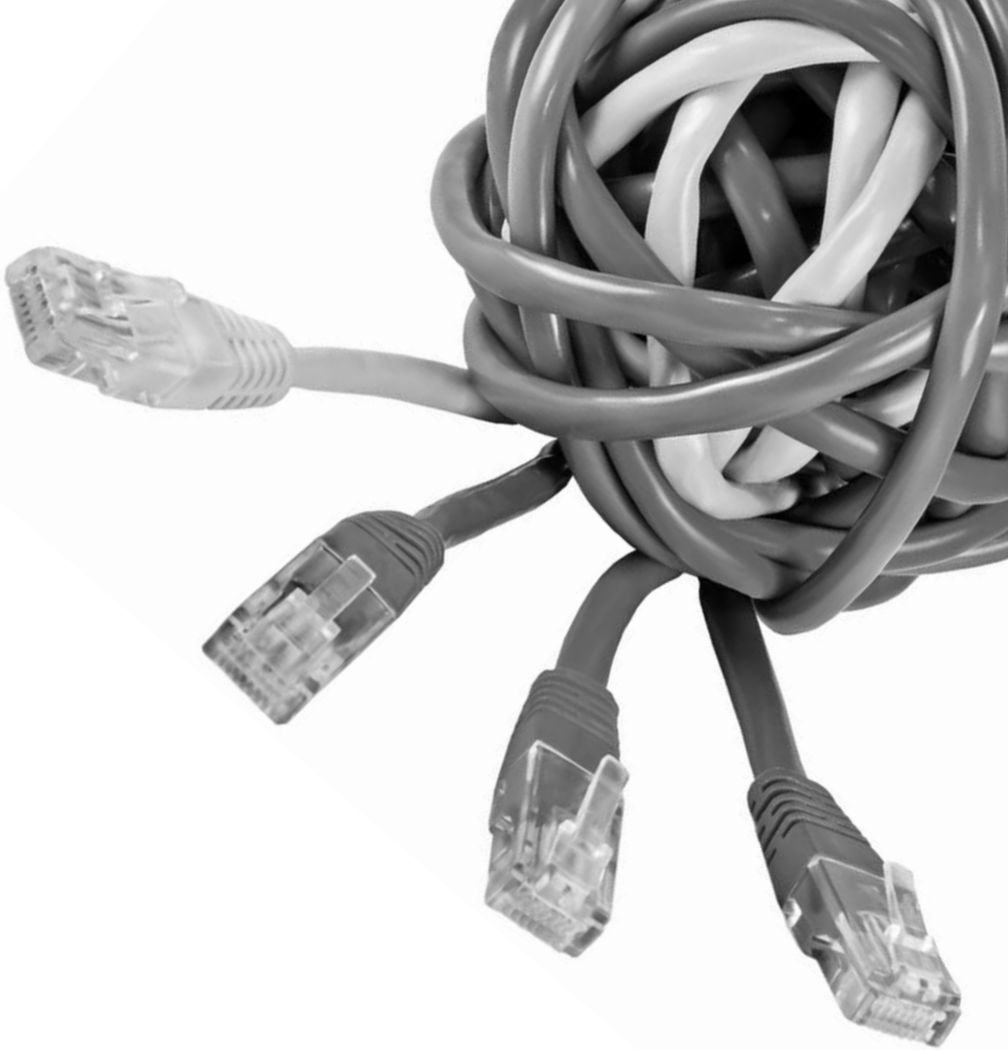
TERENA COMPENDIUM

of National Research and Education Networks in Europe

2010 Edition

www.terena.org/compendium



TERENA

« networking the networkers »

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CONTENTS

INTRODUCTION

The first edition of the TERENA *Compendium* was published in 2001, which makes this 2010 edition the tenth in the series. In that ten-year period, the *Compendium* has grown into a much sought-after and authoritative reference source for all who are interested in the development of research and education networking. With each successive edition, the information contained in the *Compendium* has grown in variety and dependability, although, as always, the data should be interpreted with the necessary caution.

This year's edition, the second to be published as part of the GN3 (GÉANT) project, is enhanced with input from activity leaders in that project. As in previous years, we have attempted to aggregate data for groups of National Education and Research Networks (NRENs) and to examine and partially explain multi-year trends. Summaries and analyses of the most important information are presented in 'overview' subsections at the start of each section.

The new **Key findings** section that follows this introduction provides a more general analysis of recent developments.

Production of this edition was overseen by the Review Panel: Tryfon Chiotis (GRNET), Lars Fischer (NORDUnet), András Kovács (HUNGARNET), Ingrid Melve (UNINETT) and Mike Norris (HEAnet).

An attempt was made to further simplify the survey questions. As before, NRENs from outside Europe were invited to submit their data. In order To reduce production time, NRENs were given a relatively short period in which to submit their responses. Although this yielded fewer responses than last year, they still cover 51 NRENs from the same number of countries.

The year 2010 is the 10th anniversary of the GÉANT[1] European backbone network, which was inaugurated on 1 November 2000. To mark the occasion, this edition of the *Compendium* includes the 2001 and 2010 GÉANT topology maps. In other respects, the *Compendium* generally looks back over five years, comparing 2010 with 2006. This year's edition includes several other new features, such as an at-a-glance overview of various services offered by NRENs, and sections on wavelengths (lambdas) that NRENs now make available to their clients.

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 contributed to the gathering, submitting, clarifying and checking of 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 first list all the European Union (EU)[2] and European Free Trade Association (EFTA)[3] countries and then other countries. The data are usually presented in alphabetical order, sorted on the English name of each country. All the NRENs included in the *Compendium* are listed in Section 1.1. NRENs in all other parts of the world are listed in Section 1.2. In a few cases, information on non-European NRENs is included for illustrative purposes. The full data is available at **www.terena.org/activities/compendium**.

Please note that, unless otherwise specified, the data indicate the situation at or close to 31 January 2010.

We hope that this tenth 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

[1] The GÉANT partner countries include all the EU/EFTA countries plus Croatia, Israel, FYRoMacedonia, Montenegro, Serbia and Turkey.

[2] As Bulgaria and Romania joined the EU on 1 January 2007, wherever the *Compendium* presents data on the EU/EFTA region from 2006 and earlier these two countries are not included. From 2007 onwards, data on EU/EFTA countries do include Bulgaria and Romania.

[3] The EFTA consists of four countries: Iceland, Norway, Switzerland and Liechtenstein. As Liechtenstein is serviced by SWITCH (Switzerland), it is not separately included in this *Compendium*.

KEY FINDINGS: A BRIEF OVERVIEW

Enabling communities

The Internet basically began as a technological innovation for which growing numbers of institutions and people found an ever-increasing variety of uses. Internet developments were essentially driven by further technological innovations. Currently, the emphasis on technology is decreasing and more importance is being attached to meeting user demands. This does not mean that the technology is no longer developing; it does mean that, more than in the past, developments in services and in technology have to go hand in hand.

Thus, the Programme Committee for the TERENA Networking Conference 2011 writes:

> *Networks have evolved from being a pure data transporter to being an enabler of global communities with shared resources and goals. Networks enable new pervasive forms of collaboration and sharing, affecting all aspects of our lives. Networks enable teams, institutions and countries to come together to develop innovative solution to complex challenges.*[1]

New and advanced services

In view of this evolution of networks, services are becoming increasingly important. Because many NRENs combine excellent technical expertise with close contacts with the user community, they have been able to develop high-end services that are currently not available, or not affordably available, from commercial Internet Service Providers (ISPs).[2]

- A case in point is the Identity Federation, a 'meta-service' developed by NRENs and their communities. In 2010, its total number of users passed the 16-million mark. For the Internet, a consistent identity layer continues to be deployed for both eduroam (WiFi access) and federations (web authentication and attributes). Over the past few years, both services have increased exponentially in terms of numbers of users, numbers of logins and the number of NRENs that provide them to their users. The rapid growth of Identity Federations is expected to continue in future years; they will become a standard service of NRENs (as is the case today for eduroam)[3]. More generally, many NRENs are reviewing and diversifying their service portfolios.

New technologies and traffic increase

Not only services but also technologies continue to develop. Many NRENs have made substantial progress towards deploying hybrid IP-optical networks and offering the associated end-to-end services.

- Eighteen of the EU/EFTA NRENs currently offer dedicated wavelengths (lambdas) to their customers;
- On the European level, these are complemented by the GÉANT Plus and GÉANT Lambda services;
- Over 200 wavelength circuits (lambdas) are now in use for high-bandwidth, low-jitter transport.

At the same time, traffic continues to grow: total IP levels have increased six-fold in the past six years. The current rate of growth is approximately 30% a year.

- In the 29 countries that submitted the relevant data for this *Compendium*, average traffic per inhabitant has grown from 93 MB/month in 2006 to 163 MB/month in 2009, an average annual growth rate of 21.3%;
- Analysis confirms that there is still a substantial 'digital divide' in Europe: Bulgaria, Moldova, Serbia and Turkey lag far behind the rest of Europe in terms of traffic;
- In Romania, however, there has been a marked growth of traffic due to the country's changeover to a fibre network.

IPv4 address space is likely to run out soon; some predict that this will happen as soon as in early 2011. Most European NRENs have been quick to adopt IPv6 and, because they already support it, are ready to make the transition. However, the actual proportion of IPv6 traffic remains minimal, which indicates that clients are not yet making the change.

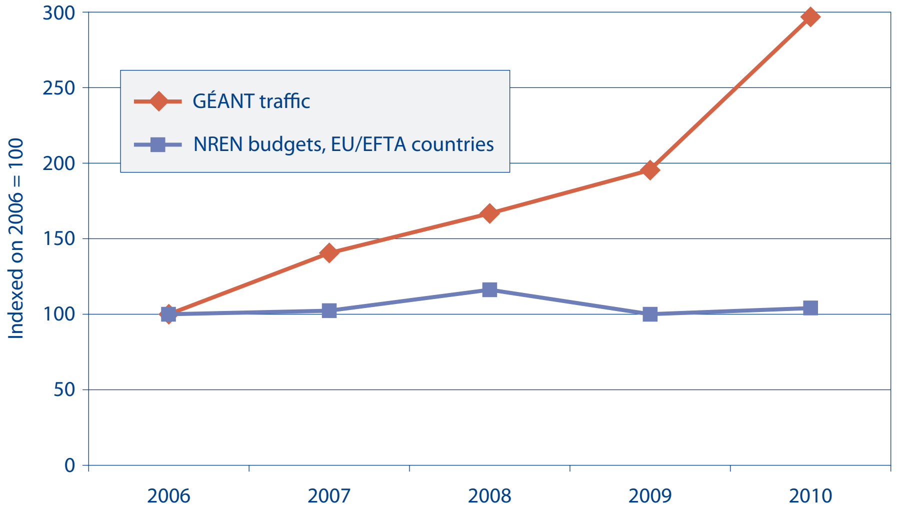
[1] tnc2011.terena.org/participate
[2] For more information, see John Dyer, *The Case for NRENs* (2009), available at www.terena.org/publications/files/20090127-case-for-nrens.pdf
[3] For more detailed information, see Section 5.2.1 of this Compendium.

Economic and organisational challenges

In summary, NRENs now support more users, a greater usage volume, and a wider range of services than ever before. All this has been achieved even though, over the past five years, overall budgets have remained virtually unchanged and staffing levels have been reduced, the latter often as a result of bars on recruitment.

- The overall budget figures do not (yet) show that NRENs are significantly affected by the current economic crisis;
- Four EU/EFTA NRENs were faced with budget cuts of 20% or more compared with the year before.

Budgetary and traffic growth, 2006-2010 (2006 level = 100)



NRENs are coping with budgetary difficulties in several ways, including diversifying funding sources and entering into new activities (such as brokerage, negotiating deals for clients, and becoming involved in secondary schools). There may also be shifts from general funding to more project-related funding or from longer-term funding to short-term funding, for example. There is no clear overall picture.

What does seem clear, however, is that NRENs generally constitute an important asset for the research and educational community of the country in which they operate. In order to stay relevant, it is important that NRENs should be able to devote resources to deploying new services for their users.

In 2010, for the first time, global sales of laptop devices exceeded those of desktop devices. The trend is clearly towards greater mobility, and this is reinforced by the uptake of mobile broadband, which overtook fixed broadband in 2009. NRENs' rollout of eduroam anticipated this demand for mobility, but NRENs must now pursue greater ubiquity and utility of their services.

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, such as funders and users. For NRENs, a governing model that allows these 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 partially explain why this model is more common in countries where, after many years of development, research and education networking is well established.

1 BASIC INFORMATION

The TERENA *Compendium* is an authoritative reference on the development of research and education networking in Europe and beyond. Below, Section 1.1 presents information on the European NRENs that responded to the questionnaire distributed by TERENA. Section 1.2 includes a comprehensive list of NRENs in other continents. Section 1.3 covers their legal status and their relationship with government. Section 1.4 details major changes in NRENs, their services and/or users. Section 1.5 briefly looks at environmental policies.

1.1 European NRENs that responded to the questionnaire

There are 54 countries in the area covered by this 2010 edition of the *Compendium* (basically, Europe and nearby countries in the Middle East and North Africa). In three of those countries, there is either no NREN or we have no knowledge of NREN work there. A total of 41 NRENs in the same number of countries responded to the questionnaire; many, though not all, of them answered all the questions. The map and Tables 1.1.1, 1.1.2 and 1.2.1 give an overview of the NRENs that submitted responses and an impression of how complete their responses were. 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 lists the European and Mediterranean NRENs that submitted responses. The list is divided into two categories: EU/EFTA countries and non-EU/EFTA countries. The table also shows which countries are partners in the GÉANT project, as well as the associate NRENs. Table 1.1.2 lists several European and Mediterranean countries where research and education networking is known to exist but from which no responses were received. Table 1.2.1 lists NRENs in other continents that submitted responses for this *Compendium*, which are available at **www.terena.org/activities/compendium**

All the NRENs were asked to double-check their responses and ensure that the information was up to date.

Relevant in this context are several projects connecting research communities around the globe. These projects are listed at **www.geant.net/Network/GlobalConnectivity**

In several countries outside the EU/EFTA area, for example Ukraine, two or more NRENs exist.

For further information on NRENs in the Asia/Pacific region, see APAN, **www.apan.net**; for Latin America, see CLARA, **www.redclara.net**; for Eastern and Southern Africa, see the UbuntuNet Alliance, **www.ubuntunet.net**. For Canada, see **www.canarie.ca**; for the United States of America, see Internet2, **www.internet2.edu**, the National Lambdarail, **www.nlr.net** and the National Regional Networks Consortium, **www.thequilt.net**.

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

Country	NREN	URL	Relationship with GÉANT
EU/EFTA countries			
Austria	**ACOnet**	www.aco.net	partner
Belgium	**BELNET**	www.belnet.be	partner
Bulgaria	**BREN**	www.bren.bg/index.php?lang=en	partner
Cyprus	**CYNET**	www.cynet.ac.cy/english	partner
Czech Rep.	**CESNET**	www.ces.net	partner
Denmark	**UNI-C**	www.forskningsnettet.dk/en	partner
Estonia	**EENet**	www.eenet.ee/EENet/EENet_en	partner
Finland	**Funet**	www.csc.fi/english/institutions/funet	partner
France	**RENATER**	www.renater.fr/?lang=en	partner
Germany	**DFN**	www.dfn.de/en	partner
Greece	**GRNET S.A.**	www.grnet.gr/default.asp?pid=1&la=2	partner
Hungary	**NIIF/HUNGARNET**	www.niif.hu/en	partner
Iceland	**RHnet**	www.rhnet.is/english	partner
Ireland	**HEAnet**	www.heanet.ie	partner

Table 1.1.1 – continued

Country	NREN	URL	Relationship with GÉANT
EU/EFTA countries			
Italy	**GARR**	www.garr.it/eng	partner
Latvia	**SigmaNet**	www.sigmanet.lv/?lang=en	partner
Lithuania	**LITNET**	www.litnet.lt	partner
Luxembourg	**RESTENA**	www.restena.lu/restena/en	partner
Malta	**UoM/RicerkaNet**	www.um.edu.mt/itservices/about	partner
Netherlands	**SURFnet**	www.surfnet.nl/en	partner
Norway	**UNINETT**	www.uninett.no/english	partner
Poland	**PIONIER**	www.pionier.net.pl/online/en	partner
Portugal	**FCCN**	www.fccn.pt/eng	partner
Romania	**RoEduNet**	www.roedu.net/en	partner
Slovakia	**SANET**	www.sanet.sk/en	partner
Slovenia	**ARNES**	www.arnes.si/en	partner
Spain	**RedIRIS**	www.rediris.es	partner
Sweden	**SUNET**	www.sunet.se/English/Home	partner
Switzerland	**SWITCH**	www.switch.ch	partner
UK	**JANET(UK)**	www.ja.net	partner
Other European and Mediterranean countries			
Algeria	CERIST	www.arn.dz	
Azerbaijan	**AzScienceNet**	www.cert.az/elmnet.html	
Belarus	**BASNET**	www.basnet.by	associate
Croatia	**CARNet**	www.carnet.hr/en	partner
Georgia	GRENA	www.grena.ge/eng	
Israel	**IUCC**	www.iucc.ac.il	partner
Jordan	JUNet	www.junet.edu.jo	
Macedonia	**MARNet**	dns.marnet.net.mk/index-en.php	partner
Moldova	**RENAM**	www.renam.md	associate
Montenegro	**MREN**	www.mren.ac.me	partner
Morocco	MARWAN	www.marwan.ma	

Table 1.1.1 – continued

Country	NREN	URL	Relationship with GÉANT
Other European and Mediterranean countries			
Russian Fed.	e-ARENA	www.e-arena.ru	associate[1]
Serbia	**AMRES**	www.amres.ac.rs/index.php?lang=en	
Tunisia	CCK	www.cck.rnu.tn	
Turkey	**ULAKBIM**	www.ulakbim.gov.tr/eng	partner

Table 1.1.2 – Countries and NRENs not included in this *Compendium*

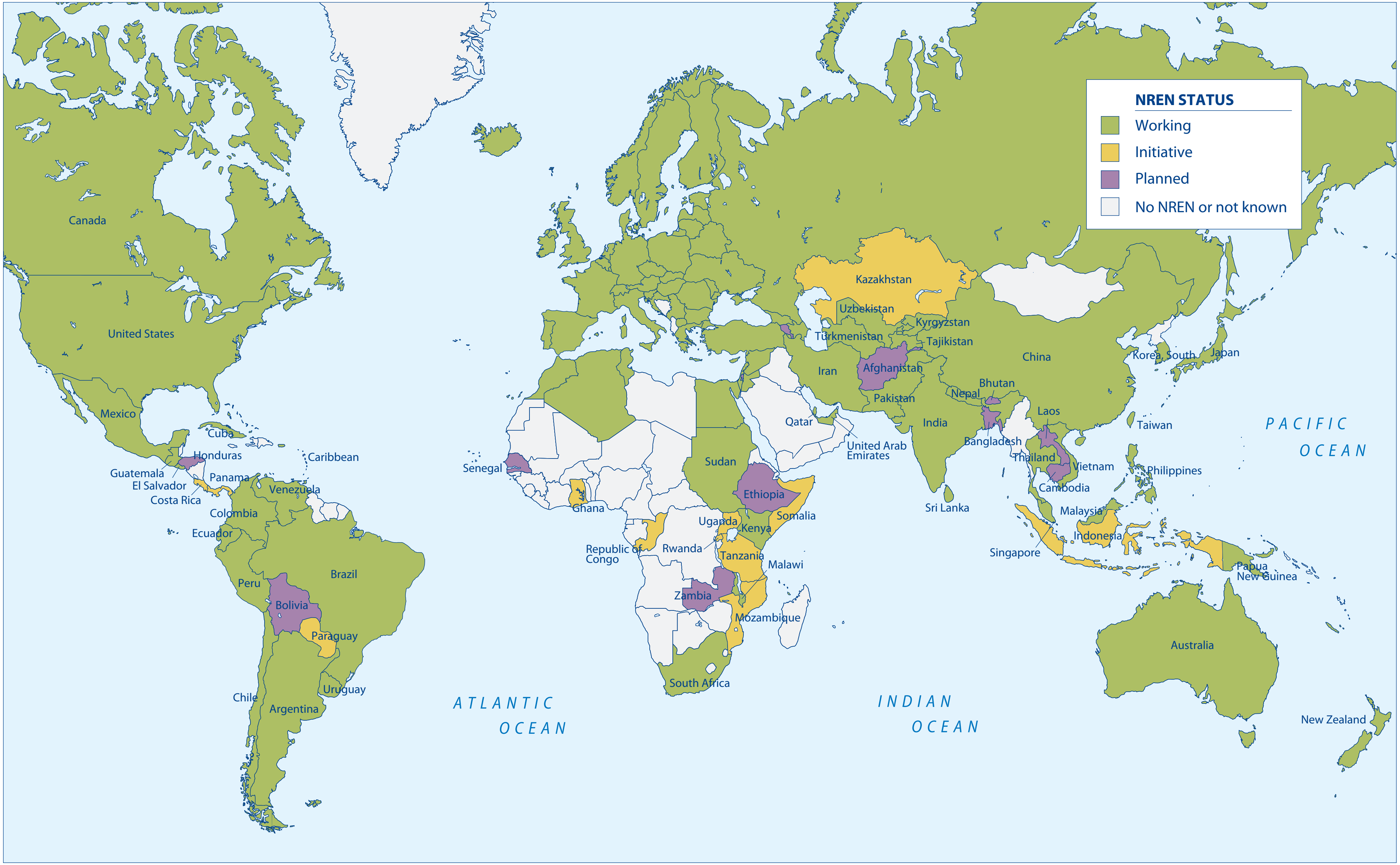
Country	NREN	URL	Relationship with GÉANT
Albania			
Armenia	ARENA	www.arena.am	
Armenia	ASNET-AM	www.asnet.am/index.php?langid=2	
Bosnia/Herzegovina			
Egypt	EUN	www.eun.eg	
Lebanon	CNRS	www.cnrs.edu.lb	
Libya			
Palestinian Territory	PADI2	www.padi2.ps	
Syria	HIAST	www.hiast.edu.sy	
Ukraine	UARNet	www.uar.net/en	
Ukraine	URAN	www.uran.net.ua/~eng/frames.htm	associate

Legend for Tables 1.1.1, 1.1.2 and 1.2.1

light green	Complete responses received
dark green	Partial responses received
purple	No responses received
yellow	No NREN or no known NREN work in this country

[1] The Russian partner organisation is the JSCC, the Joint Supercomputer Center of the Russian Academy of Sciences.


