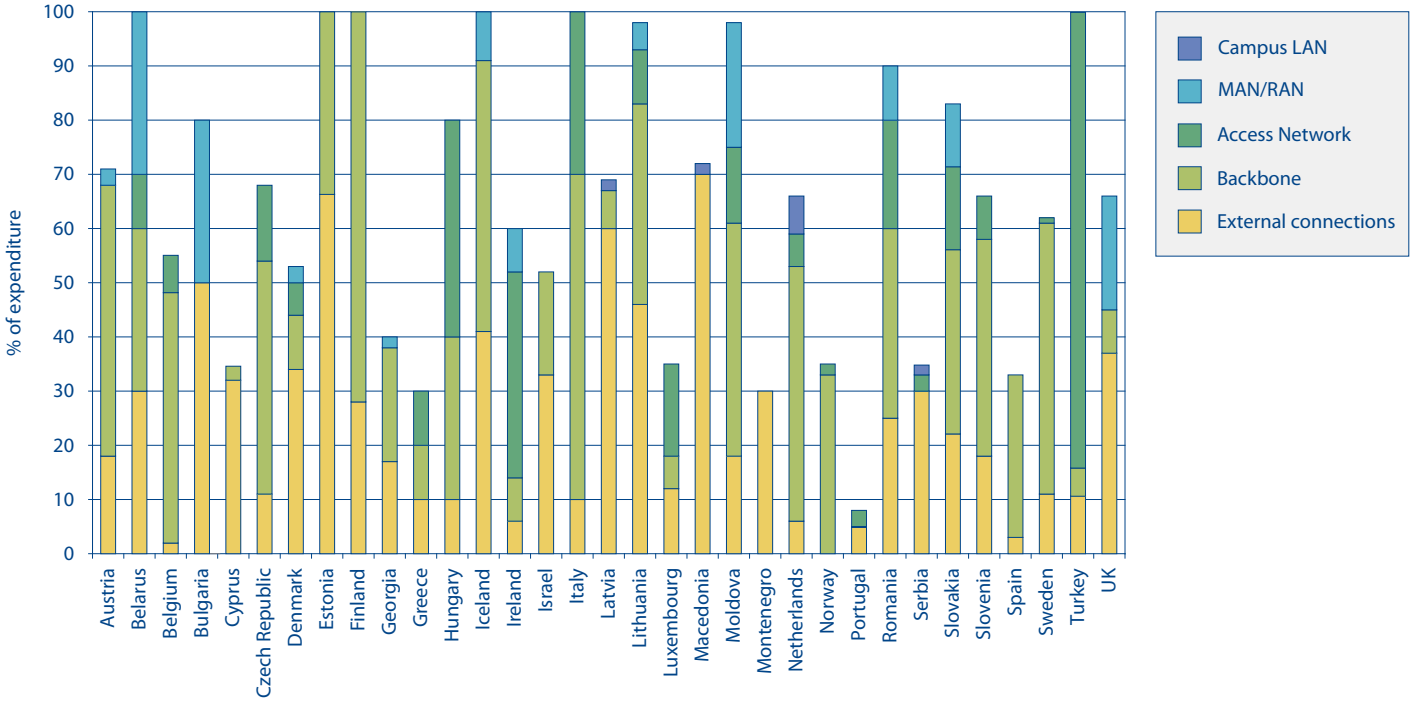
Although most NRENs pay for their external connections, the budget proportion actually spent on this network level differs widely from country to country. On average, the GÉANT partner NRENs spend 24% of their annual budget on external connectivity and pay for 80% of its total cost. These figures are very similar to those of 2013.

NRENs also differ in how they account for their expenditure. HEAnet (Ireland) reports that it spends 6% of its budget on external connections. That this figure seems unusually low is explained by the fact that HEAnet's most expensive external connection – i.e. to GÉANT – is regarded as part of the core infrastructure, not as part of the external connections. In the case of UNINETT (Norway), the external connections are not funded through the NREN budget.

Expenditure on other network levels also differs widely. In some GÉANT partner countries, metropolitan area networks (MANs) and regional area networks (RANs) are financed under the NREN budget. In other countries, this is not the case.

