« networking the networkers »

TERENA COMPENDIUM

of National Research and Education Networks in Europe

2012 Edition

www.terena.org/compendium

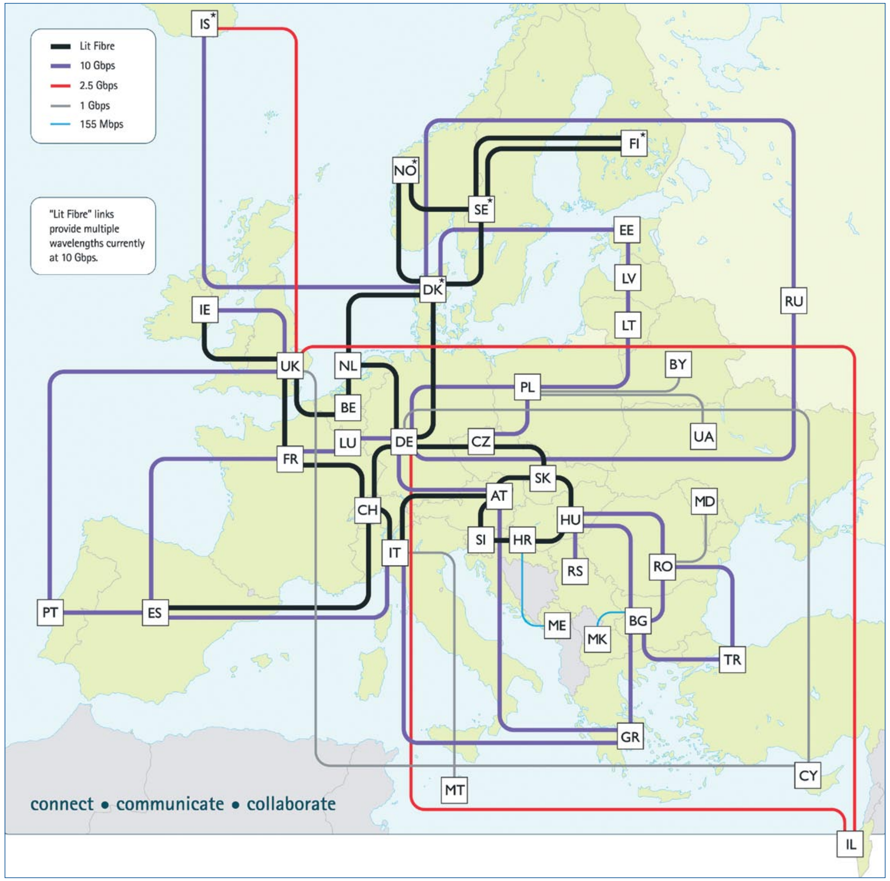
What is GÉANT?

GÉANT is the pan-European research and education network interconnecting Europe's National Research and Education Networks (NRENs). Altogether, we connect over 40 million researchers and students across Europe, facilitating collaborative research in a diverse range of disciplines, including high-energy physics, radio astronomy, bio-medicine, climate change, earth observation and arts & culture.

GÉANT is part-funded by, and works in close cooperation with, the European Commission (EC). Its key characteristics are robustness, flexibility and high capacity.

The GÉANT (GN3) project is a collaborative effort of 34 project partners – 32 European NRENs, DANTE and TERENA – and four associate NRENs. Through the NREN partners, GÉANT delivers a range of services across its network to institutions, projects and researchers. The GÉANT project encompasses the high-speed pan-European network, connectivity and networking services, and new initiatives.

GÉANT backbone topology as at March 2012.



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CONTENTS

INTRODUCTION

In the more than ten years since its inception, the TERENA *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, the fourth to be published as part of the GÉANT (GN3) project, has been enhanced with input from activity leaders working in that project. In most cases, all GÉANT partner NRENs are presented together in the tables and graphs. As in previous years, we have attempted to examine and partially explain multi-year ('longitudinal') trends. Summaries and analyses of the most important information are presented in 'overview' subsections at the start of each section. The continual growth in the services area has meant that the section titled 'Other services' in the 2011 *Compendium* has been divided into two sections: Section 5 focusing on middleware services and Section 6 on collaboration support services.

The section on key findings, which follows this introduction, provides a more general analysis of recent developments.

The production of this edition was supervised by the Review Panel: Claudio Allocchio (GARR); Helmut Sverenyák (CESNET), Janne Kanner (CSC/Funet), Laurent Gydé (RENATER), Mike Norris (HEAnet), Thomas Lenggenhager (SWITCH), Tryfon Chiotis (GRNET). Mirjam Kühne of RIPE NCC acted as advisor to the Review Panel.

As before, non-European NRENs except those in Latin America were invited to submit their data for inclusion in the *Compendium*. Information on Latin American NRENs is available on the RedCLARA website (**www.redclara.net**). This year's responses cover a total of 54 NRENs operating in the same number of countries (46 in Europe and the Mediterranean region; 8 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.

In general, this edition of the *Compendium* looks back five years, comparing 2012 with 2008. Collecting such data requires contributions from, and careful checking by, several staff members of each NREN. TERENA would like to thank all those in the NREN community who gathered, submitted, clarified and checked the data included in this publication.

The *Compendium* consists of two parts: the information submitted by the individual NRENs (available in full at **www.terena.org/activities/compendium**) and this publication.

Most of the tables and graphs below first list all the 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 the *Compendium* are listed in Section 1.1. The NRENs in all other parts of the world are listed in Section 1.2. In several tables, the responses received from the NRENs were edited and abridged. The full responses are always available on-line.

Please note that, unless otherwise specified, the data indicate the situation on or around 31 January 2012.

We hope that this twelfth 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
TERENA

KEY FINDINGS: A BRIEF OVERVIEW

Innovating together

David Foster, Chairman of the Programme Committee for the 2013 TERENA Networking Conference, writes in the Call for Papers for that conference:

> *National Research and Education Networks are facing a period of change and evolving their business models and service offerings. With increasing emphasis on international collaborations, user communities need innovative approaches to exploit the rapid evolution of technologies that are increasingly reliant on excellent networking.*

This edition of the *Compendium* documents that evolution in several different ways.

Technological innovation remains at the heart of what National Research and Education Networks (NRENs) are about. Due to the advent of high-capacity networks, congestion at the levels of campus, backbone and external connections seems to have been largely resolved for the time being.

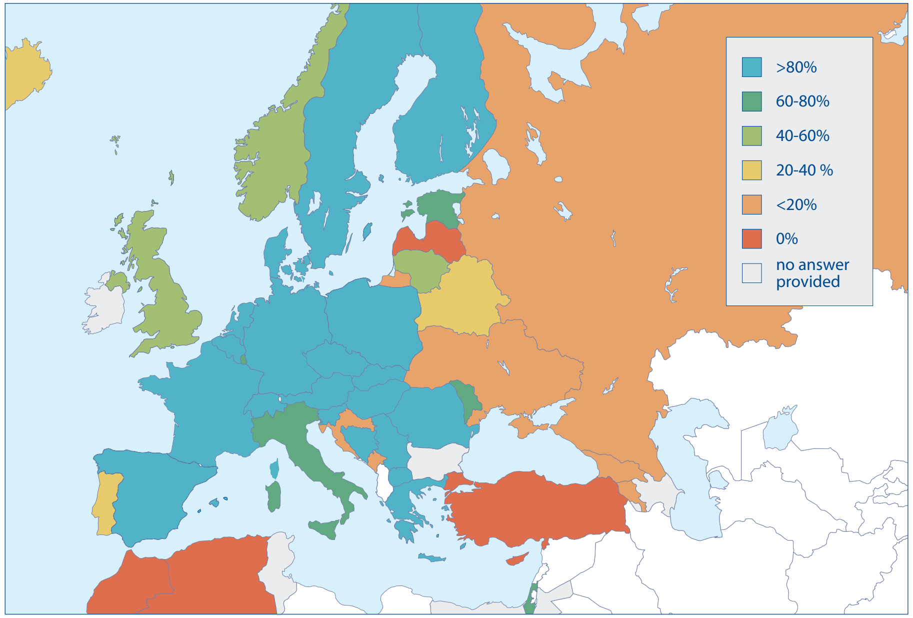
In recent years, two key innovations have shaped NREN developments:
- NRENs have started to develop and deploy new Authentication and Authorisation Infrastructures;
- The spread of 'dark fibre' networks has enabled novel network architectures that are both more cost-effective and better able to meet changing user demands.

Authentication and Authorisation Infrastructures (AAI) are key to giving users access to services independently of the user's and the service's physical location. AAI is now offered by 25 GÉANT partner NRENs, which has enabled the introduction of new services and the development of collaborative platforms that were not previously possible. Thus, compared to 2011, there has been considerable growth in the area of **services for collaborative groups**. Fifteen GÉANT partner NRENs currently offer such services, up from nine in 2011. Similarly, compared to 2011, there has been growth in the area of cloud resources. Eleven of the GÉANT partner NRENs currently offer virtualisation services, up from seven last year. Fourteen others are planning to introduce them. Furthermore, work in the area of e-learning is increasing: fifteen of the GÉANT partner NRENs currently provide an e-learning service, up from ten in 2011. Note that an AAI itself does not require high-capacity networks — although a number of the services that can be made accessible via such an AAI do depend on high-performance networks.

Most of the GÉANT partner NRENs have joined or are planning to join the **eduGAIN** interfederation service; this holds the promise of service access across federations.

In recent years, there has been a rapid spread of **dark fibre** links in the European NREN community, not only in NREN backbones (to more than 110 000 km in 2012), but also in links between NRENs and in connections to client institutions.

Dark fibre on NREN backbones, 2012



Approximately half of the GÉANT NRENs already connect all or nearly all of the universities within their national borders with dark fibre, which is also being provided to many other client institutions. NRENs beyond the GÉANT area are also connecting clients with dark fibre.

The move from managed network links to their own transmission infrastructure has enabled NRENs to develop new features and services at various levels and in various areas, including:

- Campus networks at regional and national levels;
- Premium IP networks;
- Hybrid and multi-protocol networks;
- Wavelength or lambda services;
- Dynamic lambdas.

Via a dark fibre infrastructure, NRENs can offer virtual private networks (VPNs) as a service. Thus, 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. In the GÉANT area, this is currently being done by ten NRENs.

Economic and organisational challenges

In summary, European NRENs now support more users, greater usage volumes and wider ranges of services than ever before. All this has been achieved even though, over the past five years, overall budgets have remained virtually unchanged. Transmission capacity costs have decreased — but staff costs have increased. This is a logical development: in order to actually deliver the services that are now becoming possible, increased staffing is needed. This point should be stressed: investments in state-of-the-art networks lead to cost savings but can only yield their full potential with appropriate NREN staff levels.

This year, several NRENs have been significantly affected by the current economic crisis. Greece, Italy, Portugal and Spain all suffered budget cuts of more than 15%. This is a worrying development: for several years, the 'digital divide' between European countries has been diminishing, in part because of the advent of new, optical networking technologies. Excessive budget cuts in some countries may threaten this development and lead to a new widening of the digital divide.

Until now, the digital divide was measured primarily by looking at connectivity; in the future, it may be necessary to see it more in terms of differences in service development.

NRENs are coping with their budgetary difficulties in several ways, including diversifying funding sources and engaging in new activities (such as brokerage, negotiating deals for clients and becoming involved in secondary schools). They may also be moving from general to more project-related funding or from long- to short-term funding. These are just examples; there is no clear overall picture.

A number of NRENs are involved in restructuring processes, either in response to Government and funder demands or for internal reasons.

Changes in traffic and in traffic growth

For many years, the *Compendium* used IP traffic growth as an indicator of the demand for NREN services. 2012 data show that traffic has grown again, by over 20%. This figure is less than the global IP traffic growth of just under 40% that was estimated by Cisco[1].

However, IP traffic growth alone no longer tells the whole story. With the advent and growth of optical networking, it has become possible to interconnect high-end users directly through a dedicated physical connection. In principle, the users that are connected in this way determine how they use their connection. Therefore not all traffic passes the NREN routers. As a result, it is no longer feasible for the NREN to measure the traffic on such links. Given that they are normally supplied only to high-end users, it seems safe to assume that these traffic volumes are substantial and increasing.

[1] See section 4.3 for more information.

Twenty-one GÉANT partner NRENs now provide dedicated wavelengths (lambdas) to their customers. Per NREN, the number of lambdas provisioned in 2012 varies between zero and 151 (DFN of Germany). At present, the number of circuits seems to be the only measurable parameter that can be used to monitor the evolution of lambda traffic. Within GÉANT, around 875 wavelength circuits are now in use — four times greater than the figure in 2010.

Furthermore, users now use the Internet differently than in the past. One major change is that many users now access the Internet using a variety of mobile devices. Although mobility services to end users are usually provided by conventional ISPs and mobile network operators, the Croatian, Irish and UK NRENs are now active in this area. Trials are underway in Finland and the Netherlands, while the Czech Republic, Greece, Lithuania, Luxembourg and Portugal are in the planning phase. To summarise, 10 of the 36 GÉANT NRENs are either already active or planning to be active in this area.

Analysis of the available traffic data reveals substantial differences within Europe: traffic per inhabitant in Bulgaria, Cyprus, Latvia, Moldova, Montenegro, Serbia and Turkey remains below 15% of the European average.

Most European NRENs have deployed IPv6 on their backbones; client institutions can start to use IPv6 as and when the need arises.

Change and continuity

NRENs function as centres of excellence, in service of their clients. As such, an NREN generally constitutes an important asset for the research and educational community of the country in which it operates. In order to remain relevant, it is important that NRENs should be able to allocate resources to deploying new services for their users.

This edition of the *Compendium* shows that NRENs are aware of these challenges and are adapting to meet them. This requires a commitment from all major stakeholders, including funders and users. For NRENs, a model of governance that allows such stakeholders to participate would seem to be the most appropriate.

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. This may help to explain why this model of partial independence is more common in countries where, after many years of development, research and education networking is well established.

In this context, it seems relevant to quote from the recommendations of the ASPIRE study (2012), as published on the TERENA website[2]:

- *NRENs should re-consider their funding models and move to more diversified and sustainable models. This could embrace close collaboration with Public Service Networks but may require re-framing of some regulatory positions, connection policies, and acceptable use policies. A major goal should be to increase inter-institutional collaboration, aggregation of demand for joint procurement, and sharing of services.*

- *NRENs will need to take a strategic approach to their business planning and delivery of services, and develop a comprehensive understanding of their own user-base, including the needs of their international users and the external operating environment.*

- *NRENs should not compete with the commercial providers, particularly on price, but should act as a trusted broker that is an integral part of the community. They should provide expertise, aggregate demand, and add value through negotiation, including the coordination and support for AAI for their community.*

[2] www.terena.org/activities/aspire

1 BASIC INFORMATION

The TERENA *Compendium*, part of the GÉANT project, is an authoritative reference on the development of research and education networking in Europe and beyond. Section 1.1 presents information on the European National Research and Education Networks (NRENs) that responded to the questionnaire distributed by TERENA in May 2012. Section 1.2 includes a comprehensive list of non-European NRENs and shows which of them submitted responses to the questionnaire. Section 1.3 covers 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 briefly examines environmental policies.

1.1 European NRENs that responded to the questionnaire

There are 54 countries in the area covered by this 2012 edition of the *Compendium* (that is, Europe, as well as Mediterranean countries in the Middle East and North Africa). In four of those 54 countries (Lebanon, Libya, Palestinian Territory and Syria), there is either no NREN or we have no knowledge of NREN work there. A total of 46 NRENs in the same number of countries responded to the questionnaire; many, though not all, answered all the questions. The map 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 (36 in total) and other countries. Some NRENs in the other countries have associate partner status with GÉANT; this is also shown in the table.

Legend for Table 1.1.1

(green)	Responses received
(orange)	No responses received
(yellow)	NREN planned but not operational
(grey)	No NREN or no known NREN work in this country

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

Country	NREN	URL
GÉANT partner countries		
Austria	**ACOnet**	www.aco.net
Belgium	**Belnet**	www.belnet.be
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	**UNI-C**	www.forskningsnettet.dk/en
Estonia	**EENet**	www.eenet.ee
Finland	**Funet**	www.funet.fi (www.csc.fi/funet)
France	**RENATER**	www.renater.fr
Germany	**DFN**	www.dfn.de
Greece	**GRNET S.A.**	www.grnet.gr/default.asp?pid=1&la=2
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
Macedonia, FYRo	**MARNet**	dns.marnet.net.mk
Malta	**UoM/RicerkaNet**	www.um.edu.mt/itservices/about
Montenegro	**MREN**	www.mren.ac.me/
Netherlands	**SURFnet**	www.surfnet.nl


NREN
Responses received
No responses received
NREN planned but not operational
No NREN or no known NREN work
SERVICE (Red = planned)
Identity federation
Collaboration support
Cloud services
Premium services
Iceland
Norway
Sweden
Finland
Estonia
Latvia
Lithuania
Denmark
Russian Federation
Ireland
United Kingdom
Netherlands
Belarus
Poland
Germany
Belgium
Luxembourg
Czech Republic
Ukraine
Slovakia
Austria
Hungary
Moldova
Switzerland
France
Slovenia
Croatia
Romania
Italy
Bosnia/
Herzegovina
Serbia
Bulgaria
Montenegro
Macedonia
Georgia
Albania
Azerbaijan
Armenia
Spain
Portugal
Greece
Turkey
Malta
Tunisia
Cyprus
Algeria
Morocco
Israel
Jordan
Egypt

Table 1.1.1 - continued

Country	NREN	URL	
GÉANT partner countries			
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	
United Kingdom	**Janet**	www.ja.net	
Country	**NREN**	**URL**	**Relationship with GÉANT**
Other European and Mediterranean countries			
Albania	ANA	www.rash.al	
Algeria	CERIST	www.arn.dz	
Armenia	**ASNET-AM**	www.asnet.am	
Azerbaijan	**AzScienceNet**	www.science.az	
Azerbaijan	AzRENA	www.azrena.org	
Belarus	**BASNET**	www.basnet.by	associate
Bosnia/Herzegovina	SARNET[1]	www.jusarnet.net	
Egypt	EUN	www.eun.eg	
Georgia	GRENA	www.grena.ge	
Jordan	JUNet	www.junet.edu.jo	
Lebanon	CNRS	www.cnrs.edu.lb	
Libya			
Moldova	**RENAM**	www.renam.md	associate
Morocco	MARWAN	www.marwan.ma	
Palestinian Territory		www.qou.edu, www.birzeit.edu	

[1] SARNET is active only in the Republika Srpska entity of Bosnia/Herzegovina.

Table 1.1.1 - continued

Country	NREN	URL	Relationship with GÉANT
Other European and Mediterranean countries			
Russian Federation	e-ARENA	www.e-arena.ru	associate
Syria	HIAST	www.hiast.edu.sy	
Tunisia	CCK	www.cck.rnu.tn	
Ukraine	UARNet	www.uar.net/en	
Ukraine	URAN	www.uran.ua	associate

1.2 NRENs in other regions and continents

Table 1.2.1 (below) lists sources of information on NRENs in other continents.

Table 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 Africa	WACREN	www.wacren.net
Asia/ Pacific	APAN	www.apan.net
Central Asia	CAREN	caren.dante.net/server/show/nav.2290
Latin America	CLARA	www.redclara.net
Caribbean	CKLN	www.ckln.org
Canada	CANARIE	www.canarie.ca
USA	Internet2	www.internet2.edu
	National Lambdarail	www.nlr.net
	National Regional Networks consortium	www.thequilt.net

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

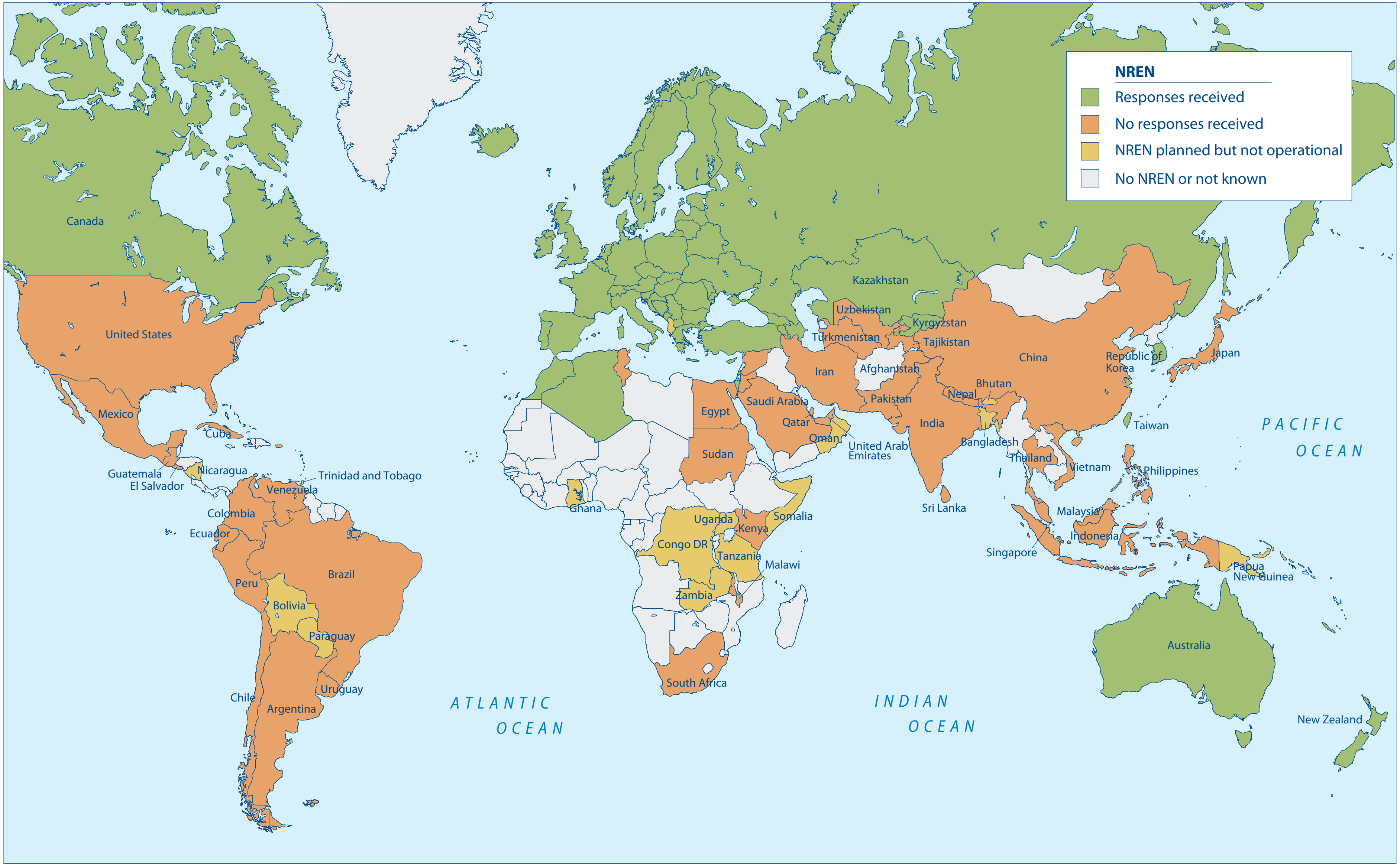

NREN
Responses received
No responses received
NREN planned but not operational
No NREN or not known
Canada
United States
Mexico
Cuba
Guatemala
El Salvador
Nicaragua
Trinidad and Tobago
Venezuela
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Argentina
Uruguay
ATLANTIC OCEAN
Ghana
Egypt
Sudan
Uganda
Kenya
Somalia
Congo DR
Tanzania
Malawi
Zambia
South Africa
Saudi Arabia
Qatar
Oman
United Arab Emirates
Iran
Afghanistan
Pakistan
Kazakhstan
Uzbekistan
Turkmenistan
Kyrgyzstan
Tajikistan
India
Nepal
Bhutan
Bangladesh
Sri Lanka
China
Republic of Korea
Japan
Taiwan
Thailand
Vietnam
Philippines
Malaysia
Indonesia
Singapore
Papua New Guinea
INDIAN OCEAN
PACIFIC OCEAN
Australia
New Zealand

Table 1.2.2 (below) lists those NRENs and NREN initiatives in other parts of the world of which we are currently aware. Note that this list is not complete: there may be other NRENs of which we have no knowledge. Also, in some countries the situation may be subject to rapid change. Eight NRENs from non-European countries submitted data for this *Compendium*; they are highlighted in green. Their full responses are available at **www.terena.org/activities/compendium**.

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

(green)	Responses received
(orange)	No responses received
(yellow)	NREN planned but not operational

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
Bhutan	DrukREN	
Bolivia	BOLNET	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
Congo DR	eb@le	www.ebale.cd

Table 1.2.2 - continued

Country	NREN	URL
Cuba	RedUNIV	www.mes.edu.cu
Ecuador	CEDIA	www.cedia.org.ec
Egypt	EUN	www.eun.eg
El Salvador	RAICES	www.raices.org.sv
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
Japan	SINET	www.sinet.ad.jp
Japan	JGN2plus	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
Kyrgyzstan	KRENA-AKNET	www.krena.kg
Malawi	MAREN	www.malico.mw/maren
Malaysia	MYREN	www.myren.net.my
Mexico	CUDI	www.cudi.edu.mx
Nepal	NREN	www.nren.net.np
New Zealand	REANNZ	www.karen.net.nz
Nicaragua	RENIA	www.renia.net.ni
Oman	OMREN	www.trc.gov.om
Pakistan	PERN	www.pern.edu.pk
Papua New Guinea	PNGARNet	www.pngarnet.ac.pg
Paraguay	Arandu	www.arandu.net.py/cms
Peru	RAAP	www.raap.org.pe
Philippines	PREGINET	www.pregi.net
Qatar	Qatar Foundation	www.qf.org.qa

Table 1.2.2 - continued

Country	NREN	URL
Saudi Arabia	ISU	www.isu.net.sa
Singapore	SingAREN	www.singaren.net.sg
Somalia	Somaliren	www.somaliren.org
South Africa	SANReN	www.sanren.ac.za
South Africa	TENET	www.tenet.ac.za
Sri Lanka	LEARN	www.learn.ac.lk
Sudan	SUIN	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
Trinidad and Tobago	TTRENT	
Turkmenistan	TuRENA	www.science.gov.tm/en/turena
Uganda	RENU	www.renu.ac.ug
United Arab Emirates	ANKABUT	www.kustar.ac.ae/ankabut
United States	Internet2	www.internet2.edu
Uruguay	RAU	www.rau.edu.uy
Uzbekistan	UzSciNet	www.uzsci.net
Venezuela	REACCIUN	www2.reacciun.ve/reacciuncms/index_1.html
Vietnam	VinaREN	www.vinaren.vn
Zambia	ZAMREN	www.zamren.zm

1.3 Legal form of NRENs

NRENs have various legal forms. NREN names and their 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. Forskningsnettet in Denmark 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 also performs a number of other functions within Finland, such as supercomputing. Although the two parameters cited above can characterise the legal form of an NREN, the classification is not always straightforward.

Relationship with government

In this *Compendium*, we distinguish three situations:

a) Some NRENs are under direct government control. This is the case if an NREN is (part of) a government agency or a parastatal.

b) Some NRENs operate independently of government to a certain extent; for example, those which are separate legal entities with governing boards at least half of whose members are government appointed. Also, some NRENs which are government agencies enjoy a certain degree of autonomy comparable to that of NRENs which are separate legal entities.

c) Some NRENs have no direct government ties, even though, typically, the majority of their client institutions are largely government-funded.

Separate legal entity

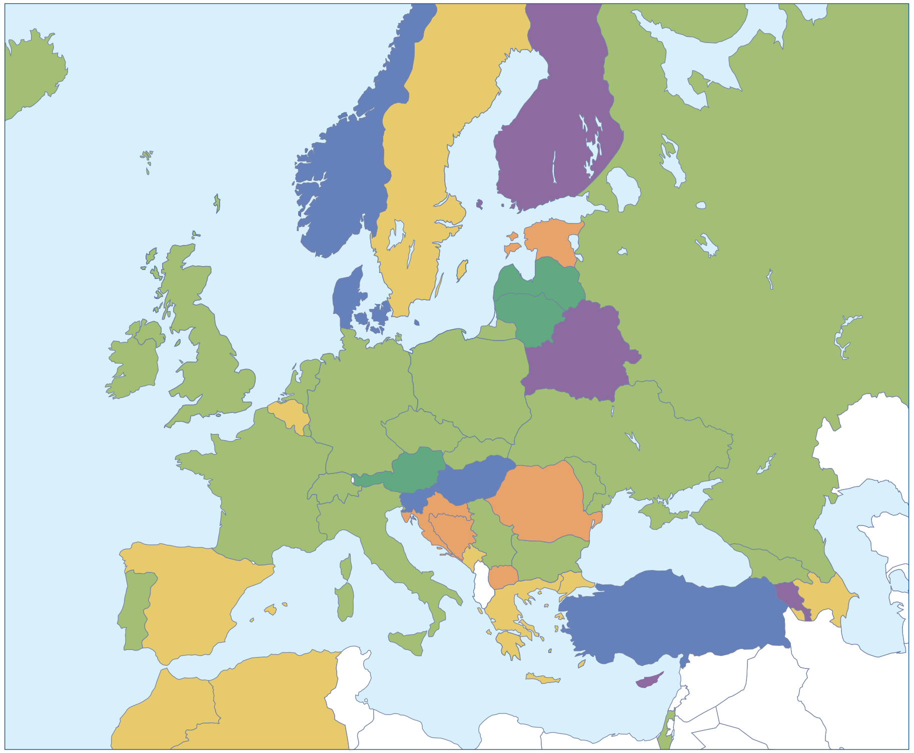
Many NRENs operate as separate legal entities.

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

Legend for Map 1.3.1

	NRENs which are not under direct government control, separate legal entities
	NRENs which are not under direct government control, not separate legal entities
	NRENs which are largely government-controlled, separate legal entities
	NRENs which are largely government-controlled, not separate legal entities
	NRENs which are entirely government-controlled, separate legal entities
	NRENs which are entirely government-controlled, not separate legal entities

Map 1.3.1 - Legal form of NRENs



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 2012 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. For the full responses, see Appendix I.

No clear trend is observable in the descriptions given by NRENs. The most striking development is that a number of NRENs are involved in restructuring processes, either because of government and funder demands (such as in Denmark, Estonia and the UK) or for internal reasons (such as in Croatia, the Netherlands and Switzerland). Several NRENs report negative effects of the economic crisis.

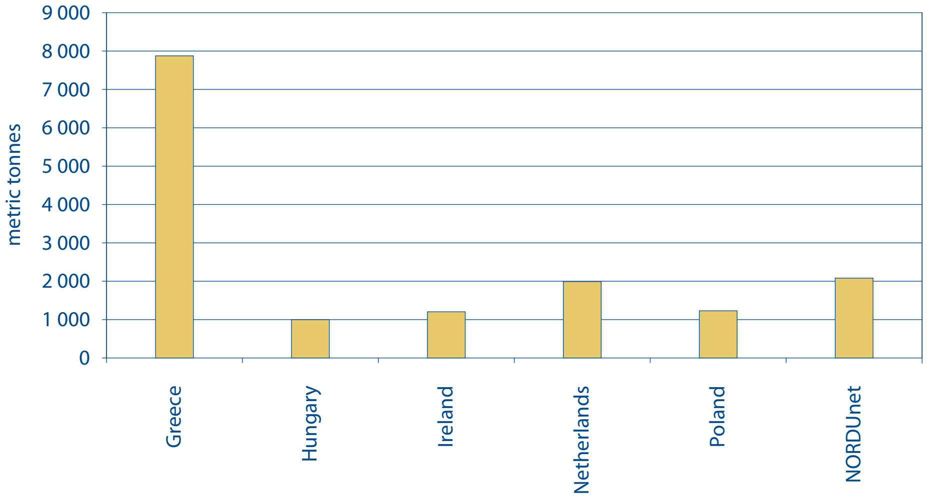
In addition, the changeover to dark fibre infrastructures, capacity and configuration is continuing. Several NRENs are now building on this changeover by preparing to deliver services via the cloud and by setting up data centres (such as in Croatia, the Czech Republic and Greece). Several NRENs mention a possible expansion of their user base, for example through increased collaboration with networks that aim to connect secondary schools.