NREN
Complete responses received
Partial responses received
No responses received
No NREN or no known NREN work
Beyond the scope of the Compendium
SERVICE (Red = planned)
Identity Federation
VoIP
Video conferencing
Multimedia repository
Clouds
Iceland
Sweden
Finland
Norway
Estonia
Latvia
Denmark
Lithuania
Russian Federation
Ireland
United Kingdom
Netherlands
Belarus
Poland
Germany
Belgium
Ukraine
Luxembourg
Czech Republic
Slovakia
Austria
Hungary
Moldova
Switzerland
France
Slovenia
Croatia
Romania
Italy
Bosnia/
Herzegovina
Serbia
Bulgaria
Montenegro
Georgia
Macedonia
Albania
Azerbaijan
Spain
Armenia
Portugal
Greece
Turkey
Syria
Tunisia
Malta
Cyprus
Lebanon
Algeria
Morocco
Palestinian
Territory
Israel
Libya
Jordan
Egypt


NREN STATUS
Working
Initiative
Planned
No NREN or not known
Canada
United States
Mexico
Cuba
Caribbean
Honduras
Guatemala
El Salvador
Panama
Costa Rica
Venezuela
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Argentina
Uruguay
ATLANTIC
OCEAN
Senegal
Ghana
Republic of Congo
Rwanda
Uganda
Kenya
Somalia
Ethiopia
Sudan
Tanzania
Malawi
Zambia
Mozambique
South Africa
INDIAN
OCEAN
Kazakhstan
Uzbekistan
Kyrgyzstan
Turkmenistan
Tajikistan
Iran
Afghanistan
Pakistan
Qatar
United Arab Emirates
India
Nepal
Bhutan
Bangladesh
Sri Lanka
China
Laos
Thailand
Vietnam
Cambodia
Malaysia
Singapore
Indonesia
Korea, South
Japan
Taiwan
Philippines
Papua New Guinea
Australia
New Zealand
PACIFIC
OCEAN

1.2 NRENs in other continents

Table 1.2.1 (below) lists NRENs and NREN initiatives of which we are currently aware in other parts of the world. Note that this list is not complete: there may be other NRENs of which we have no knowledge. Also, in some countries the formation, funding and policy in support of a NREN are not always stable. NRENs that submitted data for this *Compendium* are highlighted in colour. Further information on Latin American NRENs is published in the CLARA Compendium of Latin American National Research and Education Networks (2009), available at **alice2.redclara.net/index.php/en/documents/compendium**

Legend for Table 1.2.1

(light green)	Complete responses received
(dark green)	Partial responses received

Table 1.2.1 – NRENs known to be operating in other countries

Country	NREN	URL
Afghanistan	AfREN	
Argentina	INNOVA|RED	www.innova-red.net
Australia	AARNet	www.aarnet.edu.au
Bangladesh	BdREN	bdren.mmtvbd.com
Bhutan	DrukREN	
Bolivia	BOLNET	www.adsib.gob.bo
Brazil	RNP	www.rnp.br
Cambodia	CamREN	
Canada	CANARIE	www.canarie.ca
Caribbean	C@ribNET	www.ckln.org
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
Costa Rica	CONARE	www.conare.ac.cr
Cuba	RedUNIV	www.mes.edu.cu
Ecuador	CEDIA	www.cedia.org.ec
Egypt	EUN	www.eun.eg
El Salvador	RAICES	www.raices.org.sv
Ethiopia	EthERNet	
Ghana	GARNET	www.garnet.edu.gh
Guatemala	RAGIE	www.ragie.org.gt
Honduras	UNITEC	www.unitec.edu
India	ERNET	www.eis.ernet.in
Indonesia	INHERENT	www.itb.ac.id
Iran	IRANET/IPM	www.iranet.ir
Japan	SINED	www.sinet.ad.jp
Japan	JGN2plus	www.jgn.nict.go.jp/english/index.html
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/english/
Kyrgyzstan	KRENA-AKNET	www.aknet.kg
Laos	LERNET	
Malawi	MAREN	www.malico.mw/maren
Malaysia	MYREN	www.myren.net.my
Mexico	CUDI	www.cudi.edu.mx
Mozambique	MoRENet	morenet.mct.gov.mz
Nepal	NREN	www.nren.net.np
New Zealand	REANNZ	www.karen.net.nz
Pakistan	PERN	www.pern.edu.pk
Palestine	Al-Quds Open University	www.qou.edu/indexPage.do
Panama	RedCyT	www.redcyt.org.pa
Papua New Guinea	PNGARNet	www.pngarnet.ac.pg

Table 1.2.1 – continued

Country	NREN	URL
Paraguay	Arandu	www.arandu.net.py
Peru	RAAP	www.raap.org.pe
Philippines	PREGINET	www.pregi.net
Qatar	Qatar Foundation	www.qf.org.qa
Rwanda	RwEdNet	www.rwednet.net
Senegal	RENER	
Singapore	SingAREN	www.singaren.net.sg
Somalia	Somaliren	www.somaliren.org
South Africa	TENET	www.tenet.ac.za
Sri Lanka	LEARN	www.learn.ac.lk
Sudan	SUIN	www.suin.edu.sd
Taiwan	TAREN	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
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	www.reacciun2.edu.ve
Vietnam	VinaREN	www.vinaren.vn
Zambia	ZAMREN	

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, such as 'association'. This section distinguishes two parameters that together help to characterise the legal form of NRENs:

1) whether the NREN is a separate legal entity; and
2) its relationship with government.

These two parameters are indicated in Graph 1.3.1 (right).

Separate legal entity

Many NRENs operate as separate legal entities; many others are part of a larger organisation (often a ministry, a university or a research institution). A few NRENs have special status, operating neither as a separate legal body nor as part of a larger organisation; typically, these are transitional arrangements.

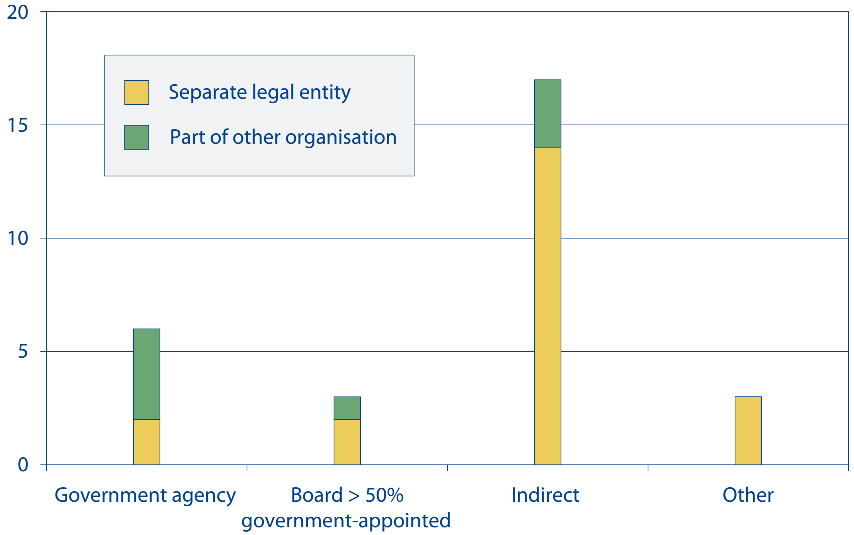
Relationship with government

In many cases, a NREN that is a government agency or part of a government ministry is controlled directly by the government. However, a number of such agencies enjoy a certain degree of autonomy, comparable to that of NRENs that are separate legal entities.

A number of NRENs that are separate legal entities have governing boards at least half of whose members are government appointed. Many NRENs have a mixed model, being governed by representatives not only of government but also of the research and education community. Those are marked 'indirect' in Graph 1.3.1 (right). Such a relationship is considered to exist if at least half the members of the NREN's governing body are appointed by research and education institutions that are themselves entirely or largely government-funded.

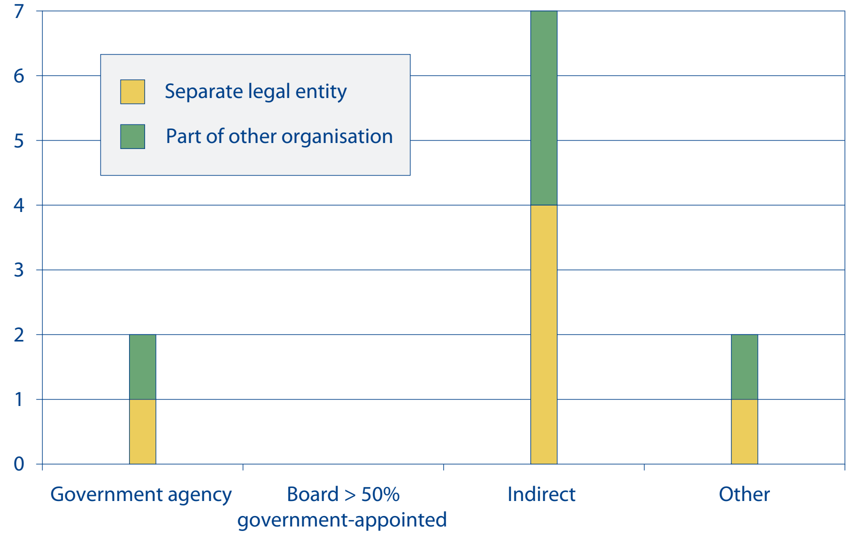
As can be seen from Graph 1.3.1, four NRENs that are separate legal entities nevertheless consider themselves to be under direct government control or have boards of which most members are government-appointed. Five NRENs that are not separate legal entities also belong to this category. Most of the NRENs (17 out of the 29 EU/EFTA NRENs that responded) have an indirect relationship with government.

Graph 1.3.1 – NREN relationship with government - EU/EFTA countries



Note that this division approximates the situation in the non-EU/EFTA countries.

Graph 1.3.2 – NREN relationship with government - other countries



It seems self-evident that for an NREN to develop, the commitment of all 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 networking is well-established.

1.4 Major changes in NRENs

All the NRENs covered by this 2010 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 are expected to occur in the coming year. Table 1.4.1 (below) presents the submitted responses, lightly edited for consistency in some cases. Note that the non-response of some NRENs does not necessarily mean that there were no major changes to their networks. For further information on network developments expected in each NREN's area, see Section 3.9.

Table 1.4.1 shows that the changeover to dark fibre infrastructures, capacity and configuration is continuing, with some countries exploring 40 Gb/s or 100 Gb/s capacities. High-quality infrastructure is built on fibre. Fibre may become available through dark-fibre, indefeasible rights of use (IRU), buying lightpaths, partnership with fibre vendors, or off-the-shelf bandwidth in the market place.

There are developments in many other areas as well. The overall picture is one of dynamic change in various areas for many NRENs.

Table 1.4.1 – Major changes in NRENs

Country	NREN	Reported change(s)
EU/EFTA countries		
Austria	ACOnet	Our CFP for a wavelength transparent fibre optic backbone, which was published in 2006, resulted in a framework contract with Telekom Austria, signed in July 2007 (www.aco.net/aconet07.html?&L=1). The migration to the fibre optic backbone was successfully completed in January 2009 (www.aco.net/technologie.html?&L=1).
Belgium	BELNET	In 2009 BELNET launched www.cert.be, the Belgian National Computer Emergency Response Team. BELNET underwent a substantial increase in personnel to be able to better serve its customers through the new CERT team and more and better services. BELNET further developed the process of moving the demarcation point of its network towards the customer's premises. In 2010-2011 BELNET foresees introducing VoIP to its customers.

Table 1.4.1 – continued

Country	NREN	Reported change(s)
EU/EFTA countries		
Bulgaria	BREN	A major achievement was accomplished during 2009: the national backbone of the network was upgraded to 1Gbit/s capacity. The topology also changed to form a nation-wide ring, allowing for failover. A similar development was accomplished on a smaller scale in the backbone within the metro area of Sofia - the capital of Bulgaria. In Sofia, dark fibre was leased, creating another network ring which connects seven large state universities in the capital. Currently, the network backbone is entirely based on Gigabit Ethernet.
Cyprus	CYNET	Some major changes that occurred at CYNET over the past year are: - upgrade of several of our members' network connection - upgrade of the GÉANT connection to 1Gb/s, which will hopefully be completed by the end of the year - Eumedgrid support infrastructure setup and update - as of 1 July 2010, CYNET is a member of the TERENA Certificate Service - CYNET participates in the FP7 project LinkSCEEM2, which started on 1 September 2010 - CYNET supports the Arab States Research and Education Network(ASREN)
Czech Rep.	CESNET	The major technology changes and upgrades during the past year are: - CESNET has been appointed as Czech National Grid Initiative representative - eduID.cz federation operation has started - CRS-1/16 deployment in Brno PoP - pilot 40 Gbit/s IP/MPLS line Prague - Brno over DWDM network - Brno PoP splitting The main technology changes anticipated for the coming year are: - upgrade of computing power of national grid infrastructure by approx. 500 cores and 100 TB storage capacity - deployment of first node of planned Distributed Storage Infrastructure Organizational and user base changes for next year: - modifying organizational structure according to new 5-year project 'Large infrastructure CESNET'; that is, establish separate 'Distributed Storage' team at least. - concentration on demands of research infrastructures in CZ
Denmark	UNI-C	During the past year, the DWDM infrastructure has been deployed to the smaller institutions and departments across the country. This process will continue over the next couple of years. It has been decided that in the future the research network will focus solely on infrastructure and connectivity services. By the end of 2010, we will no longer offer content and e-learning services.
Estonia	EENet	EENet administered the top-level domain (TLD) .ee since its creation in 1993 until July 2010. Due to the reform initiated by the Ministry of Economic Affairs and Communications, since July 2010 the TLD .ee is being administered by the Eesti Interneti Sihtasutus (www.eestiinternet.ee). As a result of this reform, the fee on .ee domain names was set and the registration services opened for foreign entities and persons. EENet became an accredited Registrar for educational, research and cultural institutions. Delivery of the .ee register with 78,000 domain names was the most labour-intensive work in 2010.

Table 1.4.1 – continued

Country	NREN	Reported change(s)
EU/EFTA countries		
Finland	Funet	The Finnish university system is currently undergoing its largest restructuring process in decades. Some mergers of universities have already occurred and more are ahead. These changes have increased the demand for fixed DWDM lightpaths between the new geographically separated university sites. In 2008, Funet started an IRU dark fibre-based DWDM network upgrade, which practically covers the whole network now. The renewal of the backbone routers has been finalized and the links between them have been upgraded to 10 Gb/s. Also, the network topology has been restructured.
Germany	DFN	The number of fibres for the X-WiN has been extended. Additional CBFs have been implemented. A 100 Gb test has been implemented.
Greece	GRNET S.A.	GRNET S.A. has already acquired 15-year IRUs for dark fibre (DF) links. GRNET owns 8,730 km of dark fibre pairs and plans to extend it this year. Alcatel DWDM equipment has been installed in our network backbone and in metropolitan area networks in Athens and Salonica. In addition, a Juniper T1600 core network router and Extreme switches have been installed in order to power up the new optical connections that were acquired in the core and access network. In 2009, GRNET upgraded its access network by connecting more than 40 clients with dark fibre pairs and upgrading connection to power users to 10Gbps. The GRNET node in Athens hosting the new node of GÉANT and the GReek Internet eXchange (GRIX) became operational at production level. Furthermore, a new data centre with 28 racks became operational by the end of 2009. Each rack is planned to host IT equipment with power consumption up to 15 kW, while the expected PUE is 1.8 by the time the data centre will be fully populated with IT equipment. GRNET S.A.'s goal with the planned migration to owned-fibre infrastructure is to operate a hybrid network that will continue to provide sound production-quality IP services to all users and at the same time provide Layer 1/Layer 2 services to its clients.
Hungary	NIIF/ HUNGARNET	1. NIIFI was previously operating under the umbrella of the Ministry of Communication and Informatics, then the Ministry of Economy and Transport, from 2008 the Office of the Prime Minister, and since early 2010 the Hungarian Academy of Sciences. 2. The research network in Hungary has been continuously developing over the past few years (backbone and access network extensions and upgrades + international connectivity upgrade to GÉANT+). No substantial changes in organisational structure and mandate are foreseen for 2008-2009, while a considerable technical development (reconstruction and upgrade of the internal NIIF/Hungarnet network) is ongoing during 2009-2011 (HBONE+ project and related network and service development activities). No significant change in the user base is forecasted.