These disparities in expenditure and accounting methods highlight the complexity of comparing NREN budgets, as illustrated by Graph 7.6.1. Note that the combined expenditures on the five network levels do not necessarily constitute 100% of the NREN's budget. This can be due to differences in the NRENs' accounting methods or because the NRENs also spend money on items that are not directly network-related.

Graph 7.6.1 – Expenditure by network level, GÉANT countries



Appendix 1 Alphabetical list of NRENs

N.B.: For additional information on these NRENs, see the country entries at **compendium.terena.org**

NREN acronym	NREN name	Country
AARNet	Australia's Academic and Research Network	Australia
ACOnet	Österreichisches akademisches Computernetz	Austria
ADSIB	Agencia para el Desarrollo de la Sociedad de la Información en Bolivia	Bolivia
AMRES	Akademska Mreza Srbije	Serbia
ANA	Rrjeti Akademik Shqiptar	Albania
Ankabut		United Arab Emirates
Arandu		Paraguay
ARENA	Armenian Research and Education Networking Association (ARENA) Foundation	Armenia
ARNES	Akademska in raziskovalna mreža Slovenije	Slovenia
ASNET-AM	Academic Scientific Research Computer Network of Armenia	Armenia
AzRena	Azərbaycan Elmi-Tədqiqat ve Təhsil Şəbəkələri Assosiasiyası	Azerbaijan
AzScienceNet	Azərbaycan Milli Elmlər Akademiyası Şəbəkəsi	Azerbaijan
BASNET	Setka Natsianalnai Akademii Nauk Belarusi	Belarus
BdREN	Bangladesh Education and Research Network	Bangladesh
Belnet	(NL): Het Belgische telematicaonderzoeksnetwerk, Belnet. (FR): Belnet, Réseau télématique belge de la recherche.	Belgium
BREN	Sdruzhenie Bulgarska Izsledovatelska i Obrazovatelna Mrezha	Bulgaria
CANARIE	CANARIE Inc.	Canada
CARNet	Hrvatska akademska i istraživačka mreža - CARNet	Croatia
CEDIA	Consorcio Ecuatoriano para el Desarrollo de Internet Avanzado	Ecuador
CERIST	Centre de Recherche sur l'Information Scientifique et Technique	Algeria
CERNET	China Education and Research Network - Zhōngguó jiàoyù hé kēyán jìsuànjī wang	China
CESNET	CESNET, zájmové sdružení právnických osob	Czech Republic
CKLN	Caribbean Knowledge and Learning Network	
CONARE	Consejo Nacional de Rectores	Costa Rica
CSC / Funet	CSC - IT Center for Science Ltd / Funet	Finland
CSTNet	China Science and Technology Network - Zhōngguó kējī wǎng	China
CUDI	Corporación Universitaria para el desarrollo de Internet	Mexico
CYNET	Kypriako Erevnitiko Kai Akadimaiko Diktio	Cyprus
DeiC	Danish e-infrastructure Cooperation	Denmark
DFN	Deutsche Forschungsnetz	Germany
e-ARENA	Nacionalnaia Associacia issledovatelskih i nauchno-obrazovatelnih electronnih infrastructur "e-ARENA"	Russian Federation
EENet / HITSA	Eesti Hariduse ja Teaduse Andmesidevork / Hariduse Infotehnoloogia Sihtasutus – Information Technology Foundation for Education	Estonia
ERNET	Education and Research Network	India
EUN	Shabaket El Gamaat ElMasria	Egypt
FCCN / FCT	Fundação para a Computação Científica Nacional / Fundação para a Ciência e a Tecnologia	Portugal
GARNET		Ghana
GARR	Consortium GARR (Gestione Ampliamento Rete Ricerca)	Italy
GRENA	Saqartvelos samecniero-saganmanatleblo kompiuteruli qselebis asociacia	Georgia
GRNET S.A.	Ethniko Diktio Ereynas & Technologias	Greece
HARNET	Hong Kong Academic and Research NETwork	Hong Kong
HEAnet	HEAnet Ltd.	Ireland
HIAST		Syria
INNOVA|RED		Argentina
INHERENT-DIKTI		Indonesia
Internet2	Internet2	United States
IRANET/IPM		Iran (Islamic Republic of)
iRENALA	Research and Education Network for Academic and Learning Activities	Malagasy Republic
IUCC	Merkaz Hachishuvim haBain Universitai	Israel