1.5 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, although recent progress has been relatively slow, perhaps due to the economic crisis.

As part of the GN3 project, five NRENs (GRNET, HEAnet, PSNC, NIIF/HUNGARNET and SURFnet) and one regional network (NORDUnet) have audited their GHG emissions.

Graph 1.5.1 – NREN greenhouse gas emissions, 2009/2010



As shown in Graph 1.5.1, the quantity of GHG emissions shows considerable variation from country to country. In part, this is attributable to differences in CO_2 emissions which result from differences in electricity generating methods. Another factor in the variation is that the networks are not easily comparable. GRNET, for example, has a large data centre, whereas the other NRENs do not.

For further information, see:
www.geant.net/Network/Environmental_Impact/Pages/home.aspx

Five GÉANT NRENs (Estonia, Hungary, Ireland, Portugal and the UK) report that they have an environmental policy in place. AARNet of Australia also has such a policy. The Irish and UK policies are available from the respective NREN websites:
www.heanet.ie/about/environmental_policy
www.ja.net/documents/company/environmental-policy.pdf

2 CLIENT INSTITUTIONS

Section 2.2 indicates how many institutions in the various categories are actually connected to the NREN (i.e. the 'market shares'); Section 2.3 estimates how many users this represents; Section 2.4 examines the typical bandwidths; and a new section, 2.5, examines dark fibre connections to client institutions.

2.1 Overview

As shown in previous editions of the *Compendium*, all the NRENs covered by this publication are allowed to connect universities and research institutes. Nearly all may connect institutes of further education, as well as libraries and museums. Information on these 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, this does not necessarily mean that it actually does. In the university sector, NRENs obviously have very high market shares; in other areas, the situation differs greatly from country to country.

For universities within the GÉANT area, the typical connection capacity is now Gigabit or greater — a tremendous increase compared with the situation a few years ago. Capacities exceeding 10 Gb/s are currently being introduced. All other categories of users have significantly lower capacities. In the European and Mediterranean countries that are not part of the GÉANT project, Gigabit connections are not yet prevalent.

Based on conservative assumptions and on data provided by NRENs themselves, we estimate that the NRENs in the GÉANT region provide services to approximately 88% of all the university-level students in the countries involved; that is, a total of 20.5 million students.

Dark fibre connections enable novel network architectures and new services. Approximately half of the GÉANT NRENs already connect all or nearly all of the universities in their respective countries with dark fibre. Dark fibre is being provided to many other client institutions as well. Five GÉANT NRENs connect their clients with dark fibre only. NRENs beyond the GÉANT area are also connecting their clients with dark fibre. Via a dark fibre infrastructure, NRENs can offer virtual private networks (VPNs) as a service. In the GÉANT area, this is currently being done by ten NRENs.

2.2 Approximate market shares

Table 2.2.1 provides an overview of the number of institutions in each user category, as well as an indication of the percentage of users that are serviced by each NREN. Only approximate percentages were obtained from *Compendium* respondents.

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: **www.terena.org/compendium**

Legend for Table 2.2.1

(dark green)	All or nearly all (more than 80%) of the institutions are connected by the NREN
(light green)	More than half (between 60 and 80%) of the institutions are connected by the NREN
(yellow)	About half (between 40 and 60%) of the institutions are connected by the NREN
(orange)	Less than half (between 20 and 40%) of the institutions are connected by the NREN
(red)	None or very few (less than 20%) of the institutions are connected by the NREN
(grey)	Unknown or not applicable

Table 2.2.1 – Approximate market shares, number of connected institutions

Country	Universities	Research institutes	Institutes of further education	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
GÉANT partner countries								
Austria	36	29	1			11	4	35
Belgium	65	37	6	5	0	11	16	50
Bulgaria	22	50	2	1500	500	15	5	
Croatia	141	36	46	426	904	10	15	9
Cyprus	6	2	3					
Czech Republic	26	25	10	105	14	50	40	39
Denmark	8	12	7	0	0	5	2	4
Estonia	21	21	16	126	21	84	1	3
Finland	51	12				6		8
France	445	368	335			12	6	20
Germany								
Greece	43	28	146	4390	9803	12	0	727
Hungary	25	73	28	34	0	210	50	4
Iceland	9	11	2	1		1		
Ireland	25	10	10	800	3200	0	0	8
Israel	12	5	0	0	0	0	0	0
Italy	139	203	0	5	1	35	53	5
Latvia	15	13	4	3	0	3	0	0
Lithuania	42	31	55	551	37	32	4	35

Table 2.2.1 – continued

Country	Universities	Research institutes	Institutes of further education	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
GÉANT partner countries								
Luxembourg	6	22	1	59	200	12	1	14
Macedonia, FYRo	19	5	0	0	0	50	0	1
Malta	1	3	2					
Montenegro	19	2	1			2		1
Netherlands	14	32	64	0	0	19	12	0
Norway	8	81	56	4	4	17	0	0
Poland	180	194						
Portugal	42	12	0	0	0	3	0	13
Romania	50	55	10	350	140	40	10	30
Serbia	87	41	9	13	5	20	5	2
Slovakia	38	20	7	250	100	6		
Slovenia	4	54	20	156	528	205	0	18
Spain	90	170	0	0	0	25	50	75
Sweden	30	4	9			19		20
Switzerland	43	10	3	2	0	0	0	6
Turkey	899	18				2		6
United Kingdom	200	35	550			9	0	6
Other countries								
Algeria	57	25	34					4
Armenia	2	35				4	4	
Azerbaijan		30				4		
Belarus	10	57				17	5	8
Bosnia/Herzegovina	25	1	1					0
Georgia	10	5	18	3		4	3	2
Moldova	5	36	1	1	0	10	5	1
Morocco	15	8	80	0	0	2	0	2
Russian Federation	250	240						

Table 2.2.1 – continued

Country	Universities	Research institutes	Institutes of further education	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
Other countries								
Ukraine	64	16				4		1
Australia	41	24	13	225	223	9		1
Canada	89	70	184	1300	700	26	62	50
Kazakhstan	51	7		5			1	2
Korea	51	61	0	1	0	3	1	18
Kyrgyzstan	27	17	0	34	0	3	3	1
New Zealand	8	13	13	81	93	5	1	2
Singapore	4	2						1
Taiwan	120	20	20	500	1000	5	5	20
Tanzania	4	1	4					

2.3 Numbers of users

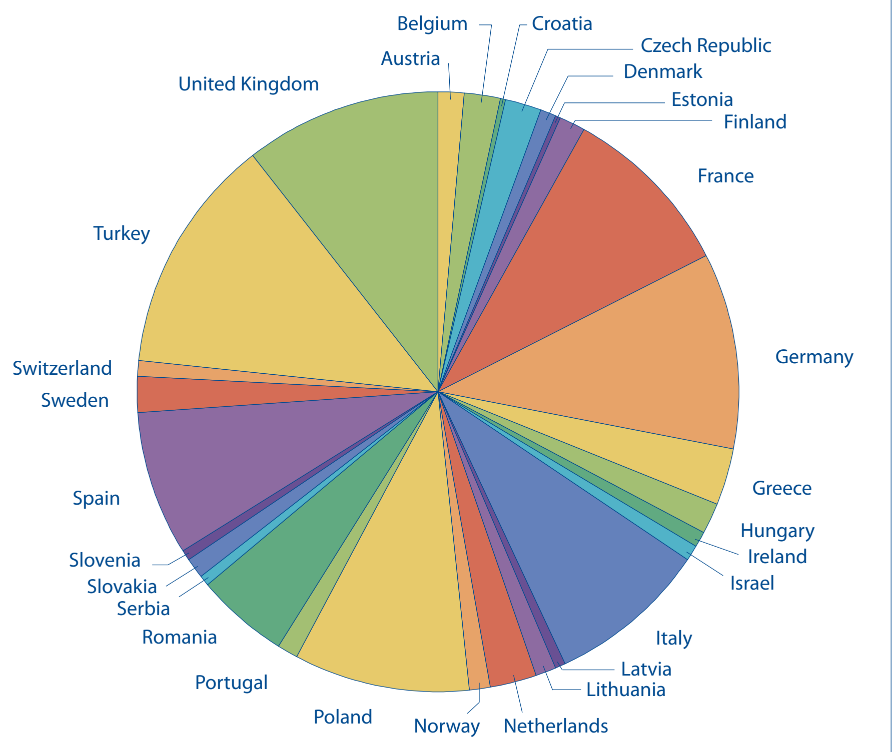
In the questionnaire for this edition of the *Compendium*, NRENs were asked to estimate the numbers of university students they serve. This information has been combined with enrolment figures derived from UNESCO statistics to produce Graph 2.3.1 (right), which gives an estimate of the total number of university students served by GÉANT NRENs. Note that not all NRENs were able to give such an estimate. In those cases, we have made conservative assumptions. For example, PIONEER in Poland is structured as a network that connects the country's regional networks. These, in turn, connect all or nearly all of the Polish universities. We have thus assumed that 90% of students in Poland benefit from PIONEER's services. In other cases, we have considered the NRENs' own estimates of the percentage of students that have an eduroam-enabled account.

Based on the data received and the assumptions explained above, we estimate that NRENs in the GÉANT region provide services to approximately 88% of all the university-level students in the countries involved; that is, a total of 20.5 million students.[2]

Of course, the fact that a student receives NREN services does not in itself tell the whole story, because the quality of service must also be taken into account. Map 2.4.3 indicates both the bandwidth available to universities and the spread of bandwidth between universities in each country. The universities in Turkey, for example, are connected at a relatively low bandwidth, whereas the spread between the most-connected and the least-connected university is relatively low. In the UK, by contrast, universities are connected with higher bandwidths, and the spread is also higher.

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

Graph 2.3.1 – Students connected by NRENs, GÉANT area



[2] Based on 2009 UNESCO data on student numbers and 2010 Eurostat data for Greece and Luxembourg.

2.4 Bandwidths

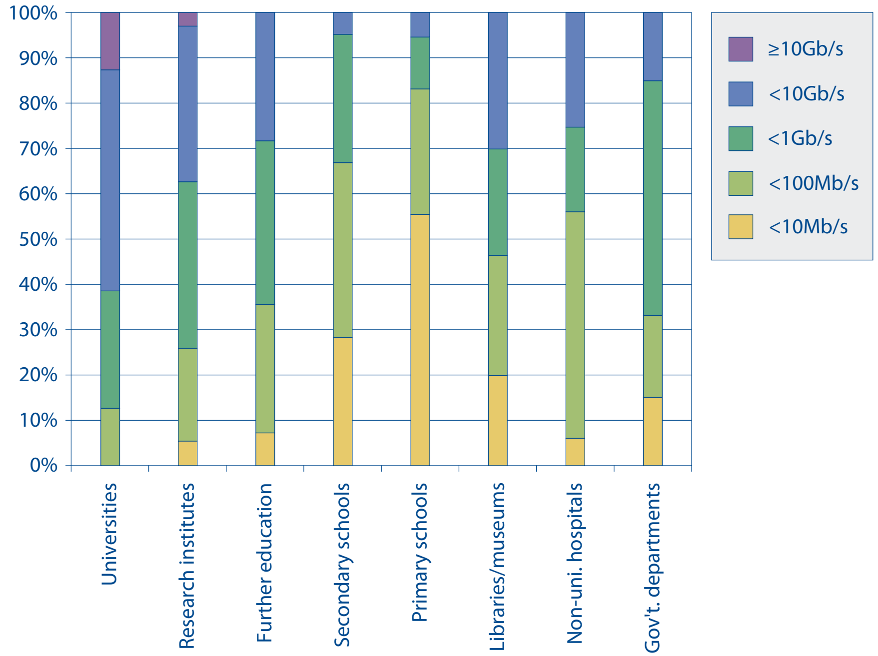
From the 2008 edition of the *Compendium*:

> *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 is now Gigabit or greater, with 10 Gb/s becoming increasingly common. All other user categories have much lower connection speeds.

Graph 2.4.1 gives an overview of the distribution of typical 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.

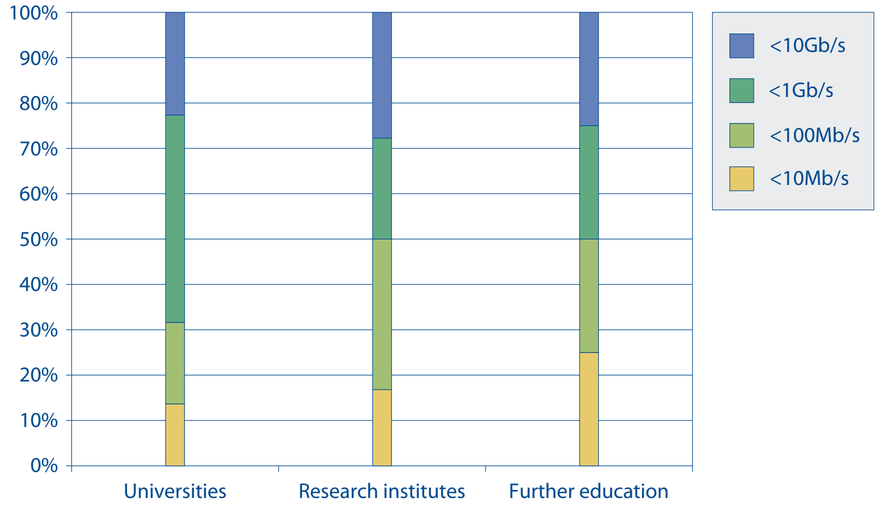
Graph 2.4.1 – Typical bandwidth, GÉANT partner countries



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

In countries outside the GÉANT region, the situation is quite different: Gigabit connections are being introduced but are not yet prevalent. Graph 2.4.2 presents a more limited set of user categories than those shown in Graph 2.4.1, because fewer countries provided the necessary information.

Graph 2.4.2 – Typical bandwidth, other countries



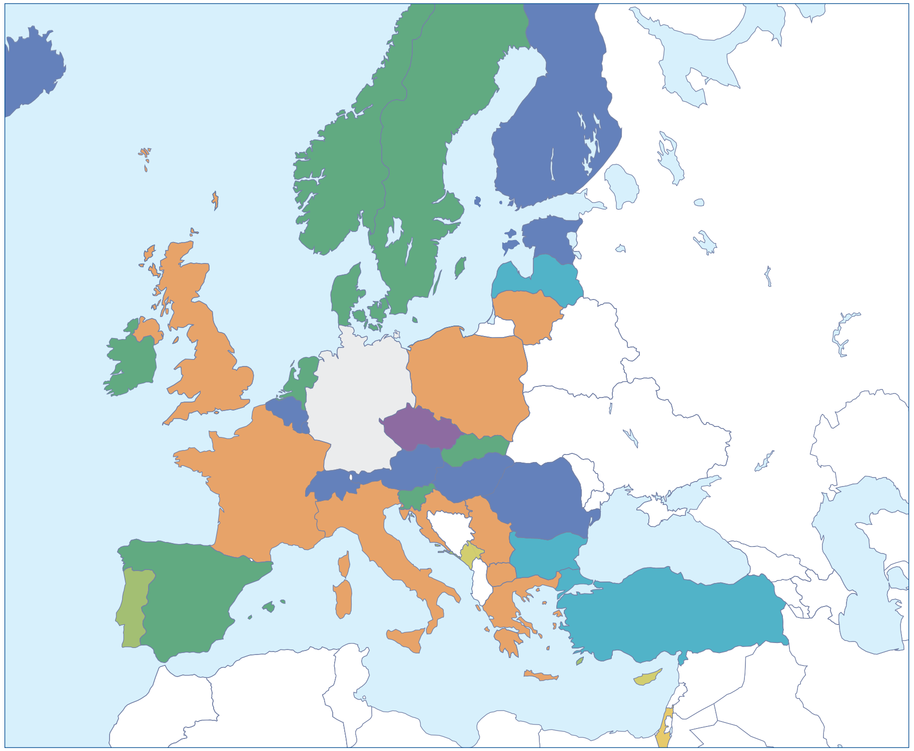
To give an impression of the distribution of bandwidths within the GÉANT area and within individual countries, we have categorised NRENs according to two dimensions: (1) the average bandwidth available to universities in the country (low, middle or high) and the spread between the lowest and highest connection categories. This, together with the traffic per inhabitant metric shown in Section 4.4, gives an impression of the digital divide in Europe, both among and within countries.

The results are shown in Map 2.4.3. The NRENs connecting their universities at low bandwidth are Bulgaria, Cyprus, Israel, Latvia, Montenegro and Turkey. The NRENs with a high spread between low-bandwidth- and high-bandwidth-connected universities are in Croatia, France, Greece, Israel, Italy, Lithuania, Luxembourg, Macedonia, Poland and the UK.

Legend for Map 2.4.3

	Spread		
Bandwidth	Low	Middle	High
Low			
Middle			
High			
No data available			

Map 2.4.3 – Distribution of bandwidth among universities



2.5 Clients connected with dark fibre

Dark fibre connections are those where the supplier of the connection provides only the physical optical cable. For actual communication purposes, this 'dark' fibre has to be 'lit', which can be done either by the NREN or by the client institution itself. As explained in Section 3.4, this creates many new possibilities. It is therefore interesting to know how many client institutions are connected with dark fibre. For the first time, we included questions about dark fibre connections to client institutions in the 2012 *Compendium* survey.

As shown by Table 2.5.1, approximately half of the GÉANT NRENs already connect all or nearly all of the universities with dark fibre. Dark fibre is also being provided to many other client institutions. Five GÉANT NRENs (Denmark, Finland, Netherlands, Poland and Switzerland) connect their clients with dark fibre only. NRENs beyond the GÉANT area are also connecting clients with dark fibre. The spread of this type of connection is probably being stimulated by both technological and price advantages.

Legend for Table 2.5.1

(dark green)	All or nearly all (more than 80%)
(light green)	More than half (between 60 and 80%)
(yellow)	About half (between 40 and 60%)
(light orange)	Less than half (between 20 and 40%)
(red)	None or very few (less than 20%)
(grey)	No answer provided or not applicable

Table 2.5.1 – Percentage of institutions connected to the NREN with dark fibre

Country	Universities	Research institutes	Further education	Secondary schools	Primary schools	Libraries,/museums	Non-uni. hospitals	Government departments
GÉANT partner countries								
Austria	100	80	80	5	0	50	80	100
Belgium	7		33	50	0	30	0	25
Croatia	7	1	1	4	4	1	2	1
Cyprus	0	0	0					
Czech Republic	100	15	0	0	0	10	5	15
Denmark	100				0			
Finland	100	100				100		100
France	10	10				10		
Germany	19	19	19					
Greece	100	8	56	4	2	100		1
Hungary	90	25	10	0	0	5	0	0
Iceland	70	90	0	0	0	100		
Ireland	100	5	10	1	0	0	0	10
Israel	0	0	0	0	0	0	0	0
Italy	40	50		16		23	61	100
Latvia	0	0	0	0	0	0	0	0
Lithuania	98	90	54	15	56	60	50	50
Luxembourg	100	62	0	65	25	40	100	33
Macedonia, FYRo	100	0				50		2
Malta	100	30	0					
Montenegro	19	2	1			2		1

Table 2.5.1 – continued

Country	Universities	Research institutes	Further education	Secondary schools	Primary schools	Libraries,/museums	Non-uni. hospitals	Government departments
GÉANT partner countries								
Netherlands	100	100	100			100	100	
Norway	100	95	100	80	80	95		
Poland	100	97	100	100	100	100	100	100
Portugal	70	30	0	0	0	0	0	25
Romania	20	34	5	15	5	12	2	5
Serbia	80	30	40	70	0	40	80	100
Slovenia	100	44	55	30	6	22	0	90
Spain	45	10						
Sweden	97	100	100			100		100
Switzerland	100	100	100	100				100
Turkey	2	28				0		67
United Kingdom	20	15	1	0	0	0	0	0
Other countries								
Algeria	0	0	0					0
Bosnia/Herzegovina	100	100	100					
Georgia	100	100	50	0		100	0	50
Moldova	5	36	1	1	0	10	5	1
Morocco	0	0	0	0	0	0	0	0
Russian Federation	50	60						
Ukraine	75	20	3					2
Australia	91	96	100	86		100	100	100
Canada	80	50	50			50	40	50
New Zealand	100	100	10	15	15	0	0	100
Taiwan	2	2	0	0	0	0	0	0

For this edition of the *Compendium*, we have examined the technological aspect in greater detail by asking NRENs what connectivity services they provide to client institutions that are connected with dark fibre. The replies are summarised in Table 2.5.2 (below). 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. In the GÉANT area, this is currently being done by ten NRENs.

Table 2.5.2 – Connectivity services and institutions serviced specifically by non-IP connectivity

Country	Connectivity services besides IP connectivity	Details of institutions serviced specifically by non-IP connectivity	Are institutions allowed to share a common IP connection?
GÉANT partner countries			
Austria			Institutions can use one connection with different VLANS configured to connect to ACOnet.
Belgium	Optical, Fibre Channel		Some organisations share the bandwidth with other smaller organisations in the neighbourhood, for various reasons (pricing, maximisation of bandwidth usage,...) Belnet contracts with only 1 party.
Croatia	Optical		If we have two or more institutions on the same address, we provide them one link with separate IP ranges for each of them.
Cyprus	Ethernet		
Czech Republic	Optical		
Denmark	Optical		
Estonia	Optical		Cost efficiency and optimal cabling are primary targets.
Finland	Optical		Small remote sites may use connections of local institutions.
France	L2 services	L2 or L3 VPNs are provided when there is no need to access to Internet	Institutions are often connected via regional or metropolitan networks.
Germany	Optical	Various VPN structures	Several institutions share an IP-access-link to the X-WIN-router.

Table 2.5.2 – continued

Country	Connectivity services besides IP connectivity	Details of institutions serviced specifically by non-IP connectivity	Are institutions allowed to share a common IP connection?
GÉANT partner countries			
Greece	Optical	In addition to the IP network topology, L2 VPNs are established among many GRNET clients. This applies mainly to customers that have multiple points of presence and a single point of exit to our IP network.	GRNET has presence within the largest institutions. In several cases, smaller institutions connect to these institutions and share their uplink to GRNET.
Hungary	Optical		In a few cases, separate smaller R&E organisations access the network through a major university.
Ireland	Optical, Layer 2 point-to-point links		By mutual agreement and where the access policy and operational service is managed by a single client.
Italy	Optical, other:	L1 and L2 VPN	Share a last mile using bandwidth control like C.A.R.
Latvia	Optical, ADSL, LMDS		If they are in one building, they can share costs of the connectivity.
Lithuania	Optical		According to the LITNET AUP.
Luxembourg	Optical		If 2 or more institutions are in the same building they share the same connection.
Macedonia, FYRo			If they share the premises (building) and are both eligible to be connected.

Table 2.5.2 – continued

Country	Connectivity services besides IP connectivity	Details of institutions serviced specifically by non-IP connectivity	Are institutions allowed to share a common IP connection?
GÉANT partner countries			
Montenegro			In a few cases where it is too expensive and not cost-effective to establish additional fibre optic, institutions share existing connections and interconnect via copper UTP.
Netherlands	Optical, LightPath / Ethernet	All institutions have IP from their main location. Some have OPN (Lightpath) connectivity to other sites.	
Norway	Optical		Some institutions share premises
Poland	Optical, VPNs	Project infrastructures	
Portugal	Optical, Ethernet Multipoint to multipoint VPN	A few institutions aggregate several geographically dispersed accesses using a Ethernet VPN provided by FCCN.	Connection sharing must be individually approved and must operate on a strict not-for-profit basis.
Romania	Optical	There are some institutions that connect to RoEduNet using ISPs infrastructure.	
Slovenia	Optical, PSTN		
Spain	Optical, L2 p2p connections	Institutions that are affiliated only to support their participation in some project, when that project only requires L2 connectivity.	There is no specific rule. If two institutions reach an agreement to share the connection, it is accepted by us. Each institution has its own address range. For the management of that physical connection, we require a contact technical point. For all the other services we provide, we require technical contact points for each institution.

Table 2.5.2 – continued

Country	Connectivity services besides IP connectivity	Details of institutions serviced specifically by non-IP connectivity	Are institutions allowed to share a common IP connection?
GÉANT partner countries			
Sweden	Optical		In rare circumstances, especially in rural areas.
Switzerland	Optical	8 sites with OPN-only connectivity	Universities may connect other – typically smaller – schools behind them and provide them transit to SWITCH.
United Kingdom	Optical		
Other countries			
Armenia	Optical, VLAN		
Azerbaijan	Optical		
Georgia	Optical, PSTN		
Moldova	Optical	Dedicated lines for connecting Grid Sites	
Morocco			A university can connect all the institutions belonging to it.
Russian Federation	Optical	We provide some VPN between several universities	
Australia	Optical		
Canada	Optical	Lightpath	Enabling VLAN tagging to allow sharing of a connection.
Kazakhstan	Optical, PSTN		Connection between departments and building.
Korea	Optical	e-KVN (Korean e-VLBI network), medical-KREONET and so on.	
New Zealand	Ethernet VLAN	Private VLAN	REANNZ commons
Taiwan	Optical, VPLS, VPN	We provide VPLS VPNs to some institutions.	

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. Section 3.5 focuses on cross-border dark fibre links. Section 3.6 examines other technologies used by NRENs. Section 3.7 includes an overview of major expected network developments.

3.1 Overview

In most GÉANT partner countries, the typical core capacity is now 10 Gb/s, though some NRENs have reached 20 or even 40 Gb/s. 10 Gb/s is also the median capacity, up from 2 Gb/s in 2008. As many NRENs in this 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 countries outside of the GÉANT region, the trend that was visible last year is continuing: they have profited from the introduction of affordable Gigabit Ethernet technology. Network capacity is growing stepwise rather than linearly. Nevertheless, comparing the growth in core capacity (documented in Section 3.2) with the growth in overall traffic (documented in Section 4.3) reveals that, on average these two trends are keeping pace with each other.

In general, connections not only to the European academic backbone network (i.e. GÉANT) but also to the general Internet are crucial to NRENs. Currently, connections via cross-border fibre and connections to the commercial Internet jointly account for over 60% of the total external connectivity (up from just over 50% in 2011). Compared to last year, connections to Internet exchanges have remained stable at 19% of the total external connection capacity, while connections to GÉANT and NORDUnet account for 14% of that total. Compared to the previous year, total capacity has grown, but not equally in all connection categories, as Graph 3.3.2 illustrates. The greatest expansion has been seen in connections to the commercial Internet, and cross-border fibre.

Since 2005, for the purposes of the *Compendium*, TERENA has been monitoring the uptake of dark fibre in NRENs. 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 (2012), the aggregate length of dark fibre used internally by NRENs in the GÉANT region exceeds 110 000 km and is growing at approximately 10% annually. Major differences compared to 2011 include expansion of the dark fibre network in several countries and the implementation of a dark fibre network in Spain.

There are many ways to use dark fibre cost-effectively within an NREN, all of them focused on enhanced services for clients and their 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. Maps 3.4.1 and 3.4.2 illustrate the rapid developments in dark fibre over the past five years.

Another continuing development is the implementation of cross-border dark fibre links between NRENs. Section 3.5 presents information on current and planned links of this type, in both map and table format.

Although mobility services to end-users are usually provided by conventional ISPs and mobile network operators, the NRENs in Croatia, Ireland and the UK have become active in this area. Trials are underway in Finland and the Netherlands, and the Czech Republic, Greece, Lithuania and Portugal are in the planning phase. Altogether, 10 of the 36 GÉANT NRENs are either already active or planning to be active in this area.

For this year's *Compendium*, we asked NRENs whether they are involved in operating an Internet exchange. Of the 36 GÉANT NRENs, 17 (almost half) responded that they are.

Major expected network developments reported by NRENs include:

- In many countries, dark fibre networks are already in place and being upgraded and extended to multiples of 10 Gb/s. Six GÉANT NRENs report that they are preparing for 100 Gb/s;
- In many countries, improvements to the core network are associated with increased connectivity for users, as well as users being connected to the NREN core network with dark fibre (see Section 2. 5);
- In several countries bordering on the EU, connections to GÉANT are to be increased significantly. This is expected to act as a catalyst for developments at the national level.

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 20 or even 40 Gb/s. 10 Gb/s is also the median capacity, up from 2 Gb/s in 2008. 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, Section 3.4 shows that many NRENs now have several point-to-point circuits and lightpaths, which offer additional capacity that is not usually included in normal traffic statistics.

The typical capacity of the links no longer tells the whole story. The NREN networks form a mesh, with 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 10 Gb/s (the typical link capacity) but 210 Gb/s (the capacity of the mesh as such).

In non-GÉANT countries that submitted data for the *Compendium* survey, the trend that was visible last year is continuing: they have profited from the introduction of affordable Gigabit Ethernet technology.

Network capacity is growing stepwise rather than linearly. Nevertheless, comparing the growth in core capacity with the growth in overall traffic (documented in Section 4.3) reveals that these two trends are keeping pace with each other. In the period 2008-2012, the annual average growth of core capacity in the GÉANT partner countries was 33.6%. In the same period, the annual average growth of traffic on the GÉANT backbone was 36.8% (Section 4.4).

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 2012.

Please note that the Nordic NRENs (Funet of Finland, RHnet of Iceland, SUNET of Sweden, UNINETT of Norway and UNI•C [Forskningsnettet] of Denmark) share their external connections through NORDUnet.

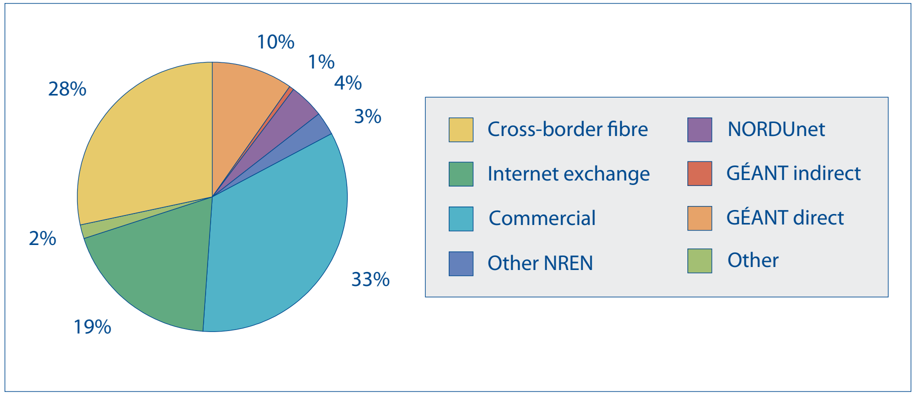
In general, connections to GÉANT and to other NRENs carry research and education traffic, while peerings and other connections convey traffic to and from the general Internet. Research and education traffic may consist of highly specialised data and is often transmitted in huge volumes within very short 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.