Table 1.4.1 – continued

Country	NREN	Reported change(s)
EU/EFTA countries		
Iceland	RHnet	One new research corporation added, connected via 1 Gbs to the RHnet backbone. International connectivity: During 2009 and early 2010, the RHnet external connectivity was finalized via the NORDUnet IceLink project: 10 Gb/s OC192 circuit to Denmark on the DANICE sea cable, 2.5 Gb/s OC48 circuit to London via the FARICE sea cable, and 4Gb/s Ethernet connection to North-America via the Greenland-Connect sea cable.
Ireland	HEAnet	Delivery of additional service resilience (consisting of path, PoP, power and equipment resilience) to major clients. A cross-border link has been provided to give path resilience to the north-west sector of the national network. Thanks to JANET, NIRAN and QUB, a Letterkenny-to-Dublin circuit has been commissioned. A three-staged IPv6 strategic plan has been formulated to manage risks associated with the problem of IPv4 depletion. The plan initially aims to deliver HEAnet services completely independently of IPv4, but still interoperating with the IPv4 network, with delivery of an IPv6-only network to HEAnet clients by 2013. Technical dialogues to inform a CfT (Call for Tender) for the replacement of the present optical/Ethernet network (backbone and MANs) is ongoing with both clients and service providers. A 10 Gb/s point-to-point inter-institute network was created for the use of the e-INIS project: to be used by the National Grid Initiative of Ireland. Continued roll-out of HD videoconferencing units to clients. A campus trial of WiMax technology was conducted with a large client. HEAnet's federated access management service, Edugate, has reached production status. A greenhouse gas (GHG) audit of the HEAnet company, and its network, was completed in compliance with the ISO 14064 standard. There has been significant PoP consolidation work carried out this year. First pilot phase of a project to deliver 100 Mb/s connectivity to all post-primary schools in Ireland is complete, with 78 schools connecting to HEAnet at 100 Mb/s capacity. Technology refresh of Schools Broadband Programme is underway, which delivers broadband connectivity to all 4,000 primary and post-primary schools in Ireland. 3G mobile broadband deal at reduced price secured for all students and staff in HEAnet client institutions.

Table 1.4.1 – continued

Country	NREN	Reported change(s)
EU/EFTA countries		
Italy	GARR	In 2011, we will start deploying our new GARR-X infrastructure, based on leased/owned dark fibres.
Latvia	SigmaNet	Last year we successful changed over to IPv6, and we already have some customers have also changed over to IPv6. No other major changes have happened to SigmaNet in the past year.
Lithuania	LITNET	There have been no significant changes during the past year. The LITNET programme ended in 2009, and a single-year contingency project was prepared for 2010 while the ministry was evaluating the concept itself.
Luxembourg	RESTENA	The RESTENA network is converging to a network based entirely on optical dark fibres for the next two years. DWDM technology is being deployed to provide 10G pt-2-pt circuits to research and Grid projects.
Netherlands	SURFnet	One of the highlights of 2009 was the grant of 32 million euro in subsidies for the implementation of the GigaPort3 innovation project over the period 2009 through 2013. In the coming years, SURFnet will raise the network to a higher level (SURFnet7) to facilitate a next generation of networks and to support dynamic services. The video-platform software was made open source and has been made available under the name MediaMosa (www.mediamosa.org). SURFnet launched the COIN project (COllaboration INfrastructure) to research the possibilities of an open online collaboration environment. SURFnet and SURFfoundation jointly started to offer a training and professionalization programme under the name of SURFacademy.
Norway	UNINETT	Improvement of general capacity and redundancy in our network and on-campus work continues. The GigaCampus programme, which provided on-campus infrastructure, terminated in 2009 and was followed by @campus and European work on Campus Best Practice. In 2009, UNINETT launched the first lightpaths for use by our research community. Federated login really took off, with more than a million logins per month by the end of 2009. The new eCampus programme is aimed at facilitating learning, teaching and research by providing simple user-friendly ICT tools for education and research, identifying and provide ICT tools for research, and making it easy to access digital learning resources nationally.
Poland	PIONIER	In the past year, we have set up our new Poznan-Hamburg DWDM system and established 10 Gigabit Ethernet lambdas connectivity to AMS-IX and GLIF in Amsterdam, as well as to Nordunet in Hamburg.
Romania	RoEduNet	Done: - 10% of counties' PoPs have been connected to NOCs using the DWDM structure with 1 Gb/s links - cross-border connection to RENAM has been realised, using dark fibre and CWDM or DWDM Planned: - finishing PoPS connections to DWDM network - 100G tests and deployment within DWDM between NOCs

Table 1.4.1 – continued

Country	NREN	Reported change(s)
EU/EFTA countries		
Slovakia	SANET	New PoPs added to serve secondary schools. Backbone capacity to those PoPs: 10GE.
Spain	RedIRIS	Red.es/RedIRIS IRIS has launched a 138 M€ project, called RedIRIS NOVA, for the provision of a dark fibre network (including optical equipment) for the next 20/30 years. Red.es launched a 130 M€ call for tenders (through competitive dialogue) in November 2008. A final decision was taken on November 2009. Additional smaller tenders might be called for afterwards. The winning bidders are expected to deploy most of the requested optical equipment and network before October 2011, when the current RedIRIS-10 contract expires.
Switzerland	SWITCH	The strategy of SWITCH is currently under review. Resulting changes in mandate or structure are expected in 2011 and later.
UK	JANET(UK)	We have made and will continue to make organisational changes to ensure that we are best able to deliver the required services in the developing financial situation.
Other countries		
Algeria	CERIST	The new backbone for the next three years is being deployed; the work started in November 2010. This backbone will permit capacities of ARN PoPs to be upgraded from STM1 to STM4 and GigaEthernet. Large and medium-sized universities will upgrade to 100M. Small universities, high schools and research centres will upgrade to 10M. The number of PoPs will increase from three to ten.
Belarus	BASNET	In 2009, our external link to European networks was expanded to 622 Mb/s. Modernization of backbone nodes and fibre-optic channels expansion.
Croatia	CARNet	CARNet is implementing several key infrastructure projects to provide optical connectivity of its user institutions to the network with dark fibre. Also, a major VoIP project is being implemented, as well as operational work on National CERT.
Georgia	GRENA	GRENA is actively participating in a Georgian secondary school connectivity programme: Deer Leap Georgia. In this programme, all 2300 schools in Georgia will receive Internet services via virtual private network (VPN), and GRENA is acting as a Network Operation Center for this network. In April 2009, GRENA established connectivity to GÉANT according to the EC Black Sea Interconnection project.
Macedonia	MARNet	MARNet has become a GÉANT member and is participating in the GN3 project. Since February 2009, MARNet has upgraded its international link to 155 Mb/s, using a connection to GÉANT through the Sofia PoP. From 1.January 2011, a second link via the Athens GÉANT PoP will be activated. A law on MARNet's status was adopted by the Macedonian Parliament. Adoption of the remaining documents concerning management, organizational structure, etc. is in progress.

Table 1.4.1 – continued

Country	NREN	Reported change(s)
Other countries		
Moldova	RENAM	New DF links were installed in Chisinau MAN, allowing us to expand our own optical infrastructure to 50 km. The DF connection between the RENAM node in Chisinau (Moldova) and the RoEduNet node in Iasi (Romania) became operational in May 2010. DWDM optical equipment was installed, allowing 10 Gb/s capacity links to be organised. At present, we are operating one 10 Gb/s connection to the RoEduNet node in Iasi and using the second 10 Gb/s link as a back-up. A second external back-up channel of 100 Mbps to commodity Internet is provided to RENAM by the local IDSP StarNet. In 2010, the development of DF backbone in Chisinau continued. New organizations were connected by fibre links to RENAM fibre infrastructure, allowing improved connectivity for campuses of the State Agricultural University of Moldova and connecting two new research institutes of the Academy of Sciences. RENAM CERT operation was promoted and appropriate services for the NREN community were developed.
Montenegro	MREN	As planned, we have acquired an M10i, which we will use as a gateway router. Also, we have acquired an ASA5540, which will filter all ingoing and outgoing traffic, segment the network, and enable IPS functionality. For the servers segment, we have acquired a Blade chassis with two powerful servers, and we expect that the majority of the servers will be migrated to Blade.
Morocco	MARWAN	In July 2010, MARWAN started a new backbone with a new telecom operator.
New Zealand	REANNZ	- Addition of a second 155 Mb/s link to Sydney, Australia (2009) - First dark fibre commissioning (2010) - Establishment of two new PoPs, bringing PoP numbers to 18 (2010) - Commissioned a videoconferencing service (2010) - Trial of National Education Network (continuing) (2008-2011) - Implementation of new national and international connectivity, including increased capacity of 1 Gb/s to Australia and the USA (2010) - Implementation of a distribution layer (layer 3 provider edge) (2010-2011)
Russian Fed.	e-ARENA	- New SDH-based infrastructure of network backbone in Russia (2006) - 2.5 Gb/s GEANT connectivity (2006) - Moscow-Amsterdam channel (GLORIAD project) (2007) - 10 Gb/s Moscow-St. Petersburg-Stockholm channel (2007) - Dark cross-border fibre (2009) - Organization of E-Arena by Joint Supercomputer Center of the Russian Academy of Sciences (JSCC), Russian Institute for Public Networks (RIPN) and State Institute of Information Technologies and Telecommunications (SIIT&T INFORMIKA) (2009)

Table 1.4.1 – continued

Country	NREN	Reported change(s)
Other countries		
Serbia	AMRES	By the end of 2010 we are expecting to establish AMRES as a separated legal entity. The Serbian government has granted permission for this and the administrative procedure has started. In the AMRES project, an organizational model of management, systematic operation and AMRES development has been established.
Taiwan	NCHC	No major change is anticipated.
Turkey	ULAKBIM	Access and backbone capacity upgrades were achieved, with the Ankara-Istanbul backbone being upgraded to 10 Gb/s. The Izmir Backbone router has been upgraded to a higher capacity.
US	Internet2	With the completed deployment of the Internet2 Network infrastructure, Internet2 Connectors and member institutions are developing, deploying, and exploring dynamic circuit networking as complementary to high-performance IP networking. Information on the Internet2 network is available at: www.internet2.edu/network Organizationally, Internet2 is focused on informing the community about the many government stimulus opportunities available, and preparing proposals to take advantage of broadband and infrastructure opportunities: www.internet2.edu/government/stimulus

1.5 Environmental policies

Environmental issues are now on most agendas, also within the NREN community. Energy and its usage are core issues for networks and their operation. It is becoming increasingly important for NRENs to address these issues, to measure and reduce consumption, and to promote green uses of network technology in order to reduce greenhouse gas (GHG) emissions. Progress on environmental issues is being made in various NRENs, and this year's *Compendium* gauges this for the first time.

In 2009, only two NRENs indicated that they had an environmental policy. In 2010, the number rose to four. Two NRENs have environmental information on their websites.

As part of the GN3 project, three NRENs (HEAnet, PSNC and NIIF/HUNGARNET) and one regional network (NorduNET) have audited their GHG emissions. Four more NRENs are planning such an audit. For further information, see **www.geant.net/About_GEANT/Environmental_Impact**

Table 1.5.1 – NREN environmental policies in place

Country	NREN	Policy	URL
Estonia	EENet	yes	
Hungary	NIIF/HUNGARNET	yes	
Ireland	HEAnet	yes	www.heanet.ie/about/environmental_policy
UK	JANET(UK)	yes	www.ja.net/documents/company/environmental-policy.pdf

2 USERS/CLIENTS

Section 2.2, below, presents information on the connection policies of NRENs (i.e. which institutions they are allowed to connect). Section 2.3 indicates how many users in the various categories are actually connected (i.e. the 'market shares'). Section 2.4 examines the typical bandwidths and Section 2.5, typical connection methods. A new section, 2.6, highlights several other technologies deployed by NRENs in their access networks or made available to end-users.

2.1 Overview

As shown by Graph 2.2.1 (below), all the NRENs covered by this *Compendium* are allowed to connect universities and research institutes. Nearly all may connect institutes of further education, as well as libraries and museums. In the EU/EFTA area, a majority of the NRENs are also allowed to connect secondary schools, primary schools, hospitals and government departments. The NRENs differ greatly in this respect: some are allowed to operate as national networks for a wide range of user segments in the non-commercial sector, whereas others are not mandated to do this.

Even though an NREN may connect a certain institution, this does not necessarily mean that it actually does. In the university sector, NRENs clearly have very high market shares; in other areas, the situation differs greatly from country to country.

We have estimated that, currently, around 40% of students in the EU/EFTA area are studying at tertiary education institutions that are connected to dark fibre.

For universities within the EU/EFTA area, the typical connection capacity is now gigabit or greater – a tremendous difference compared with the situation a few years ago. Capacities exceeding 10 Gb/s are currently being introduced. Other categories of users have significantly lower capacities. Outside the EU/EFTA area, gigabit connections are not yet prevalent.

NRENs use diverse methods of connecting institutions. For all user categories except primary and secondary schools, the direct PoP connection is the most common, followed by connections via Metropolitan or Regional Area Networks (MAN/RAN).

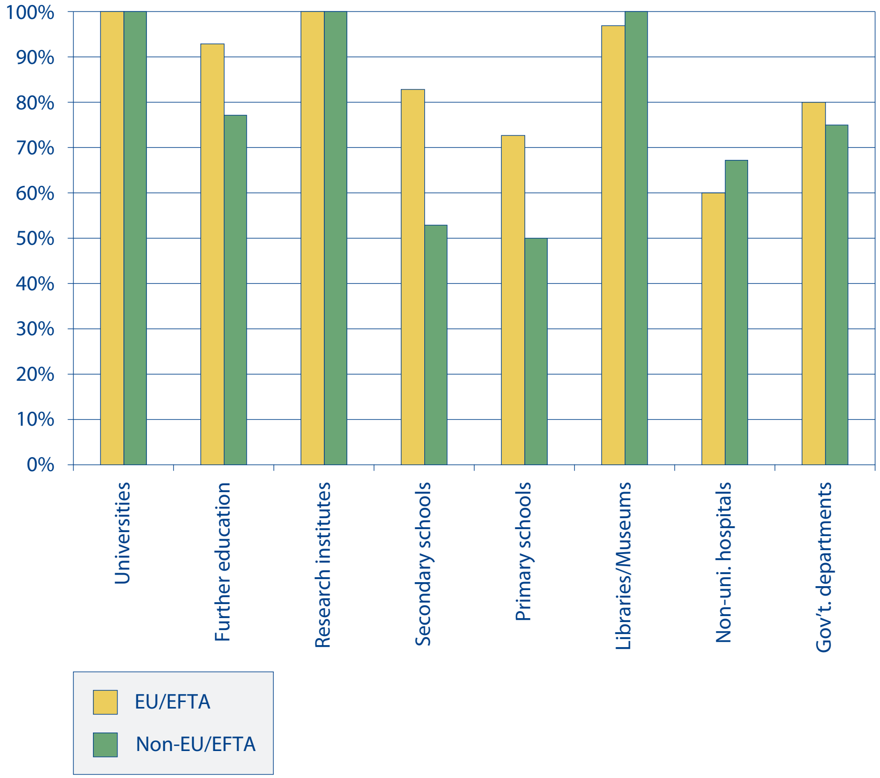
This year for the first time, we asked NRENs about the technologies they are deploying in their access networks or are making available to individual end-users. Clearly, very few NRENs are in the business of directly supporting mobility. In most cases, NRENs do this indirectly by providing fixed connections to client institutions; these, in turn, provide WiFi services to their end-users. Generally, NRENs do not directly provide connectivity to end-users.

Connectivity for mobile users is usually provided by conventional ISPs and mobile network operators. Nevertheless, 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.

2.2 Connection policies

Graph 2.2.1 (below) summarises the NREN connection policies. As in previous years, all NRENs are allowed to connect universities and research institutes. Many NRENs may also connect libraries, museums and archives, as well as institutes of further education. Note, however, that even if an NREN is allowed to connect a certain category of users, this does not necessarily mean that it does so in practice. As Section 2.3 shows, NRENs typically connect all, or almost all, the universities and research institutes in their countries. In other sectors, the percentage of users that are connected varies greatly between countries due to their different national circumstances.

Graph 2.2.1 – Connection policies of EU/EFTA and other countries



2.3 Approximate market shares

For EU/EFTA and other countries, Table 2.3.1 (right) 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 the community. For additional information on individual NRENs, see the *Compendium* website: **www.terena.org/compendium**

Table 2.3.1 – Approximate market shares

Country	NREN	Universities	Institutes of higher/further education	Research institutes	Secondary schools	Primary schools	Libraries, museums, national archives	Non-university hospitals	Government departments
EU/EFTA countries									
Austria	ACOnet	32 (≈100%)	1 (≈100%)	27 (≈<50%)	+ (≈100%)	+ (≈>50%)	10 (≈<50%)	4 (≈<50%)	30 (≈<50%)
Belgium	BELNET	67 (≈100%)	5 (≈0%)	42 (≈100%)	6 (≈0%)	+ (≈0%)	13 (≈0%)	13 (≈0%)	53 (≈<50%)
Bulgaria	BREN	22	2	50	1,500	500	15	5	-
Cyprus	CYNET	7 (≈100%)	1(≈<50%)	3 (≈<50%)	1 (≈0%)	-	-	-	-
Czech Republic	CESNET	26 (≈100%)	11(≈<50%)	22 (≈50%)	120 (≈<50%)	20 (≈0%)	32 (≈0%)	35 (≈<50%)	40 (≈<50%)
Denmark	UNI•C	8 (≈100%)	7(≈<50%)	12 (≈<50%)	+	-	5 (≈0%)	2 (≈0%)	4 (≈0%)
Estonia	EENet	27 (≈100%)	10(≈<50%)	18 (≈50%)	55 (≈>50%)	35 (≈>50%)	86 (≈0%)	+ (≈0%)	3 (≈0%)
Finland	Funet	50 (≈100%)	-	12 (≈50%)	-	-	4 (≈0%)	-	8 (≈0%)
France	RENATER	416 (≈100%)	325	353	119	+	10	5	28
Germany	DFN	+ (≈100%)	+ (≈100%)	+ (≈>50%)	+ (≈0%)	+ (≈0%)	+ (≈0%)	+ (≈0%)	+(≈0%)
Greece	GRNET	44 (≈100%)	144 (≈100%)	26 (≈100%)	4,206 (≈100%)	5,050 (≈100%)	8 (≈<50%)	-	757 (≈<50%)
Hungary	NIIF/HUNGARNET	26	31	73	29	+	235	58	9
Iceland	RHnet	7 (≈100%)	3 (≈0%)	10 (≈>50%)	1 (≈0%)	-	1 (≈0%)	-	-
Ireland	HEAnet	8 (≈100%)	30 (≈100%)	12 (≈>50%)	800 (≈100%)	3,200	+(≈0%)	-	9 (≈0%)
Italy	GARR	145 (≈100%)	0 (≈0%)	157 (≈100%)	10 (≈0%)	1 (≈0%)	26 (≈<50%)	49 (≈<50%)	3 (≈0%)
Latvia	SigmaNet 3	18(≈50%)	6(≈0%)	14 (≈<50%)	3 (≈0%)	-	6 (≈0%)	-	-
Lithuania	LITNET	66 (≈100%)	142 (≈100%)	70 (≈100%)	746 (≈50%)	52 (≈<50%)	90 (≈<50%)	11 (≈0%)	28 (≈0%)
Luxembourg	RESTENA	4 (≈100%)	2 (≈100%)	17 (≈100%)	56 (≈100%)	150 (≈>50%)	12 (≈50%)	1 (≈0%)	3 (≈0%)
Malta	UoM/RicerkaNet	1 (≈100%)	2(≈50%)	3 (≈50%)	+ (≈0%)	+ (≈0%)	+ (≈0%)	+ (≈0%)	+ (≈0%)
Netherlands	SURFnet	14 (≈100%)	64 (≈100%)	32 (≈100%)	+ (≈0%)	+ (≈0%)	19 (≈<50%)	11 (≈<50%)	-
Norway	UNINETT	7 (≈100%)	57 (≈100%)	79 (≈50%)	6 (≈0%)	2 (≈0%)	14 (≈<50%)	-	-
Poland	PIONIER	168 (≈100%)	17 (≈0%)	199 (≈100%)	106 (≈0%)	13 (≈0%)	136 (≈<50%)	35 (≈0%)	107 (≈0%)
Portugal	FCCN	42 (≈100%)	0 (≈0%)	10 (≈100%)		-	3 (≈0%)	-	14
Romania	RoEduNet	50 (≈100%)	10 (≈>50%)	55 (≈>50%)	360 (≈<50%)	140 (≈0%)	40 (≈<50%)	-	30 (≈<50%)
Slovakia	SANET	38 (≈100%)	7 (≈<50%)	20 (≈50%)	200 (≈<50%)	100 (≈<50%)	6 (≈<50%)	+ (≈0%)	+
Slovenia	ARNES	4 (≈100%)	20 (≈100%)	58 (≈100%)	160 (≈100%)	521 (≈100%)	204 (≈100%)	-	12 (≈0%)
Spain	RedIRIS	100 (≈100%)	0 (≈0%)	150 (≈100%)	-	-	25 (≈0%)	50 (≈<50%)	50 (≈0%)
Sweden	SUNET	30 (≈100%)	9 (≈>50%)	4 (≈>50%)	-	-	19 (≈>50%)	-	20 (≈0%)