NREN acronym	NREN name	Country
Janet	The JNT Association trading as Janet	United Kingdom
JUNet	Shabakat Aljamiat Al Urduniyeh	Jordan
KazRENA	Qazaqstannyn' bilim beru zhane gylymi kompyuter zhelisin koldanushylar kauymdastygy / Asociaciya polzovateley nauchno obrazovatrlnoi kompyuternoi seti Kazakhstana	Kazakhstan
KENET	Kenya Education Network Trust	Kenya
KOREN	Korea Advanced Research Network	Korea, Republic of
KRENA-AKNET	Kyrgyzskaya Nauchnaya i Obrazovatel'naya Kompyuternaya Set-AKNET	Kyrgyzstan
KREONET	Korea Research Environment Open NETwork	Korea, Republic of
LEARN	Lanka Education and Research Network	Sri Lanka
LITNET	Lietuvos mokslo ir studiju instituciju kompiuteriu tinklas	Lithuania
MAREN	Malawi Research and Education Network	Malawi
MARNet	Makedonska akademska nauchno-istrazhuvachka mrezha	Macedonia, Former Yugoslav Republic of
MARWAN	MARWAN- Réseau informatique national pour l' éducation, la formation et la recherche	Morocco
MREN	Crnogorska mreza za razvoj i nauku	Montenegro
MYREN	Rangkaian Pendidikan & Penyelidikan Malaysia	Malaysia
NASATI	National Agency for Science and Technology Information - Cuc Thông tin Khoa hoc và Công nghê Quôc gia	Vietnam
NCHC	National Center for High-performance Computing	Taiwan
ngNREN		Nigeria
NiCT	Dokuritu Gyousei Houjin Jyouhou Tuusin Kenkyuu Kikou	Japan
NII	National Institute of Informatics	Japan
NIIF/HUNGARNET	Nemzeti Informacios Infrastruktura Fejlesztesi Intezet / Magyar Kutatasi es Oktatasi Halozati Egyesulet	Hungary
NREN	Nepal Research and Education Network	Nepal
OMREN		Oman
PERN	Pakistan Education & Research Network	Pakistan
PIONIER	Polski Internet Optyczny - Konsorcjum Akademickich Sieci Komputerowych i Centrów Komputerów Dużej Mocy	Poland

NREN acronym	NREN name	Country
PREGINET	Philippine Research, Education, and Government Information Network	Philippines
Qatar Foundation		Qatar
RAAP	Red Académica Peruana	Peru
RAGIE	Red Avanzada Guatemalteca para la Investigación y Educación	Guatemala
RAICES	Red Avanzada de Investigación, Ciencia y Educación Salvadoreña	El Salvador
RAU	Red Académica Uruguaya	Uruguay
REACCIUN	REACCIUN: Red Académica de Centros de Investigación y Universidades Nacionales	Venezuela
REANNZ	Research and Education Advanced Network New Zealand Limited	New Zealand
RedCyT	Red Científica y Tecnológica - Panamá	Panama
RedIRIS	RedIRIS	Spain
RedUNIV		Cuba
RENAM	Asociatia Obsteasca RENAM	Moldova, Republic Of
RENATA	Corporación Red Nacional Académica de Tecnología Avanzada - RENATA	Colombia
RENATER	Réseau national de télécommunications pour la technologie, l'enseignement et la recherche	France
RENU	Research and Education Network of Uganda	Uganda
RESTENA	Fondation RESTENA, Réseau Téléinformatique de l'Education Nationale et de la Recherche	Luxembourg
REUNA	Red Universitaria Nacional	Chile
RHnet	Rannsókna- og háskólanet Íslands hf (RHnet)	Iceland
RNP	Rede Nactional de Ensino e Pesquisa	Brazil
RNU	Réseau National Universitaire Tunisien	Tunisia
RoEduNet	Agentia de Administrare a Retelei Nationale de Informatica pentru Educatie si Cercetare— 'RoEduNet'	Romania
SANET	Združenie používateľov slovenskej akademickej dátovej siete — SANET	Slovakia (Slovak Republic)
SANReN	South African National Research Network	South Africa
SARNET	Academic and Research Network of the Republic of Srpska	Bosnia And Herzegovina