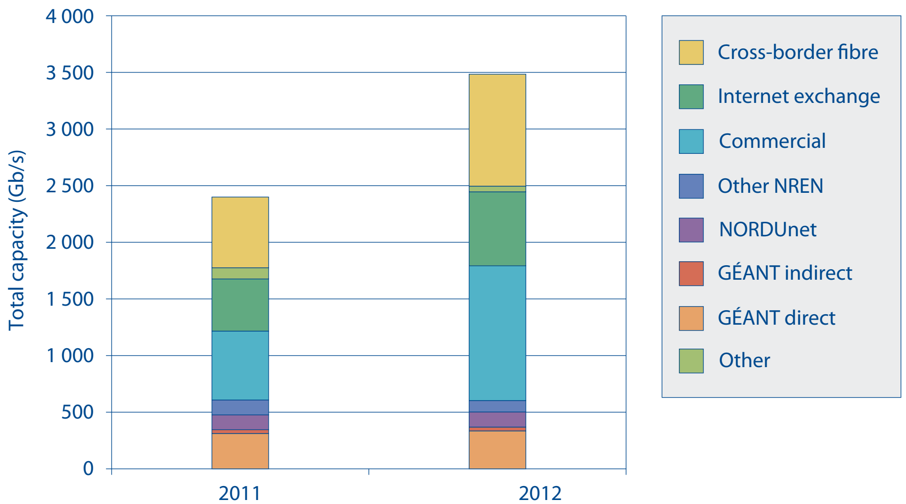
Note that in Graph 3.3.1 (below), which represents the average situation for all GÉANT partner NRENs, these two distinct categories of connections are combined.

Graph 3.3.1 – Capacity of NREN external connections, GÉANT partner countries, 2012



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. Graph 3.3.1 illustrates that, currently, connections via cross-border fibre and connections to the commercial Internet jointly account for over 60% of the total external connectivity (up from over 50% in 2011). Compared to last year, connections to Internet exchanges have remained stable at 19% of the total external connection capacity. Connections to GÉANT and NORDUnet account for 14%. Compared to the previous year, total capacity has grown, but not equally in all connection categories, as Graph 3.3.2 illustrates. The greatest expansion has been seen in connections to the commercial Internet and in cross-border fibre.

Graph 3.3.2 – Capacity of NREN external connections, GÉANT partner countries, 2011 and 2012



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.

Since 2005, TERENA has been monitoring the uptake of dark fibre in NRENs. 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 (2012), the aggregate length of dark fibre used internally by NRENs in the GÉANT region exceeds 110 000 km and is growing at approximately 10% annually. Cross-border fibres are also becoming an important feature, and in some cases these bi-lateral links are being integrated within the GÉANT pan-European infrastructure.

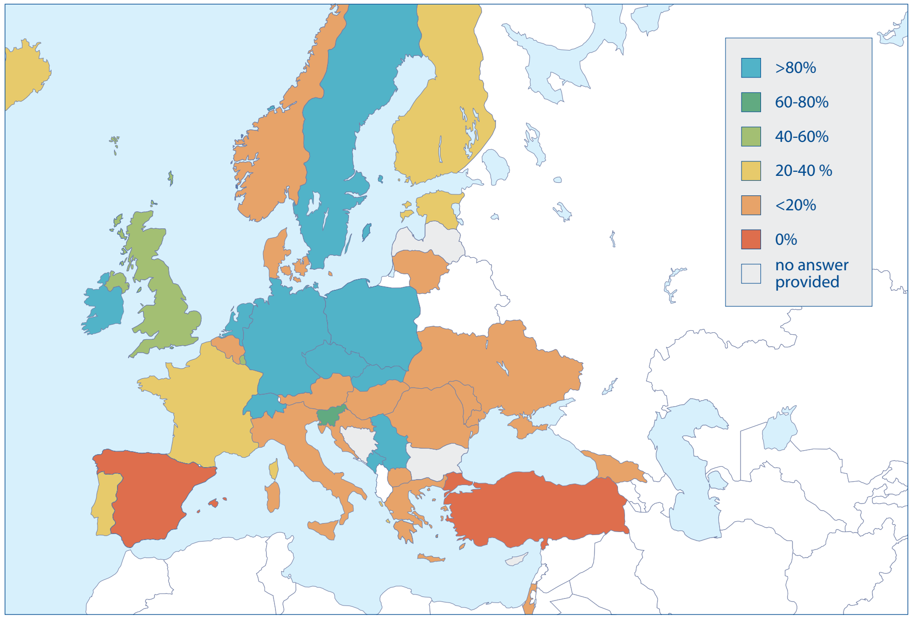
There are many ways to use dark fibre cost-effectively within an NREN, all of them focused on enhanced services for clients and their users. NRENS, as a result of moving from managed network links to their own transmission infrastructure, have been able to develop new features and services at various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

- Network engineering;
- Campus networks at regional and national scales;
- 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 since 2007 (see Section 7 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 differentiate this service from the NRENs' use of wavelengths to engineer their networks and to provide different layers for switched and routed services. Lightpaths, by contrast, arise from user requirements for specific circuits to interconnect resources. The responses to this year's Compendium questionnaire indicate that 21 European NRENs are offering lambdas as a service and are providing over separate 800 static circuits as a result.

Map 3.4.1 – Dark fibre on NREN backbones, 2007



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

[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.

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

Maps 3.4.1 and 3.4.2 illustrate the rapid developments in dark fibre in recent years.

Major differences compared to 2011 include expansion of the dark fibre network in several countries and the implementation of a dark fibre network in Spain. Table 3.4.3 shows that the length of dark fibre in Poland has expanded considerably in the past year.

Note that for certain countries that did not respond in the year in question, data from the previous year was used instead.

Map 3.4.2 – Dark fibre on NREN backbones, 2012

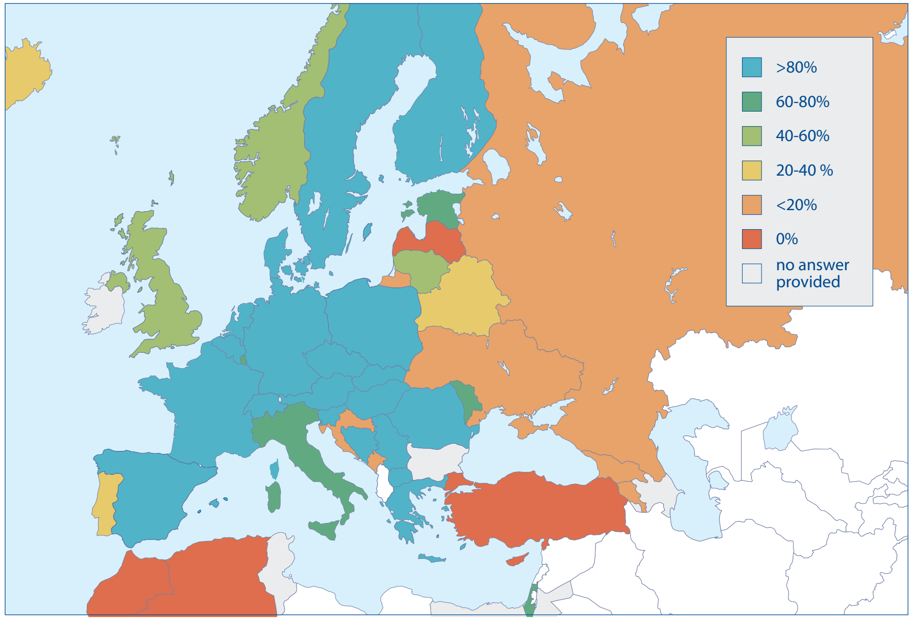


Table 3.4.3 – Dark fibre on NREN backbones, 2012

Country	Total length of dark fibre (km)	Proportion of total network length (%)	% of dark fibre length added	% decommissioned
GÉANT partner countries				
Austria		100	0	0
Belgium	2 066	100	4	0
Croatia	385	15	7	0
Cyprus	0	0		
Czech Republic	5 120	100	1	0
Denmark	2 000	95		
Estonia	1 163	75	0	0
Finland	4 090	92	7	0
France	11 900	90	9	2
Germany	10 900	98	4	0
Greece	8 968	99	25	0
Hungary	3 200	95	2	1
Iceland	190	19	0	0
Ireland	2 600		0	0
Israel	15	5	0	0
Italy	8 500	70	88	0
Latvia	0	0	0	0
Lithuania	1 166	46	0	0
Luxembourg	320	70	40	5
Macedonia, FYRo	20	95	0	0
Montenegro	10	5	0	
Netherlands	11 898	100	12	0
Norway	8 200	60	0	0
Poland	7 257	100	8	0
Portugal	1 000	25	0	0
Romania	5 636	95	25	0
Serbia	4 000	95	90	0

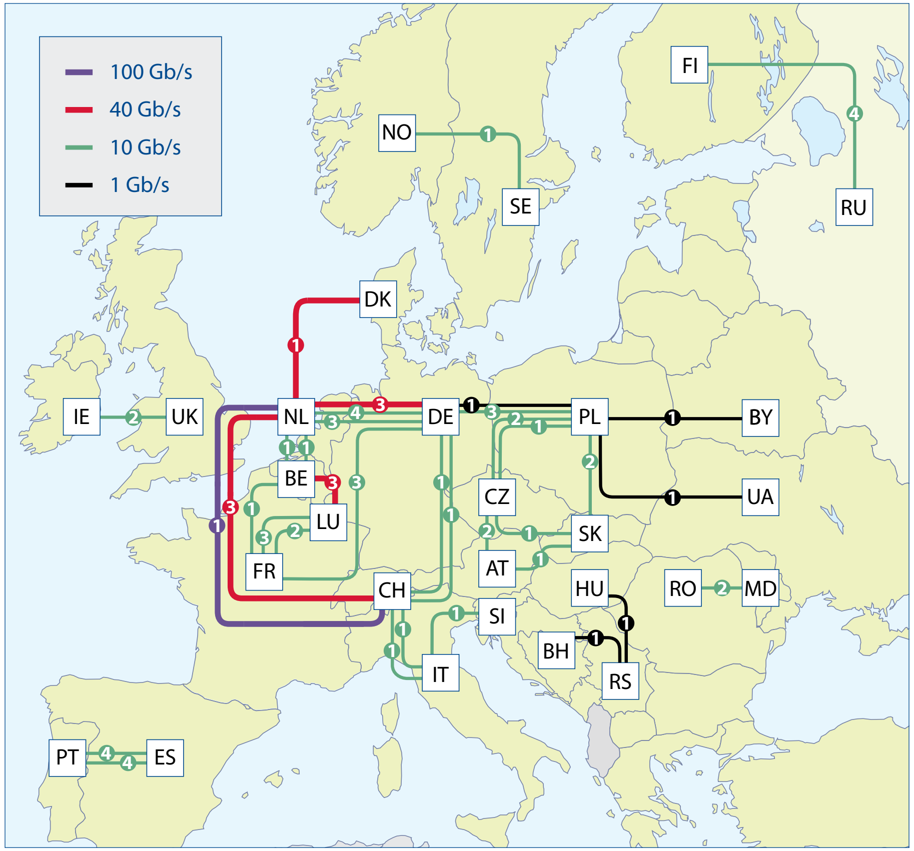
Table 3.4.3 – continued

Country	Total length of dark fibre (km)	Proportion of total network length (%)	% of dark fibre length added	% decommissioned
GÉANT partner countries				
Slovakia	2 100	100	0	0
Slovenia	1 635	100	28	27
Spain	13 500	96	80	0
Sweden	8 000	95	1	0
Switzerland	3 052	100	3	0
Turkey	155	0	7	0
United Kingdom	8 480	60	0	0
Other countries				
Algeria	0			
Armenia	50	10	20	15
Azerbaijan	35			
Belarus	18	20	0	0
Bosnia/ Herzegovina	700	100	14	0
Georgia	50	10	0	28
Moldova	165	80	0	0
Morocco	0	0	0	0
Russian Federation	600	4	0	0
Ukraine	360	9	15	2
Australia	87 300	90	63	0
Canada	5 000	35	8	0
New Zealand	80	0	0	0
Singapore	0	0	0	0
Taiwan	80	2	0	0
Tanzania	0	0	0	0

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 optical fibre dedicated to use by a single organisation — where the organisation is responsible for attaching the transmission equipment to 'light' the fibre".[3] Table 3.5.3 provides an overview of current cross-border dark fibre links, whereas Table

Map 3.5.1 – Cross-border dark fibre, current
(the numbers on the map indicate the number of lambdas)



[2] *Networks for Knowledge and Innovation: A Strategic Study of European Research and Education Networking*, Summary Report on the SERENATE studies, IST-2001-34925, p. 28, www.serenate.org/publications/d21-serenate.pdf.

3.5.4 shows which new links NRENs are planning to install. As is clear from this table, the trend is set to continue over the next few years.

Maps 3.5.1 and 3.5.2 present the same information schematically. Note that the links shown do not necessarily correspond to the actual geographical routes.

Map 3.5.2 – Cross-border dark fibre, planned
(the numbers on the map indicate the number of lambdas)

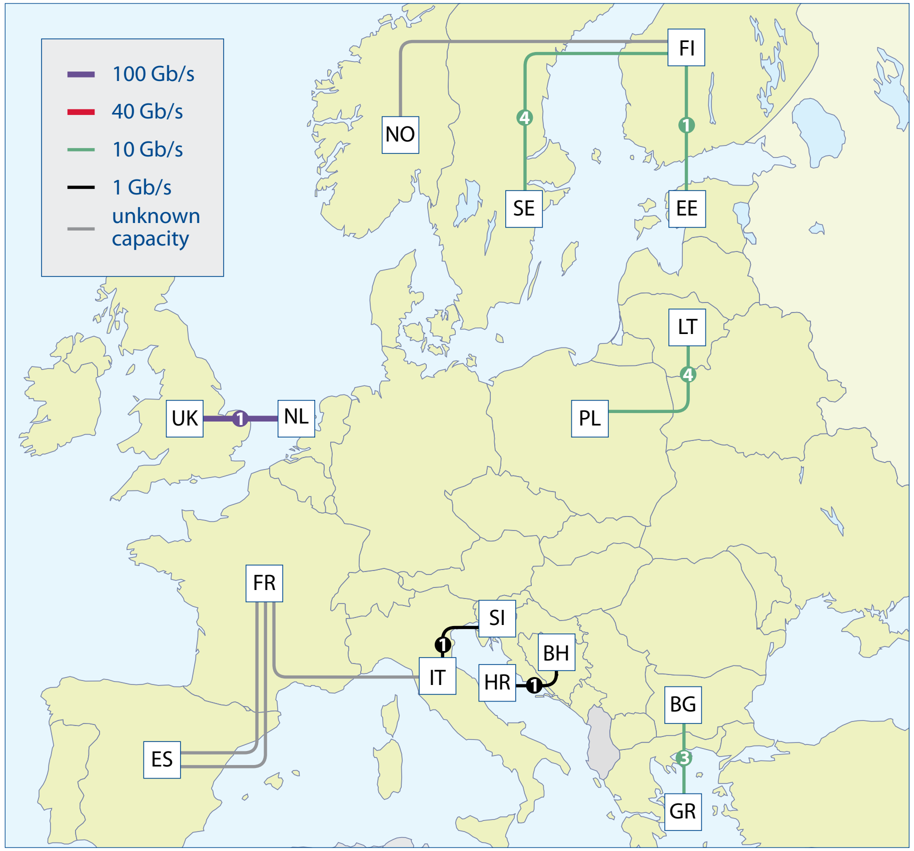


Table 3.5.3 – Cross-border dark fibre (current)

NREN	NREN	Current	Start date	Current capacity (Gb/s)	No. of lambdas
GÉANT partner NRENs					
AMRES	NIIF/ HUNGARNET	Subotica (RS) – Szeged (HU)	2005	1	1
BASNET	PIONIER	Kuźnica Białostocka (PL) – Grodno (BY)	2010	1	1
Belnet	RENATER	Brussels (BE) - Paris (FR)	01/2011	10	1
Belnet	RESTENA	Arlon (BE) – Esch (LU)	01/2011	10	3
Belnet	SURFnet	Hasselt (BE) - Maastricht (NL)	01/2012	10	1
CESNET	ACOnet	Brno (CZ) to Vienna (AT)	2006	10	2
CESNET	PIONIER	Ostrava (CZ) to Poznan (PL)	2005	10	2
CESNET	SANET	Brno (CZ) to Bratislava (SK)	2005	10	1
e-ARENA	Funet	St. Petersburg (RU) – Helsinki (FI)	01/11/09	10	4
FCCN	RedIRIS	Lisbon (PT) – Badajoz (ES)	04/06/2009	10	4
FCCN	RedIRIS	Porto (PT) – Vigo (ES)	15/12/2011	10	4
GARR	ARNES	Trieste (IT) – Sezana (SI)	31/10/2011	10	1
GARR	SWITCH	Milan (IT) – Manno (CH)	23/05/2006	10	1
GARR	SWITCH	Milan (IT) – Manno(CH)	01/01/2011	10	1
HEAnet	Janet	IE-UK	2007	1	2
PIONIER	CESNET	Bielsko Biała (PL) - Cesky Tesin (CZ)	2012	10	1
PIONIER	DFN	Poznań (PL) - Frankfurt /O (DE)		1	1
PIONIER	DFN	Poznań (PL) – Hamburg (DE)	Mar 2010	10	3
PIONIER	SANET	Zwardoń-Skalite (PL) – Žilina (SK)	Oct 2007	10	2
PIONIER	URAN	Hrebenne (PL) – Lviv (UA)	Dec 2008	1	1
RENAM	RoEduNet	Chisinau (MD) – Lasi (RO)	2010	10	2
RENATER	DFN	Strasbourg (FR)-Kehl (DE)	2007	10	3
RENATER	RESTENA	Nancy (FR)-Esch (LU)	2010	10	2
RESTENA	RENATER	Thionville (FR) - Esch (LU)	Sept 2010	10	3
SANET	ACONet	Bratislava (SK) -Wien (AT)	08/2002	10	1

Table 3.5.3 – continued

NREN	NREN	Current	Start date	Current capacity (Gb/s)	No. of lambdas
GÉANT partner NRENs					
SARNET	AMRES	Karakaj (BH) - Sabac (RS)	2006	1	1
SUNET	UNINETT	Kiruna (SE) – Narvik (NO)	Mar 2011	10	1
SURFnet	Belnet	Amsterdam (NL) – Brussels (BE)	2011	10	1
SURFnet	DFN	Amsterdam (NL) – Hamburg (DE)	2007	40	3
SURFnet	DFN	Maastricht (NL) – Aachen (DE)	2007	10	4
SURFnet	DFN	Amsterdam (NL) – Muenster (DE)	2007	10	3
SURFnet	SWITCH	Amsterdam (NL) – Geneva (CH)	2010	40	3
SURFnet	SWITCH	Amsterdam (NL) - Geneva (CH)	2011	100	1
SURFnet	UNI-C	Amsterdam (NL) - Copenhagen (DK)	2007	40	1
SWITCH	DFN	Karlsruhe (DE) - Basel (CH)	2008	10	1
SWITCH	DFN	Kreuzlingen (CH) - Konstanz (DE)	2011	10	1
Other NRENs					
NCHC		StarLight	2004	3	1
NCHC		Pacificwave	2004	3	1
NCHC		MANLAN	2006	1	2
REANNZ		Pacifc Wave	Dec 2010	1	0
REANNZ		Equinix	Dec 2010	1	0

Table 3.5.4 – Cross-border dark fibre (planned)

NREN	NREN	endpoint	Start date	Capacity	Lambdas
ARNES	GARR	Sežana(SI) – Trieste(IT)	Q3/2012	1	1
Funet	EENET	Helsinki(FI) – Tallinn(EE)	2013	10	1
Funet	SUNET	Kemi(FI) – Luleå(SE)	8/2012	10	4
Funet	UNINETT	Sodankylä (FI) – Utsjoki(NO)	2013		
GRNET S.A.	BREN	Athens(GR) - Sofia(BG)	2013	10	3
LITNET	PIONIER	Kaunas(LT) – Poznan(PL)	2012	10	4
RedIRIS	RENATER	Montpellier(FR) – Barcelona(ES)	2013		
RedIRIS	RENATER	Bordeaux(FR) – Bilbao(ES)	2013		
RENATER	GARR	Modane (FR)-Bardonecchia (IT)			
SARNET	CARnet	Gradiska(BH) – Zagreb(HR)	2013	1	1
SURFnet	Janet	Amsterdam(NL) – London(UK)	2012-2013	100	1

3.6 Other technologies used by NRENs

As in earlier years, we asked NRENs to indicate the technologies they are currently deploying in their access networks or are making available to individual end-users. The responses are shown in Table 3.6.1. Note that not all NREN respondents answered these questions. Also note that the questionnaire did not cover the extent to which these technologies are currently being deployed. The only question was whether they are being deployed at all.

Generally, NRENs do not provide mobile access to licensed spectrum. Mobility access to WiFi by using eduroam® is enabled by all GÉANT members and many other NRENs outside of the GÉANT region.

Although mobility services to end-users are usually provided by conventional ISPs and mobile network operators, the NRENs in Croatia, Ireland and the UK have become active in this area. Trials are underway in Finland and the Netherlands, and the Czech Republic, Greece, Lithuania and Portugal are in the planning phase. Altogether, 10 of the 36 GÉANT NRENs are either already active or planning to be active in this area.

In addition, NRENs may be able to provide important services to mobile student and staff populations. Middleware and security services are essential, and NRENs are best placed to deliver these to the education and research communities (for further information, see Sections 5.2 and 5.3).

This year, we asked NRENs whether they are involved in operating an Internet exchange. Of the 36 GÉANT NRENs, 17 (almost half) responded that they are. Of these 17, six are involved in an operational capacity only, four in a governing capacity only and five in both capacities. Two are involved in an advisory capacity.

Table 3.6.1 –Technologies deployed at the access-level network

Country	FTTH/ FTTO	DSL	WLAN	Satellite	Other licensed spectrum	WiFi off-campus — using eduroam	WiFi off-campus — using MNO	Other unlicensed spectrum
GÉANT partner countries								
Bulgaria	no	no	yes	no	no	no	no	no
Czech Republic	no	no	no	no	no	no	no	no
France	no	yes	no	yes	trial	yes	plan	no
Italy						yes		
Luxembourg	yes	yes	yes			yes		
Montenegro	no	no	yes	no	no	yes	no	no
Netherlands	yes				trial			
Poland	yes	yes	yes	no	no	yes	no	no
Sweden	no	no	no	no	no	plan	no	no
Turkey		yes						
Other countries								
Armenia		yes	yes			yes		
Georgia	yes	yes						
Moldova		yes	yes			yes		
Morocco	yes				yes			
Ukraine	yes		yes					
Canada				yes				
New Zealand	yes	no	no	no	no	plan	no	no
Taiwan	yes							

3.7 Major expected network developments

The NRENs covered by this edition of the *Compendium* were asked to outline major initiatives relating to the 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 3.7.2 provides a general insight into expected major developments of networks in the various countries in Europe and other continents. The expected developments reported by NRENs include:

- In developed regions of the world, dark fibre networks are already in place and being upgraded and extended to 10 Gb/s or multiples thereof. Some NRENs are preparing for 100 Gb/s. A number of NRENs report DWDM;

- For several EU neighbour countries, increased possibilities for international connectivity are acting as a catalyst for developments at the national level.

Chart 3.7.1 gives an impression of the same information, presented as a Wordle chart.

Chart 3.7.1 – Wordle chart of major expected network developments

Table 3.7.2 – Major expected network developments

Country	Developments	Timeframe	Confidence
GÉANT partner countries			
Belgium	Implementation of a new Belnet (optical) network.	2013-2014	Quite certain
	Belnet will extend its fibre network by creating smaller optical rings or by inserting new locations (PoPs or datacentres) in the existing fibre ring topology.	2012-2014	Quite certain
Croatia	QoS	2012	Quite certain
	Optical switching	2012	Quite certain
Cyprus	International (GÉANT) upgrade	1	Quite certain
Czech Republic	Network core upgrade to 100Gbit/s (IPoDWDM)	1	Quite certain
	Deployment of Terabit routers (100Gbit/s support)	1	Quite certain
	DWDM network migration (up to 80 channels support with planned capacity per channel of 100Gb/s.	1	Quite certain
Finland	Extend the coverage of the DWDM optical network and upgrade the existing multi-degree DWDM nodes to WSS (PXC).	1	Quite certain
	Expand the availability and usage of backup customer connections. Provide better availability of 10 Gbps connections to customers.	1	Quite certain
	Introduce dynamic lightpath services to complement the current static lightpath service.	2	Quite certain
Germany	Implementation of a new optical platform for the WiN.	2012	Quite certain

Table 3.7.2 – continued

Country	Developments	Timeframe	Confidence
GÉANT partner countries			
Greece	The designed architecture of the next generation of the GRNET network (GRNET-4) is based on 3 basic service layers: the optical service layer, the carrier service layer and the IP service layer. The IP service layer will provide connectivity with the Internet, the carrier network will support the deployment and provision of E-Line, E-Lan and E-Tree services, while the optical layer will support the dynamic creation and maintenance of optical paths with 1Gbps/10Gbps/40Gbps/100Gbps capacities. The part relating to the IP and the carrier service layer will be deployed in the beginning of 2013 while the part relating to the optical service layer will be deployed by the end of 2013. Expansion of the GRNET core network is also predicted for the interconnection of the GRNET data centres that are currently under deployment.	2012-2013	Quite certain
Hungary	Extending the network to primary and secondary schools.	2	Quite certain
Ireland	Upgrading of existing DWDM network to ROADM.	2 years	Quite certain
	Possible connection of large number of sensors to network.	1-3 years	Likely
	Skip 40G, using n x 10G while waiting for 100G.	1-2 years	Likely
	Virtualisation of network resources using NaaS (Network as a Service) framework. This can incorporate BoD (Bandwidth on Demand.)	1-3 years	Quite certain
	Work on integrating virtualisation of network and services — a combination of IaaS, PaaS (Platform) and SaaS (Software).	1-3 years	Quite certain
	A three-stream strategy on Ipv4/6 environment: a. IPv4 depletion processes (1 year / ongoing).	1-5 years	Quite certain
	A three-stream strategy on Ipv4/6 environment: b. Fully standalone IPv6 network.	1-5 years	Likely
	A three-stream strategy on Ipv4/6 environment: c. Clients on IPv6.	1-5 years	Likely
	Enhanced L2 & Optical resilience.	2 years	Quite certain
	Infrastructure for national centralised data storage for clients.	1 year	Quite certain

Table 3.7.2 – continued

Country	Developments	Timeframe	Confidence
GÉANT partner countries			
Israel	Plan to upgrade our core network to a dark fiber network of abut 750km— leased on a yearly basis	1	Quite certain
Italy	completion of deployment of new DWDM network (GARR-X)	end 2012	Quite certain
	completion of deployment of new routing infrastructure (GARR-X)	end of 3rd quarter 2012	Quite certain
Latvia			
Lithuania	Participation in the Baltic Ring project	4	Likely
Luxembourg	Extend cross-border fibrelinks to Germany	2	Likely
	Full 10G Ethernet coverage in the backbone	2	Quite certain
	Extend the coverage of the DWDM optical network	2	Quite certain
	Planning the replacement of IRU contracts	5	Quite certain
Macedonia, FYRo	Connect other 4 public universities	1	Quite certain
	Upgrade GÉANT link to 310 Mbps	0.5	Quite certain
Malta	Greater use of dark fibre	3-5	Uncertain
Netherlands	Further uptake of Bandwidth on Demand; more users integrating BoD into the tools they are using.	3	Quite certain
	Transition to Next Generation Ethernet	2012-2013	Quite certain
	Renewal of photonic layer of SURFnet network	2014-2015	Uncertain
	40/100G connections to the large institutes	2013-2014	Quite certain
	Several external capacity upgrades	2012-2013	Quite certain
Poland	Establish connection to SURFNet	2012	Uncertain
	Develop 100G network connecting HPC centers and MANs directly.	2016	Quite certain
Romania	Core upgrade to 100G connections	2	Quite certain
Serbia	SEELight project	2	Quite certain
Slovakia	Upgrade to 100GE	3-5	Quite certain
Switzerland	Complete update of the core network infrastructure, including optical transmission layer	4	Quite certain

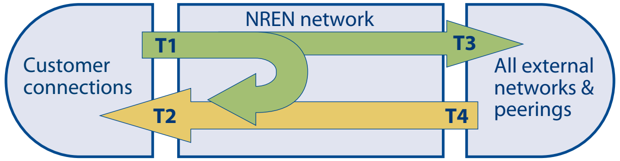
Table 3.7.2 – continued

Country	Developments	Timeframe	Confidence
GÉANT partner countries			
Turkey	Dark fibre installation in metropolitan areas	2	Quite certain
	Obtain fibre infrastructure in interurban area	5	Likely
United Kingdom	Upgrade of core infrastructure	2013	Quite certain
	All regional networks to be managed in-house	Within 4 years	Quite certain
Other countries			
Algeria	Upgrade GÉANT connection	1	Quite certain
	Upgrade Internet connection	1	Quite certain
Belarus	Increase the capacity of the link to PIONIER up to 2.5 Gbps	2012	Quite certain
	Increase the capacity of the link to PIONIER up to 10 Gbps	2013-2015	Likely
Moldova	Upgrade connectivity to GÉANT	2012	Quite certain
	Upgrade connectivity to GÉANT	2012	Quite certain
	Elaboration of detailed technical project of Eastern external connection to the Ukraine realization	2013	Likely
	GÉANT PoP in Chisinau	2012	Likely
	Implementation of cross-border connection to the Ukrainian NREN (and to possible GÉANT PoP in Kiev)	2015	Likely
Russian Federation	DWDM channel Moscow - Saint Petersburg	2013	Likely
Australia	MPLS VPN/pseudowire	2	Quite certain
Canada	40G/100G wavelength deployment	3	Quite certain
Taiwan	Future Network researches	4	Quite certain
	Cloud services	4	Quite certain

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 *and from* GÉANT, the commercial Internet, Internet Exchanges, etc. (consisting of T3 + T4 above).
Note: all IP traffic includes both IPv4 and IPv6 traffic.

This diagram does not tell the whole story: in some cases, the traffic reported may include that 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 other cases, non-routed traffic within a customer network may be switched via NREN point-to-point circuits but would not be reported here, as it does not appear as IP traffic on the NREN network.

The same 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. Traffic on such links does not go through the routed IP network and is thus not reported.

Section 4.1 gives an overview of the NRENs' responses , as well as this year's traffic trends. Section 4.2 considers traffic in 2011, whereas Section 4.3 analyses traffic trends over the past five years. Section 4.4 gives information on NREN traffic per inhabitant. Section 4.5 looks at congestion. Section 4.6 examines deployment of IPv6. Finally, Section 4.7 focuses on lambda traffic.