Table 2.3.1 – continued

Country	NREN	Universities	Institutes of higher/further education	Research institutes	Secondary schools	Primary schools	Libraries, museums, national archives	Non-university hospitals	Government departments
EU/EFTA countries									
Switzerland	SWITCH	39(≈100%)	3(≈0%)	9(≈<50%)	2(≈0%)	+(≈0%)	+(≈0%)	+ (≈0%)	6 (≈<50%)
United Kingdom	JANET(UK)	175(≈100%)	595 (≈100%)	40(≈100%)	+(≈100%)	+ (≈100%)	9	-	10
Other countries									
Australia	AARNET	41(≈100%)	13(≈<50%)	24(≈50%)	150(≈0%)	145 (≈0%)	9 (≈0%)	+ (≈0%)	1 (≈0%)
Azerbaijan	AzScienceNet	7(≈50%)	+ (≈50%)	30(≈100%)	-	-	4 (≈<50%)	-	-
Belarus	BASNET	9(≈<50%)	+	58(≈<50%)	+ (≈0%)	+ (≈0%)	15 (≈<50%)	5 (≈0%)	13 (≈0%)
Croatia	CARNet	106	41	36	422	905	10	15	11
Georgia	GRENA	9(≈50%)	10(≈50%)	35(≈100%)	1200(≈>50%)	+ (≈0%)	8 (≈0%)	3 (≈0%)	6 (≈0%)
Israel	IUCC	11	-	5	-	-	+	0	-
Macedonia	MARNet	19 (≈<50%)	0(≈0%)	5(≈50%)	-	-	50 (≈50%)	-	1 (≈0%)
Moldova	RENAM	9(≈100%)	2(≈0%)	36(≈>50%)	2(≈0%)	+ (≈0%)	14 (≈<50%)	5 (≈0%)	5 (≈0%)
Montenegro	MREN	19(≈100%)	1(≈100%)	2(≈>50%)	-	-	2 (≈<50%)	-	1 (≈<50%)
Morocco	MARWAN	14(≈100%)	77(≈100%)	7(≈50%)	-	-	2 (≈<50%)	+ (≈<50%)	2 (≈0%)
New Zealand	REANNZ	8(≈100%)	5(≈>50%)	13(≈100%)	27(≈0%)	33 (≈0%)	5 (≈0%)	-	2 (≈0%)
Russian Federation	e-ARENA	250(≈>50%)	+ (≈<50%)	240(≈<50%)	+ (≈0%)	+ (≈0%)	+(≈0%)	+ (≈0%)	null
Serbia	AMRES	84(≈50%)	6(≈0%)	36(≈<50%)	8(≈0%)	0(≈0%)	19 (≈<50%)	3 (≈0%)	2 (≈0%)
Taiwan	NCHC	120(≈100%)	20(≈0%)	20(≈0%)	500(≈<50%)	1000 (≈50%)	5 (≈0%)	5 (≈0%)	20 (≈0%)
Turkey	ULAKBIM	814(≈100%)	+ (≈100%)	14(≈100%)	-	-	3 (≈0%)	-	9 (≈0%)
United States	Internet2	785(≈100%)	677(≈100%)	+ (≈>50%)	52698(≈50%)	+ (≈50%)	3644 (≈50%)	234 (≈<50%)	14(≈<50%)

We also asked what percentage of universities are connected to the NREN via dark fibre. This percentage differs widely, between 0% and 100%, from country to country. It should be noted that there is no direct relationship between the type of fibre (dark or otherwise) and the capacity of the network. However, a dark fibre network does mean that the possibilities for quick and relatively inexpensive upgrades are, generally speaking, better than in the case of other alternatives.

Based on UNESCO student statistics and on the percentage of universities connected via dark fibre, we have estimated that, currently, around 40% of the students in the EU/EFTA area are studying at tertiary education institutions that are connected to dark fibre.

We believe that this figure also indicates that a substantial percentage of students, professors and researchers have access to abundant bandwidth and therefore enjoy high-standard, advanced internet connections and facilities. This is confirmed by Section 4.5, on the Congestion Index, which highlights that, on average, EU/EFTA countries have low congestion levels.

2.4 Typical bandwidths

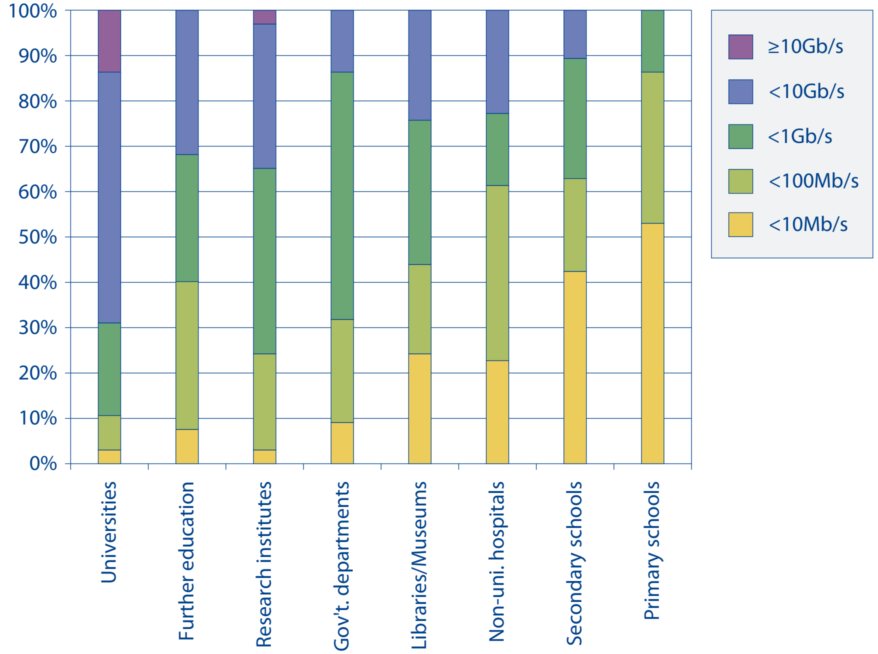
From the 2008 edition of the *Compendium*:

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

Clearly, the typical capacity for universities within the EU/EFTA area is now gigabit or greater, while 10 Gb/s is becoming increasingly common. All other user categories have much lower connection speeds.

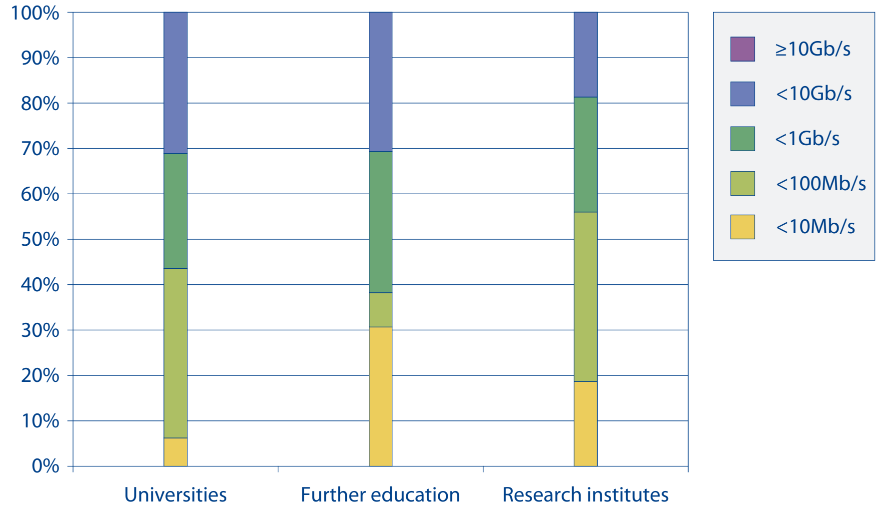
Graph 2.4.1 (below) gives an overview of the distribution of typical bandwidths available to NREN users. Note that not all NRENs provided information relevant to this overview, so the set of countries is not exactly the same in each user category.

Graph 2.4.1 – Typical bandwidth, EU/EFTA countries



In countries outside the EU/EFTA area, the situation is quite different: gigabit connections are starting to be introduced but are not yet prevalent. Graph 2.4.2 (below) presents a more limited set of user categories than those shown in Graph 2.4.1 (left), because fewer countries provided the necessary information.

Graph 2.4.2 – Typical bandwidth, other countries



2.5 Connection methods

NRENs use diverse methods of connecting institutions:

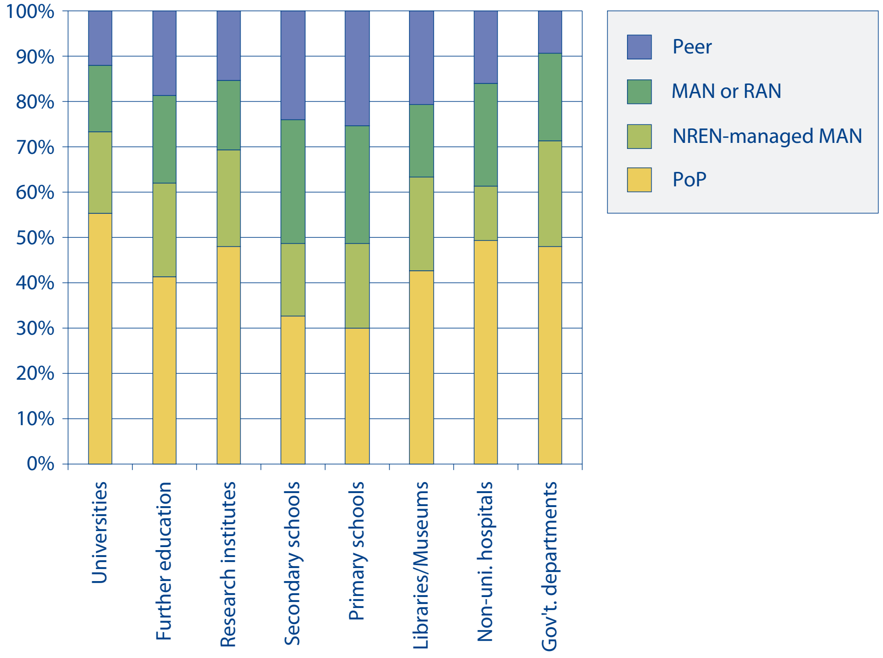
- directly to a NREN;
- via a MAN or RAN operated by the NREN;
- via a MAN or RAN not operated by the NREN; or
- via a peer with a connected site.

Graphs 2.5.1 (below) and 2.5.2 (right) indicate the prevalence of those connection methods among the various user categories. The graphs show how NRENs, on average, connect institutions.

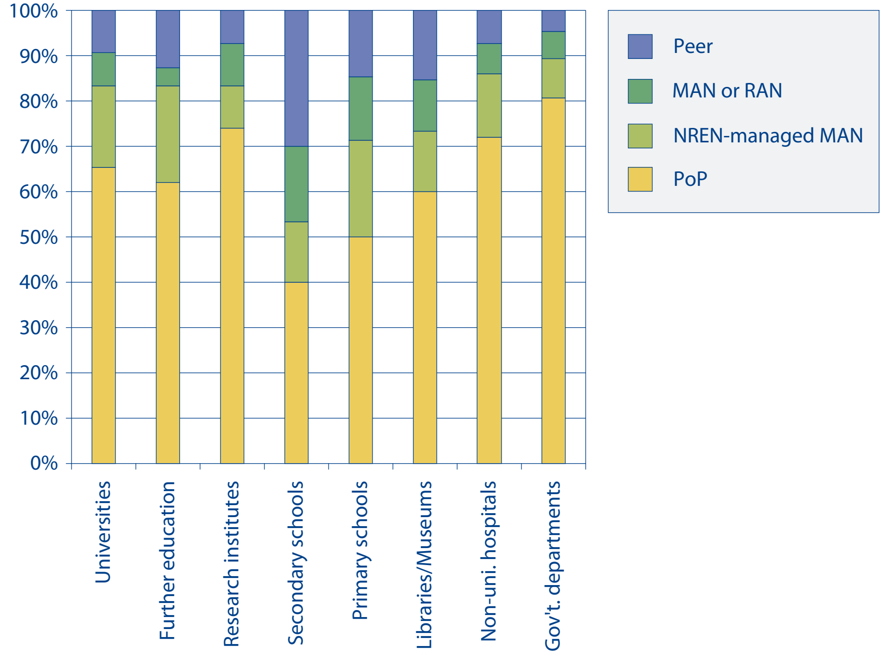
In EU/EFTA countries, for all user categories except primary and secondary schools, the direct PoP connection is the most common, followed by connections via a MAN or RAN. As Section 2.4 indicates, the bandwidths provided to the various user categories differ considerably. It should also be noted that there is great variation in the range of services provided.

In the non-EU/EFTA countries, PoP connections are more prevalent, although in these countries as well primary and secondary schools are mostly connected by other methods.

Graph 2.5.1 – Typical connection methods, EU/EFTA countries



Graph 2.5.2 – Typical connection methods, other countries



2.6 Other technologies used by NRENs[1]

This year for the first time, we asked NRENs about the technologies they are deploying in their access networks or are making available to individual end-users. The responses are shown in Tables 2.6.1 and 2.6.2. Note that not all NREN respondents answered these questions. Note also 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. Questions were asked about seven specific technologies:

- Fibre to the Home / Fibre to the Office (FTTH/FTTO): i.e. making optical fibre technology available to the home or office end-user. In the EU/EFTA area, 11 NRENs are already doing this at the access network level, while one more is planning to do so in the near future. Seven NRENs are deploying this technology at the end-user level, while one more is planning to do so. Several of the non-EU/EFTA NRENs are also deploying these technologies;
- DSL: connecting users via (A)DSL: this technology is quite common at the access network level; fewer NRENs are making it available to the end-user;
- Wireless LAN: the situation is similar to that of DSL, although the set of countries is not the same;
- Internet use via mobile phone network operators: a few NRENs (two at the access network level in the EU/EFTA area) are interested in this technology;
- A few NRENs are interested in the area of Satellite technology. Only countries outside of the EU/EFTA area are interested in making this technology available to end-users. These are countries where, in some regions, DSL and other technologies are not available and where satellite access, though perhaps not optimal, is the only choice;
- 12 countries are interested in using licensed spectrum or unlicensed spectrum (taken to mean wireless networking that uses part of the radio spectrum).

The list is not comprehensive – several NRENs use other technologies as well.

Generally, mobile access to licensed spectrum is not provided by NRENs. Mobility access to WiFi by using eduroam® is provided by all GÉANT members and many other NRENs.

[1] With contributions from Mike Norris, HEAnet.

Connectivity for mobile users is usually provided by conventional ISPs and mobile network operators. Nevertheless, 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 Section 5.2).

Table 2.6.1 – Technologies deployed at the access level network

Country	FTTH/ FTTO	DSL	WLAN	3G/use of mobile operators	Satellite	Licensed spectrum	Unlicensed spectrum	Other
EU/EFTA countries								
Austria	no	no	no	no	no	no	no	no
Belgium	now	no	no	no	no	no	no	now
Cyprus		plan	plan	no	no			
Czech Rep.	no	no	no	no	no	now	no	no
Denmark								now
Finland	now	no	no	no	no	no	no	no
France	no	no	no	no	now	no	no	now
Greece		now						
Hungary	now	now	now	now	no	now	now	now
Ireland	no	now	trial	now	now	now	no	
Italy	now	now	now			now		
Latvia	now	now	now	no	no	now	no	no
Lithuania	now	now	now	trial	no	now	now	
Luxembourg		now	now					
Malta	now	now	now					
Netherlands	now	no	no	no	no	no	no	no
Norway	now	now		no		now		now
Poland	now	no	now	no	no	no	no	
Portugal		now						
Romania	now	no	now	no	no	no	no	no
Slovakia		no		no	no	now		
Slovenia	plan	now	plan	no	no	no	no	
Sweden	no	no	no	no	no	no	no	no
UK	no	now	now	plan	no	no	no	no

Table 2.6.1 – continued

Country	FTTH/ FTTO	DSL	WLAN	3G/use of mobile operators	Satellite	Licensed spectrum	Unlicensed spectrum	Other
Other European/Mediterranean countries								
Azerbaijan	plan	now	now	no	no	no	no	
Belarus		now						
Croatia	now	now	now					now
Georgia	now	now	now				now	
Jordan	now							
Macedonia		now				now		
Moldova	now	now	now		no	now		
Montenegro	no	plan	now	no	no	no	no	no
Morocco						now		
Russian Fed.			now		now			
Serbia		now	now					
Other countries								
Australia	plan	plan	now	plan	plan	now	now	
Malawi			now		now			
Taiwan	no	no	no	no	no	no	no	no
United States	no	no	no	plan	no	no	no	no
Venezuela	no	now	now	no	no	no	no	now

Table 2.6.2 – Technologies made available to individual end-users

Country	FTTH/ FTTO	DSL	WLAN	3G/use of mobile operators	Satellite	Licensed spectrum	Unlicensed spectrum	Other
EU/EFTA countries								
Austria	no	no	no	no	no	no	no	no
Belgium	no	no	no	no	no	no	no	no
Czech Rep.	plan	no	no	no	no	now	no	no
Finland	no	no	now	plan	no	no	no	no
France	no	no	no	no	no	no	no	no
Greece		now						
Hungary	now	now	no	no	no	now	no	now
Ireland	no	no	no	trial	no	trial	no	no
Latvia	now	now	now	no	no	now	no	no
Lithuania	now	now	now	trial	no	no	now	
Luxembourg		now	now					
Malta		now	now					
Netherlands	now	no	plan	plan	no	plan	plan	
Norway	now	now		no		now		now
Poland	now	no	now	no	no	no	no	
Portugal			now					
Romania	now	no	now	no	no	no	no	no
Slovenia	no	no	no	no	no	no	no	no
Sweden	no	no	no	no	no	no	no	no
Switzerland			now	now				
UK	no	trial	now	plan	no	no	no	no
Other European/Mediterranean countries								
Algeria		now						
Azerbaijan	no	now	now	no	no	no	no	
Belarus		now						
Croatia			now	now	plan			plan
Georgia	now	now	now				now	
Israel		now	now	now				
Macedonia			now					
Moldova	now	now	now	no	no	now		
Montenegro	no	no	now	no	no	no	plan	now
Russian Fed.			now		now			
Serbia				plan				now
Other countries								
Australia	no	no	now	plan	no	no	no	
Taiwan	no	no	no	no	no	no	no	no
United States	no	no	no	no	no	no	no	no
Venezuela	no	no	now	no	no	no	no	now

3 NETWORK AND CONNECTIVITY SERVICES

This section provides insights into several important network characteristics. Section 3.2 presents information on Network Operations Centres. Then Section 3.3 examines PoPs (points of presence), optical PoPs, locations where core routing is undertaken and numbers of managed circuits and sites. Section 3.4 provides information on the GÉANT backbone and the core capacity of networks. Section 3.5 highlights the external links of NRENs. Section 3.6 documents recent developments in dark fibre. Section 3.7 focuses on cross-border dark fibre links and a new section, 3.8, on lambdas. Finally, Section 3.9 contains a new table listing network developments as foreseen by NRENs.

3.1 Overview

Although NRENs differ in many respects, including network architecture, they all have a Network Operations Centre (NOC). NOCs are vital elements in the delivery of connectivity services to NREN users. In the EU/EFTA countries, the majority of the NRENs directly employ NOC staff or use a combination of in-house and outsourced staff. That NOC staff size varies considerably – from 0.9 FTE in Cyprus to 61.0 in the UK – is due not only to network size but also to differences in the NOC functions.