NREN acronym	NREN name	Country
SigmaNet	SigmaNet, Latvijas Universitātes Matemātikas un Informātikas institūta Akadēmiskā tīkla laboratorija	Latvia
SINET		Japan
SingAREN	Singapore Advanced Research and Education Network (SingAREN)	Singapore
SnRER		Senegal
Somaliren		Somalia
SudREN		Sudan
SUNET	Det svenska universitetsdatornätet SUNET	Sweden
SURFnet		Netherlands
SWITCH	SWITCH	Switzerland
TARENA	Tajik Academic, Research and Educational Network Association	Tajikistan
TENET	Tertiary Education and Research Network of South Africa	South Africa
TERNET		Tanzania, United Republic Of
ThaiREN		Thailand
TuRENA	Türkmenistanyň milli ylym-bilim tory	Turkmenistan
TTRENT	Trinidad and Tobago Research and Education Network	Trinidad and Tobago
TWAREN	TaiWan Advanced Research & Education Network	Taiwan
UARNet	Derzavne pidpryemstvo naukovo-telekomunikacijnyj centr "Ukrainska akademichna i doslidnytska mereza" IFKS NAN Ukrainy	Ukraine
ULAKBIM	Ulusal Akademik Ag ve Bilgi Merkezi	Turkey
UniNet		Thailand
UNINETT	UNINETT AS	Norway
UoM/RicerkaNet	Is-Servizzi tal-IT, L-Università ta' Malta/RiċerkaNet	Malta
URAN	Asociacija Korystuvachiv Ukrainskoji Naukovo-Osvitnioji Telekomunikacijnoji Merezhi	Ukraine
UzSciNet	O'zbek ilmiy va o'quv tamog'i	Uzbekistan
WACREN	West and Central African Research and Education Network	
ZAMREN		Zambia

Appendix 2 Glossary of terms

Terms not listed in this glossary are either explained in the main text or presumed to be commonly understood.

AAI	Authentication and Authorisation Infrastructure: a term used for systems that support the process of determining both (1) whether users are who they declare themselves to be (authentication) and (2) that they have the appropriate rights or privileges necessary to access a resource (authorisation).
APAN	Asia-Pacific Advanced Network: a non-profit international consortium established on 3 June 1997. APAN is designed to be a high-performance network for research and development on advanced next-generation applications and services. APAN provides an advanced networking environment for the research and education community in the Asia-Pacific region and promotes global collaboration. For further information, see http://www.apan.net/.
APN	Access Point Name: a computer protocol that typically allows a user's computer to access the Internet using the mobile phone network.
ASREN	Arab States Research and Education Network.
ASPIRE	A Study on the Prospects of the Internet for Research and Education: a foresight study completed in 2012.
AUP	Acceptable Use Policy.
bit or b	Binary digit: the smallest unit of data in a computer. In this *Compendium*: kilobit (kb), Megabit (Mb), Gigabit (Gb), Terabit (Tb), Pb (Petabit).
Bandwidth on Demand (BoD)	A data communication technique for providing additional capacity on a link, as necessary, to accommodate bursts in data traffic, a videoconference, or other special requirements.
Byte or B	8 bits. In this *Compendium*: kB (kilobyte) MB (Megabyte), GB (Gigabyte), TB (Terabyte), PB (Petabyte).
CA	Certification/Certificate Authority.
CLARA	Cooperación Latino Americana de Redes Avanzadas (= Latin American Cooperation of Advanced Networks): an international organisation whose aim is to interconnect Latin America's academic computer networks. For more information, see http://www.redclara.net/.
confederation	A federation formed by multiple independent federations with a common purpose. An example in the NREN community is the European eduroam Confederation, which unites country-level eduroam federations.
congestion index	A measure of congestion at different levels of network access. Developed by Mike Norris, formerly of HEAnet.
CRM	Customer Relations Management.