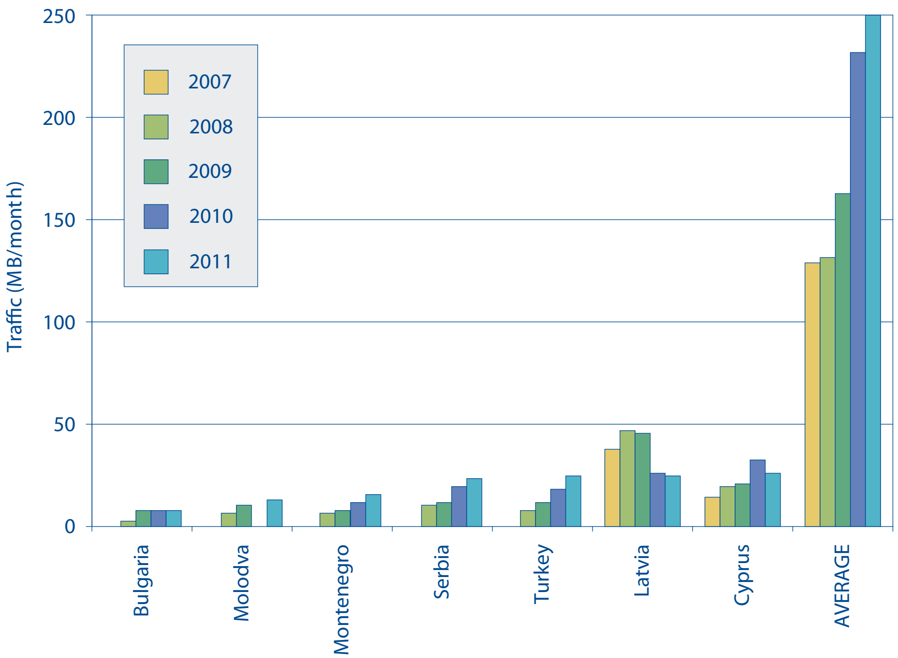
4.1 Overview

Most of the NRENs that responded to the 2012 *Compendium* questionnaire reported the annual IP traffic flows at the point where they exchange traffic with external networks (T3 & T4); 71% of the NRENs also reported the annual traffic flows between their connected sites and their backbone network (T1 & T2). The T3 & T4 traffic levels are relatively easy to measure and record, as there are only a few points on the network to monitor. Graphs 4.2.1 (2011 traffic, T3 > 4000 TB) and 4.2.2 (2011 traffic, T3 < 4000 TB) represent all the national responses submitted in 2012. Comparison with data from previous years reveals that IP traffic continues to grow. Over the past eight years, the annual rate of growth has fluctuated (but always remained positive), averaging almost 36%. In recent years, the growth rate seems to have been slowing to some extent, though it should be noted that traffic growth patterns are neither the same in all countries, nor the same from year to year. Lithuania was the country with the fastest growth of traffic over the past five years.

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 connect high-end users directly with each other through a dedicated physical connection in the form of a wavelength or 'Lambda' on an optical fibre cable. In principle, the users that are connected in this way 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 in other ways than the standard IP method.) As a result, it is no longer feasible for the NREN to measure the traffic on such links. Given that they are normally supplied only to high-end users, it seems safe to assume that such traffic volumes are substantial and growing.

Twenty-one GÉANT partner NRENs now provide dedicated wavelengths (lambdas) to their customers. Per NREN, the number of lambdas provisioned in 2012 varies between zero and 151 (DFN of Germany). At present, the number of circuits seems to be the only measurable parameter that can be used to document the evolution of lambda traffic. Within GÉANT, around 875 wavelength circuits are now in use for high-bandwidth, low-jitter transport (up from 700 last year and 200 two years ago). Nearly all lambdas reported by the 21 NRENs concerned are static or fixed. Only one NREN is currently using dynamic lambdas, which can be set up and taken down (by the NREN or its customers) for short-term requirements.

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



Analysis of the available traffic data reveals substantial differences within Europe: traffic per inhabitant in Bulgaria, Cyprus, Latvia, Moldova, Montenegro, Serbia and Turkey remains below 15% of the European average level. (See Section 4.4 for the full graph.)

For the GÉANT partner countries, average estimated congestion at campus level has consistently decreased. However, it seems that recent investments in increased capacity at the external and backbone levels are causing some bottlenecks at the access network level. For the time being, congestion at the backbone and external connections levels seems to have been largely resolved.

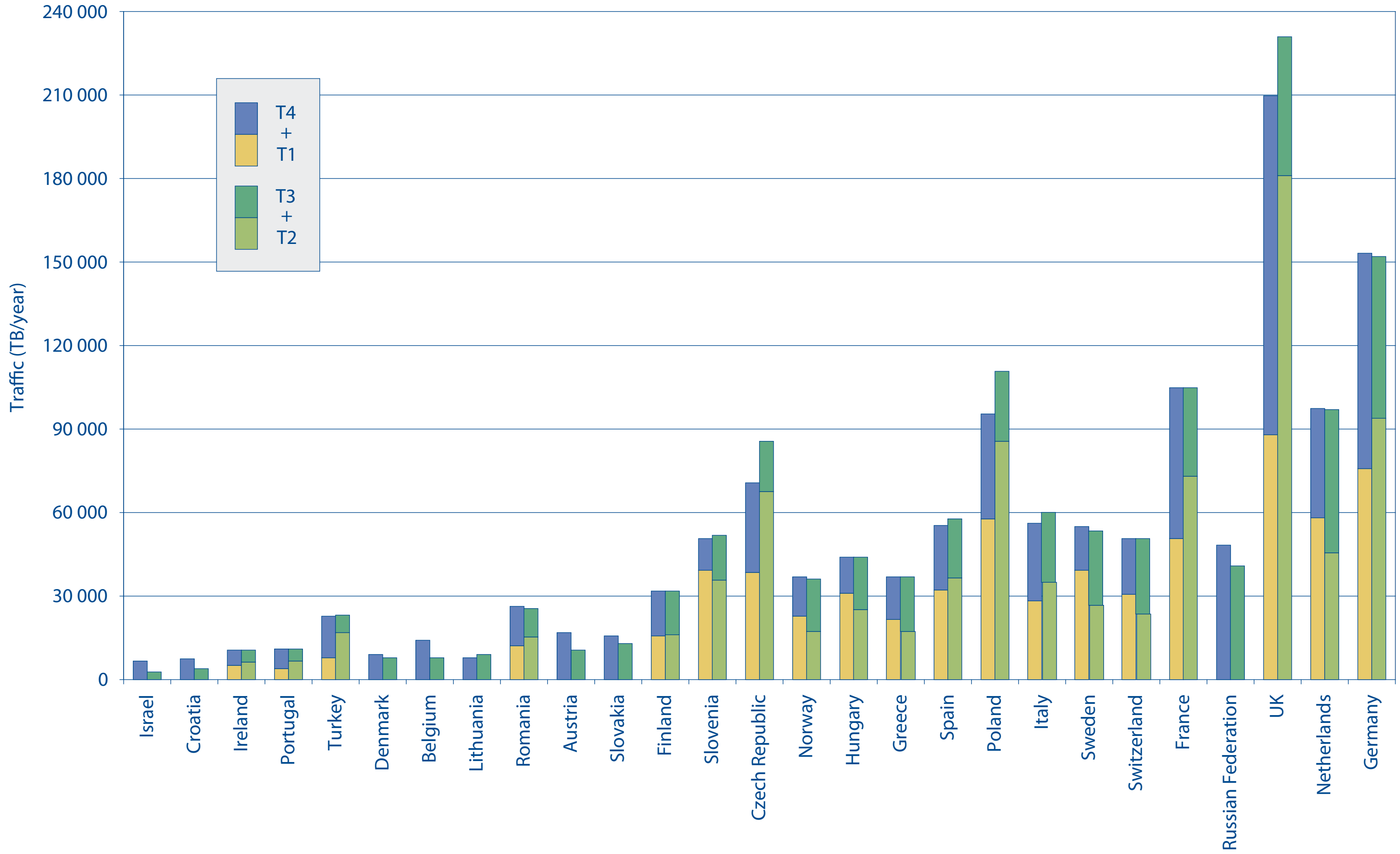
Most NRENs believe that they will be unaffected by a shortage in IPv4 address space, at least in the immediate future. Most NRENs see no problem for their client institutions either, although more NRENs see a problem for their institutions than for themselves. This year, 38% of the GÉANT NRENs envisage a problem in this area, compared to 26% last year.

The vast majority of NRENs provide some or all of their clients with both IPv4 and IPv6 connectivity.

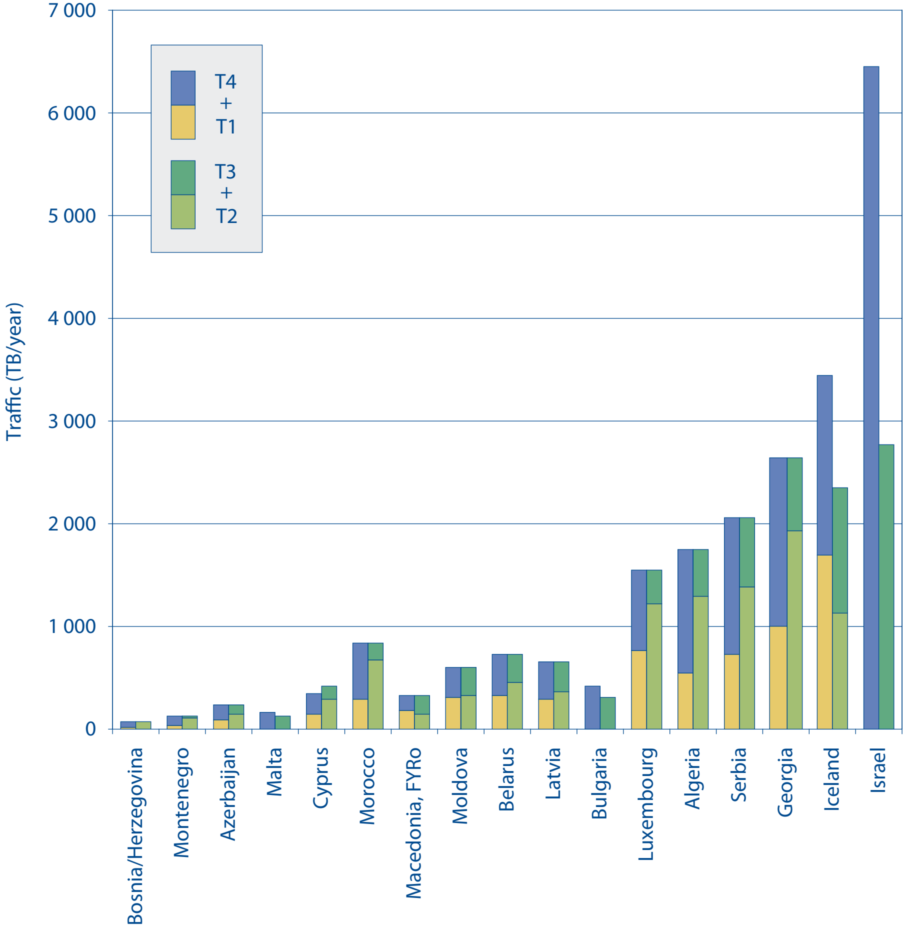
4.2 Traffic in 2011

Graph 4.2.1 (below) represents the data submitted by those NRENs whose T3 traffic exceeds 4000 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.

Graph 4.2.1 – 2011 traffic, T3 > 4000 TB



Graph 4.2.2 – 2011 traffic, T3 < 4000 TB

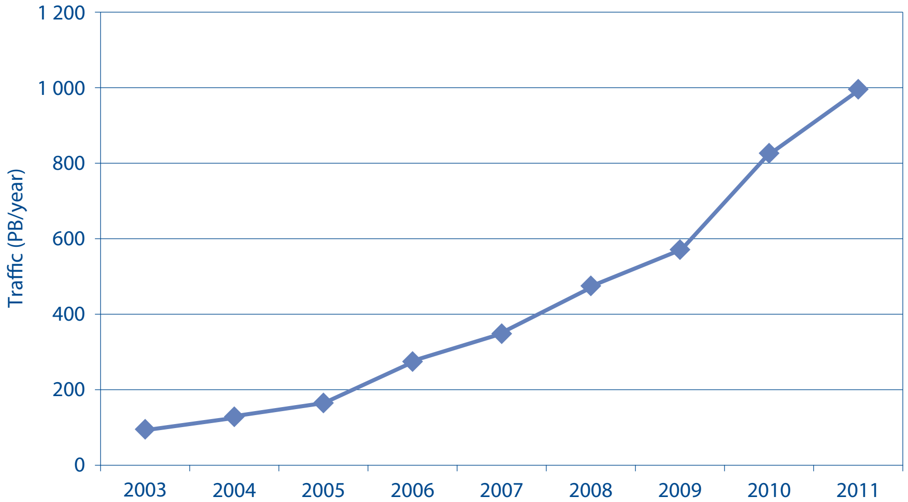


In most NRENs, the traffic sent into the NREN backbone (T1+T4) is equal or nearly equal to the traffic sent out of the backbone (T2+T3). There can be various reasons why, in a few NRENs, this is not the case. In this context, NRENs cite the effects of traffic-monitoring efforts, hosting of Content Delivery Networks such as Akamai, and difficulties in separating out the various traffic types.

4.3 Traffic trends, 2004-2011

As in the 2011 edition of the *Compendium*, Graph 4.3.1 (below) shows T3+T4 values for a subset of 22 NRENs that have consistently submitted complete data.

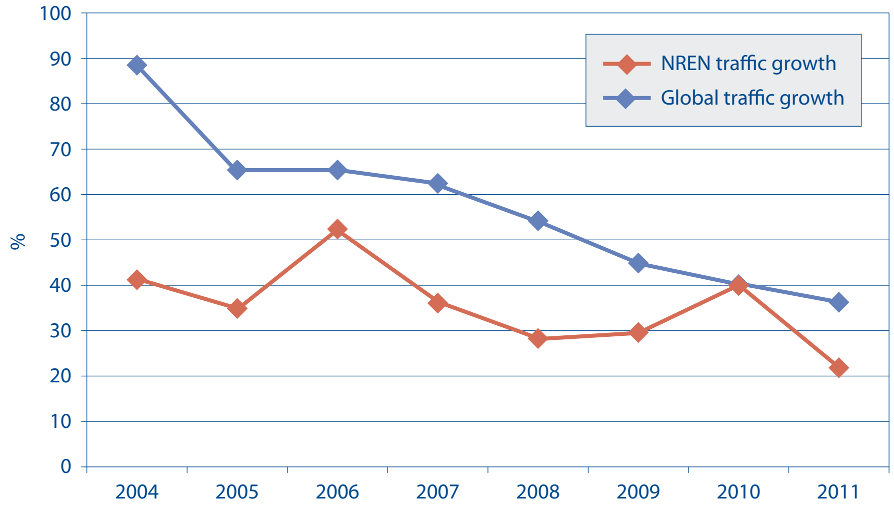
Graph 4.3.1 – NREN annual traffic flows (T3+T4), 2003-2011, n = 22 NRENs



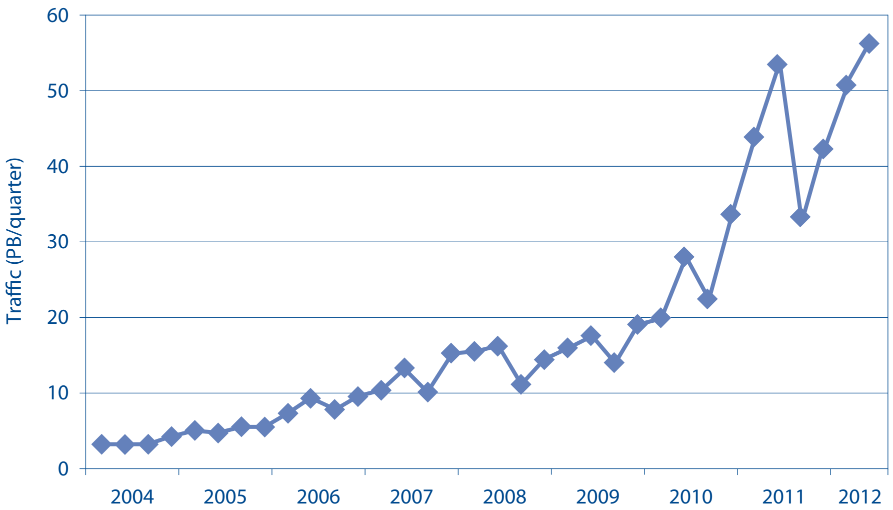
Clearly, over this eight-year period (2003-2011) traffic has continued to grow at an annual average rate of almost 36%. Graph 4.3.2 shows how the growth rate has varied over the same period; over the past years, the growth rate seems to be slowing down somewhat. Figures from Cisco (see **en.wikipedia.org/wiki/Internet_traffic**) show **global** IP traffic growing from 784 Petabytes/month in 2003 to 27 483 Petabytes/month in 2011, equivalent to a constant annual growth rate of 56%. The rate has slowed somewhat in recent years, averaging 44% growth per year in the four years to 2011.

Using data from GÉANT service reports, the GÉANT IP traffic growth has been plotted in Graph 4.3.3 (right), which exhibits a trend similar to that evident in Graph 4.3.1 (above).

Graph 4.3.2 – NREN traffic growth and global IP traffic growth rates, 2004-2011 (in %, T3+T4)



Graph 4.3.3 – GÉANT IP traffic 2004-2012



In mid-2005, sections of the underlying GÉANT infrastructure were migrated to dark fibre. Many NRENs started their transition to optical/dark fibre in the early years of the decade (2001-2010); for some NRENs, the transition is still proceeding. That such migration takes years to complete is probably the main, though not the sole, factor in the marked acceleration in growth since 2010. One explanation that has been offered for the recent apparent slowing of growth is that increasingly, end-users are connecting to the Internet with mobile devices, often bypassing the NREN structure. However, another possible explanation is the increase in P2P circuits.

In the period 2007-2010, the number of P2P circuits on the GÉANT network increased from 29 to 69. Unfortunately, we have no data on the traffic volumes in those circuits.

Note that the traffic growth pattern tends to be somewhat erratic: it is not the same in all countries, nor is it the same 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. For example, leading up to the launch of the Large Hadron Collider (LHC), a great deal of traffic was generated to test and refine the Grid processing of LHC experiments.

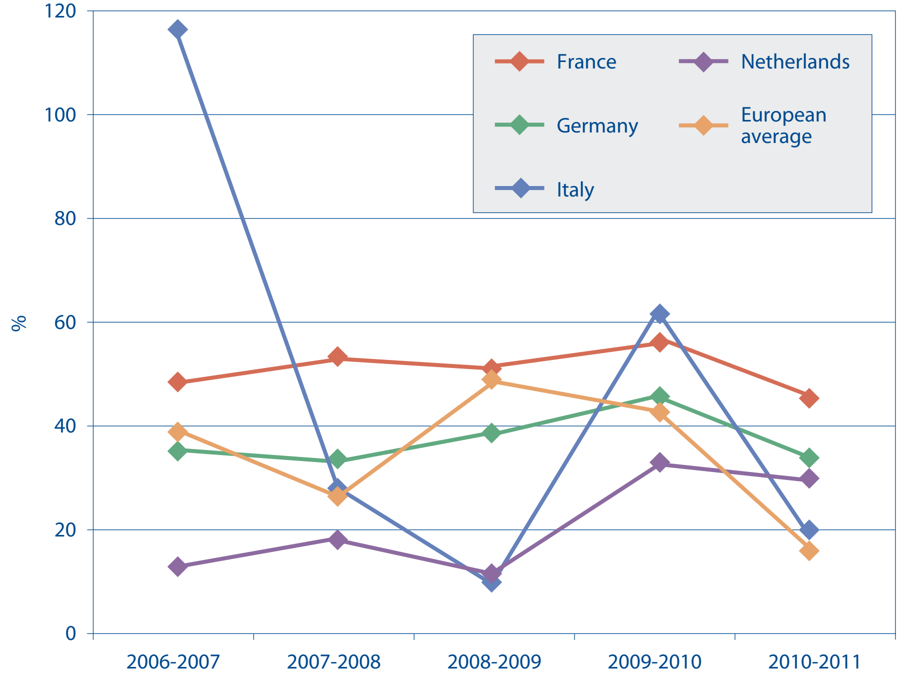
The erratic pattern of growth is illustrated by Graph 4.3.4, which shows annual growth-rate changes for a small selection of countries. Note that for presentation reasons, the fastest overall growth rate, achieved in Lithuania, not been included in the graph. From 2008 to 2009, traffic quadrupled in that country. In later years, it remained high, dropping to 37% in 2010-2011 (still well above the average growth of 16% for those years).

In Italy, growth was above average in most years, but varied erratically. Traffic more than doubled from 2006 to 2007, but the growth rate then decreased to below 10% from 2008 to 2009 and increased again to over 60% from 2009 to 2010.

Most countries saw less variation in their growth rate. In France and Germany, for example, it ranged from 56% (France, 2009 to 2010) to 33% (Germany, 2010 to 2011), still above average. Growth was less pronounced in the Netherlands, hovering between 10 and 33% per year.

As a consequence of these erratic patterns, average T3+T4 growth rate in the GÉANT countries also varied within a fairly broad band, between 16 and 48% a year.

Graph 4.3.4 – Traffic growth rates for selected countries



4.4 NREN traffic per inhabitant

In 2009, TERENA 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.

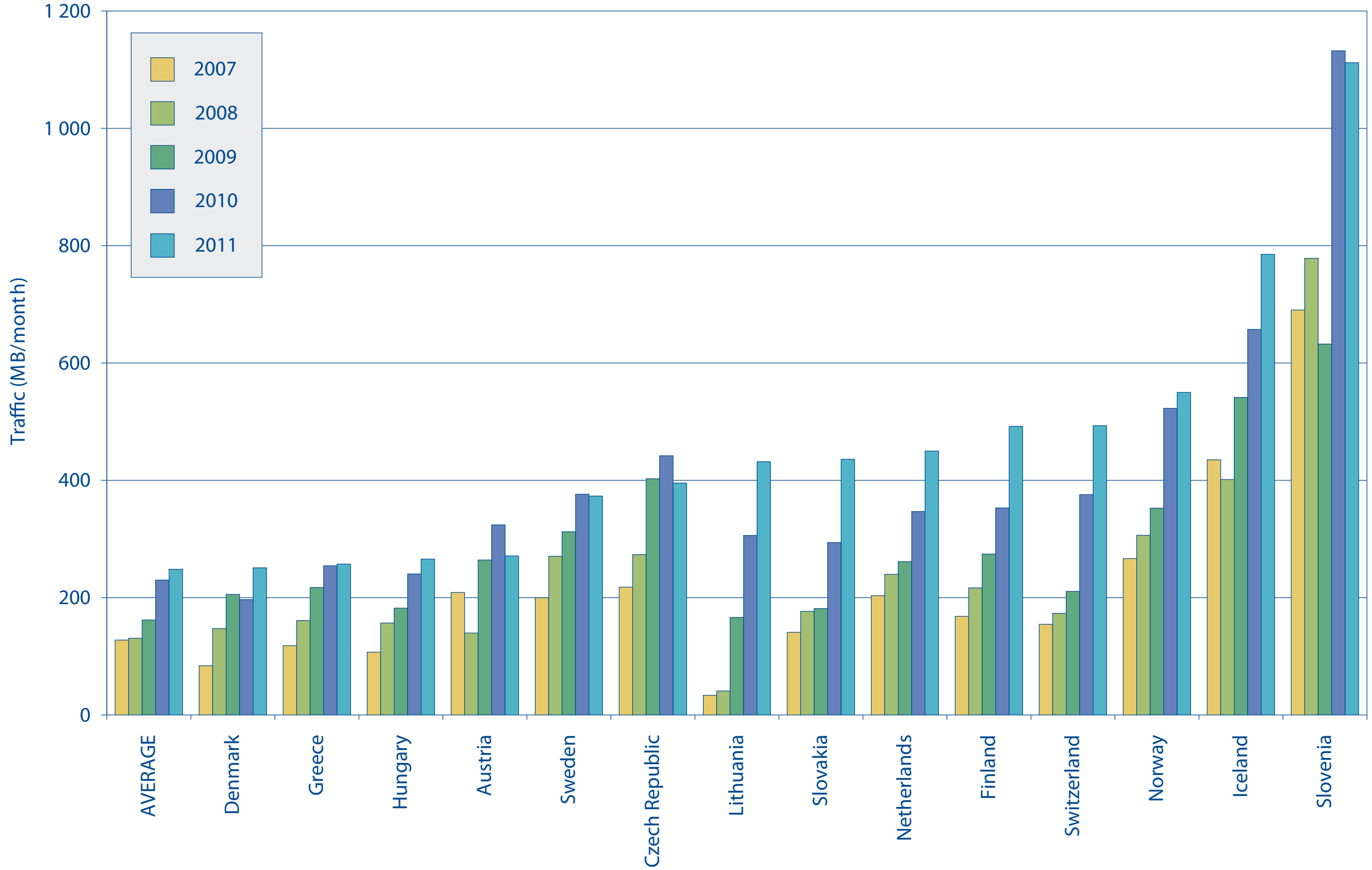
Graphs 4.4.1 and 4.4.2 show NREN annual T3+T4 traffic in 34 countries over the period 2007-2011, normalised according to the total national population in each corresponding year. Note that this figure should not be taken as an indicator of the network traffic generated by a typical NREN user.

In these 34 countries, the average traffic per inhabitant grew from 128 MB/month in 2007 to 250 MB/month in 2011, with an average annual growth rate of 14.2%.

Slovenia, at the right, has had consistently high nominal traffic (per inhabitant) over the five-year period (2007-2011). Although Slovenia has a relatively small population, it has a relatively high proportion of traffic generated by primary and secondary schools: indeed, nearly 700 schools and just 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.

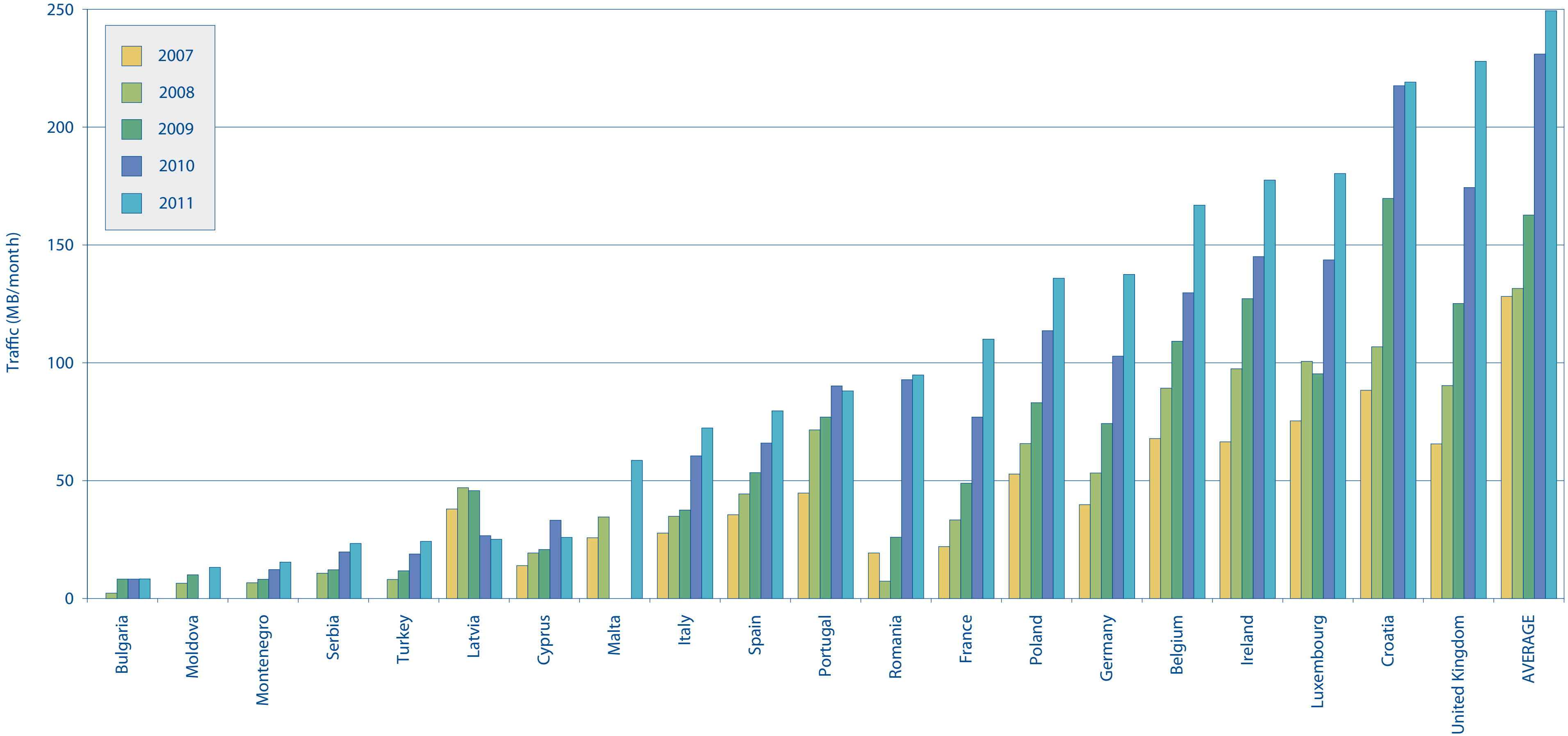
Note that the vertical scale of Graph 4.4.2 is much smaller than that of Graph 4.4.1. Clearly, there is still a substantial 'digital divide' in Europe: Bulgaria, Cyprus, Latvia, Montenegro, Serbia and Turkey show much lower values than the rest of Europe. Note the marked growth in Romania, following that country's changeover to a fibre network.

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



Many countries with a relatively small population have relatively high traffic per inhabitant. Simply having an NREN 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 influence the traffic statistics.

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



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.

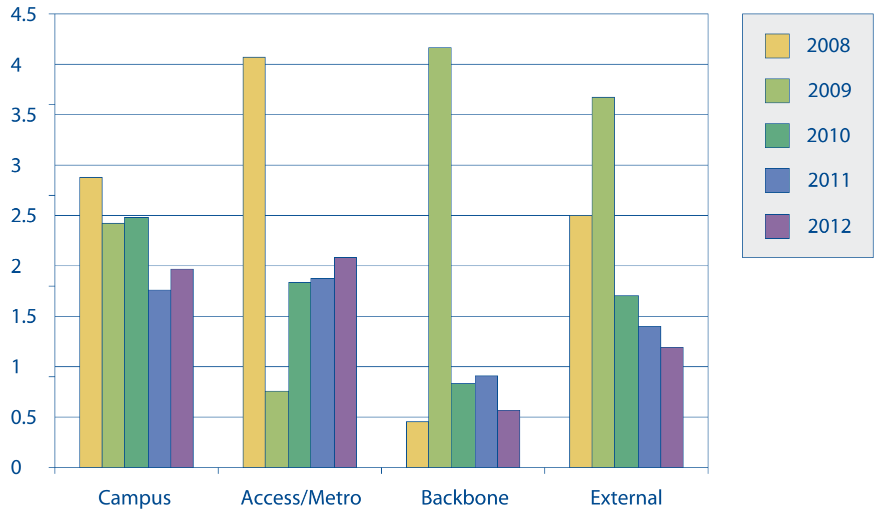
From the subjective levels reported by NRENs, a metric was derived for the level of congestion in each network element, using the following formula:[1]

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 at campus level has decreased over the past five years. 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=33



Congestion at backbone and external connections seems to have been largely resolved for the time being.

4.6 Deployment of IPv6

There have been numerous reports about the impending shortage of IPv4 address space[2] and the need to start deploying IPv6. As shown in previous editions of the *Compendium*, most European NRENs have deployed IPv6 on their backbones; client institutions can start to use IPv6 as and when the need arises. Currently, the proportion of IPv6 traffic as compared to IPv4 traffic is very low and has not risen much over the last few years.