The number of PoPs on a network is one indicator of the amount of resources that the NREN needs in order to maintain that network. Section 3.3 on PoPs and routing shows that, in this respect, there are major differences between NRENs. Many NRENs now provide optical PoPs in various locations.

There are also major differences in the number of managed circuits and sites. These differences are related both to the categories of users that are connected and to the way in which they are connected.

In most EU/EFTA countries, the typical core capacity is now 10 Gb/s. This is also the median capacity, up from 2.5 Gb/s in 2005. This capacity is no longer a hard limit: many NRENs have access to dark fibre (see Section 3.7), which is potentially able to handle high capacities, so they can increase capacity easily and economically whenever required.

In the other countries, the trend that was evident last year continues: they have profited from introducing affordable Gigabit Ethernet technology. Network capacity is not growing linearly. Comparing the growth in core capacity with the growth in overall traffic – documented in Section 4.3 – reveals that, roughly speaking, these two trends keep pace with each other. In addition, many NRENs now offer several point-to-point circuits and lightpaths, which provide additional capacity that is not usually included in normal traffic statistics.

In general, connections not only to the European academic backbone network (i.e. GÉANT) but also to the general Internet are of crucial importance to NRENs. On average, for all EU/EFTA NRENs, connections to Internet Exchanges and to commercial Internet providers jointly account for almost 50% of the total external connectivity. The remaining 50% is divided between connections to GÉANT and NORDUnet, cross-border fibre connections and direct NREN-to-NREN connections. However, there are major differences between NRENs. There is also a considerable fluctuation from year to year, because this area is highly dynamic.

The maps in Section 3.6 illustrate the rapid developments in dark fibre that have occurred in recent years. Many, though not all, NRENs predict a further increase in the percentage of their network accounted for by dark fibre by 2012.

Another continuing development is the implementation of cross-border dark-fibre links between NRENs. Section 3.7 presents information on current and planned links of this type, in both map and table format.

Eighteen of the EU/EFTA NRENs currently offer dedicated wavelengths (lambdas) to their customers. One more is planning to do this.

According to NREN respondents, the expected developments include:

- Preparation for 100 Gb/s, reported by various NRENs. Several NRENs also report the advent of DWDM;
- Acquisition of dark fibre by countries outside Europe, which seems to be the way forward if NRENs there want to make quick progress on a manageable upgrade path;
- In many developing countries, NREN expansion into areas outside the capital, which is one of the greatest challenges they face.

3.2 Network Operations Centres

A Network Operations Centre (NOC) is responsible for operating and monitoring a NREN's network and associated services. Some NRENs have separate centres for the various categories of services that they operate or users to which they provide them.

NOCs are a vital element in delivering a mission-critical service such as an NREN network, which entails handling an extensive range of services including physical infrastructure, network administration and network monitoring. Most NOCs have national coverage. They are responsible for national and international links, including those to other NRENs and to GÉANT, to Internet exchange points and to the commercial Internet. Manning such centres can be a major challenge, and different NRENs take different approaches to staffing, as shown by Tables 3.2.1 and 3.2.2 (right).

Table 3.2.1 – NOC staff, EU/EFTA countries

EU/EFTA countries	NOC staff employed by NREN in-house[1]	NOC staff outsourced by NREN	Total NOC staff
NRENs directly employing NOC staff – 67% of the 24 NREN respondents			
Austria	4		4
Estonia	2		2
Finland	5		5
Germany	9		9
Greece	13		13
Hungary	5		5
Ireland	10		10
Italy	6		6
Latvia	5		5
Lithuania	6		6
Luxembourg	3		3
Norway	18		18
Portugal	8		8
Romania	14		14
Slovenia	5		5
Switzerland	13		13
NRENs outsourcing NOC staff – 17% of the 24 NREN respondents.			
Denmark		5	5
Netherlands		16	16
Slovakia		3.5	3.5
Sweden		14	14
NRENs using a combination of in-house/outsourced staff – 20% of the 24 NREN respondents			
Belgium	2.76	1	3.76
Bulgaria	2	3	5
Cyprus	0.8	0.1	0.9
Czech Republic	1	4.5	5.5
Iceland	0.2	0.8	1
Spain	6	3	9
UK	16	45	61[2]

[1] All figures are in full-time equivalents (FTE).

[2] JANET(UK) appears to have such a large NOC staff because the number includes the NOC's staff at the 16 MANs connected to JANET.

Table 3.2.2 – NOC staff, other countries

Non EU/EFTA countries	NOC staff employed by NREN in-house	NOC staff outsourced by NREN	Total NOC staff
NRENs directly employing NOC staff – 67% of the 15 NREN respondents			
Azerbaijan	12		12
Croatia	3		3
Georgia	3		3
Jordan	17		17
Macedonia, FYRo	2		2
Morocco	4		4
Russia	2		2
Serbia	6		6
Taiwan	26		26
Turkey	6		6
NRENs outsourcing NOC staff – 7% of the 15 NREN respondents			
Israel		1	1
NRENs using a combination of in-house/outsourced staff – 27% of the 15 NREN respondents			
Australia	6	0.5	6.5
Belarus	4	1	5
Moldova	2	1	3
Montenegro	9	2	11

3.3 PoPs and routing

The number of PoPs (points of presence) on a network is one indicator of the amount of resources that the NREN needs in order to maintain the network. A PoP is defined as a point on the NREN backbone which can connect client networks or aggregations of client networks, such as MANs or external networks.

There are various ways in which a network can be built, leading to different requirements in terms of the number of PoPs. Thus, Germany's (i.e. DFN's) network – with 54 optical PoPs and 54 locations where core routing is undertaken – has an architecture that is quite different to that of the Netherlands (i.e. SURFnet) – with 308 optical PoPs but only two locations where core routing is undertaken. (For further information on optical PoPs, see Section 5.4 below.) For this reason, statistics indicating the total number of PoPs in Europe are not as meaningful as might be imagined.

In Table 3.3.1 (below), NRENs in which all PoPs are optical and offer Layer 3 routing are highlighted in colour.

Table 3.3.1 – Numbers of PoPs

Country	NREN	No. of PoPs	No. of locations where core routing is undertaken	No. of locations offering optical PoPs	No. of PoPs where L3 routing is provided
EU/EFTA countries					
Austria	ACOnet	20	–	20	12
Belgium	BELNET	20	2	22	20
Bulgaria	BREN	14	1	0	–
Cyprus	CYNET	2	2	0	0
Czech Republic	CESNET	41	15	19	13
Denmark	UNI•C	14	5	14	5
Estonia	EENet	16	16	4	4
Finland	Funet	57	6	57	11
France	RENATER	60	3		45

Table 3.3.1 – continued

Country	NREN	No. of PoPs	No. of locations where core routing is undertaken	No. of locations offering optical PoPs	No. of PoPs where L3 routing is provided
EU/EFTA countries					
Germany	DFN	54	54	54	54
Greece	GRNET	40	9	9	9
Hungary	NIIF/HUNGARNET	43	43	43	43
Iceland	RHnet	13	13	0	0
Ireland	HEAnet	16	2	13	2
Italy	GARR	53	14	15	11
Latvia	SigmaNet 3	5	1	1	1
Lithuania	LITNET	48	5	6	5
Luxembourg	RESTENA	13	13	6	6
Malta	UoM/RicerkaNet	2	2	–	–
Netherlands	SURFnet	308	2	308	2
Norway	UNINETT	51	51	28	28
Poland	PIONIER	39	3	86	3
Portugal	FCCN	2	2	15	2
Romania	RoEduNet	42	8	35	10
Slovakia	SANET	31	20	31	20
Slovenia	ARNES	42	42	42	42
Spain	RedIRIS	20	18	0	
Sweden	SUNET	23	6	21	6
Switzerland	SWITCH	34	34	34	34
United Kingdom	JANET(UK)	18	8	46	18
Other European/Mediterranean countries					
Algeria	ARN/CERIST	4	4	4	
Azerbaijan	AzScienceNet	2	3	3	3
Belarus	BASNET	27	5	27	5
Croatia	CARNet	769	120	603	603

Table 3.3.1 – continued

Country	NREN	No. of PoPs	No. of locations where core routing is undertaken	No. of locations offering optical PoPs	No. of PoPs where L3 routing is provided
EU/EFTA countries					
Georgia	GRENA	13	12	9	9
Israel	IUCC	2	9	0	0
Macedonia, FYRo	MARNet	1	1	1	1
Moldova	RENAM	42	2	20	5
Montenegro	MREN	13	1	28	28
Morocco	MARWAN	15	0	12	15
Russian Federation	e-ARENA	15	15	4	–
Serbia	AMRES	13	13	6	6
Turkey	ULAKBIM	3	3	0	–

With the *Compendium* questionnaire, we collected data on the number of NREN-managed circuits that carry production traffic. This is one indicator of the overall size and complexity of a network. We also collected data on the number of managed sites, i.e. where the NREN manages routing or switching equipment. Information from both these data sets is presented in Table 3.3.2 (right).

As Table 3.3.2 shows, NRENs differ considerably in these respects. The differences in the number of managed circuits reflect differences in network architecture and number of clients connected. The differences in the number of managed sites are related both to the categories of users that are connected and to the way in which they are connected; for example, some NRENs may manage intra-client circuits as part of a MAN or regional network, in addition to the main access circuits connecting institutions as a whole to the national network. In Table 3.2.2 (right), increases in the number of managed sites by at least 25% are highlighted in colour.

Table 3.3.2 – Managed circuits and sites

Country	NREN	No. of client institutions	No. of managed circuits	No. of managed sites 2010	No. of managed sites 2009	No. of managed sites 2008
EU/EFTA countries						
Austria	ACOnet	104	24	21	21	15
Belgium	BELNET	199	148	20	21	21
Bulgaria	BREN	2,049	30	14	30	14
Cyprus	CYNET	12	0	2	2	3
Czech Republic	CESNET	306	62	41	40	39
Denmark	UNI•C	38	22	13	20	20
Estonia	EENet	234	20	16	16	16
Finland	Funet	74	145	27	25	18
France	RENATER	1,256	–	60	50	50
Germany	DFN	–	134	54	55	54
Greece	GRNET	10,235	490	100	79	79
Hungary	NIIF/ HUNGARNET	461	48	43	43	42
Iceland	RHnet	22	18	13	14	14
Ireland	HEAnet	4,059	569	120	63	12
Italy	GARR	391	81	53	47	42
Latvia	SigmaNet 3	47	40	5	5	10
Lithuania	LITNET	1,205	200	458	458	200
Luxembourg	RESTENA	245	80	57	57	57
Malta	UoM/ RicerkaNet	6	17	4	4	2
Netherlands	SURFnet	140	336	308	308	256
Norway	UNINETT	165	245	385	385	385
Poland	PIONIER	781	38	30	25	25
Portugal	FCCN	69	85	30	30	9
Romania	RoEduNet	685	55	80	80	40
Slovakia	SANET	371	35	31	26	26
Slovenia	ARNES	979	1,341	1,108	946	1,190

Table 3.3.2 – continued

Country	NREN	No. of client institutions	No. of managed circuits	No. of managed sites 2010	No. of managed sites 2009	No. of managed sites 2008
EU/EFTA countries						
Spain	RedIRIS	375	67	20	20	20
Sweden	SUNET	82	210	6	5	3
Switzerland	SWITCH	59	50	41	34	35
United Kingdom	JANET(UK)	829	1,009	551	504	742
TOTAL		**25,523**	**5,611**	**3,711**	**3,413**	**3,439**
Other European and Mediterranean countries						
Algeria	ARN/CERIST	–	3	4	4	–
Azerbaijan	AzScienceNet	41	4	5	–	–
Belarus	BASNET	100	52	49	42	38
Croatia	CARNet	1,546	769	769	677	613
Georgia	GRENA	1,271	10	13	13	13
Israel	IUCC	16	16	10	10	10
Jordan	JUNET	12	–	–	–	–
Macedonia	MARNet	75	25	1	–	–
Moldova	RENAM	73	50	58	58	51
Montenegro	MREN	25	31	31	25	31
Morocco	MARWAN	102	34	1	1	–
Russian Federation	e-ARENA	490	–	56	56	12
Serbia	AMRES	245	80	57	54	52
Turkey	ULAKBIM	840	160	3	3	3
TOTAL		**4,8367**	**1,234**	**1,057**	**943**	**823**

3.4 GÉANT backbone and core capacity on the 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.

Of course, the evolution in core capacities at the nation level should be matched by a similar evolution in the international backbone. The evolution of the pan-European GÉANT backbone, which was inaugurated in November 2000, is illustrated by Maps 3.4.1 (2001 topology) and 3.4.2 (2010 topology) below. The maps show not only that the number of 10 Gb/s links has increased but also that many of these links are now over dark fibre, which makes it relatively easy to increase the capacity to match demand. In 2001, the smallest links had a capacity of 34 Mb/s; by 2010, this had risen to 155 Mb/s. Furthermore, in 2010, the GÉANT backbone connected several countries that were not yet connected in 2001.

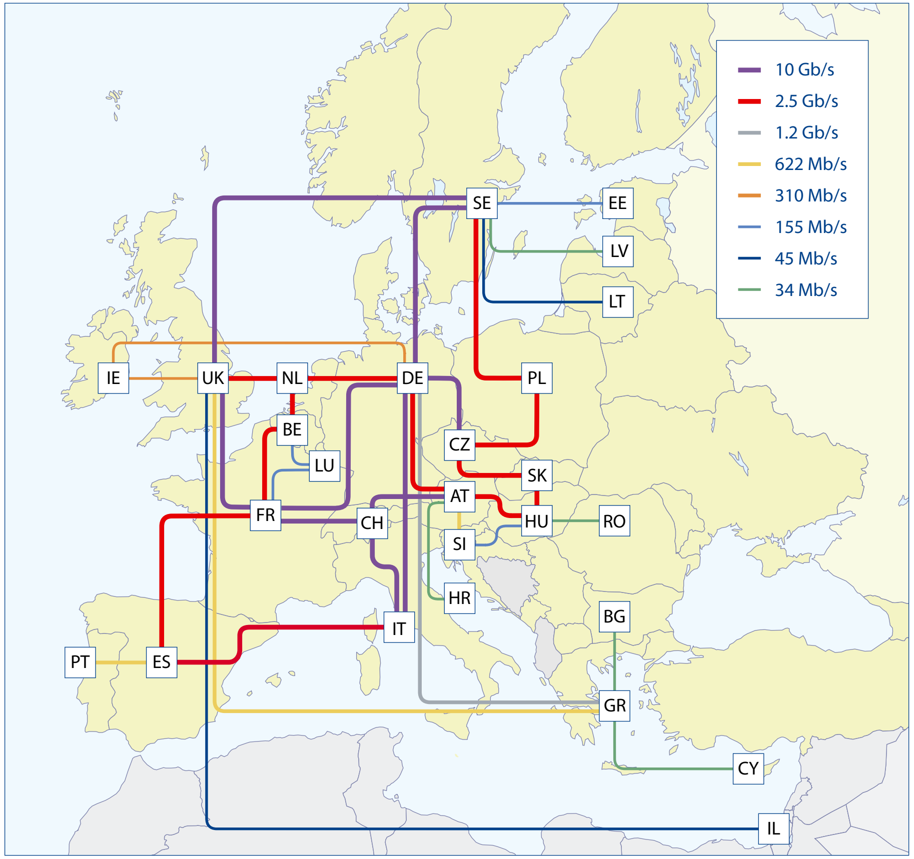
Over this same period, GÉANT's intercontinental links have also expanded. It should be noted that, as shown in Section 3.6 (below), many NRENs have external links in addition to those to GÉANT.

How network capacities evolved in the period 2006-2010 is represented by Graphs 3.4.3 (for the EU/EFTA countries) and 3.4.4 (for the other countries). In addition, as Section 3.6 shows, many NRENs now have several point-to-point circuits and lightpaths, which offer additional capacity that is not usually included in normal traffic statistics.

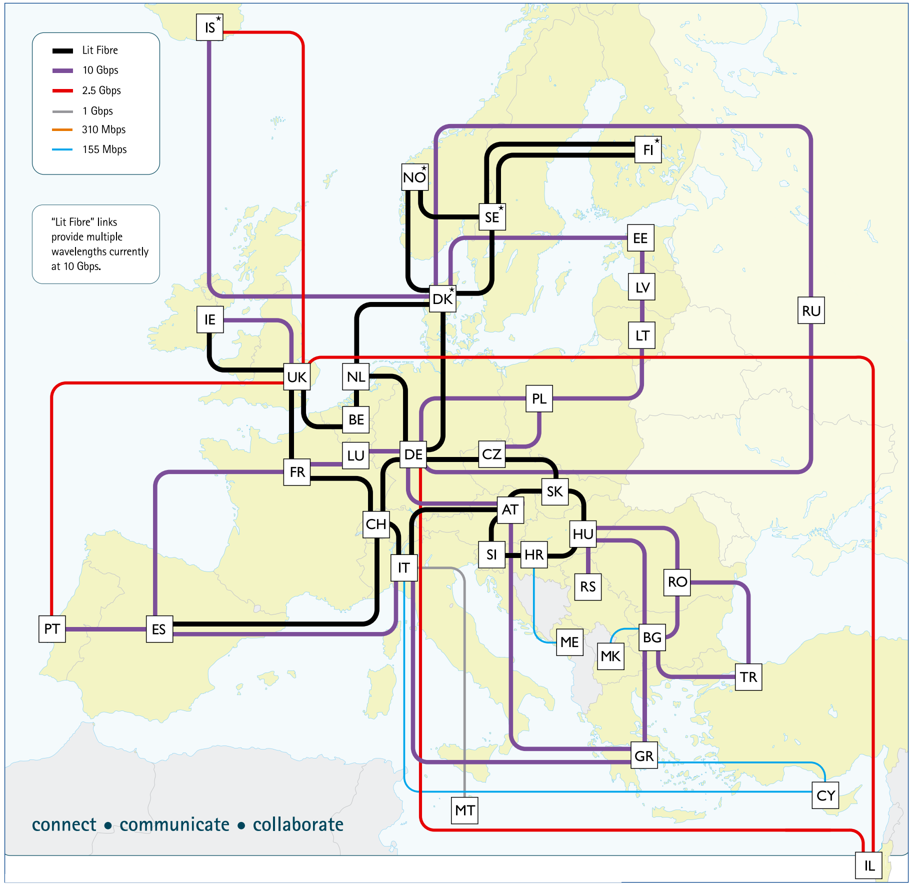
In most EU/EFTA countries, the typical core capacity is now 10 Gb/s, though some NRENs have reached 20 or even 40 Gb/s. 10 Gb/s is also the median capacity, up from 2.5 Gb/s in 2006. As many NRENs in this region have access to dark fibre (see Section 3.7), which is potentially able to handle high capacities, they can increase capacity easily and economically whenever required. In 2006, the typical capacity was 2.5 Gb/s and the transition to dark fibre had not yet taken place.

In the non-EU/EFTA countries, the trend that was visible last year continues: they have profited from the introduction of affordable Gigabit Ethernet technology. Network capacity is not growing linearly. Comparing the growth in core capacity with the growth in overall traffic – documented in Section 4.3 – reveals that, roughly speaking, these two trends keep pace with each other. In the period 2006-2010, average growth of core capacity in the EU/EFTA countries was 29%. In the same period, average growth of traffic on the GÉANT backbone was 32%.