ccTLD	Country-code Top-Level Domains: Internet Top-Level Domains (TLDs) are geographically specific and can be assigned to a dependent territory in addition to a country.
CSIRT	Computer Security Incident Response Team.
Dark Fibre	Optic fibre cable that is not connected to transmission equipment by the vendor or owner of the cable and therefore has to be connected (i.e. 'lit') by the NREN or the client institution.
DNSBL	A DNSBL (DNS-based Blackhole List, Block List or Blacklist) is a list of IP addresses published through the Internet Domain Name Service (DNS). DNSBLs are most often used to publish the addresses of computers or networks linked to spamming; most mail server software can be configured to reject or flag messages which have been sent from a site listed on one or more such lists.
DNSSEC	The Domain Name System Security Extensions (DNSSEC) is a set of extensions to DNS which provide to DNS clients (resolvers) origin authentication of DNS data, authenticated denial of existence, and data integrity, but not availability or confidentiality.
DWDM	Dense Wavelength-Division Multiplexing: in fibre-optic communications, a technology that uses multiple wavelengths of light to multiplex signals in a single optical fibre.
E.164	The ITU recommendation that defines the international public telecommunication numbering plan used in the PSTN and some other data networks.
eduroam®	education roaming service: provides a secure international roaming service to users in the international research and education community. It allows a user visiting another institution that is connected to eduroam to log on to the WLAN using the same credentials he/she would use if he/she were at his/her home institution.
EC	European Commission.
eduGAIN	The eduGAIN service is intended to enable the trustworthy exchange of information related to identity, authentication and authorisation between federations (in the GÉANT area and beyond).
ENUM	E.164 NUmber Mapping, a suite of protocols to unify the telephone system with the Internet.
EU	European Union.
EUGridPMA	The international organisation that coordinates the trust fabric for e-Science grid authentication in Europe.
FTE	Full-Time Equivalent.
GDS	Global Dialling Scheme: a hierarchy of video-conference gatekeepers that support the mapping of a telephone number format to access MCUs and VC end-points worldwide.

GÉANT	a) GÉANT Association: association consisting mainly of European NRENs, with offices in Amsterdam (formerly known as TERENA) and Cambridge (GÉANT Limited, formerly known as DANTE). b) GÉANT project: a project mainly to develop the multi-gigabit pan-European data communications network 'GÉANT', which is used specifically for research and education.
GN3plus	The Multi-Gigabit European Research and Education Network and Associated Services (GN3plus) project of the European Community's Seventh Framework Programme (FP7). It succeeds the GN3 project. It operates and develops the GÉANT network.
Grid computing	Applying the resources of many computers in a network to a single problem.
Honeypots	A honeypot is a trap set to detect, deflect, or in some manner counteract attempts at unauthorized use of information systems. Generally, it consists of a computer, data or a network site that appears to be part of a network but is actually isolated and monitored, and which seems to contain information or a resource of value to attackers.
Identity Management System	IdM: a system that combines technologies and policies to allow institutions to store users' personal information and keep it up to date. An IdM is the first step to providing AAI for a local or federated environment.
interfederate	Exchanging of metadata by two or more federations to allow members within different federations to connect via a federated access management exchange.
IP	Internet Protocol: the method whereby data, in the form of packets, is transmitted over a network.
IPv4	Internet Protocol version 4: the fourth iteration and first widely deployed implementation of the Internet Protocol. IPv4 supports 32-bit addressing and is the dominant Internet-layer protocol.
IPv6	The latest generation of the Internet Protocol (designated as the successor to IPv4) with 128-bit addressing as its most significant feature.
IPR	Intellectual property rights.
IRU	Indefeasible Right to Use: the granting of temporary ownership of a fibre-optic cable, allowing the unencumbered use of DWDM technology to maximize the capacity of the link.
Kalmar	The Kalmar e-identity Union, which is building an infrastructure for exchanging personal information across Nordic borders.
Lightpath	A dedicated point-to-point optical connection created through the use of wavelengths in an optical network, to provide guaranteed service levels for demanding applications bypassing the shared IP network.
MAN	Metropolitan Area Network: covers a geographical region such as a city. This term is often used interchangeably with Regional Area Network (RAN), which generally covers a wider geographic area.