Even though IPv4 address shortage may soon become a problem in the Internet community in general, the situation may be different for the NRENs. We therefore asked NRENs whether they or their client institutions see a threat in this area.

As Table 4.6.1 clearly shows, most NRENs believe that they will be unaffected by an address space shortage, at least in the immediate future. Indeed, compared to last year, fewer NRENs now see a problem in this area, though several NRENs are already affected. We also asked whether NRENs envisage a problem for their client institutions. Most NRENs see no problem in that area either, although the number of NRENs that do see a problem there has increased since last year. In 2011, 26% of the GÉANT NRENs envisaged address space shortages for client institutions; by 2012, this had increased to 38%. In more cases than in 2011, the shortage is affecting the connection of new clients and/or the deployment of services.

A few 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. Three NRENs (Belnet, FCCN and SUNET) provide this to all of their clients. The GÉANT network itself has been carrying IPv6 traffic, along with IPv4, since 2000.

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

[2] See, for example, information on IPv4 exhaustion at: www.ripe.net/internet-coordination/ipv4-exhaustion

The situation for the non-GÉANT NRENs is similar: they are unaffected by a possible shortage. However, in some countries there does seem to be a shortage for client institutions.

Legend for Tables 4.6.1 and 4.6.2 – Percentage of clients provided with IPv4 + IPv6
(italicised numbers in brackets indicate the situation in 2011, if different from that in 2012)

	0%
	<40%
	40 - 60%
	>60%
	100%

	No shortage foreseen
	Shortage foreseen in the medium term
	Shortage

Table 4.6.1 – IPv4 and IPv6, GÉANT partner countries

Country	IPv4 shortage?	IP4 shortage for client institutions?	Comment	Affecting new clients?	% of clients using IPv4 only	% of clients provided with IPv4 + IPv6	% of clients using IPv6 only	% of IPv6 address space allocated to client institutions
GÉANT partner countries								
Austria		no		no	70 (*75*)	30 (*25*)	0	80
Belgium		no		no	0	100	0	0
Bulgaria		no		no	100	0	0	
Croatia		no		no	98 (*27.8*)	2 (*72.2*)	0	1
Cyprus		yes	IPv4 address shortage foreseen.	yes	100	0	0	0
Czech Republic		no		no	75 (*88*)	25 (*12*)	0	2
Denmark		no		no	99 (*20*)	1 (*80*)	0	1
Estonia		no		no	95 (*92*)	5 (*8*)	0	
Finland		yes	Some institutions have no problems with their address space, but for new customers or institutions currently using private addresses, that could be a problem. We are monitoring the situation.	no	74 (*77*)	26 (*23*)	0	1
France		no		no	90	10	0	0.3
Germany	Possibly in the medium-term future	yes	Possibly in the medium-term future	no			0	
Greece	Since GRNET is deploying a cloud infrastructure aiming at the provision of virtual machines to students and researchers in Greece, in the event that public routable IPs will be required, IPv4 address space shortages may be faced.	no		no	68 (*75*)	32 (*25*)	0	1
Hungary		yes	Many client institutions already face a continuous shortage of IPv4 address space.	yes	30 (*80*)	70 (20)	0	10

Table 4.6.1 – continued

Country	IPv4 shortage?	IP4 shortage for client institutions?	Comment	Affecting new clients?	% of clients using IPv4 only	% of clients provided with IPv4 + IPv6	% of clients using IPv6 only	% of IPv6 address space allocated to client institutions
GÉANT partner countries								
Iceland		no		no	80 (*98*)	20 (*2*)	0	< 1
Ireland		yes	Larger institutions are reaching the limits of current allocations.	no	93 (*92*)	7 (*8*)	0	> 1
Israel		no		no	64 (*91*)	36 (*9*)	0	
Italy		yes	Some institutions have to use NAT because they are out of IPv4 addresses	no	89	11	0	
Latvia		yes	Some universities will run out of IPv4 addresses.	no	85	15 (*14*)	0 (*1*)	0.02
Lithuania		no		no	91 (*100*)	9 (0)	0	0.3
Luxembourg		no		yes	95	5	0	1
Macedonia, FYRo					80 (*95*)	20 (*5*)	0	0.05
Montenegro		no		no	100	0	0	
Netherlands		no		no	64 (*69*)	36 (*31*)	0	0.4
Norway		yes	Shortage of large blocks of IPv4 addresses	no	85	15	0	0.3
Poland		yes	Clients request address spaces larger than are available.	no				1
Portugal		no		no	0 (*35*)	100 (*65*)	0	0.12
Romania		yes		no	80 (*10*)	20 (*90*)	0	2
Serbia	There are plans for connecting schools, and we estimate that the whole network will need to use private IPv4 addresses with a carrier-grade NAT solution, because of the lack of IPv4 address space.	yes	Many client institutions do not have adequate IPv4 address allocation, so they are forced to use NAT. This is a problem especially with large faculties and student dormitories that were recently connected.	no	50 (*92*)	50 (*8*)	0	5
Slovakia		no		no				
Slovenia		yes	We predict the first IPv4 address space shortage next year, especially if eduroam® continues to grow.	no	97 (*98*)	3 (*2*)	0	
Spain		no		yes	85 (*60*)	15 (*40*)	0	11
Sweden				no	0	100	0	

Table 4.6.1 – continued

Country	IPv4 shortage?	IP4 shortage for client institutions?	Comment	Affecting new clients?	% of clients using IPv4 only	% of clients provided with IPv4 + IPv6	% of clients using IPv6 only	% of IPv6 address space allocated to client institutions
GÉANT partner countries								
Switzerland		yes	When adding new organisations	yes	72	28	0	0.1
Turkey		yes		no	78 (*85*)	22 (*15*)	0	0.11
United Kingdom		no		no	85 (*87*)	15 (*13*)	0	0.2

Table 4.6.2 - IPv4 and IPv6, other countries

Country	IPv4 shortage?	IP4 shortage for client institutions?	Comment	Affecting new clients?	% of clients using IPv4 only	% of clients provided with IPv4 + IPv6	% of clients using IPv6 only	% of IPv6 address space allocated to client institutions
Other countries								
Algeria		no		no	100	0	0	0
Armenia		no		no	80	20	0	1
Azerbaijan		no		no	100	0	0	0
Belarus		no		no	100	0	0	
Bosnia/Herzegovina	Generally concerned	yes	Yes, we are generally concerned.	no	100	0	0	
Georgia		no		no	100	0	0	0
Moldova		yes		yes	100	0		40
Morocco		no		no	95 (*0*)	5 (*100*)	0	1
Russian Federation		no		no	93 (*95*)	7 (*5*)	0	
Ukraine		no		no	100	0	0	2
Australia		yes		yes	80 (*67*)	20 (*33*)	0	
Canada		no		no	90 (*55*)	10 (*45*)	0	1
Kazakhstan		yes		yes	95	5	0	15
Korea		yes		no				
Kyrgyzstan				no				
New Zealand		yes	Lack of space.	no	90	10	0	2
Singapore		no		no	90	10	0	0
Taiwan		no		no	80	15	0	5

4.7 Lambda traffic

Twenty-one of the GÉANT partner NRENs who responded to our questionnaire currently offer dedicated wavelengths (lambdas) to their clients. As of 31 January 2012, only the Netherlands had dynamic lambdas live. Measuring the traffic on such lambdas is inherently different to measuring traffic on the rest of the network. This is because this traffic is not always monitored by NRENs and is not necessarily transported as IP data packets.

The number of lambdas provisioned in January 2012 ranges from zero to 151 (DFN of Germany, the NREN that also reported the highest number of lambdas last year: 141). Surprisingly, provisioning time is between one hour (PSNC of Poland) and three months. Typically, the lambda capacities are either 1 Gb/s or 10 Gb/s. Table 4.7.1 (below) shows that around 875 wavelength circuits are now in use, up from 700 last year and 200 two years ago.

The 2010 *Compendium* originally signalled the problems with measuring lambda traffic. Many NRENs do not measure this type of traffic at all, whereas others are only able to measure such traffic via their own routers and/or IP-based traffic. An alternative method to measure lambda take-up and traffic needs to be found. One proposal is to measure the number of circuits, rather than the traffic itself. Tables 4.7.1 and 4.7.2 at least provide an overview of the number of lambdas provisioned as of 31 January 2012.

Table 4.7.1 – Lambda provisioning, GÉANT partner countries (italicised numbers in brackets indicate the situation in 2011, if different from that in 2012)

Country	Lambdas?	Number static	Number dynamic	Charge?	Provisioning time	Number leaving country or NREN
GÉANT partner countries						
Austria	no					
Belgium	yes	81 (*63*)	0	yes	24 hours	2
Bulgaria	no					
Croatia	no					
Cyprus	no					
Czech Republic	yes	71	0	no, but planned	3 months	5
Denmark	yes	25 (3 full 10Gs and 15 1G connections through shared lambdas)	0	yes	3 weeks	0
Estonia	no					
Finland	yes	80 (*75*)	0	Yes. 1 Gb/s costs 5000 €/year and 10 Gb/s 10 000 €/year, excluding possibly needed access fibre costs. Usually, we provide access via passive CWDM channels, so we can use existing fibre infrastructure for the lightpaths.	1 Gb/s, typically 1 week if fibre infrastructure exists. 10 Gb/s, 8-12 weeks.	3
France	yes	117 (*125*)	0	no	3 months	8
Germany	yes	151(*141*)	0	yes	On average, 4 months	13, Only CBF
Greece	yes	73 (8 of them have no customer connected) (*58*)	0	no	2 days to provision a new λ on an existing link.	0

Table 4.7.1 – continued

Country	Lambdas?	Number static	Number dynamic	Charge?	Provisioning time	Number leaving country or NREN
GÉANT partner countries						
Hungary	yes	65 (*6*)	0	no	Depends on availability of transponders	2
Iceland	no					
Ireland	yes	51 (*44*)	0	No, they are charged as per a normal circuit	4-6 weeks	0
Israel	no					
Italy	yes	35 (*29*)	0		60-90 days	3
Latvia	no					
Lithuania	yes	2 (*0*)	0	No, but in practice users speed up the process by buying their own coloured interfaces.	It is quick in principle, but we do not have surplus transponders, so new ones must be purchased by means of public procurement.	0
Luxembourg	yes	17	0	no	3 month	1
Macedonia,FYRo	no					
Malta	no					
Montenegro	no					
Netherlands	yes	27 (*17*)	11	yes	3 weeks excluding new fibre orders	17
Norway	yes	4	0	yes	4-8 weeks	0
Poland	yes	20	0	yes	1h	8
Portugal	yes	2 (*20*)	0	Historically, no costs were charged, but the official policy states that costs could be charged.	If no purchases are needed, one week. If purchases are needed, one month.	3
Romania	no					
Slovakia	no					
Slovenia	yes	1 (*0*)	0	no	1 month	0
Spain	yes	10 (*planned*)	0	no	Less than a day, just hours if hardware (TRBDs) is available on equipment	
Sweden	yes	around 25 (*20*)	0	yes	Between 10 min and 12 weeks	10
Switzerland	yes	3	0	yes	2 months	3
Turkey	no					
United Kingdom	yes	5 (*19*)	0	Yes, over 1Gb	40 working days	4

Table 4.7.2 – Lambda provisioning, other countries

Country	Lambdas?	Number static	Number dynamic	Charge?	Provisioning time	Number leaving country or NREN
Other countries						
Moldova	planned					
Russian Federation	yes	4		yes	1 month	4
Australia	yes	85 (*71*)	0	yes	2 months	4
Canada	yes					
Korea	planned					
New Zealand	planned					

5 MIDDLEWARE SERVICES

All NRENs provide a range of important services to their customers. The TERENA Task Force on Management of Service Portfolios is developing a typology of such services. The current draft has the following categorisation[1]:

1. Network & connectivity services (covered in Section 3 of this *Compendium*);
2. Security services (5.2)
3. Authentication & mobility service (5.3)
4. Housing, storage, hosting and content-delivery services (6.2)
5. Network collaboration tools & conferencing (6.3)
6. Network computing resources (6.4)
7. E-learning / distance teaching & learning: e-research (6.5)
8. User interaction & knowledge dissemination (6.6)
9. NREN side activities/services (not NREN user-specific) (6.7)

5.1 Overview

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

Important new developments in the area of 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. In the past year, there has been a marked expansion of NREN activities in the area of DNS Security Extensions, at least in the GÉANT region.

Almost all GÉANT partner NRENs currently provide an **Authentication and Authorisation Infrastructure** (AAI) or are planning to do so. (25 NRENs now provide an AAI, eight 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 other NRENs) have joined or are planning to join the **eduGAIN interfederation service**; this development holds the promise of service access across federations.

By 31 December 2011, approximately 120 000 valid outstanding **server certificates** had been issued by GÉANT partner NRENs. Of those, more than half had been issued under the TERENA Certificate Service.

Section 5.3.3. gives information on the eduroam take-up across Europe.

5.2 Security services

Security services are increasingly important to NRENs. In this year's *Compendium* survey, we have asked questions on some topics in the security area, as are summarized in Table 5.2.1. For further information on how NRENs have recently been collaborating in the area of security, see for example the web pages of TF-CSIRT, at **www.terena.org/activities/tf-csirt**.

One question asked in the questionnaire was whether NRENs are using a structured format for the exchange of computer-incident information. Such a format is useful in speeding up the exchange of information internationally and helps to avoid misunderstandings. Six of the GÉANT partner NRENs currently use such a format; five others are planning to introduce it. X-ARF is the most commonly used, but by no means the only, format.

Table 5.2.1 also provides information on whether network devices are used for addressing security threats and, if so, which types of devices.

[1] Developed by Koen Schelkens, BELNET

Table 5.2.1 – Security services

Country	Structured format?	Network devices?	Anti-spam measures?	Honeypots? Which and why?
GÉANT partner countries				
Belgium	Planning to implement new in long term, not clear yet what formats, further investigation needed.	Again under investigation	Centralized anti-spam system based on blacklisting, Bayesian analyses, optional: SPF, DKIM, etc.	We had honeypots in the past, now investigating new possibilities (for ex. Dragon research Pods).
Croatia	no	routers, firewalls, web application firewalls	DNSBLs, SPF record, SpamAssassin	Low interaction honeypot as integral part of the Early Warning System.
Czech Republic	Planned, IDMEF	Firewalls, IDS, NetFlow, honeypots.	Greylisting, nolisting.	IDS based on LaBrea, Kippo and Dioanea. Purpose — to detect anomalies in network, source of the data for Forensic laboratory.
Denmark	no	NetFlow	Anti-spam filter as a service	no
Estonia	no	routers, firewalls, IDPSs	DNSBLs, DNS SPF records, detection software	no
Finland	no	routers for rate limiting and filtering traffic	DNSBLs, DNS SPF records	no
France	xml	Routers, RTBH (Remotely Triggered Black Hole) deployed and used in case of major threat.	National mutualised anti-spam services are implemented (DNS RBL + DNS SPF)	no
Germany	X-ARD, DAF	yes	DFN wide spam filter	yes
Greece	no	Simple access lists are applied to our core routers. However, network security in our services is implemented by other means. Namely, restricted access to the servers by specific IP domains and firewalls (based on Iptables) in all hosts. No dedicated firewalls or similar cards are deployed. We are also planning to implement a new secure architecture consisting of IDS/IPS flow monitoring and SIEM technologies on our network.	DNSBLs, DNS SPF, DKIM	For research purposes in liaison with FORTH team we deployed NOAH sensors to record attacks in non-routable IP space.
Hungary	no	Remote blackhole triggering via BGP		no
Ireland	no	Cisco ACLs, Palo Alto Firewall, Juniper ACLs – general network traffic filtering	Trend Micro DNSBL, SpamHaus DNSBL, DNS SPF records	Network +SSH honeypots, for intelligence gathering & research
Israel	no	Routers and firewalls	Multiple actions	no
Italy	Planned, X-ARF	no		Nepenthes, Amun, Dionaea for prevention
Latvia	AIRT system - IODEF	Traffic filters on routers, stateless/statefull fw, IDPSs to protect certain domains	Greylisting, DNSBLs	Kippo, Artemisa (SIP honeypot)
Lithuania	no	firewalls, IDS, honeypots	DNSBL, greylist	detection of worm activities in local networks
Luxembourg	no	firewalls	DNSBLs, DKIM	no
Macedonia, FYRo	no	yes	DNSBL, SPF, teergrubing (tarpitting), greylisting, Bayesian filtering	no

Table 5.2.1 – continued

Country	Structured format?	Network devices?	Anti-spam measures?	Honeypots? Which and why?
GÉANT partner countries				
Montenegro	no	ASA 5540	SPAM BL ACL's, SpamAssassin,	no
Netherlands	no	yes	Running spam-filter service SURFmailfilter	no
Norway	no	router ACL, host-based firewalls	greylisting and content filtering	malware collection
Poland	We are planning to support a modified (to take into account Polish legislation specificity) version of formats proposed in ETSI TS 102 657 for retention data handover. We have postponed fully automatic processing of X-ARF and IODEF reports due to the limited number of such notifications received in the past year.	Firewalls: to protect crucial services and infrastructure. Routers: for border blackholing and also for load balancing in case of e.g. DDoS attacks. Additionally, we plan to deploy an IDS solution and an anti-DDoS system.	We are using RBLs to protect our internal users. We are also using firewalls to limit SMTP access via port 25 from some network segments. We also try to react promptly to notifications from external spam traps that are send to PIONIER-CERT's incident reporting address.	no
Portugal	IODEF	IDS, firewalls, routers	SPF	Honeyd and Nepenthes for detecting compromised IPs
Romania	no	Fortigate and Cisco SCE are used on the border of the network.	DNSBL, black-hole filtering	Classified information.
Serbia	no	Routers with ACLs. Firewalls are planned for some specific type of institutions, i.e. schools and libraries	SpamAssassin	no
Slovakia	no	routers, firewalls	all of the above	no
Slovenia	ARF	Routers using ACL, firewalls for additional blocking	DNSBLs, DKIM signatures	Honeypot/Darknet: Honeyd, Kippo / NfSen, TCPdump
Spain	X-ARF, IODEF	Routers implement firewall filters. Content firewalls are planned	DNSBL (with community whitelisting and spamhaus), SPF, spamtraps	Homegrown. To collect malware samples, and identify spam sources
Sweden	no	yes	Canit Domain Pro	For our CERT group
Switzerland	no	Router access lists, firewalls in some segments of the network	commercial spam filtering service	spamtraps
Turkey	Planned, X-ARF, Jason	Routers for collecting flows. Each node is operating its own firewall and/or IDS.	Whitelisting of SMTP servers at node sites	IPv4, IPv6. For detecting potential network threads.
United Kingdom	no	yes	DNSBLs and DNSWLs	JANET(UK) have tried a number of different ideas combining NetFlow, snort and darknet IP addressing

Table 5.2.1 – continued

Country	Structured format?	Network devices?	Anti-spam measures?	Honeypots? Which and why?
Other countries				
Algeria	no	Routers for backbone, Firewalls for data centre, Traffic shaper	DNS SPF records, anti-spammer device	no
Azerbaijan	no	routers, firewalls	DNSBLs, SPF records, anti-spam software (licensed)	no
Belarus	no	Firewalls, routers, IDS, IPS, Webfilters	DNSBLs, DNS SPF, Greylisting	no
Bosnia/ Herzegovina	no	Planned, routers-traffic filtering; Linux based IDS systems	DNS PTR, Mail Gateway	Honeypot, Kippo-gathering statistics about potential network threats
Georgia	planned	Routers, firewalls, IDPSs, UTM Appliance	DNSBLs	no
Moldova	VEDEF	Routers	SpamAssassin, RBL	Planned, Honeynet project; for detection and identification of malware and attacks
Morocco	no	yes	DNS SPF	no
Ukraine	no	no		yes
Australia	no	router ACLs		no
Kazakhstan	no	firewalls , routers for security		no
Korea	no	Planned, FWSM, TMS (Threat Management System)		yes
Kyrgyzstan	planned	Planned, Cisco ASA / firewall / IDS	DNSBLs, DNS SPF records	Research and analyse security treats
New Zealand	no	Endace 3000 probe deployment		planned
Taiwan	no	Routers, firewalls, IDPs,		no

In addition, Table 5.2.1 provides an overview of the anti-spam measures taken by many NRENs, as well as their use of honeypots[2].

DNS Security Extensions (DNSSEC) are a set of Internet Engineering Task Force (IETF) standards created to address vulnerabilities in the Domain Name System (DNS) and protect it from online threats. The purpose of DNSSEC is to increase the security of the Internet as a whole by addressing DNS security weaknesses. Essentially, DNSSEC adds authentication to DNS to make the system more secure[3].

Table 5.2.2 (right) lists the NRENs that have DNSSEC-related activities and indicates their status. The DNSSEC column indicates whether or not there is DNSSEC for the country-code top-level domain[4]. All but one of the GÉANT partner NRENs responded to this question; 19 of them reported some level of activity. Several of the NRENs who reported no activity did mention that they were looking into the issue or planning some future activity. Several NRENs reported that they did not consider this topic a priority and/or that there is no interest in their constituency.

[2] A honeypot is a computer system on the Internet that is expressly set up to attract and 'trap' people who attempt to penetrate other people's computer systems (source: www.techtarget.com).

[3] Information courtesy of whatis.techtarget.com.
[4] As listed on http://en.wikipedia.org/wiki/List_of_Internet_top-level_domains

Several activities are related to DNSSEC. Seven NRENs mention that they operate a signed country-code top-level domain (ccTLD), up from five last year. Eleven operate a signed zone for the NREN itself, up from six last year. Five operate signed zones for the constituency as a service; in addition, Janet (UK) operates the signed .ac.uk domain. Eleven NRENs operate validating DNS resolvers for their constituencies.

Several NRENs have more than one activity. In the other countries that responded to this question there is far less interest.

Legend for Table 5.2.2

A	Activities related to DNSSEC?
B	NREN operates a signed cc zone
C	NREN operates a zone for itself
D	NREN operates validating DNS resolvers for its constituency

Table 5.2.2 - DNSSEC (Green highlight indicates that the NREN has activities related to DNSSEC)

Country	A	B	C	D	Remarks	DNSSEC
GÉANT partner countries						
Austria	yes	X				yes
Belgium	yes		X	X		yes
Bulgaria	no				We do not operate any DNS infrastructure so there is no need for us to do this	yes
Croatia	yes				Planning to introduce DNSSEC in our ccTLD	no
Cyprus	no				We feel DNSSEC is not important enough for us at this time	no
Czech Republic	yes		X	X		yes
Denmark	yes		X	X	We operate signed zones for our constituency as a service	yes

[1] Developed by Koen Schelkens, BELNET

Table 5.2.2 - continued

Country	A	B	C	D	Remarks	DNSSEC
GÉANT partner countries						
Estonia	no				We feel DNSSEC is not important enough for us at this time	no
Finland	yes	X		X		yes
France	no				DNSSEC is important, but we haven't yet allocated enough resources to address the topic.	yes
Germany	yes		X	X		yes
Greece	yes			X		yes
Hungary	yes		X	X		no
Iceland	no				Our constituency is not interested in the topic, lack of resources	no
Ireland	yes		X	X		no
Israel	no				We will be getting to it in the future	no
Italy	no				We are studying the opportunity for its introduction	no
Latvia	no				We are closely related to ccTLD. We are planning to 1) operate a signed zone for our NREN;2)operate signed zones for our constituency as a service	yes
Lithuania	yes	X			We operate a signed country-code top-level domain (ccTLD)	no
Luxembourg	yes	X	X	X	We operate signed zones for our constituency as a service	yes
Malta	yes				looking at implementing signed country-code top-level domain (ccTLD)	no
Montenegro	no				DNSSEC is planned	yes
Netherlands	yes		X	X	We operate signed zones for our constituency as a service	yes
Norway	no				We feel DNSSEC is not important enough for us at this time	no
Poland	no				We feel DNSSEC is not important enough for us at this time	yes
Portugal	yes	X	X		We operate signed zones for our constituency as a service	yes

Table 5.2.2 - continued

Country	A	B	C	D	Remarks	DNSSEC
GÉANT partner countries						
Romania	no				Our constituency is not interested in the topic	no
Serbia	no				Currently we do not have enough manpower to dedicate to DNSSEC activities	no
Slovakia	no				We feel DNSSEC is not important enough for us at this time	no
Slovenia	yes	X	X	X	We operate signed zones for our constituency as a service	yes
Spain	yes				Planned to operate. In test phase now	no
Sweden	no				We had some zones signed, but backed off due to bugs and immature software	yes
Switzerland	yes	X	X			yes
Turkey	no				Included in the work plan of 2012	no
United Kingdom	yes				Janet operates two signed country-code second-level domains (ccSLD)	yes

Country	A	Remarks	DNSSEC
Other countries			
Algeria	no	It's planned	no
Belarus	no	We feel DNSSEC is not important enough for us at this time	no
Bosnia/ Herzegovina	no	We feel DNSSEC is not important enough for us at this time	no
Russian Federation	no	We do not operate any DNS infrastructure so there is no need for us to do this	no
Ukraine	no	We feel DNSSEC is not important enough for us at this time	yes
Australia	no	We feel DNSSEC is not important enough for us at this time	no
Canada	no	We do not operate any DNS infrastructure so there is no need for us to do this	no
Kazakhstan	no	Our constituency is not interested in the topic	no
New Zealand	no	We do not operate any DNS infrastructure so there is no need for us to do this	yes
Singapore	no	We do not operate any DNS infrastructure so there is no need for us to do this	no
Taiwan	no	Our constituency is not interested in the topic	yes

5.3 Authentication and mobility services

Increasingly, the Internet is being used as a mechanism for delivering a range of services to specific user-groups. Thus, user access to services is becoming less dependent on the physical location either of the user or of the service. At the forefront of this development is the research and education community. Security is a key issue in this area: it is important 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.

In Europe, a pioneering mobility service is eduroam®[5], which was established in 2003 under the TERENA umbrella and has developed into a secure roaming access service for the international research and education community. This service is currently offered by all 36 GÉANT partner NRENs and by NRENs in a growing number of countries in other regions (for further information, see Section 5.3.3).

It should be noted that eduroam offers general Internet access but does not by itself permit access to any more specific services. In order to provide such access, identity services and authorisation are needed.

5.3.1 Identity federations

An identity federation enables a user registered in the identity management system of his university to access services either provided 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. a project within an NREN, a consortium, a separate entity, collaboration

[5] A registered trademark of TERENA.

with primary education, etc.). Normally, each country has a single federation for higher education and research. NRENs either operate the research and education federation themselves or have close organizational 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. Note that an AAI itself does not require high-capacity networks — but most of the services that can be made accessible via such an AAI do depend on high-performance networks.

As reported in the *Compendium* since 2006, the number of identity federations has been growing constantly. 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 GN3 project.

Table 5.3.1.1 lists the current situation. Differences with respect to 2011 are highlighted in colour. Almost all GÉANT partner NRENs provide an Authentication and Authorisation Infrastructure (AAI) or are planning to do so. There are only three exceptions (CYNET of Cyprus, RHnet of Iceland and SANET of Slovakia). In most cases, the web single sign-on federation is operated by the NREN.

Most of the GÉANT partner NRENs (and a few other NRENs) are planning to join the eduGAIN interfederation service, although seven of the GÉANT partner NRENs have no such plans.

Table 5.3.1.1 – AAI (highlights denote differences with respect to 2011)

Country	AAI provided?	Federation	NREN-operated?	Interfederate?
GÉANT partner countries				
Austria	yes	yes	yes	no, but planned
Belgium	yes	yes	yes	yes: eduGAIN
Bulgaria	plan	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	no	yes: Kalmar
Estonia	yes	yes	yes	no, but planned
Finland	yes	yes	yes	yes: Kalmar
France	yes	yes	yes	no, but planned: eduGAIN
Germany	yes	yes	yes	yes: eduGAIN

Table 5.3.1.1 – continued

Country	AAI provided?	Federation	NREN-operated?	Interfederate?
GÉANT partner countries				
Greece	yes	yes	yes	yes: eduGAIN
Hungary	yes	yes	yes	yes: eduGAIN
Iceland	no	no		no
Ireland	yes	yes	yes	no, but planned: Metadata Exchange Agreement with UKAMF
Israel	plan	no		no
Italy	yes	yes	yes	yes: eduGAIN
Latvia	plan	no		no, but planned
Lithuania	plan	no		no
Luxembourg	yes	yes	yes	no, but planned: Right now, only one IdP and our own services as SPs use federation technology. Once we have 2-3 IdPs and at least one non-RESTENA-operated service on board, we will work on the required paperwork and technical work to interfederate using eduGAIN.
Macedonia, FYRo	plan	no		no
Malta	yes	no	no	no, but planned
Montenegro	yes	no		no, but planned
Netherlands	yes	yes	yes	yes: eduGAIN
Norway	yes	yes	yes	yes: Kalmar
Poland	plan	no	yes	no, but planned: eduGAIN
Portugal	yes	yes	yes	no, but planned: eduGAIN integration planned for 2012
Romania	plan	no		no, but planned
Serbia	plan	no		
Slovakia	no	no		no
Slovenia	yes	yes	yes	no, but planned: eduGAIN in 2012
Spain	yes	yes	yes	

Table 5.3.1.1 – continued

Country	AAI provided?	Federation	NREN-operated?	Interfederate?
GÉANT partner countries				
Sweden	yes	yes	yes	
Switzerland	yes	yes	yes	yes: other: interfederation based on eduGAIN as well as bilateral agreements
Turkey	yes	yes	yes	
United Kingdom	yes	yes	no	no, but planned: eduGAIN
Other countries				
Algeria	plan	no		no, but planned
Armenia	plan	no		
Azerbaijan	plan	no		no
Belarus	yes	no		no
Bosnia/ Herzegovina	plan	no		
Georgia	no	no		no
Moldova	plan	no		no
Morocco	plan	no		no
Russian Federation	plan	no		
Ukraine	no	no		no
Australia	no	yes	no	
Canada	no	yes	yes	yes: eduGAIN
Kazakhstan	yes	no		
Korea	plan	no		
Kyrgyzstan	plan	no		
New Zealand	plan	yes	no	
Singapore	no	no		no
Taiwan	no	no		no

5.3.2 Digital Certificates

Digital certificates are issued by Certification Authorities (CAs) and are used to guarantee secure and reliable communication between servers, between users, or between a user and a server. For example, digital certificates can be used by:

- A user securely connecting to a web server and using a web browser;
- A user authenticating with a server using a digital certificate;
- Two users exchanging encrypted emails using personal certificates.

The Grid community requires secure authentication for users to login 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 between servers, or between a client and server, is needed.

In order to support the user community (for example, in e-Science) in deploying services securely, 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). In September 2012, the TCS supported 27 NRENs for server certificates (26 from the GÉANT area, plus Serbia), 17 for personal certificates and eight for code-signing certificates.

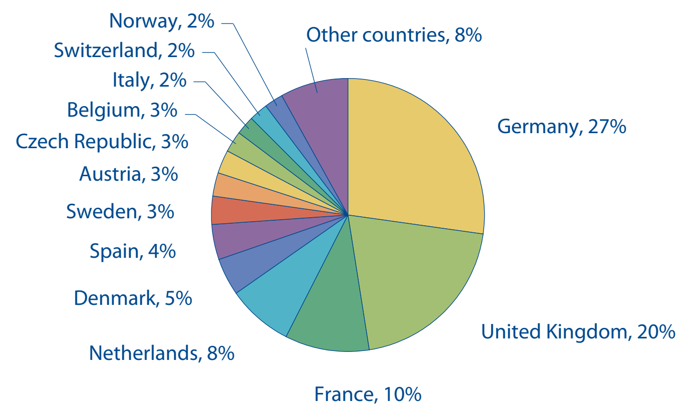
Many NRENs do not rely solely on the TCS for issuing certificates. Sixteen GÉANT partner NRENs operate certification authorities in addition to, or independent of, the TCS. By far the largest of these is in Germany. In fourteen cases, the CA is operated by the NREN itself; two NRENs (SWITCH of Switzerland and EENet of Estonia) use a commercial certification authority. Beyond the GÉANT area, many NRENs also operate their own CA. These CAs usually issue server certificates; most issue personal certificates as well. In recent years, several initiatives have been set up to create a trust fabric in 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.