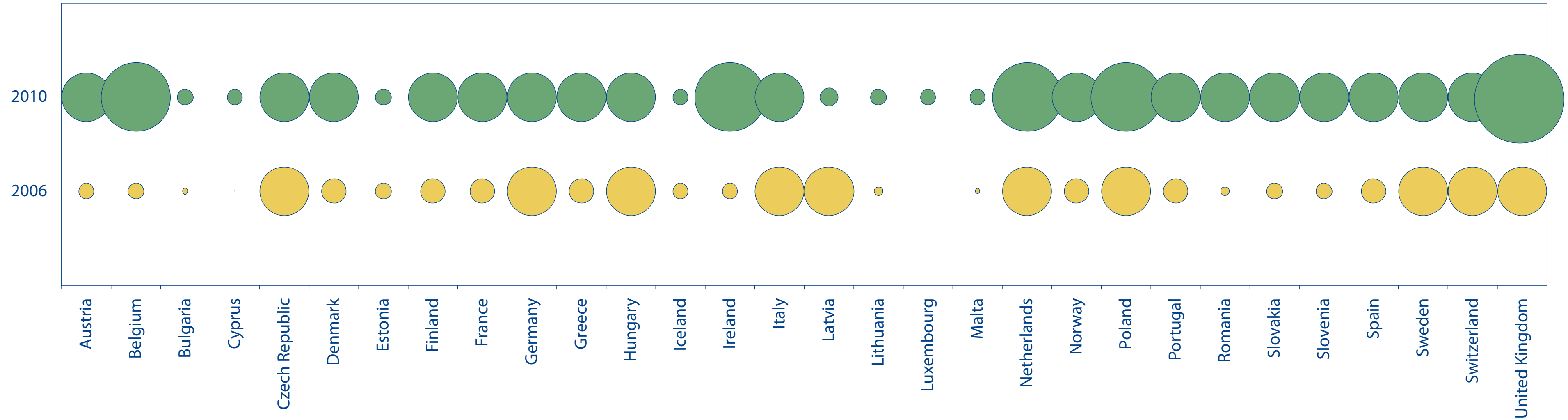
Map 3.4.1 – GÉANT topology, 2001



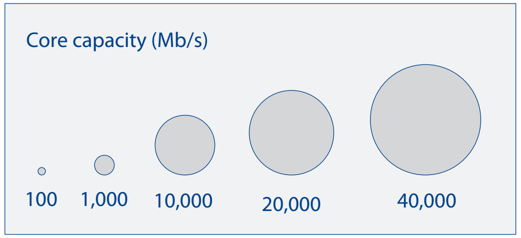
Map 3.4.2 – GÉANT topology, 2010



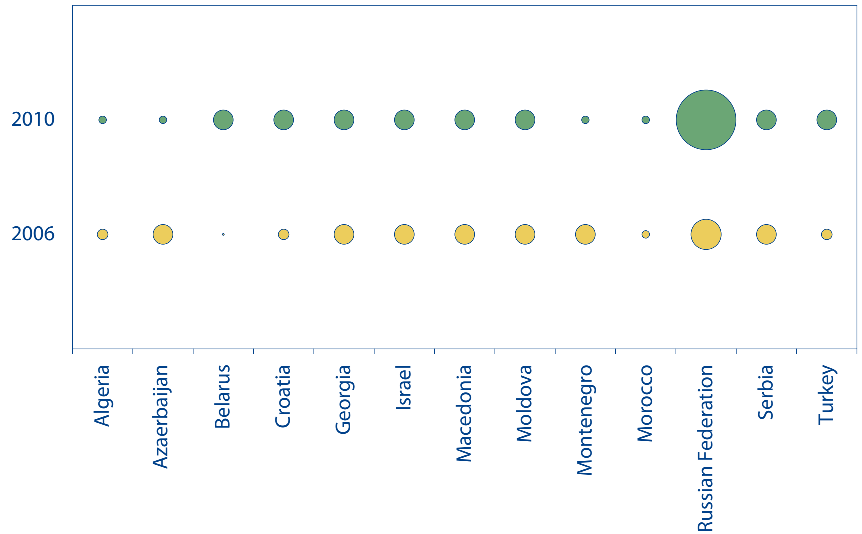
Graph 3.4.3 – Core capacity on the networks, 2006-2010, EU/EFTA countries



Legend for graphs 3.4.3 and 3.4.4



Graph 3.4.4 – Core capacity on the networks, 2006-2010, other countries



3.5 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 2010.

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.

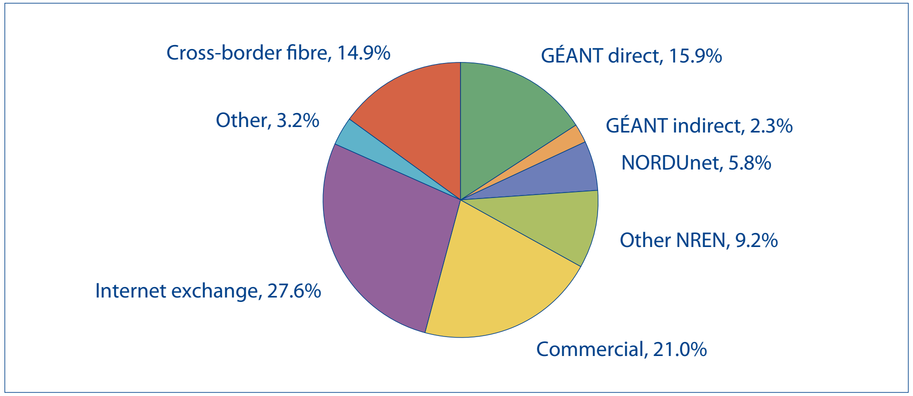
In general, connections to GÉANT and to other NRENs carry research and education traffic, while peerings and other connections convey traffic to and from the general Internet. Research and education traffic may be highly specialised data and is often transmitted in huge volumes within very short time-frames; 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 Graphs 3.5.1 to 3.5.4, these two distinct categories of traffic are combined.

In general, this means that connections not only to the European academic backbone network (i.e. GÉANT) but also to the general Internet are crucially important to NRENs. Graph 3.5.1 (right), which represents the average situation for all EU/EFTA NRENs, illustrates that connections to Internet Exchanges and to commercial Internet providers jointly account for more than 50% of the total external connectivity. The remaining 50% is divided between connections to GÉANT and NORDUnet, cross-border fibre connections (see Section 3.9) and direct NREN-to-NREN connections.

Graph 3.5.1 – Capacity of NREN external connections, EU/EFTA countries



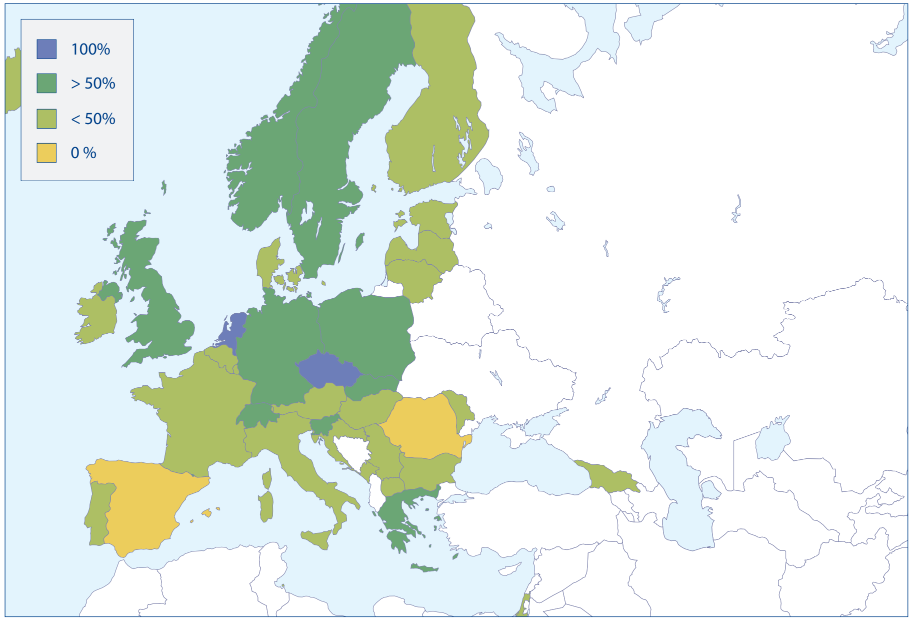
It should be noted that there are large differences between NRENs, as was illustrated in greater detail in the 2009 edition of the *Compendium*. Also note that this graph does not include the additional international point-to-point circuits (other than the IP circuits already covered) that some EU/EFTA NRENs have, mostly for specific projects.

3.6 Dark fibre

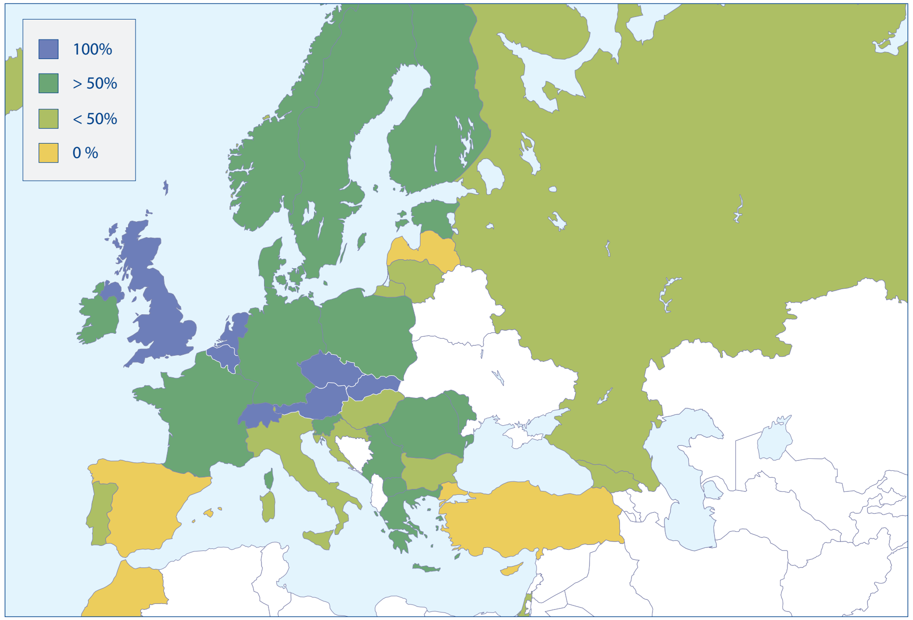
Some NRENs own, have indefeasible rights of use (IRUs)[3] to, or lease dark fibre, and can therefore decide what technology and speeds to use on it. The NRENs covered by this edition of the *Compendium* were asked whether they currently own, or have IRUs to, dark fibre, or plan to acquire it within the coming two years. The NRENs were also asked to state approximately what percentage of their backbone is accounted for by dark fibre.

Maps 3.6.1 and 3.6.2[4] (below) illustrate the rapid developments in dark fibre in recent years. Many, though not all, NRENs predict a further increase in the percentage of their network accounted for by dark fibre by 2012. It should be noted that dark fibres may not always be the best or the cheapest solution for NRENs. When current IRU contracts expire, conditions may have changed and it may be appropriate for some NRENs to consider other options as well.

Map 3.6.1 – Dark fibre on NREN backbones, 2006



Map 3.6.2 – Dark fibre on NREN backbones, 2010



Note that for 2010, 2009 data has been used for some countries that did not respond this year.

[3] 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, these two categories have been combined in this section.

[4] Concept developed by RedIRIS, Spain.

3.7 Cross-border dark fibre

A number of countries have 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" [5]. Table 3.7.1 (below) provides an overview of current and planned cross-border dark fibre links. Links which entered service since the 2009 issue of the *Compendium* are highlighted in colour.

Map 3.7.2 presents the same information schematically. Note that the links shown do not correspond to the actual geographical routes.

As Table 3.7.1 and Map 3.7.2 reveal, the majority of the cross-border links are in central Europe. As indicated in Section 3.5, cross-border dark fibre is becoming an increasingly important component of the total external connection capacity of many NRENs.

Table 3.7.1 – Cross-border dark fibre

NREN to NREN	Current	Start date
ACOnet - SANET	Vienna, Austria - Bratislava, Slovakia	Aug. 2002
CESNET - PIONIER	Ostrava, Czech Republic - Cieszyn, Poland	2005
ACOnet - CESNET	Brno, Czech Republic - Vienna, Austria	2006
AMRES - NIIF/HUNGARNET	Subotica, Serbia - Szeged, Hungary	2006
GARR - SWITCH	Milano, Italy - Manno, Switzerland	2006
RESTENA – RENATER	Nancy, France - Esch/Alzette, Luxembourg	2009
PIONIER-BASNET	Kuźnica Białostocka - Grodno	2010
RENAM-RoEduNET	Chisinau, Moldova - Iasi, Romania	2010
DFN - PIONIER	Gubin, Poland - Guben, Germany	May-06
DFN - SURFnet	Aachen, Germany - Maastricht, Netherlands	2007 Q2
DFN - SURFnet	Hamburg, Germany - Amsterdam, Netherlands	2007 Q2
BELNET-SURFnet		2009 Q4
FCCN-RedIRIS	Lisbon - Badajoz	2009 Q4

Table 3.7.1 – continued

NREN to NREN	Current	Start date
CESNET - SANET	Brno, Czech Republic - Bratislava, Slovakia	Apr. 2003
PIONIER - URAN	Hrebenne, Poland - Rava Ruska, Ukraine	Dec. 2008
DFN - RENATER	Kehl, Germany - Strasbourg, France	Jun. 2006
DFN - SWITCH	Lorrach, Germany (BelWu) - Basel, Switzerland	Jun. 2006
HEAnet - JANET(UK)	Dublin, Ireland - Belfast, UK	Nov. 2006
e-Arena-FUNET	St.Petersburg - Helsinki	Nov. 2009
DFN – PIONIER	Frankfurt (Oder), Germany - Słubice, Poland	Oct. 2007
PIONIER - SANET	Zwardoń-Skalite , Poland - Žilina, Slovakia	Oct. 2007
DFN - SURFnet	Muenster, Germany - Enschede, Netherlands	
NREN to NREN	**Planned**	**Start date**
ARNES - GARR	Sežana - Trieste	
BASNET – PIONIER	Kuznica, Poland - Grodno, Belarus	2011
BELNET – RESTENA	Arlon - Esch	2011
BELNET-SURFnet	Hasselt - Maastricht	2011 Q1
FCCN - RedIRIS	Porto, Portugal - Vigo, Spain	2011 Q3
GARR - SWITCH	Milano, Italy - Manno, Switzerland	2011 Q1
GRNET – Bulgaria	Athens, Greece - Sofia, Bulgaria	2011
LITNET - PIONIER	Kaunas, Lithuania - Poznan, Poland	2011
PIONIER-DFN	Kołbaskowo, Poland - Prenzlau, Germany	2012
PIONIER – RBNet/RUNnet	Granowo, Poland - Mamonovo, Russia	2011
PIONIER -LITNET	Ogrodniki - Kauna	2010
RESTENA-RENATER	Esch - Longwy	2011
RESTENA-RENATER	Esch - Thionville	End 2010
SUNET-UNINETT	Kiruna - Narvik	Nov. 2010

[3] *Networks for Knowledge and Innovation: A strategic study of European research and education networking*, SERENATE Summary Report, IST-2001-34925, p. 28, www.serenate.org/publications/d21-serenate.pdf

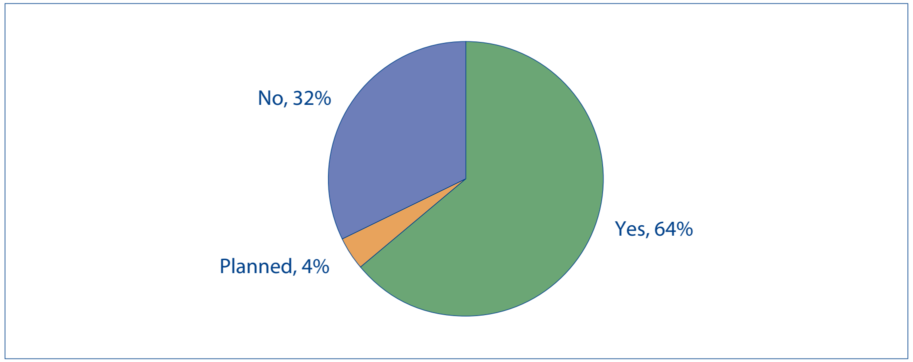
Map 3.7.2 – Cross-border dark fibre

3.8 Lambdas

Eighteen of the EU/EFTA NRENs currently offer dedicated wavelengths (lambdas) to their customers. One more is planning to do this (see Graph 3.8.1 below). In addition, at the pan-European level, there is the GÉANT lambda service, which provides private, transparent 10 Gbps wavelengths between any two GÉANT NRENs connected to the GÉANT dark fibre cloud.

Comparing the European data with the data from other continents clearly shows that Europe and European NRENs have a leading position in this field.

Graph 3.8.1 – Lambda provisioning, EU/EFTA countries



In most cases, the number of lambdas has increased since last year; however, overall, the numbers are still low. The highest number of lambdas (64) was provisioned by CESNET.

As shown by Table 3.8.2 (right), there is large variety not only in the charging method for lambdas (if there is a charge) but also in the procurement times and mechanisms.

Table 3.8.2 – Lambda numbers, charging and provisioning times

Country	NREN	Number	Charging	Provisioning time
Europe	GÉANT lambda service	22	yes	10 weeks
Belgium	BELNET	4	yes	1 day
Czech Republic	CESNET	64	no, but planned	3 months
Denmark	UNI•C	10	yes	3 month
Finland	Funet	30	Yes. 1 Gb/s costs €5000/year and 10 Gb/s 10000e/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.
France	RENATER		no	3 months
Germany	DFN	44	yes	2 months
Greece	GRNET	11 GRNET clients are using dedicated lambdas for accessing GRNET L3/2 core equipment. For these clients, the GRNET Lightpath Service is also possible, which includes establishing a wavelength path interconnecting two clients.	no	Circuit installation is performed by specialized DWDM vendor's personnel. Assuming that spare transponder cards are available, circuit provisioning is performed within one week after the GRNET request.
Hungary	NIIF/HUNGARNET	1	no	
Ireland	HEAnet	4	There is a separate charge in the form of one-off costs associated with procuring the components required to provision that lambda. In practical terms, this is a pair of transponders at the end points of the circuit. There are no extra recurring charges.	4 to 6 weeks, which is the time associated with the vendor sourcing the components required.
Italy	GARR	6		3 month on average
Lithuania	LITNET	2	no	1-2 weeks after all equipment is supplied. Up to 6 months if public procurement is required.
Luxembourg	RESTENA	1	no	Weeks
Netherlands	SURFnet	2	yes	Between 4 and 16 weeks, depending on equipment ordering and installation
Norway	UNINETT	1	yes	4 to 8 weeks
Portugal	FCCN	6	no, not yet.	3 days
Sweden	SUNET	around 20	yes	-
Switzerland	SWITCH	44	yes, based on a full-cost calculation	EoMPLS circuit, a few days; dedicated lambda, 2 months.
United Kingdom	JANET(UK)	6	10Gb/s lightpaths are chargeable; 1Gb/s lightpaths are free of charge.	40 working days.

Table 3.8.3 gives an overview of the interfaces that are provided by NRENs. Clearly, GigE and 10 GigE are dominant.

Table 3.8.3 – Lambda interfaces (as percentages of total)

Country	NREN	GigE	10GigE	STM-16	STM-64	Other
EU/EFTA countries						
Belgium	BELNET	10	90			
Denmark	UNI•C	50	50			
Czech Republic	CESNET	33	67			
Finland	Funet	60	20	20		
France	RENATER		100			
Germany	DFN	61	34		5	
Greece	GRNET	50	50			
Ireland	HEAnet		100			
Italy	GARR	77	8	11		4
Lithuania	LITNET	50	50			
Luxembourg	RESTENA		100			
Moldova	RENAM	60				40
Netherlands	SURFnet		50		50	
Norway	UNINETT	100				
Portugal	FCCN		17			
Switzerland	SWITCH	84	8			8
UK	JANET(UK)	90	10			
Other countries						
Australia	AARNet	70	20	10		
USA	Internet2	20	80			

3.9 Major expected network developments

The NRENs covered by this edition of the *Compendium* were requested to outline major initiatives relating to development of their underlying network that they expect to realise within the next two to five years. Several NRENs that did not respond to this question did provide more general answers; these are listed in Section 1.4.