MCU	Multi-point Conferencing Unit: used to interconnect multiple video-conferencing (VC) end-points. An MCU is also able to translate between different video formats, including SD (standard definition) and HD (high definition), in order to provide an optimized viewing experience for each VC unit connected.
NaaS	Network as a Service: creates dynamic bandwidth reservation capabilities for cloud users.
NAT	Network Address Translation.
NOC	Network Operations Centre: a place from which a network is supervised, monitored, and maintained.
NORDUnet	An international collaboration between the Nordic NRENs. It interconnects those networks with the worldwide network for research and education, as well as with the general purpose Internet. NORDUnet is a member of the GÉANT Association.
NREN	National Research and Education Network (May also refer to the operator of such a network).
PKI	Public Key Infrastructure: enables the use of encryption and digital signature services across a wide variety of applications.
PoP	Point of Presence: the location of an Internet access point.
PSTN	Public Switched Telephone Network: the traditional circuit-switched telephony service using dedicated circuits for the duration of a call.
RAN	Regional Area Network: covers a wider geographic area than a Metropolitan Area Network (MAN).
SAML	Security Assertion Markup Language: a fundamental component of federated identity and access management systems.
SDN	Software-Defined Networking: a method that allows the creation of virtual networks.
SIP	Session Initiation Protocol: an IETF-defined signalling protocol widely used for controlling communication sessions such as voice and video calls over Internet Protocol (IP).
SPF	Sender Policy Framework: an email validation system designed to prevent email spam by detecting email spoofing, a common vulnerability, by verifying sender IP addresses. SPF allows administrators to specify which hosts are allowed to send mail from a given domain. Mail exchangers use the DNS to check that mail from a given domain is being sent by a host sanctioned by that domain's administrators.
TCP	Transmission Control Protocol: one of the core protocols of the Internet Protocol suite.
TCS	TERENA Certificate Service: offers a variety of digital certificates for server, personal and e-Science use at research and educational institutions served by participating National Research and Education Networks (NRENs).
UbuntuNet Alliance	A not-for-profit association of NRENs that aims to provide a research and education backbone network for Africa.
University	Institution providing courses of education equivalent to ISCED levels 5 and 6. 'Higher/further education' is equivalent to ISCED level 4; 'secondary education' corresponds to ISCED levels 2 and 3, and 'primary education' to ISCED level 1. For more information on ISCED levels, see http://www.uis.unesco.org
VoIP	Voice-over-Internet Protocol: a protocol for transmitting voice via the Internet or other packet-switched networks. VoIP is often used to refer to the actual transmission of voice (rather than the protocol implementing it). This concept is also referred to as IP telephony, Internet telephony, voice over broadband, broadband telephony, or broadband phone.
VPN	Virtual Private Network: a network that uses a public infrastructure such as the Internet to provide remote offices or individual users with secure access to their organisation's network. A virtual private network can be contrasted with an expensive system of owned or leased lines that can only be used by one organization. The goal of a VPN is to provide the organization with the same capabilities, but at a much lower cost.
WACREN	West- and Central African Research and Education Networks.
X-ARF	Network Abuse Reporting Format: an email format for reporting network abuse.

GÉANT
ASSOCIATION
Networking • Services • People

What is the GÉANT Association?

The GÉANT Association is the leading collaboration on network and related infrastructure and services for the benefit of research and education.

The GÉANT Association is made up of its members. This includes 36 National Members, which are European national research and education network (NREN) organisations, and one Representative Member - NORDUnet - which participates on behalf of five Nordic NRENs. In addition, there are a number of Associates , including commercial organisations and multi-national research infrastructures.

The GÉANT Association:

- provides practical support for members, educators, researchers and other partners to collaborate, innovate, share knowledge and agree on policies and strategies;
- plans, procures, builds and operates large-scale, advanced international high-speed networks, including the 500 Gb/s pan-European GÉANT network;
- organises events such as workshops, meetings and conferences, including TNC – Europe's largest networking conference for research and education;
- develops, operates and supports services relating to such areas as trust and identity, security and certification, mobility and access, and media and real-time communications;
- provides staff expertise in procurement, project management, community engagement, network operations, and outreach including dissemination and training;
- liaises with other e-infrastructure organisations, user communities, industry and with the European Union.

The GÉANT Association was formed on 7 October 2014, when TERENA and DANTE joined forces. The association has two offices, one in Cambridge (formerly DANTE) and one in Amsterdam (formerly TERENA).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