TCS Certificates are recognized by all major browsers and also accepted outside of the Grid community.

Although there were some problems with the underlying dataset, we estimate that on 31 December 2011, there were around 120 000 valid outstanding server certificates in the GÉANT region. More than half of these had been issued under the TCS. By September 2012, the total number of valid outstanding certificates issued under the TCS had risen to 90 000. Almost 85 000 of these were server certificates.

The division of server certificates among the countries is presented approximately in Graph 5.3.2.1 below.

Graph 5.3.2.1 – Division of Server Certificates, GÉANT partner countries



In addition to server certificates, there are several other categories of certificates. In numbers issued, personal certificates are the second most important category after server certificates. Germany has issued the vast majority of these, almost 270 000 out of a total of nearly 275 000.

5.3.3. Eduroam

A secure, world-wide roaming access service has been developed for the international research and education community. This is called eduroam.

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

As of August 2012, eduroam is available in 54 countries worldwide, including all 36 GÉANT partner countries. Up-to-date information on eduroam is available from **www.eduroam.org**.

However, the fact that eduroam is available in a particular country does not necessarily mean that it is available at all institutions or to all students in that country. In order to gauge the coverage, this year we asked the NRENs to estimate: (1) the percentage of the connected universities in their country that provide eduroam credentials to their users, and (2) the percentage of students in their country that have an eduroam-enabled account. Of course, the fact that a student's e-mail account is eduroam-enabled does not yet mean that such a student actually uses the service.

Combining the information from both columns in Table 5.3.3.1 (right) shows, that – for example, in Italy and Finland – most large universities with high numbers of students give credentials to their students. However, many smaller universities still do not have eduroam.

Information about the numbers of eduroam authentications is available on several national eduroam websites.

Table 5.3.3.1 – eduroam take-up

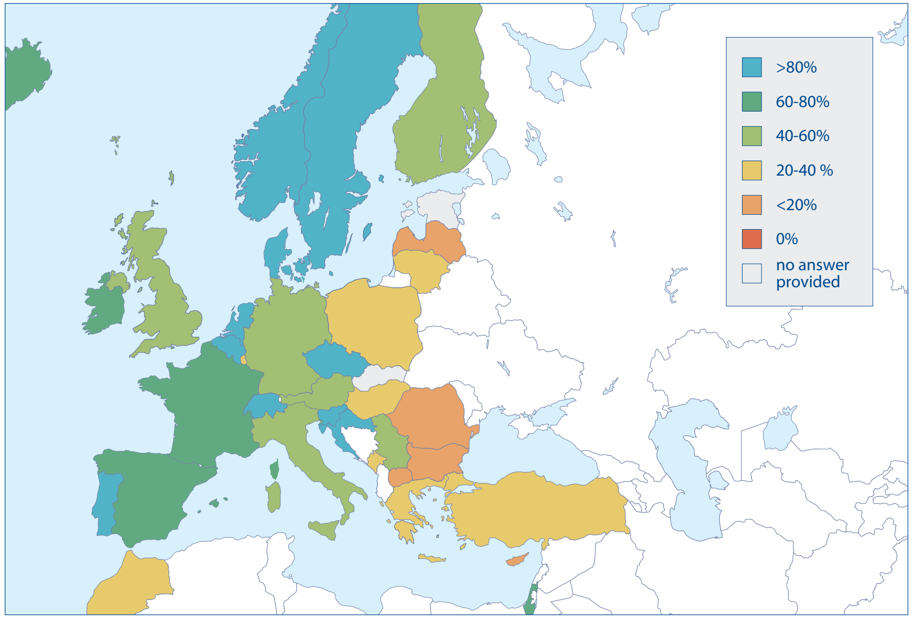
Country	Percentage of universities providing eduroam credentials to users	Percentage of students with an eduroam-enabled account
GÉANT partner countries		
Austria	50	80
Belgium	100	25
Bulgaria	10	2
Croatia	100	60
Cyprus	10	15
Czech Republic	90	96
Denmark	100	
Finland	50	80
France	80	
Germany	45	
Greece	25-30	40-60
Hungary	20	45
Iceland	72	95
Ireland	77	>80
Israel	62	53
Italy	55	70
Latvia	13	75
Lithuania	25	50
Luxembourg	50	90
Macedonia, FYRo	5	0
Malta	100	100
Montenegro	30	0
Netherlands	100	50
Norway	95	90

Table 5.3.3.1 – continued

Country	Percentage of universities providing eduroam credentials to users	Percentage of students with an eduroam-enabled account
GÉANT partner countries		
Poland	30	
Portugal	100	100
Romania	6	10
Serbia	47	15
Slovenia	100	>80
Spain	77	
Sweden	95	93
Switzerland	85	80
Turkey	38	45
United Kingdom	60	60
Other countries		
Morocco	20	1
Australia	100	
New Zealand	100	100
Taiwan	25	25

Map 5.3.3.2 illustrates the percentage of universities that provide eduroam credentials to their users in the various countries.

Map 5.3.3.2 – Percentage of universities that provide eduroam credentials



6 COLLABORATION SUPPORT SERVICES

This section provides information on collaboration support services, which are becoming easier to introduce now that middleware services (see Section 5) are becoming widespread. Firstly, Section 6.2 considers housing, storage and related services. Section 6.3 looks at network collaboration tools, such as Voice over IP and group collaboration services. Section 6.4 documents NREN involvement in the provision of networked e-Science resources, including cloud resources. Section 6.5 examines e-learning and Section 6.6 interaction with NREN clients. Finally, Section 6.7 explores the relatively new areas of broker services and software development.

6.1 Overview

Many NRENs already provide, or are planning to provide, some kind of housing or **storage service**. The service that is currently offered by the largest number of NRENs is mirroring, mostly of open source software archives.

Just over one-third of the GÉANT partner NRENs currently offer a centrally-administered **VoIP (voice over IP) service** — a proportion that does not differ significantly from last year's figure. A further 14% of NRENs in the GÉANT region are planning to introduce such a service.

Twenty-nine of the GÉANT partner NRENs provide or plan to offer a centrally managed **video-conferencing service** — a number that is similar to last year's. The ITU-T H.323 communication protocol remains the most widely deployed technology.

To assess the take-up of this service, in this year's *Compendium* questionnaire we asked NRENs to provide us with information on the total time of videoconferencing sessions on the MCU[1] in 2011. By far the highest figure – 72 000 hours – was provided by DFN of Germany and the second largest – nearly 39 000 hours – by Janet (UK). Clearly, the uptake of this service differs greatly from country to country, which seems to imply that there is room for considerable growth in this area. However, in this regard NRENs are adopting a variety of strategies. For example, SURFNet is planning to phase out its service in 2012, whereas AARNet of Australia is working with its customers to enable a cost-effective scalable conferencing infrastructure to cater for the growing demand.

In the past year there has been considerable growth in **services for collaborative groups**. Fifteen GÉANT partner NRENs currently offer such services, up from nine in 2011.

This year, 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 many countries, these three related resources are supplied in the same manner. In some countries, however, the situation is mixed.

The most common model, especially for the larger countries, is that these services are not provided by the NREN but by one or more individual institutions, often in collaboration with the NREN.

There has been some growth in the area of cloud resources compared to 2011. Eleven of the GÉANT partner NRENs currently offer virtualisation services, up from seven last year, and fifteen others are planning to introduce them.

Increasing amounts of work are being done in the area of **e-learning**. Fifteen of the GÉANT partner NRENs currently provide an e-learning service, up from ten in 2011. Two others are planning work in this area.

[1] Multipoint Control Unit, the device that enables video conferencing between more than two points.

Twenty-two of the GÉANT partner NRENs have separate customer-support departments. Twenty-one publish, on their website, lists of the services they offer.

NRENs function as centres of excellence, in service of their clients. Since last year, the number of GÉANT partner NRENs involved in **premium services** such as consultancies and security audits has risen from seven to twelve. A new question in this year's questionnaire was whether NRENs are involved in e-government public services, such as e-voting, e-ID issuing or e-ID related applications. Eleven GÉANT NRENs report that they are currently active in this area.

Seven of the GÉANT NRENs own the intellectual property rights to pieces of network software. Fifteen are involved in open-source software development.

6.2 Housing, storage, hosting and content-delivery services

NREN users require access to a range of services to support their teaching, learning and research activities. One important category of services includes housing, storage, hosting and content delivery.

This year's questionnaire focused on five areas in this category:
1. Is there a national storage service and, if so, who provides this service?
2. Is a commercial storage service provided by the NREN through a brokered deal?
3. Does the NREN host commercial-content servers or commercial content on the NREN network?
4. Are there video or multimedia content servers for use by NREN sites?
5. Is there mirroring of content from outside the NREN network?

For each of these areas, NRENs were asked to indicate whether they currently deploy the service, are planning to deploy it, or have no plan to do so. The results are summarised in Table 6.2.1. (below). Mirroring is the service that seems most popular in the GÉANT region.

Table 6.2.1 – Storage and related services 2012 (2011 data is shown between brackets)

	Grid storage	Peered commercial	Hosted commercial	Video service	Mirroring
GÉANT partner NRENs	29% (*26%*)	3% (*0%*)	53% (*45%*)	51% (*52%*)	65% (*67%*)

In these areas the situation has not changed significantly since 2011, though a number of NRENs have started making plans. Full country information is available from the TERENA *Compendium* website.

6.3 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 providers of higher education. Although technology has not changed profoundly during the last few years, the significantly increased quality and reduced price of collaboration hardware and software have made network-based virtual meetings more appealing than ever before. In research and education, collaboration techniques 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 optimize 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. Voice over IP (VoIP) to connect institutional IP telephony deployments or, to a lesser extent, 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.
3. Group collaboration services, bundling services that allow collaborative groups to form and work together easily, independent of their location.

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

6.3.1 IP telephony

The situation with regard to IP telephony seems to be fairly stable. As in 2011, just over one-third of the GÉANT partner NRENs currently offer a centrally administered VoIP service. A further 14% are planning to introduce such a service. Cyprus and Luxembourg have abandoned their plans to introduce such a service, but Spain is now planning to start one.

Many other countries are also planning such a service; however, in the past year, no planned services became operational.

Most of the NRENs that offer a centrally managed VoIP service also provide an IP telephony interconnection facility to the institutions connected to their networks. Most, though not all, of those countries support the propagation of serviced E.164 numbers in ENUM or NRENUM.net.[2] Since 2011, a few more countries have started to, or are planning to, support this propagation. Far fewer NRENs also provide a VoIP-to-PSTN[3] service, probably due to issues with accounting, billing and cost recovery. Generally, NRENs do not offer a VoIP service to individual users, probably because of security policies and difficulties in user authorisation[4].

6.3.2 Video and web-conferencing

As with IP telephony, there has been little change in the area of video- and web-conferencing since 2011. Cyprus and Spain have dropped their plans to introduce such a service, though Finland and France have implemented theirs. Currently, 29 of the GÉANT partner NRENs provide or plan to offer a centrally managed video-conferencing service, which clearly indicates the strategic importance of videoconferencing. Such services are usually complemented by deployment of a multipoint conferencing unit (MCU) and availability of a central user-support team. The ITU-T H.323 communication protocol is still the most widely deployed technology. The more recent Session Initiation Protocol (SIP) is gaining ground, with 25 GÉANT partner NRENs now offering or planning to offer a SIP-enabled service (up from 23 in 2011). The H.323 protocol is still used in conjunction with the Global Dialling Scheme (GDS), a virtual numbering scheme that is supported by 23 NRENs within the GÉANT region (up from 20 last year); H.323 is also utilised by countries beyond the region.

Nineteen of the GÉANT partner NRENs offer high definition (HD) video-conferencing (up from 15 in 2011); three others are planning to introduce it. Seventeen GÉANT partners currently offer a centrally managed webmeeting desktop service (up from 14 in 2011). The most commonly used platform is Adobe Connect.

To assess the take-up of this service, we asked NRENs to provide us with information on the total time of videoconferencing sessions on the MCU in 2011. Thirteen NRENs were able to do this. The theoretical maximum usage time of any single MCU is 8 760 hours (i.e. an entire year of 365 days). However, most MCUs can handle several video conferences simultaneously, and several NRENs have more than one such unit. By far the highest figure – 72 000 hours – was provided by DFN of Germany and the second largest – nearly 39 000 hours – by Janet (UK). The other 10 GÉANT NRENs that responded all reported less than 8 000 hours. Beyond the GÉANT region, New Zealand reported 30 000 hours of use and Australia nearly 13 000 hours.

Clearly, the uptake of this service differs greatly from country to country, which seems to imply that there is room for considerable growth in this area. However, in this regard NRENs are adopting a variety of strategies. For example, SURFNet

[2] ENUM is a scheme for unifying the telephone number system of the Public Switched Telephone Network (PSTN) with the Internet addressing and identification namespaces. NRENUM.net is a pilot service run by TERENA for NRENs in countries that cannot yet participate in ENUM.

[3] Public Switched Telephone Network.

[4] For more information, see page 69 of the 2011 edition of the *Compendium*.

is planning to phase out its service in 2012 and hopes to broker one or more commercial services for its customers, whereas AARNet of Australia is working with its customers to develop a coordinated approach to videoconferencing on a number of fronts. AARNet is enabling increased video accessibility via unified communications and personal video mobiles across multi-vendor UC platforms. In addition, it has launched a Cisco Telepresence exchange alongside its open-standards offering. Work is underway to make the two platforms interoperate via AARNet's Unified Communications exchange. Finally, AARNet and vendors are devising new solutions for multi-tenant MCU capabilities, to enable customers to purchase their own MCU ports and have options to burst at peak, thus reducing the cost and overheads of local MCUs. The AARNet strategy is to enable the widest possible support to connect to video 1-2-1 and to enable a cost-effective scalable conferencing infrastructure to cater for the growing demand for such services.

6.3.3 Supporting group collaboration

Collaborative groups, sometimes referred to as virtual organisations, can serve individuals from more than one home institution, so the group is not bound to a single institution.

There has been considerable growth in this area since 2011. Fifteen GÉANT partner NRENs currently offer a platform of bundled services for collaborative groups of users (up from nine in 2011), while four others are planning to introduce this (down from eight in 2011). In most cases, these services are federated, allowing access to the services through a web-based authentication scheme.

The most common bundled services include mailing lists (reported 15 times), a wiki (15 times), a document store (12 times) and calendar/appointment planning (7 times).

Table 6.3.3.1 (right) provides further information on such services.

6.3.3.1 – Supporting group collaboration

Country	Platform of bundled services	Size of target groups	Services bundled	Services federated	Charging model
GÉANT partner countries					
Austria	plan	0-100	wiki, mailing list	yes	free
Croatia	yes	100+	wiki, document store, calendar, mailing list	yes	free
Cyprus	plan	0-20	calendar, mailing list	no	
Czech Republic	yes	0-20	wiki, document store, mailing list, Repositories - SVN, GIT. Redmine.	yes	free
Denmark	no	100+	document store	yes	free
Estonia	yes	100+	wiki, document store, mailing list	no	free
Finland	yes	0-20	wiki	yes	free
France	yes	100+	wiki, document store, appointment planning, mailing list, Planned: survey and mailbox hosting	yes	free
Greece	plan	0-20	wiki, document store, calendar, Redmine	yes	free
Hungary	yes	100+	mailing list	no	free
Latvia	yes	0-20	wiki, mailing list	no	free
Lithuania	no			yes	free
Luxembourg	yes	100+	calendar, mailing list	no	free
Montenegro	yes	0-100	wiki, document store, calendar, appointment planning, mailing list	no	free
Netherlands	yes	100+	wiki, document store, calendar, appointment planning, mailing list, whole collection of IaaS, PaaS and SaaS deliveries: storage, educational, video, research, virtualization	yes	Fully recovered: Service providers (or SURFmarket as intermediate) have contracts and bill the connected institutions.

6.3.3.1 – continued

Country	Platform of bundled services	Size of target groups	Services bundled	Services federated	Charging model
GÉANT partner countries					
Norway	yes	0-20	wiki, document store, calendar, appointment planning	yes	Partly subsidised. The tariffs have two parts: one fixed and one variable, depending on some measurement of size or usage
Poland	yes	0-20	wiki, document store, appointment planning, mailing list	no	free
Romania	plan	100+	wiki, mailing list	no	free
Slovenia	no	0-100		yes	free
Spain	yes	0-100	wiki, document store, calendar, appointment planning, mailing list. Interaction with other NREN services (identity/ storage/instrument access/...)	yes	free
Sweden	yes		document store	yes	fully recovered: a fee per active user
Switzerland	yes	0-20	wiki, document store, mailing list	yes	free
Other countries					
Algeria	plan	0-20	wiki	yes	partly subsidised
Armenia	plan	0-20	wiki, mailing list	no	
Azerbaijan	plan	0-100	wiki, document store, calendar, appointment planning, mailing list	yes	free
Bosnia/ Herzegovina	plan	0-20	document store, calendar, appointment planning, mailing list	yes	free

6.3.3.1 – continued

Country	Platform of bundled services	Size of target groups	Services bundled	Services federated	Charging model
Other countries					
Moldova	plan	0-20	wiki, document store, calendar, appointment planning, mailing list	no	partly subsidised
Russian Federation	yes	100+	wiki, mailing list	no	free
Canada	yes	0-20	wiki, mailing list	no	free
Kazakhstan	yes	0-20	document store	no	free
Korea	yes	0-7	wiki, mailing list	no	partly subsidised
Kyrgyzstan	plan	100+	wiki, document store, calendar, appointment planning, Moodle	yes	free
New Zealand	yes	0-20	wiki	yes	free
Taiwan	yes	0-20	wiki, mailing list	no	free

6.3.4 Multimedia repositories and streaming

As in the questionnaire for last year's *Compendium* (2011), we asked NRENs about their use of multimedia repositories (audio/video archives) and the streaming services they offer. Since last year, there have been few changes. Cyprus has dropped its plan in this area, and Greece has discontinued its service. Norway and Slovenia have implemented their plans. All in all, eighteen GÉANT partner NRENs currently offer a multimedia content repository (the same number as last year) and seven others are planning to establish one (down from nine last year).

The number of objects stored in the repositories varies greatly, from around one hundred to hundreds of objects in the Czech Republic and 20 000 object references in Spain. Clearly, there is scope for considerable growth in this area.

6.4 Networked e-Science resources

Increasingly, many of the resources that scientists need are being made available through the Internet, and this has therefore become an important area for NRENs. In many cases, the NRENs provide the networking infrastructure for such services and are expanding into 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:

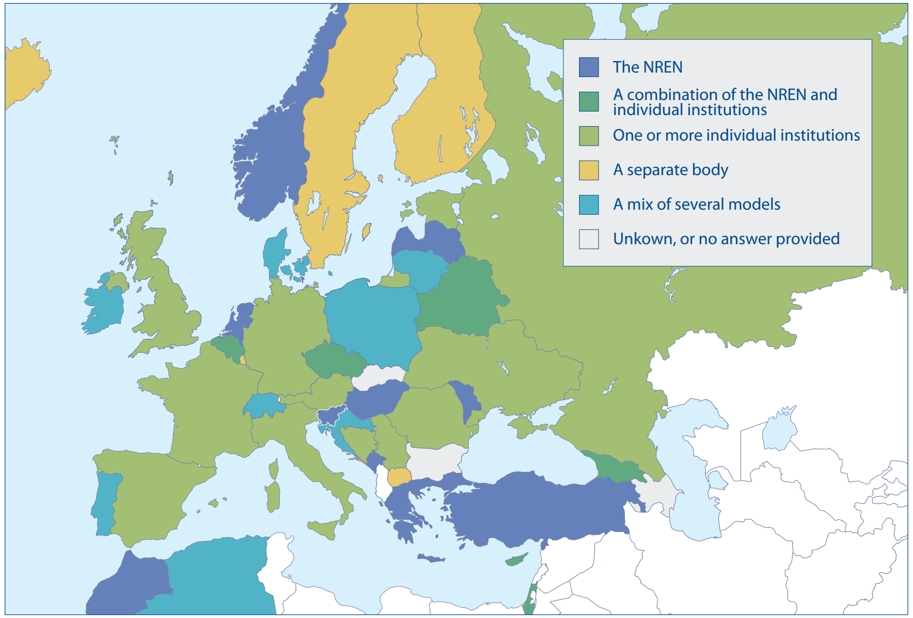
- Grid middleware;
- Computing power;
- Storage facilities.

In many countries, these three related resources are supplied in the same manner, though in other countries the situation is mixed. In some countries, not all these resources are available. Map 6.4.1 summarises the situation; for more precise information on a specific country, please consult the information on individual NRENs, available on the *Compendium* website.

The most common model, especially for the larger countries, is that these services are not provided by the NREN but by one or more individual institutions, often in collaboration with the NREN.

Radio telescopes are a specific type of e-Science resource for which several NRENs provide connectivity. Such instruments pose special challenges: they are often located in remote areas yet require high-capacity connections due to the huge amounts of data generated.

Map 6.4.1 – Availability of networked e-Science resources in Europe



6.4.1 Cloud resources

There has been some growth in the area of cloud resources since 2011. Eleven of the GÉANT partner NRENs currently offer virtualisation services, up from seven last year, and fifteen others are planning to introduce them. In most cases, these services have been developed and are hosted by the NREN. Only SURFnet of the Netherlands offers services provided by Google, Microsoft and Rackspace. Beyond the GÉANT region, a number of NRENs are planning to introduce such services; REANNZ of New Zealand already offers them.

In most cases, the number of CPU cores available through the cloud service is limited. Notable exceptions are PIONIER of Poland with 1528 cores and GRNET of Greece, which has increased from 512 cores in 2011 to more than 6 000 cores this year.

Table 6.4.1.1 additionally indicates the storage volume, the individuals and groups to whom the service is addressed, and the types of resources offered. The countries that have implemented this service in the past year are highlighted in green.

Table 6.4.1.1 – Cloud resources details

Country	Who provides it?	Other suppliers?	How many CPU cores?	What storage volume?	To whom is this service addressed?	What kind of resources are offered?
GÉANT partner countries						
Croatia	NREN		32	30 TB	our member institutions (universities, schools, research institutes, etc.)	computing, storage
Czech Republic	NREN		100	20 TB	end-users, laboratories	computing, IAAS
Estonia	NREN (plan)		8	12 TB	end-users, laboratories	computing, storage
Greece	NREN		6640	1584 TB	laboratories and end-users	computing, storage, storage as a service
Hungary	NREN		450	2.5 PB	end-users, laboratories, organizations	computing, storage, virtual networks
Israel	NREN, other	Amazon AWS	60	6 TB	end-users	computing, storage
Malta					UoM users, both for research and administrative services	
Netherlands	Google Apps, Microsoft, Rackspace, NREN, other	Several other service providers for document sharing, IaaS (virtualization and storage), educational and research services, etc.	Unknown (several providers provide these cloud services)	Unknown (several providers provide these cloud services)	institutions, teams (VOs) and individuals	computing, storage, storage as a service, IaaS
Poland	NREN		1528	12.5 PB and ~1 TB (OPen Stack Swift) pilot	end-users, laboratories, projects and R&D community	computing, storage
Slovenia	NREN		160	24 TB	research and academic institutions in Slovenia	computing, storage, storage as a service
Sweden	other	Box			all users	storage
Turkey	NREN		1200	240 TB	e-learning, governmental organizations, national projects	computing, storage
Other counties						
Azerbaijan	NREN		128	50 TB	end-users, laboratories	computing, storage, storage as a service
Ukraine	Microsoft		8	2 TB	internal URAN	
Canada	NREN		384	48 TB	small and medium enterprise	computing, storage
New Zealand	Google Apps, Microsoft, other	Amazon				

6.5 e-Learning

As Table 6.5.1 shows, fifteen of the GÉANT partner NRENs currently provide an e-learning service, up from ten in 2011. Two others (highlighted in yellow) are planning work in this area, down from four last year. In many cases, further information can be found on the NREN websites. Several NRENs beyond the GÉANT region are also active in this area. Countries that have started work in this area since the 2011 edition of the *Compendium* are highlighted in green.

Table 6.5.1 – e-Learning services of NRENs

Country	E-learning service provided?	URL
GÉANT partner countries		
Croatia	yes	www.carnet.hr/education/e-learning_academy www.carnet.hr/education/moodle_in_carnet www.carnet.hr/education/e_courses_for_teaching www.carnet.hr/education/nikola_tesla_national_distance_learning_portal www.carnet.hr/education/skolska_ucilica www.carnet.hr/education/edu.hr www.carnet.hr/education/online_encyclopedia www.carnet.hr/education/eLektire
Estonia	yes	www.koolielu.ee www.viko.edu.ee
Germany	yes	
Israel	yes	meital.iucc.ac.il/meital/English/English.htm
Italy	yes	learning.garr.it/learning/
Lithuania	yes	moodle.litnet.lt
Macedonia	plan	
Malta	yes	www.um.edu.mt/vle
Montenegro	yes	moodle.ac.me
Netherlands	no	Through e-learning service providers connected to the SURFconext middleware structure
Norway	yes	We are building an infrastructure to support e-Learning in our eCampus programme
Poland	yes	fbc.pionier.net.pl/elearning
Portugal	yes	educast.fccn.pt
Serbia	yes	elearning.amres.ac.rs
Slovenia	yes	www.sio.si
Switzerland	yes	www.switch.ch/eduhub
Turkey	plan	
United Kingdom	yes	www.ja.net/training/edlab
Other countries		
Algeria	plan	
Azerbaijan	yes	
Georgia	yes	elearning.grena.ge
Moldova	plan	www.renam.md/moodle
Russian Federation	plan	
Australia	yes	AARNet provides unmetered access to third-party providers of learning management systems, also many institutions have their own arrangements in place.
Kazakhstan	yes	www.rmeb.kz
Kyrgyzstan	plan	

6.6 Interaction with clients, 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 and this aspect is therefore not included in this year's *Compendium*. 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-two of the GÉANT partner NRENs have separate customer-support departments. Twenty-one publish, on their website, lists of the services they offer. Further information is provided in Table 6.6.1.

Table 6.6.1 – Interaction with clients

Country	Customer support department?	CRM solution?	Catalogue of services?
GÉANT partner countries			
Austria	no	no	www.aco.net/services.html?&L=1
Belgium	yes	Since 2008, StayInfront CRM, but currently procuring a new CRM (going live Q1 2013)	www.belnet.be/en/services/general
Croatia	yes	SedamCRM	www.carnet.hr/services
Czech Republic	no	no	hwww.cesnet.cz/sluzby
Denmark	no	WEBCRM	no
Estonia	yes		www.eenet.ee/EENet/services_en.html
Finland	no	no	www.csc.fi/hallinto/funet/palvelut
France	yes	no	www.renater.fr/services
Germany	yes	Access management, contract management, security management	www.dfn.de/dienstleistungen
Greece	yes	no	noc.grnet.gr/en/node/53
Hungary	yes	Self-developed Drupal-based Customer Relationship Manager application	webform.niif.hu
Ireland	yes	In house solution: ClientDB	www.heanet.ie/services
Italy	yes	no	www.servizi.garr.it
Latvia	yes	no	www.sigmanet.lv
Luxembourg	yes	no	www.restena.lu/restena/en/EN-UserSpace.html
Montenegro	yes	no	no
Netherlands	yes	SugarCRM	www.surfnet.nl/en/organisatie/Dienstverleningsoverzicht/Pages/Dienstverleningsoverzicht.aspx
Norway	yes	no	yes
Poland	yes	no	no
Portugal	no	no	www.fccn.pt/pt/servicos
Romania	yes	customized SharePoint	yes
Serbia	yes	no	www.amres.ac.rs/index.php?option=com_content&task=view&id=122&Itemid=154
Slovakia	yes	no	no
Slovenia	yes	Internal application	www.arnes.si/fileadmin/dokumenti/zavod-arnes/publikacije/brosura-arnes-2011.pdf
Spain	no	no	www.rediris.es/servicios
Switzerland	yes	Sugar CRM	yes
Turkey	yes	no	www.ulakbim.gov.tr/ulaknet
United Kingdom	yes	SUGAR	community.ja.net/library/janet-policies/janet-service-catalogue

Table 6.6.1 – continued

Country	Customer support department?	CRM solution?	Catalogue of services?
Other countries			
Algeria	yes	no	
Azerbaijan	yes	no	
Belarus	yes		
Georgia	yes	no	hgrena.ge/eng/services/services
Russian Federation	yes	no	yes
Ukraine	no	no	www.uran.ua/~eng/prices-1.htm
Australia	no	no	www.aarnet.edu.au/services/services-catalogue.aspx
Canada	yes	no	no
Kazakhstan	yes	no	no
Korea	no	no	ims.kreonet.net
Kyrgyzstan	yes		
New Zealand	yes	Salesforce	www.reannz.co.nz/services
Singapore	no	no	www.singaren.net.sg/Connect.php
Taiwan	yes	no	(Only in Chinese) noc.twaren.net/noc_2008/Services/index.php

6.7 Broker and professional services, software development

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 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 customers and in which there is therefore potential for expansion, especially given the current economic climate.

NRENs are also undertaking framework procurements for network and related equipment. These 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.

Since last year, two NRENs (Estonia and Netherlands) have moved from the planning to the implementation phase, while four NRENs have become active in broker or professional services. Table 6.7.1 provides an overview of NREN activities in this area.

In addition, the number of GÉANT partner NRENs involved in premium services such as consultancies and security audits has risen from seven to twelve.

A new question for this year's edition of the *Compendium* was whether NRENs are involved in e-government public services, such as e-voting, e-ID issuing or e-ID related applications. The responses reveal that eleven of the GÉANT NRENs are currently active in this area.

Table 6.7.1 – Broker and professional services

Country	Broker services, current	Broker services, planned	Premium services	E-government public services
GÉANT partner countries				
Belgium			consultancy, security audits	yes
Croatia	software licenses		security audits	yes
Estonia				no
Finland	software licenses		consultancy	yes
Greece	software licenses			no
Ireland	software licenses, procurement		security audits	no
Italy	limited common procurement for specific projects			no
Latvia			consultancy	no
Lithuania			consultancy, security audits	yes
Macedonia, FYRo		Establishing the MK exchange point is planned for Q4 2012		no
Netherlands	software licenses, digital library, licenses, procurement, SURFconext as cloud integrator		consultancy, security audits	no
Norway	software licenses, procurement		consultancy, security audits	no
Poland	software licenses, procurement		consultancy, security audits	yes
Portugal			consultancy, security audits	yes
Serbia	digital library, licenses		consultancy	no
Slovenia				yes
Spain			consultancy	yes
Sweden				yes

Table 6.7.1 – continued

Country	Broker services, current	Broker services, planned	Premium services	E-government public services
GÉANT partner countries				
Switzerland	joint procurement of software and software licenses	establish in 2012 a service for joint procurement of software and software licenses	consultancy	yes
Turkey	digital library, licenses			yes
United Kingdom	procurement			no
Other countries				
Algeria	Proxy services related to NGI		consultancy	no
Azerbaijan			consultancy, security audits	
Georgia			consultancy	yes
Russian Federation				yes
Ukraine	digital library, licenses			yes
Australia				no
Kazakhstan	digital library, licenses, procurement			no
Kyrgyzstan			consultancy	
Taiwan			consultancy, security audits	no

Seven of the GÉANT NRENs own intellectual property rights to certain pieces of network software. Fifteen are involved in open-source software development. Table 6.7.2 provides an overview and also lists the new services that NRENs are introducing in 2012.