Table 3.9.2 (right) provides a general insight into expected major developments of networks in the various countries in Europe and other continents. (For information on other kinds of developments, see Table 1.4.1.) The expected developments reported by NRENs include:

- In more developed regions of the world, dark fibre networks are already in place and are being upgraded and extended to 10 Gb/s or multiples thereof. Some NRENs are already preparing for 100 Gb/s. DWDM is reported by a number of NRENs;
- Several NRENs are introducing a dual (or hybrid) network structure: while continuing to provide 'traditional' connections, i.e. based on the Internet Protocol, they are planning to provide dedicated light paths to high-end users, allowing them to use whatever protocols or methods they want to transmit data;
- For several EU neighbour countries, increased possibilities for international connectivity are acting as a catalyst for developments at the national level;
- Some NRENs in less developed regions are starting to acquire dark fibre. This seems to be the way forward if they want to make rapid progress;
- In many developing countries, one of the greatest challenges is to extend the NREN network beyond the capital.

Figure 3.9.1 (right) illustrates the expected developments in the form of a Wordle chart. This clearly shows that NRENs are concerned largely with fixed infrastructure and fixed clients. Mobile broadband seems to be largely beyond current NREN development plans, as indicated in Section 2.6.

Figure 3.9.1 – Major expected network developments as a Wordle chart

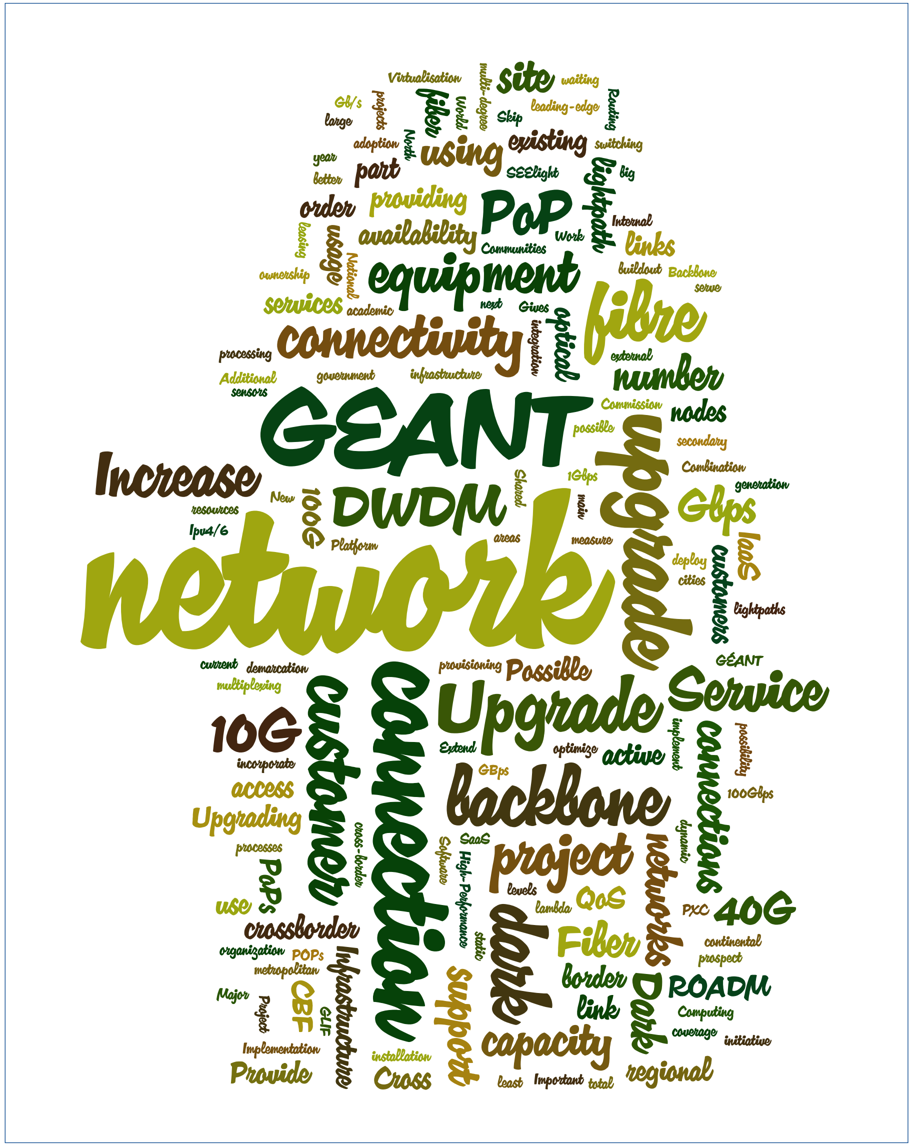


Table 3.9.2 – Major expected network developments

Country	NREN	Developments	Time frame	Certainty
EU/EFTA countries				
Belgium	BELNET	BELNET will put the demarcation point at the customer site by entering the customer site with both connectivity and active equipment (CPE).	2011	Quite certain
		BELNET will use the active equipment at the customer site to measure and report Service Level Parameters.	2011	Quite certain
		BELNET wants to deploy smaller optical rings by connecting R&D customers around big cities.	2012	Likely
		BELNET will implement QoS on: - the backbone; - the access network between the customer and the BELNET PoP.	2011	Quite certain
Bulgaria	BREN	SEELIGHT Project, which presents the prospect of providing cross-border dark-fibre links and dark fibre to at least part of the national backbone.	1 yr	
Cyprus	CYNET	Upgrade the GÉANT connection to 2.5 Gb/s.	2 yrs	Quite certain
Denmark	UNI•C	10 → 100G Core	5 yrs	Quite certain
		Private 10G wavelength	3 yrs	Quite certain
Finland	Funet	Extend the coverage of the DWDM optical network and upgrade the existing multi-degree DWDM nodes to WSS (PXC).	2 yrs	Quite certain
		Expand the availability and usage of backup customer connections. Provide better availability of 10 Gbps connections to the customers.	2 yrs	Quite certain
		Introduce dynamic lightpath services to complement the current static lightpath service.	3 yrs	Quite certain

Table 3.9.2 – continued

Country	NREN	Developments	Time frame	Certainty
EU/EFTA countries				
Germany	DFN	100 Gb/s, flexible Lambda Switching	2-3 yrs	Uncertain
Greece	GRNET	40Gb/s Internal links	1 yr	Quite certain
		Cross-border fibre to Bulgaria	1 yr	Quite certain
		End-to-end lightpaths using provisioning tools.	2 yrs	Quite certain
		Cross-border fibre to FYRo Macedonia, Albania and Turkey.	3 yrs	Uncertain
Hungary	NIIF/ HUNGARNET	Major network developments within the frameworks of our NDP projects.	2010-2011	Quite certain
Iceland	RHnet	10G buildout in Reykjavik	3 year	Likely
		1Gb/s connection to Akureyri	2 years	Likely
Ireland	HEAnet	1) Upgrading of existing DWDM network to ROADM.	2 years	Quite certain
		2) Possible support of WiMAX networks on campus networks.	1 - 4 years	Uncertain
		3) Possible connection of large number of sensors to network.	1 - 4 years	Uncertain
		4) Skip 40G, using n x 10G while waiting for 100G.	1 - 2 years	Quite certain
		5) Virtualisation of network resources using IaaS (Infrastructure as a Service) framework. This can incorporate BoD (Bandwidth on Demand).	1 - 4 years	Uncertain
		6) Work on the integration of virtualisation of network and services (Combination of IaaS, PaaS (Platform) and SaaS (Software)).	1 - 4 years	Likely
		7) A three-stream strategy on IPv4/6 environment: a. IPv4 depletion processes (1 year / ongoing); b. Fully standalone IPv6 network (1 - 2 years).	1 - 5 years	Quite certain

Table 3.9.2 – continued

Country	NREN	Developments	Time frame	Certainty
EU/EFTA countries				
		8) Service resilience (path, PoP, power and equipment) for clients. (Largely completed)	1 year	Quite certain
Italy	GARR	Deployment of next generation national network (GARR-X) - ownership of dark fibre at backbone and access levels; - the adoption of leading-edge multiplexing technologies (DWDM), in order to optimize their usage; - support of 40G, 100G.	2	Quite certain
Latvia	SigmaNet 3	GÉANT connection upgrade.	2	Likely
		Dark fibre to Estonia, Lithuania.	4	Uncertain
Lithuania	LITNET	Shared infrastructure use with the government enterprise "Infostruktura" will create a possibility to upgrade the Northern part of the ring to 10G.	2011	Quite certain
		CBF connection with Poland	2012	Uncertain
Malta	UoM/RicerkaNet	Connectivity to GÉANT at 1Gb/s	0.75	Quite certain
Norway	UNINETT	Upgrade to lambda capability between mainland and Longyearbyen (Svalbard). 2*1400 km.	2012	Quite certain
Poland	PIONIER	Increase capacity to GÉANT Plus	2011	Likely
		Increase capacity to DANTE World Service.	2011	Likely
		Establish connectivity to GLIF and Nordunet.	2010	Quite certain
Portugal	FCCN	The major initiative is the enlargement of the dark fibre footprint to those institutions in the interior of continental Portugal.	3	Likely
		The conclusion of the second CBF link to Spain, in the North.	1	Quite certain

Table 3.9.2 – continued

Country	NREN	Developments	Time frame	Certainty
EU/EFTA countries				
Romania	RoEduNet	Core upgrade to 40G - 100Gb/s.	1	Quite certain
		Cross-border with Serbia, Hungary, Bulgaria.	2	Quite certain
Slovakia	SANET	Increase the number of PoPs to a total of 79 in order to serve secondary schools in all regional centres.	4	Quite certain
		100-Gigabit Ethernet in the backbone.	5	Quite certain
Spain	RedIRIS	New RedIRIS backbone network based on dark fibre deployment and ROADM technology. More than 50 add/drop PoPs.	< 1 year	Quite certain
		Important cut (approx. 50%) in the number of PoPs providing L3 Routing.	< 1 year	Quite certain
		Provide wavelengths to the regional networks to support their own network and project requirements.	< 1 year	Quite certain
Other countries				
Algeria	ARN/CERIST	Direct to GÉANT2 - upgrade to STM4.	2	Likely
Belarus	BASNET	Increase the capacity of the link to PIONIER to 1 Gb/s.	2010	Quite certain
Croatia	CARNet	QoS	2011	Quite certain
		Optical switching	2012	Likely
Georgia	GRENA	European Commission FP7 project High-Performance Computing Infrastructure for South East European Research Communities will upgrade connectivity to GÉANT.	2011	Quite certain
Macedonia, FYRo	MARNet	SEELight project	2011	Likely
		Additional 155 Mb/s	2011	Quite certain

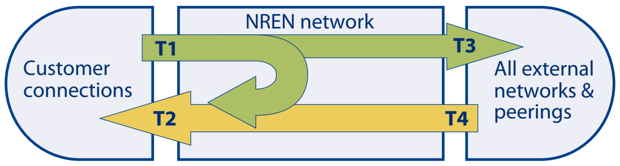
Table 3.9.2 – continued

Country	NREN	Developments	Time frame	Certainty
Other countries				
Moldova	RENAM	Upgrade connectivity to GÉANT.	2011-2012	Quite certain
		Upgrading internal network equipment in Chisinau MAN for processing and distribution of 10 GBps traffic in 5 main nodes of RENAM.	2011	Quite certain
		Elaboration of detailed technical project of Eastern external connection to the Ukraine realization.	2011	Likely
		GÉANT PoP in Chisinau organization.	2012	Quite certain
		Implementation of cross-border connection to the Ukrainian NREN (and to possible GÉANT PoP in Kiev)	2012	Likely
Montenegro	MREN	Upgrade of link/capacity enhancement.	2	Quite certain
		Connection of private universities.	2	Likely
		Upgrade security level of academic network.	1	Quite certain
Serbia	AMRES	SEElight	2010	Quite certain
Turkey	ULAKBIM	Dark fibre installation on metropolitan areas.	2	Quite certain
		Dark fibre leasing for backbone connections.	2	Quite certain

4 TRAFFIC

As in questionnaires sent out 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 (below).

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 to external networks.
T4	All IP traffic to the NREN from external networks.

External traffic = all traffic to GÉANT, the commercial Internet, Internet Exchanges, etc. (i.e. composed of T3 and T4 above)

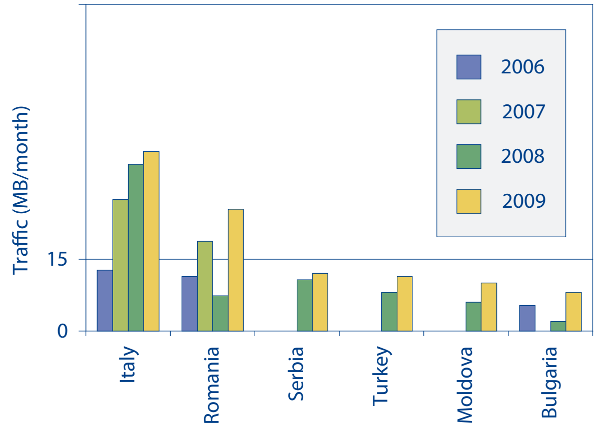
Section 4.1 gives an overview of the response from NRENs and traffic trends. Section 4.2 considers traffic in 2009, whereas Section 4.3 analyses traffic trends over the past five years. Section 4.4 gives information on NREN traffic per inhabitant. Section 4.5 looks at congestion and, finally, Section 4.6 focuses on IPv6 traffic.

4.1 Overview

Most of the NRENs that responded to the 2010 *Compendium* questionnaire reported the level of annual traffic flows at the point where they exchange traffic with external networks (T3 & T4); 78% of the NRENs also reported the level of 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 (2009 traffic, T4 > 5000 TB) and 4.2.2 (2009 traffic, T4 < 5000 TB) represent all the national responses submitted in 2010. Comparison with data from previous years reveals that traffic continues to grow. Over the past six years, the annual rate of growth has fluctuated, averaging just under 40%.

Analysis of the available traffic data reveals that there is still a substantial 'digital divide' in Europe: Bulgaria, Moldova, Serbia and Turkey lag far behind the rest of Europe. Note the marked growth in Romania, which is the result of that country's changeover to a fibre network.

Graph 4.1.1 – Traffic per inhabitant and the digital divide



IPv4 address space is likely to run out soon; some predict that this will happen as soon as in early 2011. Most Europeans NRENs have been quick to adopt IPv6 and, because they already support it, are ready to make the transition. However, many connected user groups and institutions see few compelling reasons to migrate to IPv6. As a result, IPv6 traffic remains only a small fraction of the total traffic, hovering around 1.0-1.5%.

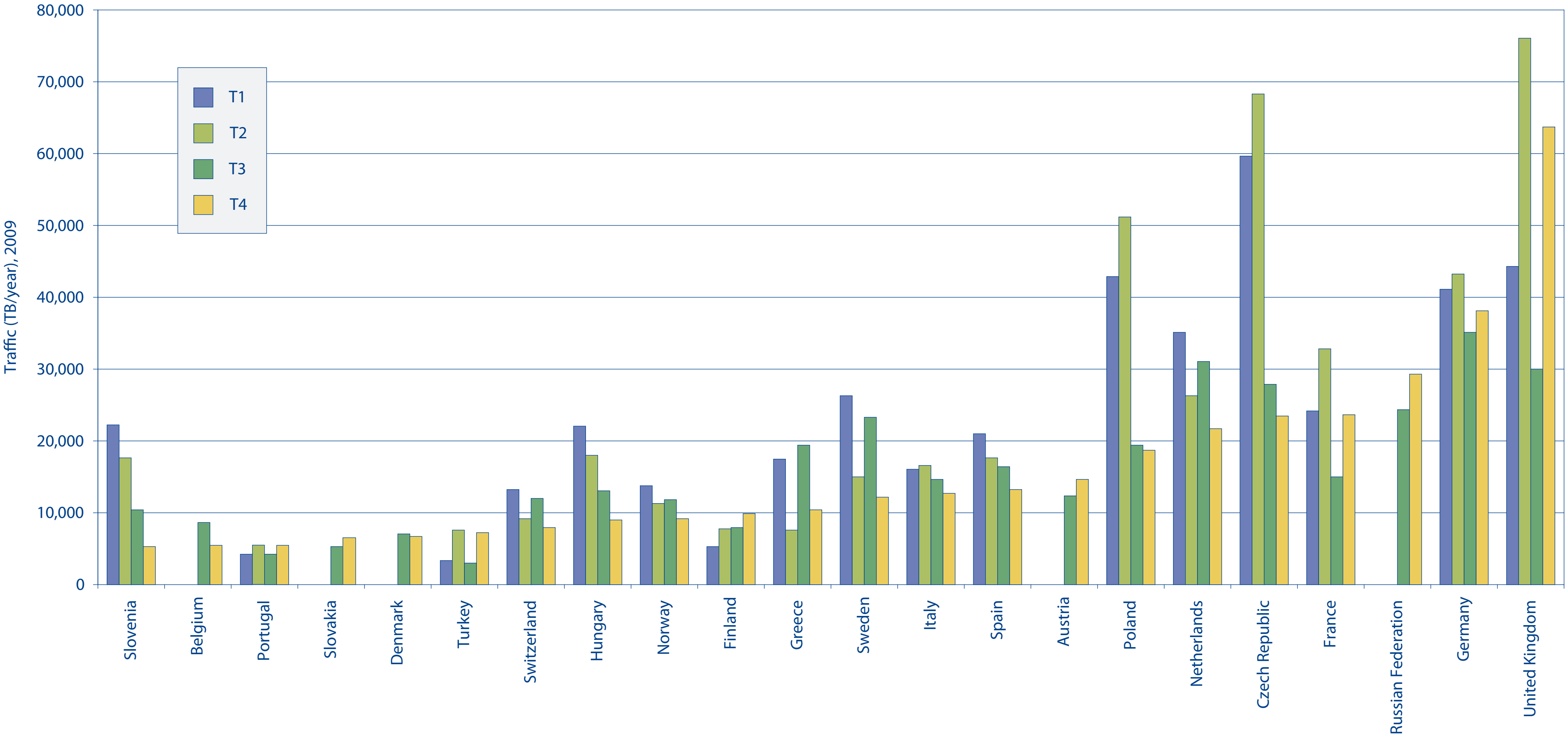
At least 18 NRENs now provide dedicated wavelengths (lambdas) to their customers. Per NREN, the number of lambdas provisioned in 2009 varies between one and 64 (CESNET). There is still a considerable growth potential in this area. There is no consensus yet on how to document the traffic on these wavelengths. Measuring the number of circuits may be an appropriate alternative way of measuring and documenting the evolution of lambda traffic.