Table 6.7.2 – Open source software and new services

Country	Owner of IPR for network software?	Categories of software products owned	Involved in open-source software development for network services?	URL to software repository	New services in 2012
GÉANT partner countries					
Belgium	no		no		Voice, Storage, e-collaboration (Mconf), virtual organisation for R&E federation, roaming service for government inst.
Croatia	no		yes	Microsoft Download Center, www.carnet.hr/internet_services/MSDC	
Cyprus			no		
Czech Republic	yes	monitoring tools, security, multimedia and middleware	yes	in preparation	
Finland	yes	Small scale monitoring and management tools.	yes		
France	no		yes	www.sympa.org	
Greece	no		yes	code.grnet.gr 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.	Yes, we plan to introduce a plethora of SaaS services, PaaS as well as elastic cloud IaaS in addition to the VPS service currently offered. Furthermore, we anticipate introducing the 'Scientific' SaaS that will enable researchers to access instances of scientific commercial tools that might not be affordable of a small institution.
Hungary	no		yes		
Ireland	no		yes	We don't have a public repository – rather, all software we write is developed under the BSD licence model, and is available for free for others to use.	EduStorage - HEAnet Data Storage Service
Italy	yes	Network Monitoring tools (GINS)	yes	not yet deployed	Video Storage/Streaming services for GARR users
Lithuania	no		yes		Filesender, complex authorized network connectivity for schools
Luxembourg	no		no		Filesender

Table 6.7.2 – continued

Country	Owner of IPR for network software?	Categories of software products owned	Involved in open-source software development for network services?	URL to software repository	New services in 2012
GÉANT partner countries					
Macedonia, FYRo	no		no		Eduroam for several other universities
Montenegro	no		no		
Netherlands	yes	MediaMosa, OpenDRAC, Openconext, Tiqr, Apache RAVE, Mujina and some older products (e.g. A-select)	yes		New connected (commercial and non commercial) services through SURFconext as a broker/cloud integrator.
Norway	yes	Tools for Network Monitoring, (software. uninett.no)	yes	software.uninett.no	e-learning-support, multimedia services, cloud service
Poland	yes		yes	No repository yet	
Portugal	no		no		LISP pilot
Slovakia	no		yes		
Slovenia	no		no		Multimedia portal, online questionnaire, WebDAV service for end-users, CalDAV service for end-users, AAI based account management for end-users.
Switzerland	yes	AAI middleware, video management	yes		Spam filtering
Turkey	no		yes	ftp://ftp.ulakbim.gov.tr/KOVAN	
Other countries					
Georgia	no		yes		
Morocco	no		yes		
Australia	no	FileSender (co-owned with UNINETT, HEANet and SURFnet)	yes	www.filesender.org	Enhancements to video services such as Skype Gateway to MCUs, scheduling for Cisco TP exchange services, a production-ready UC exchange service, enhancements to our personal video services.
Kyrgyzstan	yes		no		
New Zealand	no		yes		VOIP, eduroam, storage, DR
Taiwan	no		yes	Not yet publicized.	

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 2012 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'.

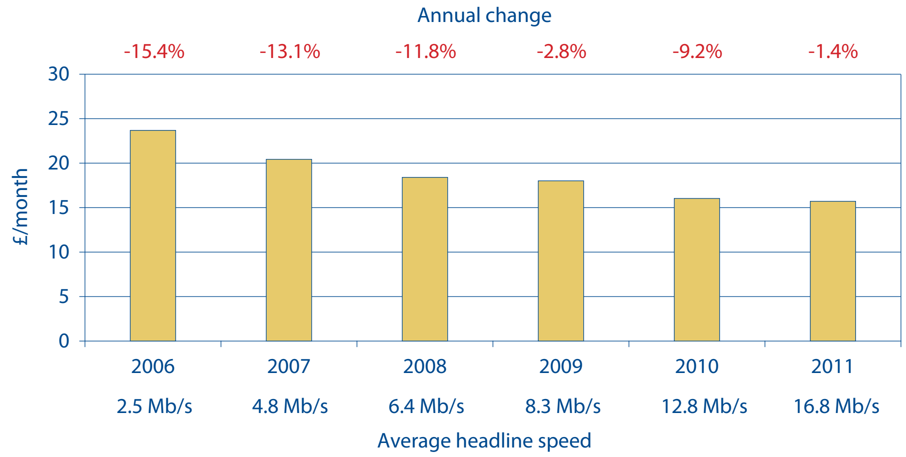
Below, Section 7.1 gives an overview. Section 7.2 details the considerable differences in the number and types of staff that NRENs employ and attempts to explain some of these differences. Section 7.3 provides information on, and explains the variety of, NREN budgets. Sections 7.4 and 7.5 give further 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; their funding also differs greatly.

Comparing 2012 budget data with those from previous editions of the *Compendium* reveals that, overall, NREN budgets tend to be relatively stable, though this is not necessarily the case for individual NRENs. Several NRENs have experienced budget cuts that cannot be explained by the normal year-to-year fluctuations that depend on multi-year investment cycles. 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 the previous year. This reflects a continuing trend in the Internet sector, where the price per megabit of bandwidth continues to fall. Graph 7.1.1 illustrates this with an example from the UK.

Graph 7.1.1 – Average monthly cost of a residential fixed broadband connection in the UK*



This year, several NRENs have been significantly affected by the current economic crisis. Greece, Italy, Portugal and Spain all suffered budget cuts of more than 15%; the budget of Cyprus was cut by more than 60%. Nevertheless, some NRENs were able to obtain budget increases, as shown on Map 7.3.4.

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 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.

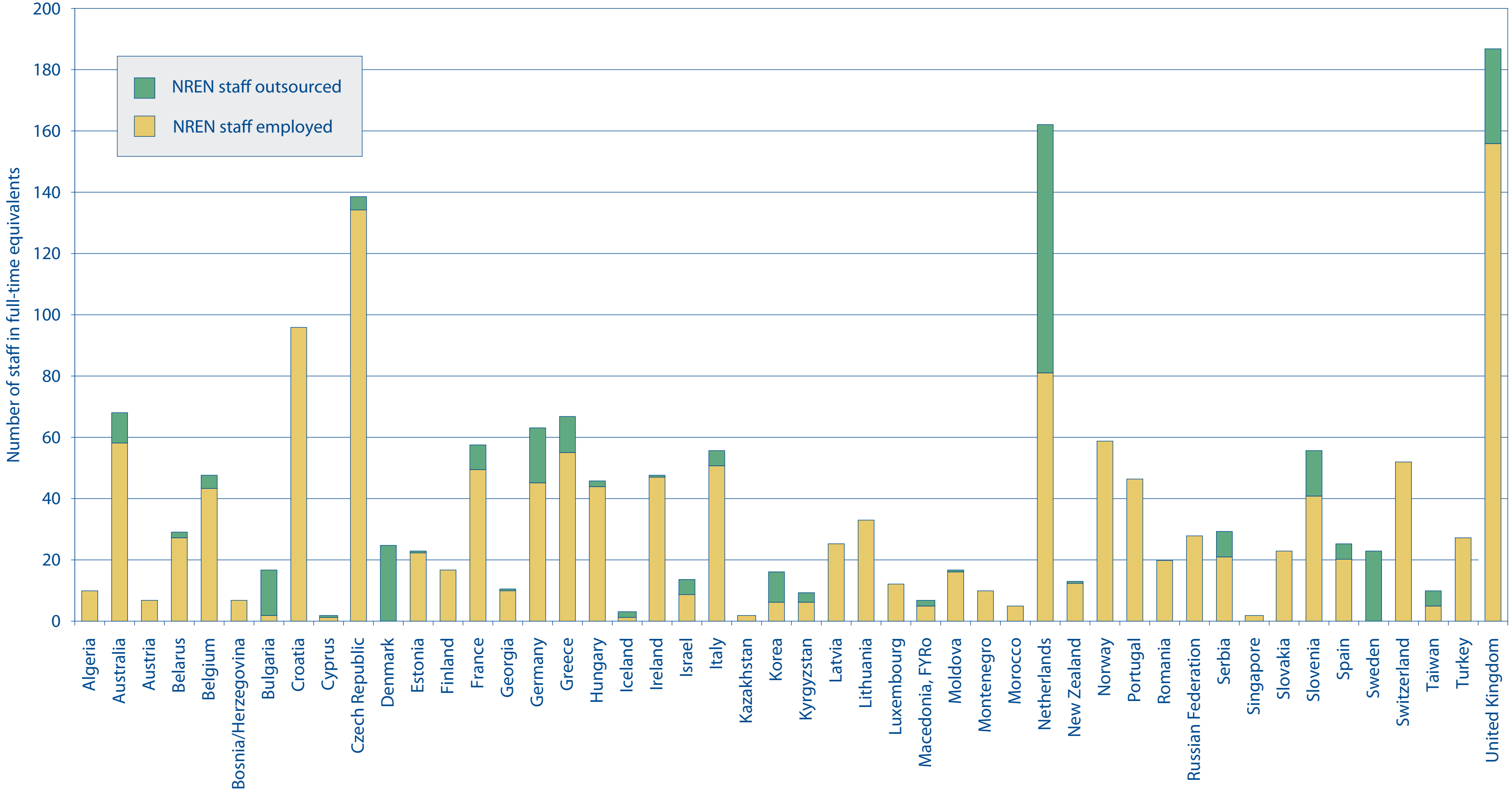
* Source: Ofcom/operators.

7.2 Staffing

Graph 7.2.1 gives an overview of the staff that are directly employed in NREN activities, as well as subcontracted staff, in full-time equivalents (FTE). Graph 7.2.4 provides similar information specifically for technical staff. The data is presented in this way because many NRENs use subcontractors; therefore, staff size alone is not a reliable indicator of the total amount of person-power available to an NREN.

As in previous years, there are considerable differences from NREN to NREN, 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

Graph 7.2.1 – Total NREN staff in FTE



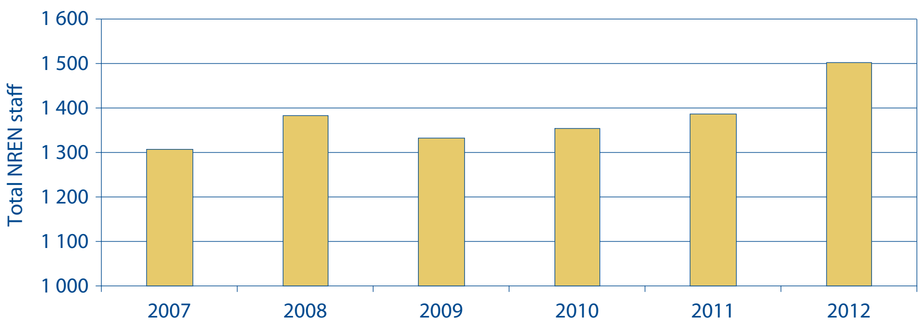
and human resources, etc.) devoted to NREN activities. This partially explains why some NRENs have a higher ratio of technical to total staff than others.

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 seen in staff numbers in Graphs 7.2.1 and 7.2.3.

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 (below) seems to indicate that the economic crisis has not (yet) had an impact on overall staff size. In the GÉANT partner countries, the total number of NREN-employed staff increased in 2008. This was mostly related to major infrastructural investments in some countries. The total staff size decreased in 2009 but has been increasing again since 2010. Financially, these increases

Graph 7.2.2 – Total NREN staff in GÉANT partner countries, 2007- 2012[1]



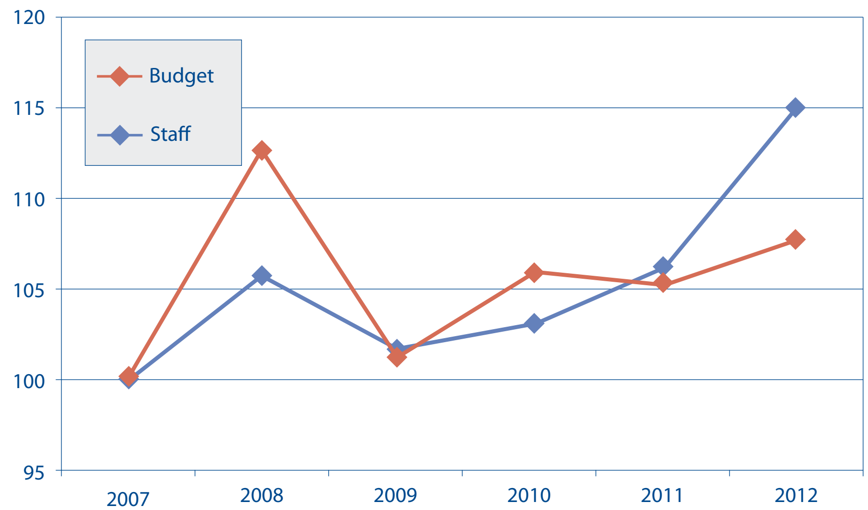
[1] Excluding data from Poland.

have been compensated by the fact that the infrastructural improvements were coupled with cost savings, as illustrated by Graph 7.2.3 and Graph 7.5.1.

Please note that it is impossible to discern a trend for the situation in the other (i.e. non-GÉANT) countries, because the data sets are not directly comparable.

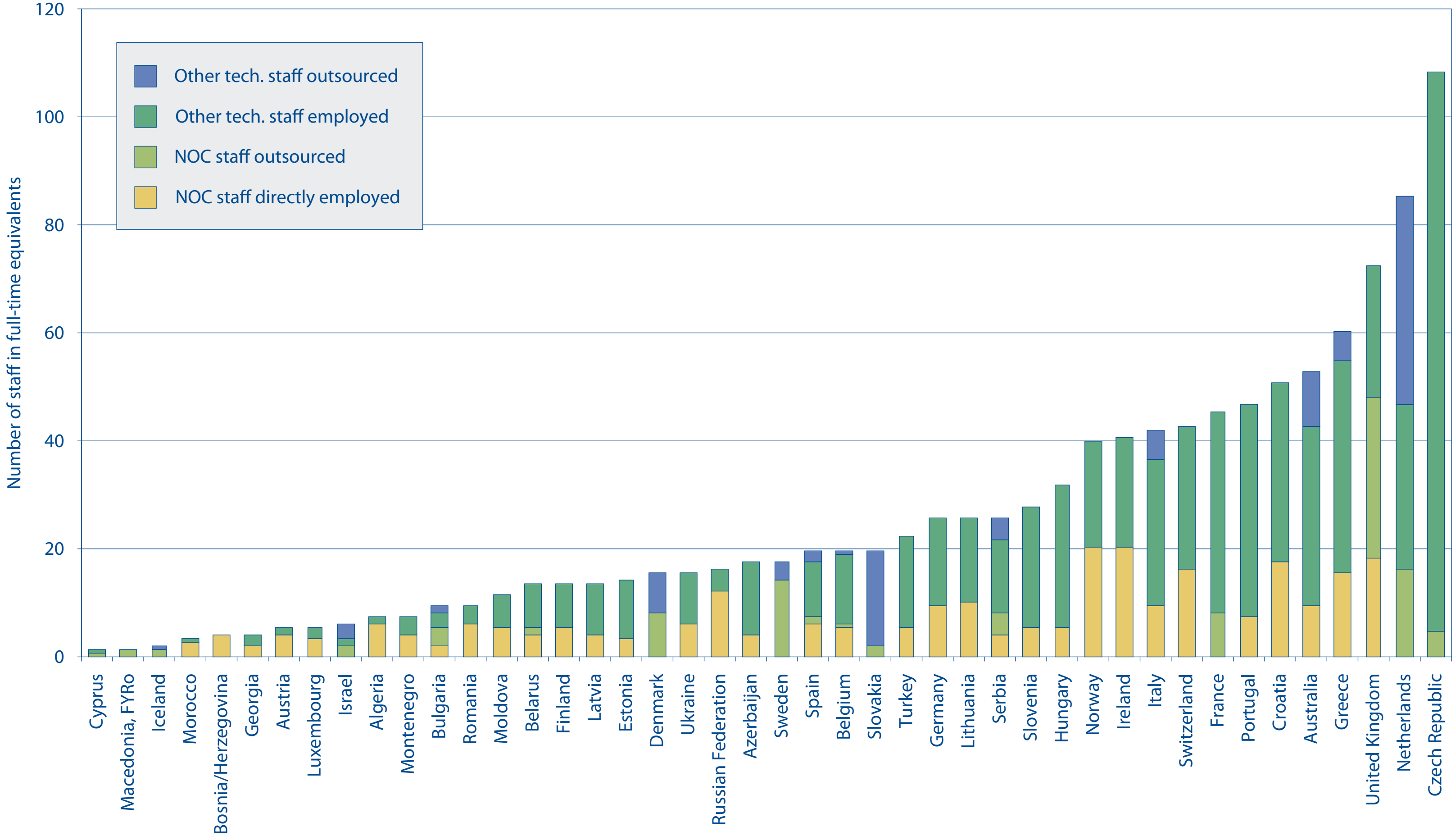
Graph 7.2.3 compares budget with staff size for the entire GÉANT region, indexed on 2007 (=100). This illustrates the points made above in this section. In 2008, there was a relatively large increase in the total NREN budget, which was related to major infrastructural investments in some GÉANT partner countries. These infrastructural investments led to transmission cost savings. However, the resulting infrastructural improvements, coupled with innovations in the area of authentication and authorisation, also enabled a new generation of networked services. Where these services are administered by NRENs, they require more staff. The staff size increases evident in 2012 are due mainly to a large increase in the

Graph 7.2.3 – Total NREN budget and staff size in the GÉANT partner countries, 2007–2012, indexed on 2007 (=100)



Czech Republic due to increased funding and a reorganisation in Denmark leading to more services being offered via the NREN. Although several countries have reported staff size reductions, the overall trend in the GÉANT region is upward.

Graph 7.2.4 – NREN technical staff in FTE



7.3 Total budgets, 2007-2009 and 2010-2012

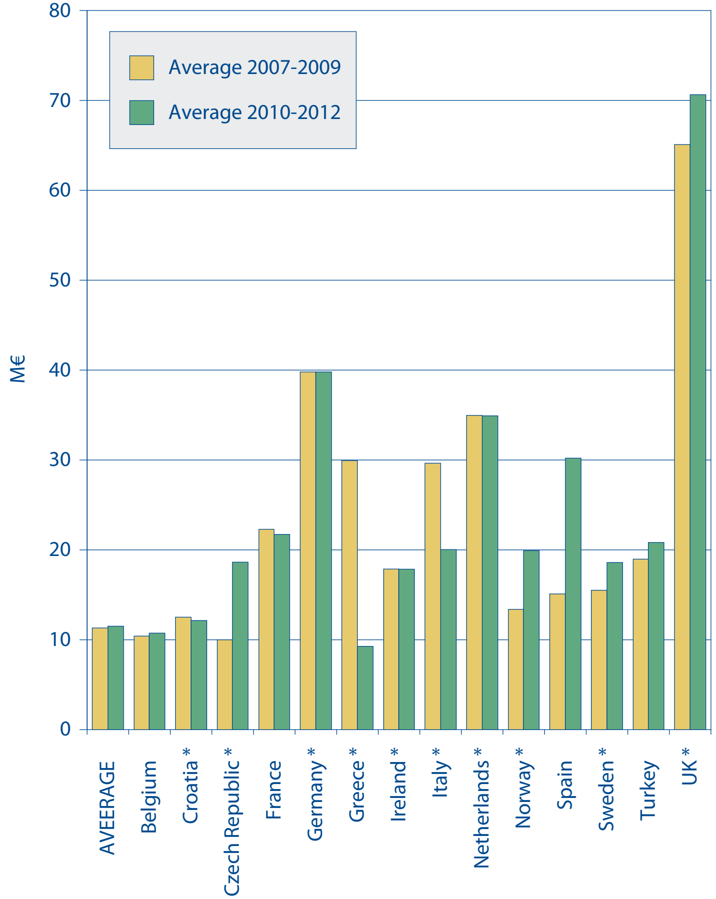
NREN budgets may fluctuate due to annually varying investment levels. In order to filter out as much of this effect as possible, in Graphs 7.3.1 and 7.3.2 (for the GÉANT partner countries) we have compared the total NREN budgets for two three-year periods: 2007-2009 and 2010-2012. Note that for Janet (UK), the financial year is from August to July; thus, its 2012 budget is actually its 2011/2012 figure.

The total annual budgets are shown in Graph 7.3.5, together with the growth in GÉANT traffic[2].

For several reasons (see bulleted list below) it remains difficult to directly compare budgets. We asked the NRENs whether their submitted budget figure includes 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 7.3.1 and 7.3.2, 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:

- 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 exist in other expenditure categories as well.

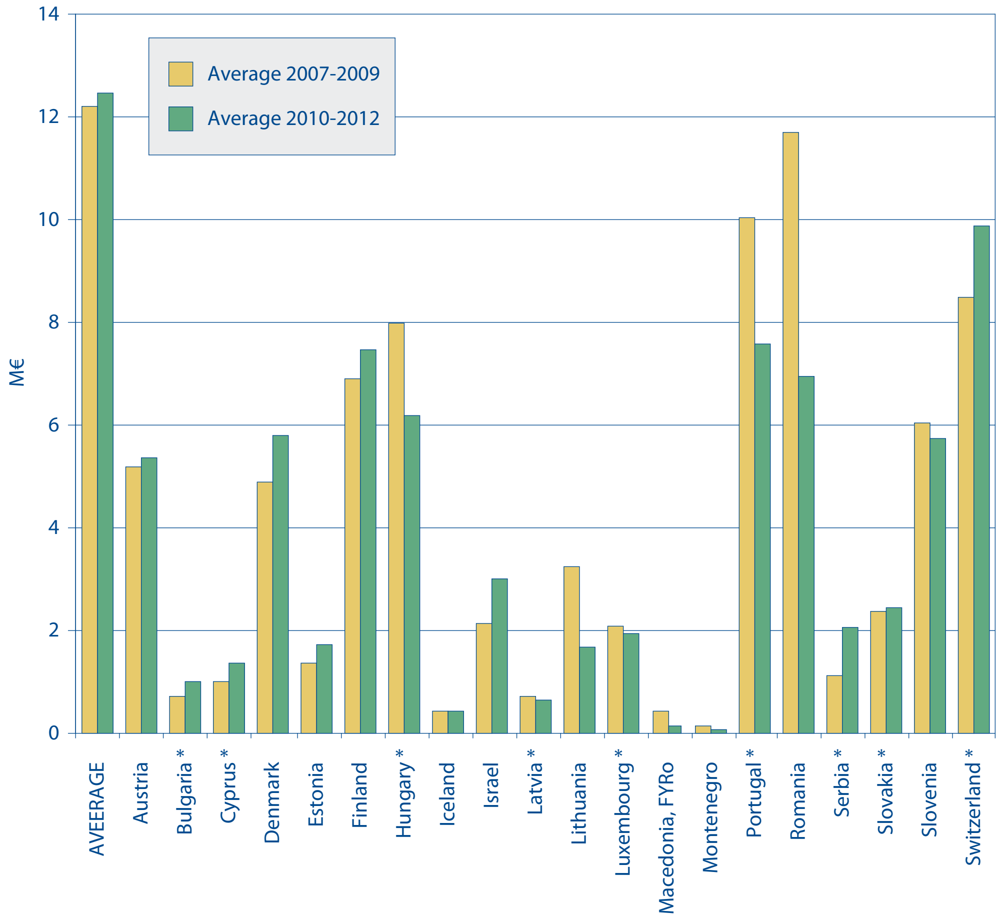
Graph 7.3.1 – Total budgets, 2007-2012 averages, GÉANT partner countries with annual budgets > 10 M€



[2] Traffic through the GÉANT network is only one of many components of a NREN's traffic. Nevertheless, it is used here as a comparator because it reflects the overall activity of an NREN and is measured centrally.

* Budget includes GÉANT subsidy.

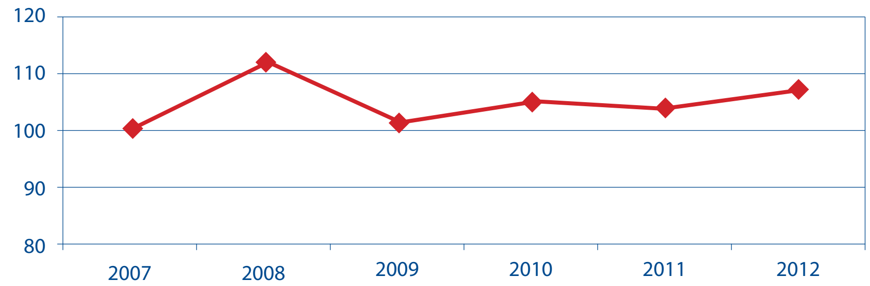
Graph 7.3.2 – Total budgets, 2007-2012 averages, GÉANT partner countries with annual budgets < 10 M€



As Graphs 7.3.1 and 7.3.2 show, the picture is mixed: some NREN budgets have increased, others have decreased, but the average has remained practically the same. Notable exceptions are the relatively large budget decreases in Italy, Greece, Portugal, Lithuania and Romania, and the relatively large increase in Spain. In these cases, both the increases and the decreases are related mainly to major one-time infrastructural investments.

The overall trend is also illustrated by Graphs 7.3.3 and 7.3.5, which confirm that the total budget for the GÉANT partner countries[3] has remained stable over the past five years at approximately 400 million euro. The notable exception, the small peak in 2008, was due to major investments in network infrastructure in Greece, Italy and Romania.

Graph 7.3.3 – NREN budgets, GÉANT partner countries, indexed on 2007 (= 100)

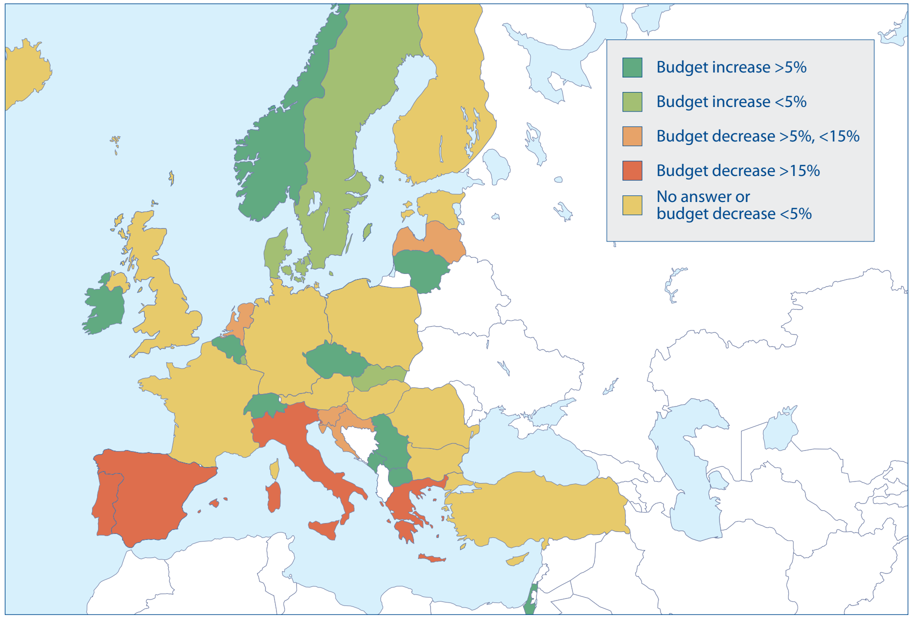


The combined budget of GÉANT NRENs has increased slightly since last year (2011), though there are large differences from country to country. Several countries have faced significant budget cuts, as illustrated by Map 7.3.4. Note that budget cuts of less than 5% have not been marked on the map. The significant cuts are a worrying development: for several years, the 'digital divide' between European countries has been diminishing, in part because of the advent of new, optical networking technologies. Excessive budget cuts in some countries may put this development at risk and lead to a widening of the digital divide.

Until now, the digital divide has been determined primarily by considering connectivity. In the future, it may be necessary to assess it more in terms of service development.

[3] Excluding data from Poland.

Map 7.3.4 – Budget increases and decreases in the GÉANT area, from 2011 to 2012

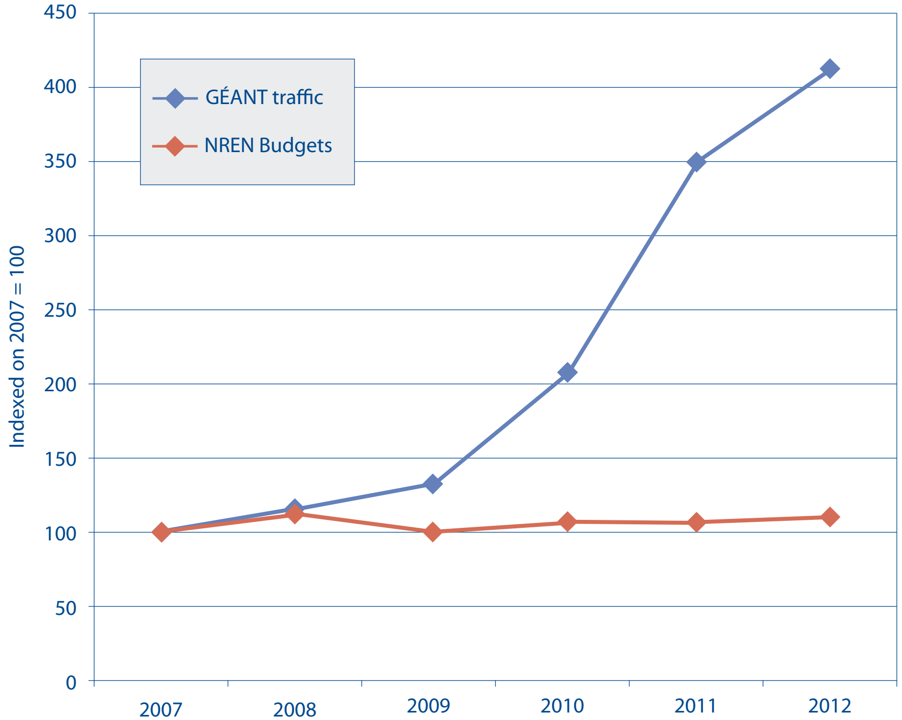


Traffic has more than quadrupled since 2007, as illustrated by the figures for traffic on the GÉANT backbone, which are plotted in Graph 7.3.5.[4]

As Graph 7.3.5 shows, the investments in infrastructure upgrades that have been made in many countries in recent years have enabled further traffic growth for roughly the same amounts of money each year. This has also enabled growth both in the diversity and in the number of services offered on the network.

The data 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.

Graph 7.3.5 – Total NREN budgets and traffic growth, 2007-2012, GÉANT partner countries



For several of the non-GÉANT partner countries, their current funding levels are unlikely to be sufficient for them to bridge the digital divide, even in light of the falling prices of connectivity in recent years.

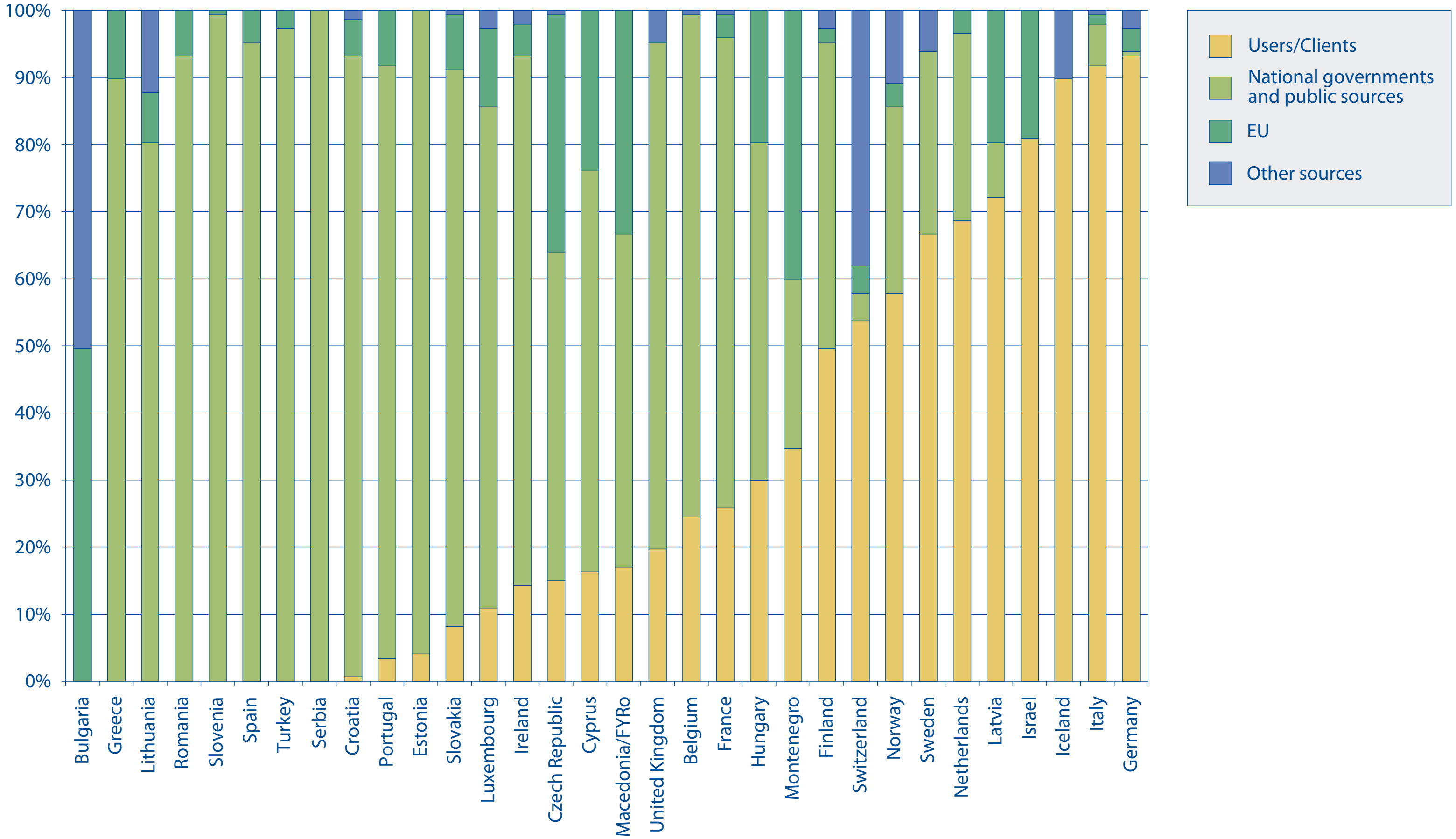
[4] The 2012 traffic data are an estimate, based on extrapolating the figures for the first six months of 2012.

7.4 Income sources

NRENs are funded in various ways: some receive all of their funding directly from the 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 funds comes from which source. Note that in many cases (see also Graphs 7.3.1 and 7.3.2) the amount of funding received from the EU is not included.

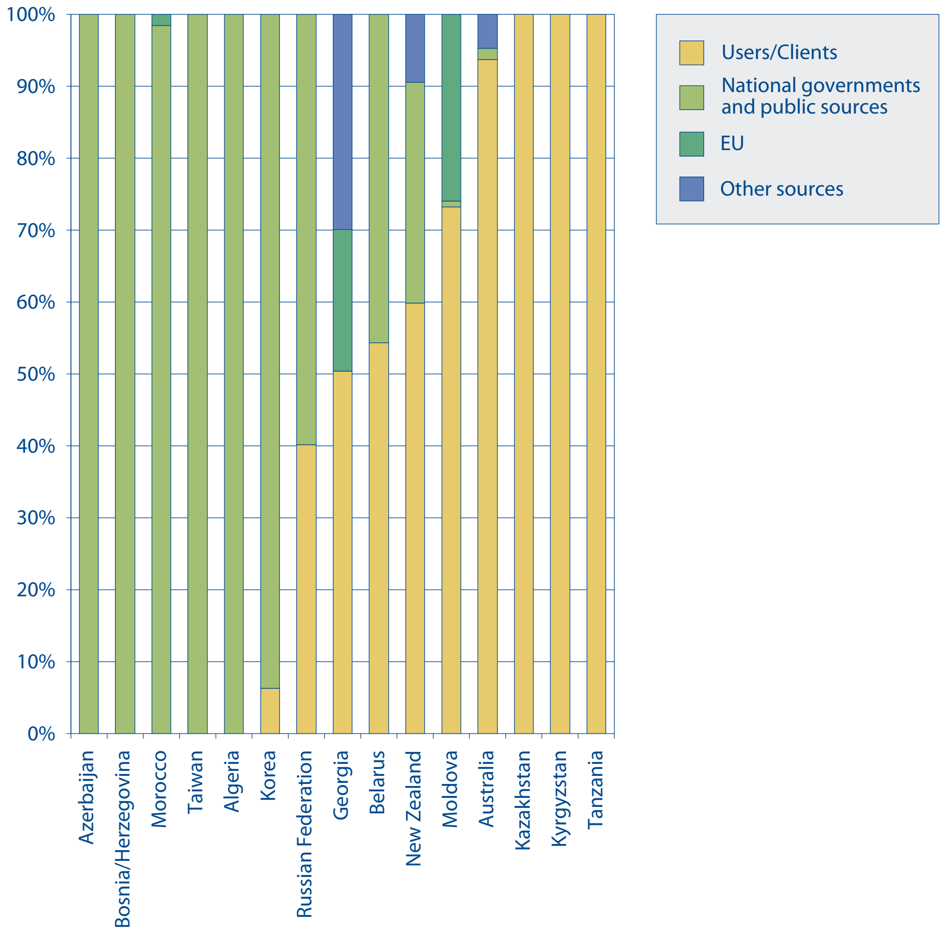
Although it is impossible to make general recommendations on NREN funding mechanisms, a model that in some way involves the various stakeholders in an NREN would seem to provide the best guarantees for its continued success. It should be noted that, in their respective fields, many NRENs are engaged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

Graph 7.4.1 – Income sources, GÉANT partner countries



As in 2011, this year the NRENs were asked whether they can make use of multi-annual budgeting. Of all the GÉANT partner NRENs, 47% (up 3% from 2011) confirmed that they can, whereas the remaining NRENs cannot. Lithuania now reports that it has a multi-year development programme, which was not yet in place last year.

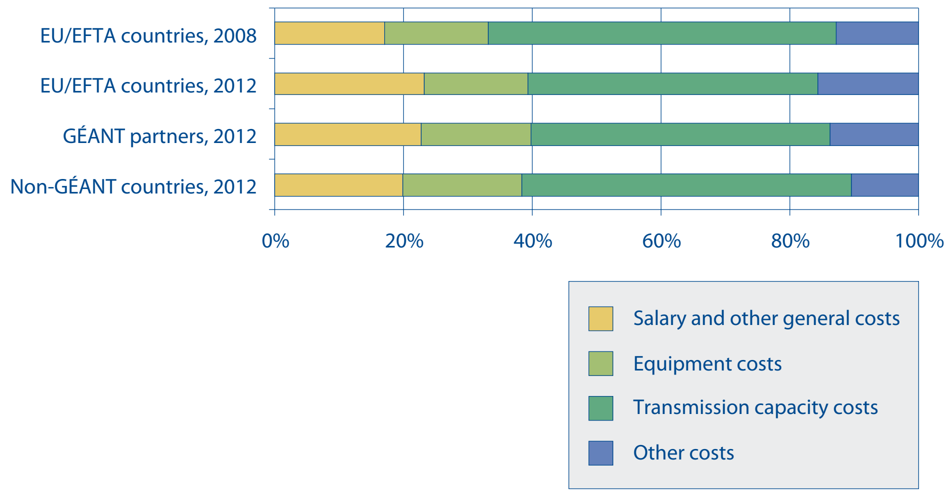
Graph 7.4.2 – Income sources, other countries



7.5 Expenditure by category

Graph 7.5.1 shows the average percentage of NREN income spent on various cost categories. On average, non-GÉANT countries spend more on equipment and transmission capacity and less on salary and other items than GÉANT countries. These differences are more pronounced when comparing the European Union/ European Free Trade Association countries with the non-GÉANT countries. Note, however, that there are considerable differences between individual NRENs in this respect.

Graph 7.5.1 – Expenditure by category



Since 2008, the proportion of transmission capacity costs in the EU/EFTA countries has decreased considerably, from 54% of total expenditure to 44%. The proportion of salary and others costs has increased (though this does not necessarily mean that salaries have increased in absolute terms). The proportion of equipment costs has remained the same.

7.6 Expenditure by network level

NRENs in GÉANT partner countries differ widely in terms of what levels of the network they specifically fund from their budget and how these levels are accounted for. This makes it difficult to effectively compare NREN budgets.

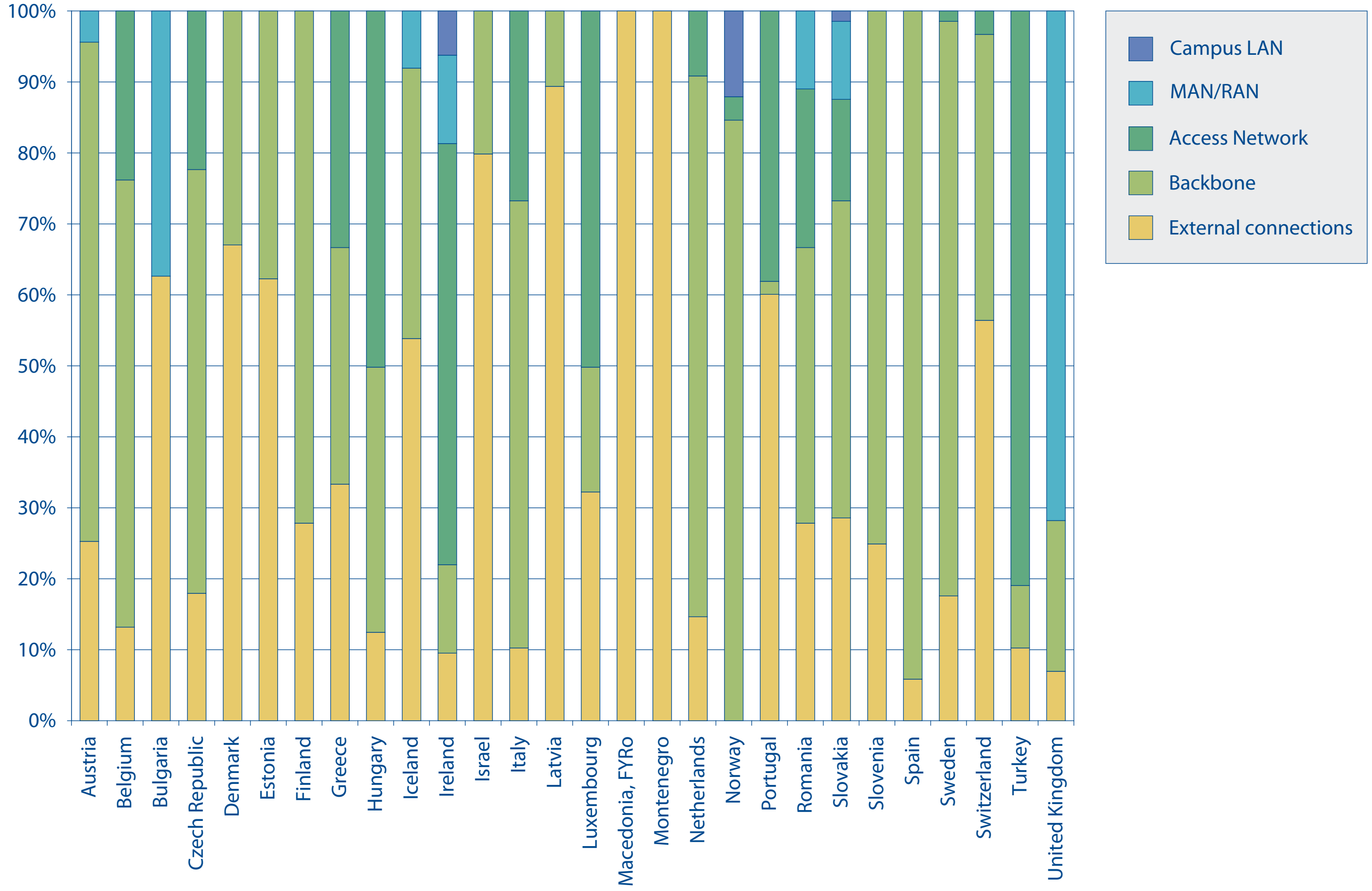
Although most NRENs pay for their external connections, the budget proportion actually spent on this network level differs widely from country to country. On average, the GÉANT NRENs spend 23% of their annual budget on external connectivity and pay for 80% of its total cost. However, some NRENs in small countries (e.g. Macedonia and Montenegro) spend their entire budget on external connections.

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 counted 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 at all.

Expenditure on other network levels also differs widely. In some GÉANT partner countries, metropolitan area networks (MANs) and regional area networks (RANs) are paid for through 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.

Graph 7.6.1 – Expenditure by network level, GÉANT countries



APPENDICES

1 Major changes in NRENs

Country	NREN	Changes
GÉANT partner countries		
Bulgaria	BREN	No change is planned.
Croatia	CARNet	In the coming year, CARNet will optimize its internal organization, i.e. restructure departments and services. We will become more flexible in order to (1) pursue migration of our services into the cloud and (2) facilitate access to them via mobile devices. In May 2012, CARNet took over responsibility for the e-Matica resource – a database of all schools, pupils and teachers in the Republic of Croatia – from our Ministry of Science, Education and Sports. We will continue to integrate it with the e-Dnevnik (e-Class Register — a web application for management of the class register in electronic form). We will intensity activities that relate to EU funds, since Croatia is scheduled to become a full EU member state on 1 July 2013.
Cyprus	CYNET	CYNET has moved from 310 Mbps to 1+1 Gbps. There are plans to upgrade even further to 2.5 Gbps in the future.
Czech Republic	CESNET	The first part of national distributed storages will be deployed in 2012.
Denmark	UNI-C	Forskningsnettet and the Danish Center for Scientific Computing were merged into DeIC (Danish e-Infrastructure Cooperation) in April 2012. The new organisation will provide a broad spectrum of e-Infrastructure services to e-Science. By the end of 2012, the part of UNI-C that manages NOC and NREN services will be separated from the rest of the organisation. The new organisational form is not yet known. DeIC (like Forskningsnettet) is a virtual organisation with no employees.
Estonia	EENet	Discussions about organizational arrangements of the academic network are currently in progress.
France	RENATER	Dany Vandromme has been replaced by Patrick Donath as General Manager
Germany	DFN	At the beginning of 2013, a new generation of the optical platform of the Wissenschaftsnetz (WiN) will go into operation.
Greece	GRNET S.A.	GRNET S.A. has already acquired 15-year IRUs for Dark Fibre (DF) links for the largest part of its core and access network. GRNET now owns almost 9000 km of dark fibre pairs in more than 50 PoPs, while DWDM equipment is installed in its network backbone and the metropolitan area networks in Athens and Salonika. In addition to the networking equipment, GRNET has deployed a large computational infrastructure based on two data centres in Athens. In 2011, GRNET extended its computational infrastructure with processing, storage and networking equipment, aiming to permit the provision of advanced cloud computing services and to enhance their scalability and reliability. These services include online storage services, provision of virtual machines, and group collaboration services. The new phase of the GRNET network (GRNET-4) was also designed, taking into account next-generation networking trends and technologies. The GRNET-4 network is going to be based on three service layers: the optical service layer, the carrier service layer and the IP service layer. In 2012, the GRNET-4 network is going to be realized, while the specifications for the optical backbone network upgrade are going to be finalized. Regarding the expansion of the computational infrastructure, an HPC infrastructure and an energy-efficient (green) data centre is going to be installed, aiming at a low PUE through the exploitation of green technologies and renewable energy sources.
Hungary	NIIF/ HUNGARNET	The organisational and operational embedding and environment of the NIIF Institute under the Ministry of National Development has been consolidated. The 2010-2011 technological reconstruction of our infrastructure (DF network, HPíC, storage, VC, etc.) has practically been completed. Discussions are going on with the related government bodies about integrating the as yet separately operated school network (primary and secondary schools) into the NREN (NIIF/Hungarnet).

Country	NREN	Changes
GÉANT partner countries		
Iceland	RHnet	The gradual 10 Gb/s build-up in Reykjavik will continue, so that all institutions connected to the fibre ring in Reykjavik will be able to connect at 10 Gb/s if they so choose. The connection to RIX (Reykjavik Internet Exchange) will also be upgraded to 10 Gb/s. Work is underway to connect FS-net – the network of secondary schools and distance educational centres – directly to RHnet, although the FS-net itself will continue to be run and managed by others.
Ireland	HEAnet	**Client Service Review Programme** The Client Service Review Programme continued throughout 2011 and remains an important means of staying in touch with and gathering feedback on what matters to our clients. As part of this process, we undertook a formal Client Survey, which achieved a high response rate of 64%. The subsequent Client Survey Findings Report (published in Q1 2012) details the survey results and will be used to measure HEAnet's performance over time and as input into ongoing service strategy and operational planning. **Client Requirements Process** Sustaining high-quality services is at the heart of Client Services Management, and during 2011 we launched a Clients Requirements Process. This process enables client organisations, or groups of organisations within the HEAnet client community, to submit proposals for new services that clients would like HEAnet to consider. The significant output from this process will feed into a Service Plan, detailing the engagements we plan to undertake, on the basis of their strategic fit, engagement type and available resources.
Latvia	SigmaNet	This year [2012], the main changes relating to network were that SigmaNet has upgraded the international commodity traffic from 235 to 600 Mbps. No organisational changes have occurred.
Macedonia, FYRo	MARnet	As a separate legal body, MARnet has actually existed since the beginning of 2011, with the election of the management board and director. All of 2011/2012 has been devoted to transfer of obligations, hiring employees, and establishment of the national backbone. As of Q4 2012 we expect the link to GEANT to be upgraded to 2 x 155 Mbps.

Country	NREN	Changes
GÉANT partner countries		
Netherlands	SURFnet	SURFconext – a new-generation collaboration infrastructure – became operational in 2011. SURFconext links together the services and tools of a large number of providers and institutions. Telecom operator KPN and SURFnet concluded an agreement for a joint study into improved integration of mobile data networks. The aim is to build knowledge and gain experience working with new 'fourth generation' (4G)mobile networks. The connection will be based on eduroam authentication. In the course of 2011, SURFnet laid the foundations for the new generation SURFnet7 network infrastructure. In March, CTO Erik-Jan Bos left SURFnet after more than 23 years. SURFnet's Managing Director Kees Neggers announced in the summer that he would be leaving us on 1 July 2012, when he reaches retirement age. The General Board of the SURF Foundation has therefore decided on a change in the management structure of SURFnet as of that date. The management will then consist of Erwin Bleumink (Chief Executive Officer), Karen de Bruijn (Chief Financial Officer), and Erik Huizer (Chief Technology Officer).
Poland	PIONIER	We have installed a new ADVA optical system in the whole network. It enables transmission of 80 signals over a single fibre pair. We have also installed a new set of MPLS core switches in every PoP.
Portugal	FCCN	The most important change in the past year was funding. The economic situation of Portugal is a big challenge for any institution that relies on public funding. To make our operations as efficient as possible was our main objective last year [2011]. This will be a major concern in the current and future years.
Spain	RedIRIS	This year [2012], the new dark fibre network, RedIRIS-NOVA, will become fully operational (including the sea cable to the Canary Islands). We are working on possible new centralised services (VoIP, improved e-mail interface, etc.). We are also working on a possible change of our user base, so that it could include cultural centres, hospitals and/or administrative bodies (this would have to be approved by the Ministry for Economy and Competitiveness)

Country	NREN	Changes
GÉANT partner countries		
Switzerland	SWITCH	The SWITCH organisation underwent a restructuring in 2011 in an attempt to implement the new strategy adopted in 2010. The internal structure is based on the user groups served by SWITCH.
United Kingdom	Janet	Due to the economic climate in the UK, there is uncertainty about the funding model for the coming financial years. There may also be some restructuring, as an outcome of a number of Higher Education reviews and reports. As of the date of this submission, we have no complete details.
Other countries		
Algeria	CERIST	A major upgrade of the backbone was carried out during the past year [2011], moving from 3 PoPs to 10 PoPs, with Gigaethernet connectivity between PoPs. ARN is now an MPLS network and the backbone is ready for IPv6 routing. Connectivity upgrade of all (100) connected sites from SDH to FE links. A fully operated Certification Authority (DZ e-Science CA) for Grid services.
Australia	AARNet	Planning has commenced for AARNet4, which will entail, among other developments, moving to a 100 Gbps WDM transmission backbone. A large number of long-distance fibre extension projects are being executed: the Sunshine Backbone Tails Project for Queensland, the outer Brisbane Metropolitan link, the Sydney Basin Rings, the upgrade of AARNet's Adelaide-to-Perth optical network, the Western Australian fibre rings, and lighting the fibre from Perth to Geraldton — the gateway to Australia's SKA site.
Korea (South)	KREONET	This year [2012], the KREONET centre was built in KISTI. Until last year, KREONET was a department in the Supercomputing Centre of KISTI.
Kyrgyzstan	KRENA-AKNET	As of 1 March 2012, KRENA transferred to 155Mbps. Increase in user base: September 2011: 63 institutions -> March 2012: 85 institutions. Eduroam testing finished. Membership applications have been submitted. Currently 100% of connections are fibre optic. Several universities have been transferred to fixed-bandwidth allocation. A backup channel has been established (Elcat ISP). A series of trainings has been conducted for our users' IT administrators.
Moldova	RENAM	Past year: New DF links were installed in Chisinau MAN (~3,5 km of own DF cable was installed and 3 new links were rented) that allowed to wider the own optical infrastructure up to 70 km. Finalized implementation of eduRoam; Coming year: Pilot deployment of videoconferencing service.
New Zealand	REANNZ	REANNZ reached financial sustainability, with 2/3 coming from membership and 1/3 from Government. New Chief Executive Steve Cotter joined REANNZ in November 2011. The REANNZ Internet service was launched February 2012 to deliver commodity Internet to subscribed members. REANNZ and Pacific Fibre announced that they have agreed Key Commercial Terms for a substantial contract to supply international capacity on the new Pacific Fibre cable system starting from mid-2014.
Taiwan	NCHC	OpenFlow switches will be deployed to our international connections in 2013, if approved. 100G links are planned in some segments of the backbone.
Ukraine	URAN	Modernization of main links to 10G.

2 Alphabetical list of NRENs

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

NREN acronym	NREN name	Country
AARNet	Australia's Academic and Research Network	Australia
ACOnet	Österreichisches akademisches Computernetz	Austria
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		Azerbaijan
AzScienceNet	Azerbaycan Milli Elmler Akademiyası Şebekesi	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
CESNET	CESNET, zájmové sdružení právnických osob	Czech Republic
CKLN	Caribbean Knowledge and Learning Network	
CSTNet		China
CUDI	Corporación Universitaria para el desarrollo de Internet	Mexico

NREN acronym	NREN name	Country
CYNET	Kypriako Erevnitiko Kai Akadimaiko Diktio	Cyprus
DeiC	Danish e-infrastructure Cooperation	Denmark
DFN	Deutsche Forschungsnetz	Germany
DrukREN		Bhutan
e-ARENA	Nacionalnaia Associacia issledovatelskih i nauchno-obrazovatelnih electronnih infrastructur 'e-ARENA'	Russian Federation
eb@le	eb@le	Congo, Democratic
EENet	Eesti Hariduse ja Teaduse Andmesidevork	Estonia
ERNET	Education and Research Network	India
EthERNet		Ethiopia
EUN	Shabaket El Gamaat ElMasria	Egypt
FCCN	Fundação para a Computação Científica Nacional	Portugal
Funet	Funet	Finland
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
HEAnet	HEAnet Ltd.	Ireland
HIAST		Syria
INNOVA|RED		Argentina
INHERENT-DIKTI		Indonesia
Internet2	Internet2	United States
IRANET/IPM		Iran (Islamic Republic of)
ISU		Saudi Arabia
IUCC	Merkaz Hachishuvim haBain Universitai	Israel
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

NREN acronym	NREN name	Country
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
LANET		Latvia
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
MoRENet	Mozambique Research and Education Network	Mozambique
MREN	Crnogorska mreza za razvoj i nauku	Montenegro
MYREN	Rangkaian Pendidikan & Penyelidikan Malaysia	Malaysia
NCHC	National Center for High-performance Computing	Taiwan
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
PNGARNet		Papua New Guinea
PREGINET	Philippine Research, Education, and Government Information Network	Philippines
Qatar Foundation		Qatar
RAAP	Red Académica Peruana	Peru
RADEI	Red Avanzada Dominicana de Educación e Investigación	Dominican Republic
RAGIE	Red Avanzada Guatemalteca para la Investigación y Educación	Guatemala

NREN acronym	NREN name	Country
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
RedCONARE		Costa Rica
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
RENIA		Nicaragua
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
RNRT	Secretariat of State for Scientific Research and Technology responsible for the National R&D Network	Tunisia
RNU	Réseau National Universitaire Tunisien	Tunisia
RoEduNet	Agentia de Administrare a Retelei Nationale de Informatica pentru Educatie si Cercetare— 'RoEduNet'	Romania
RwEdNet		Rwanda
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
SigmaNet	SigmaNet, Latvijas Universitātes Matemātikas un Informātikas institūta Akadēmiskā tīkla laboratorija	Latvia

NREN acronym	NREN name	Country
SINET		Japan
SingAREN	Singapore Advanced Research and Education Network (SingAREN)	Singapore
Somaliren		Somalia
SUIN	The Sudanese Universities Information Network	Sudan
SUNET	Det svenska universitetsdatornätet SUNET	Sweden
SURFnet	SURFnet B.V.	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
UNI-C	Danish Research Network, UNI-C	Denmark
UniNet		Thailand
UNINETT	UNINETT AS	Norway
UoM/RicerkaNet	Is-Servizzi tal-IT, L-Università ta' Malta/Riċerka Net	Malta
URAN	Asociacija Korystuvachiv Ukrainskoji Naukovo-Osvitnioji Telekomunikacijnoji Merezhi	Ukraine
UzSciNet	O'zbek ilmiy va o'quv tamog'i	Uzbekistan
VinaREN	Mang Nghiên cúu và Ðào tao Viêt Nam	Vietnam
WACREN	West and Central African Research and Education Network	
ZAMREN		Zambia

3 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 supporting 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 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.
ASPIRE	A Study on the Prospects of the Internet for Research and Education: a foresight study following on from the successful SERENATE and EARNEST studies completed in 2003 and 2008, to be 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).
Bandwidth on Demand	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*: MB (Megabyte), TB (Terabyte), PB (Petabyte).
CA	Certification (or Certificate) Authority
CERT	Computer Emergency Response Team: an historic term used for Computer Security Incident Response Team (see below).
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 www.redclara.net
CO2 equivalent	Carbon dioxide equivalency is a quantity that describes, for a given mixture and amount of greenhouse gases, the amount of CO2 that would have the same global warming potential (GWP), when measured over a specified timescale (generally, 100 years).

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.
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.
DANTE	Delivery of Advanced Network Technology to Europe: responsible for the not-for-profit organization that plans, builds and operates the pan-European and international interconnection of research and education networks.
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.
EARNEST	The Education And Research Networking Evolution Study: an activity coordinated by TERENA in the framework of the GN2 project, see www.terena.org/activities/earnest
EC	European Commission

eduGAIN	The eduGAIN service is intended to enable the trustworthy exchange of information related to identity, authentication and authorisation between the GÉANT (GN3) Partners' federations
ENUM	E.164 NUmber Mapping, a suite of protocols to unify the telephone system with the Internet
EU	European Union
EUGridPMA	The international organisation to coordinate the trust fabric for e-Science grid authentication in Europe
FEIDE	National federated identity management system for the education sector in Norway, see www.feide.no
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 project mainly to develop the multi-gigabit pan-European data communications network 'GÉANT', used specifically for research and education.
GN3	The Multi-Gigabit European Research and Education Network and Associated Services (GN3) project of the European Community's Seventh Framework Programme (FP7). It succeeds the GN2 project, which developed the GÉANT2 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 (see above) 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 (see above) technology to maximize the capacity of the link.
Kalmar	The Kalmar e-identity Union builds an infrastructure for exchanging personal information across 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.
MVNO	Mobile Virtual Network Operator: a company that provides mobile phone services but does not have its own licensed frequency allocation of radio spectrum, nor does it necessarily have all of the infrastructure required to provide mobile phone services.
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.
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, see above).
RedCLARA	Latin American advanced network, managed by CLARA.
SAML	Security Assertion Markup Language: a fundamental component of federated identity and access management systems.
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, see above).
UbuntuNet Alliance	A not-for-profit association of NRENs that aims to provide a research and education backbone network for Africa.
University	Institution providing an 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 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.
X-ARF	Network Abuse Reporting Format: an email format for reporting network abuse.

TERENA

What is TERENA?

TERENA, the Trans-European Research and Education Networking Association, fosters the development of computer network technology, infrastructure and services for use by the research and education community. TERENA provides a forum for collaboration, innovation and knowledge sharing. The primary members of the association are National Research and Education Networking (NREN) organisations operating in countries in and around Europe. They offer advanced, high-speed, high-performance connectivity and associated services to universities, research institutions and schools on the national level.

TERENA members also include regional research networking organisations, research organisations that are major users of networking infrastructure and services, and equipment vendors and telecommunication operators.

Since the very beginning of the Internet, some four decades ago, the academic community has led the development and deployment of computer network infrastructures and technology. Although much has changed since then, the academic community remains a pioneer in networking development. In recent years, Europe has become a world leader in important aspects of research and education networking. This leading role has been made possible by cooperation and collaboration between network engineers, managers and researchers in the research and education networking community throughout the region. TERENA plays a crucial role by facilitating the coordination of policies and activities, the planning and execution of joint initiatives, and collaboration between experts working in its member organisations and the wider research networking community.

The TERENA *Compendium of National Research and Education Networks in Europe* presents abundant documentary evidence that research and education networks are at the leading edge of technological and service developments, and that Europe is at the forefront in this field of networking. The *Compendium* also highlights areas that require further work; some of that work is already being undertaken through the various TERENA activities.

The TERENA *Compendia* form a series of annual publications that began in the year 2000. They are a valuable source of information for researchers and policy makers in various countries.

TERENA GÉANT