4.2 Traffic in 2009

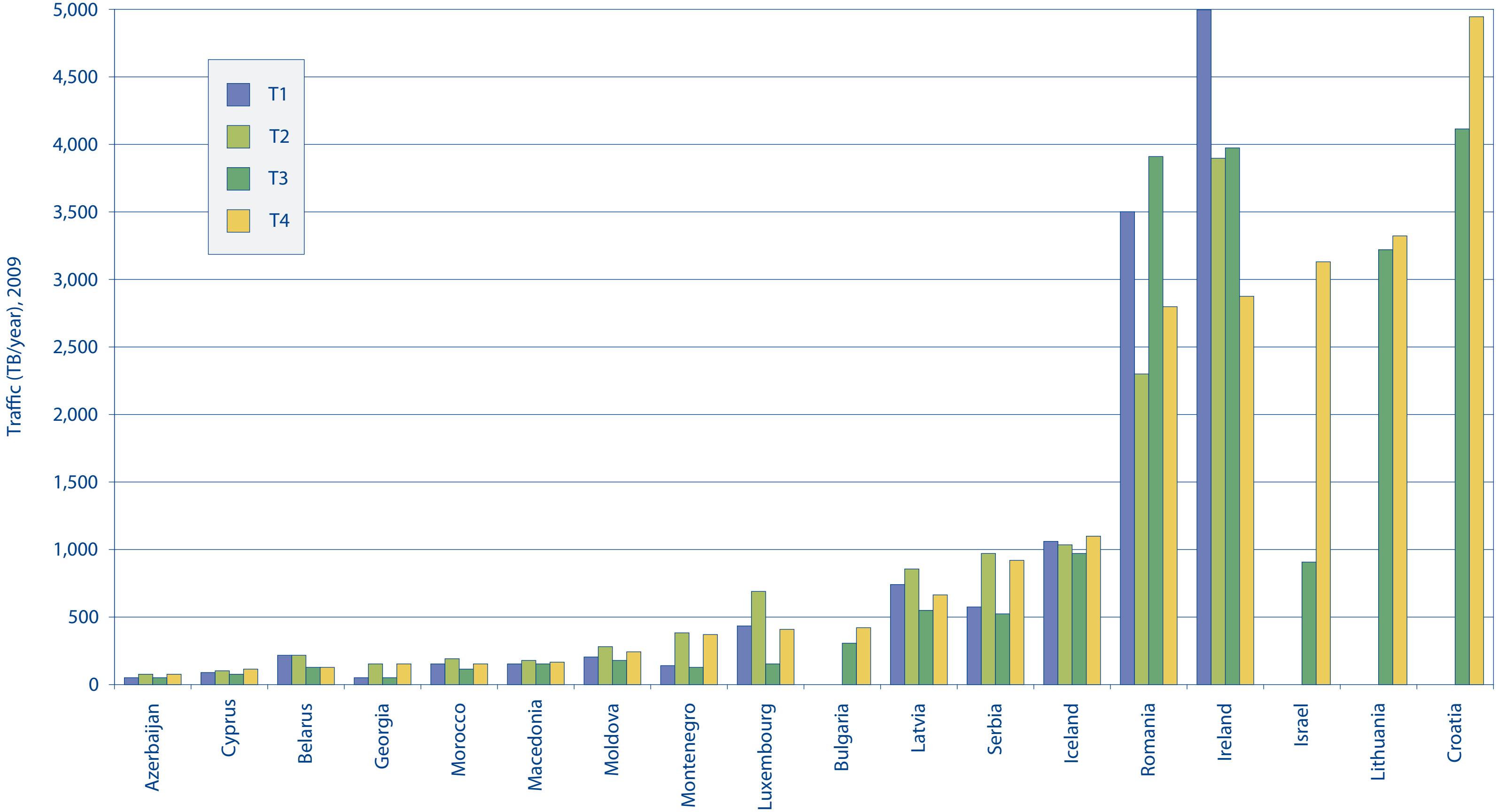
Graph 4.2.1 (below) represents the data submitted by those NRENs with T4 traffic exceeding 5,000 terabytes per year, whereas Graph 4.2.2 represents the data submitted by NRENs with lower levels of T4 traffic. These graphs clearly show how the division of total traffic between the four categories (T1 to T4) differs from NREN to NREN.

In most NRENs, the traffic sent into the NREN backbone (T1+T4) is equal or nearly equal to the traffic sent out of the NREN backbone (T2+T3). In a few NRENs, the situation is different. This may be due to traffic transiting agreements or because certain features (such as caching and multicasting) are sometimes regarded as services that belong in the backbone itself.

Graph 4.2.1 – 2009 traffic, T4 > 5000 TB



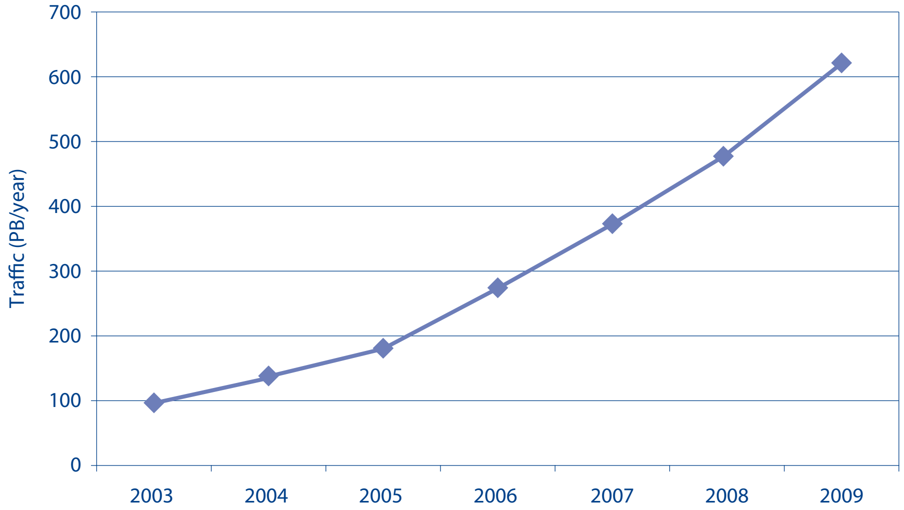
Graph 4.2.2 – 2009 traffic, T4 < 5000 TB



4.3 Traffic growth, 2003-2009

As in the 2009 edition of the *Compendium*, Graph 4.3.1 (below) shows T3+T4 values for a sample of 23 NRENs that have consistently submitted complete data for at least five successive years.

Graph 4.3.1 – NREN annual traffic flows (T3+T4), 2003-2009, n = 23 NRENs

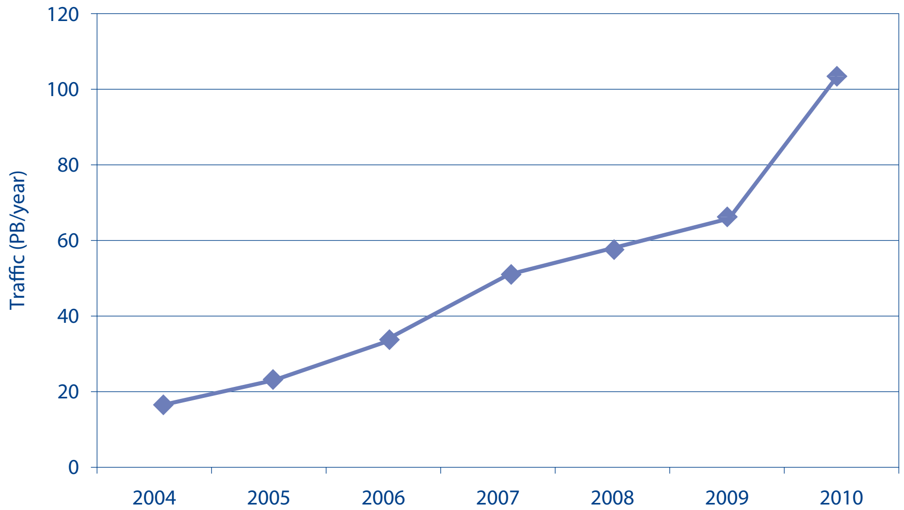


Clearly, over the six-year period (2003-2009) traffic has continued to grow at an average annual rate of just under 40%. Graph 4.3.2 shows how the growth rate has varied over the same period.

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 shown in Graph 4.3.1 (above), but with a marked acceleration of growth in 2010.

Graph 4.3.2 – NREN traffic growth rate, 2004-2009

Graph 4.3.3 – GÉANT IP traffic 2004-2009



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 steady growth rate evident in Graph 4.3.3.

It should be noted that the GÉANT network also includes p2p circuits. In the period 2007-2009, their number increased from 29 to 69. Unfortunately, we have no data on the traffic volumes in those circuits.

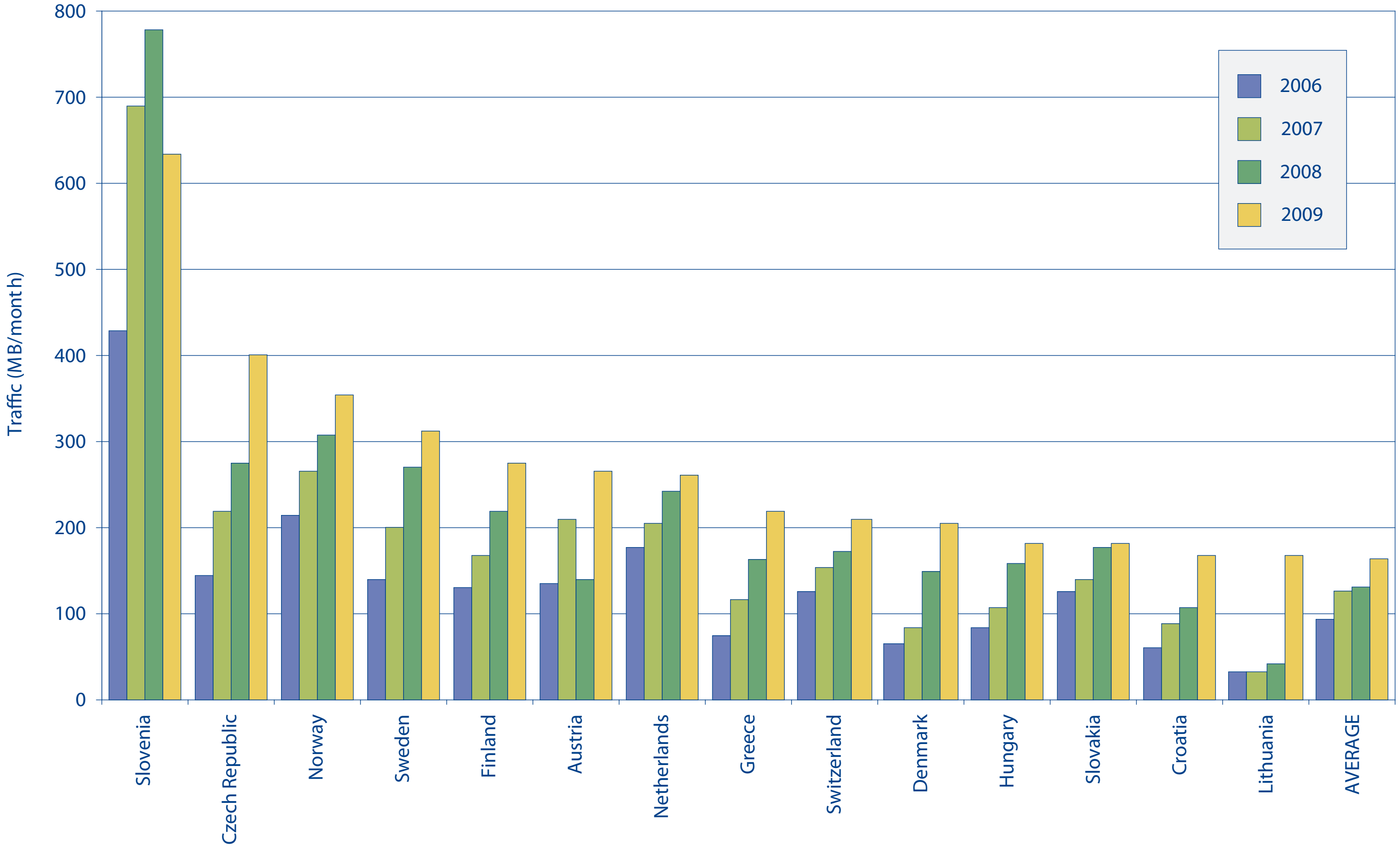
4.4 Traffic per inhabitant

In 2009, we attempted to identify an indicator that would enable NRENs to be compared in terms of traffic. After considering several alternatives, the simplest indicator – traffic-per-inhabitant metric – was found to be the most reliable.

Graphs 4.4.1 and 4.4.2 show NREN annual T3+T4 traffic in 29 countries over the period 2006-2009, 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. Fortunately, for most countries, there is a strong proportional relationship between a country's total population and the size of the education and research community. Therefore, no other assumptions or data convolutions need to be made.

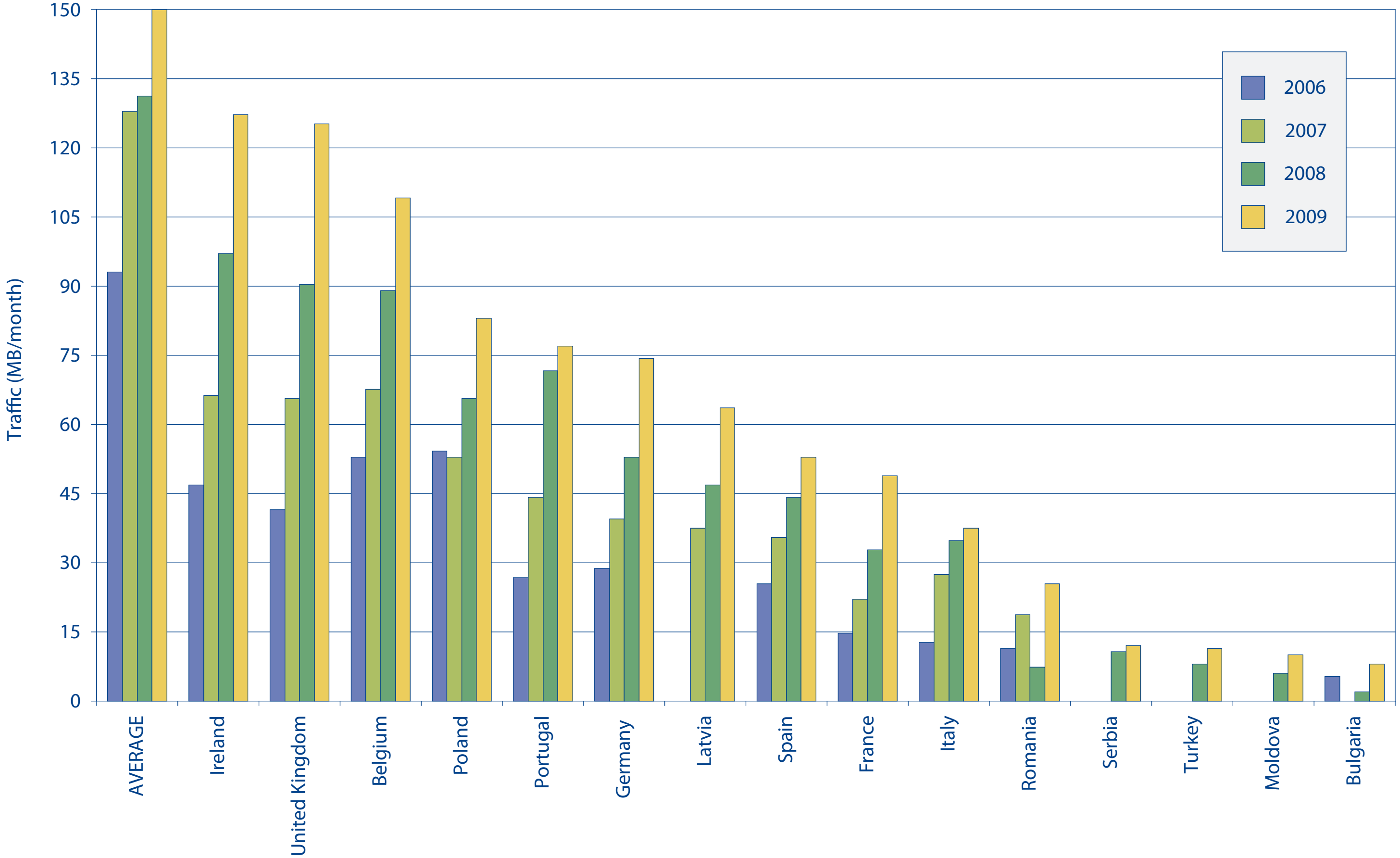
The average traffic per inhabitant in these 29 countries has grown from 93 MB/month in 2006 to 163 MB/month in 2009, with an average annual growth rate of 21.3%.

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



Slovenia, at the left, has had consistently high nominal traffic (per inhabitant) over the four-year period (2006-2009). In terms of population, Slovenia is a relatively small country, yet it has a relatively high proportion of traffic generated by primary and secondary schools: nearly 700 schools and just a few universities are connected to the ARNES backbone. Some of the schools are connected with gigabit capacities. Therefore, the proportion of the population that is connected by the NREN is relatively high, and Slovenia's external traffic is higher than that of the other European countries shown.

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



Note that the vertical scale of Graph 4.4.2 is much larger than that of Graph 4.4.1. Clearly, there is still a substantial 'digital divide' in Europe: Bulgaria, Moldova, Serbia and Turkey lag far behind the rest of Europe. Note the marked growth in Romania, which is the result of that country's changeover to a fibre network.

4.5 Congestion

The NRENs covered by this edition of the *Compendium* were asked to roughly 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]

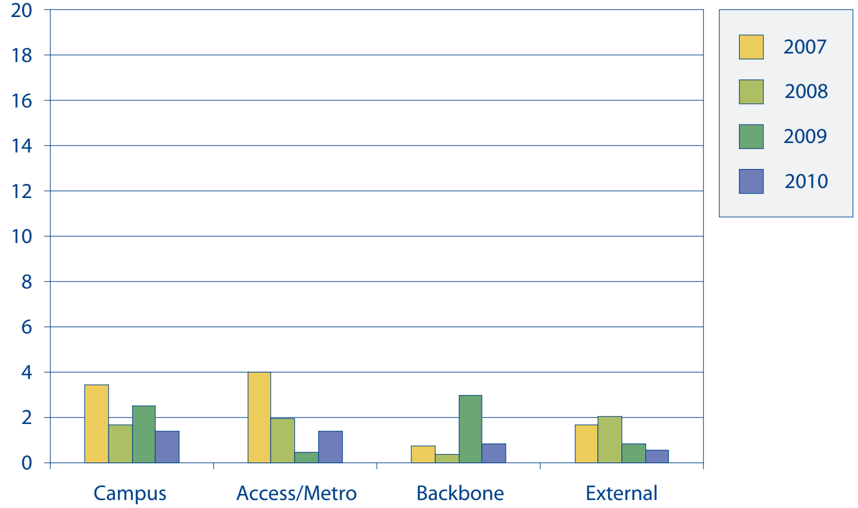
congestion index = (0.05*little + 0.2*some + 0.5*serious) - 5

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.

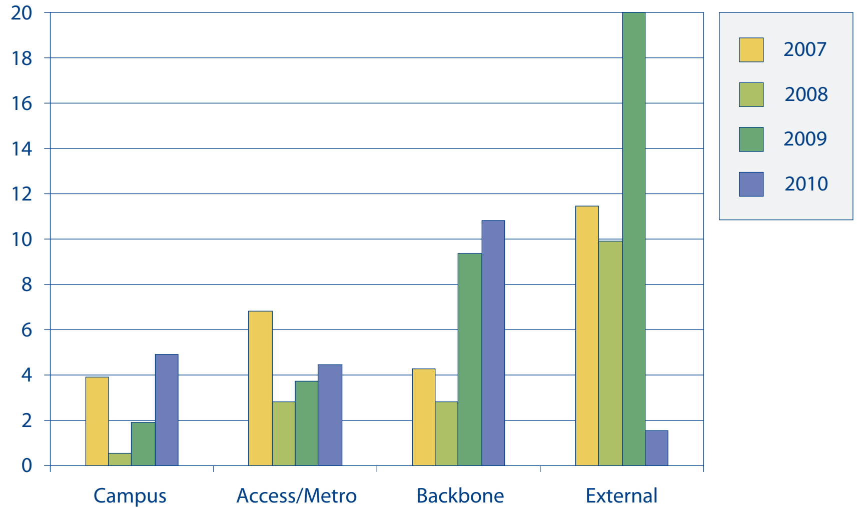
As shown by Graph 4.5.1 (right), for the EU/EFTA countries, following a slight increase in 2009, the average estimated congestion at campus level decreased in 2010. It seems that recent investments in capacity increases at the external and backbone levels are leading to some bottlenecks at the access network level.

As shown by Graph 4.5.2 (right), for the other (i.e. non-EU/EFTA) countries, there seems to have been a considerable reduction of congestion at the external connections level. This should be the effect of new links created within the framework of the GÉANT network. It will be interesting to see whether this development leads to improvements at the other network levels in future years. Note that the reliability of these figures is questionable: the set of countries is smaller than in Graph 4.5.1 and the respondents are not the same from year to year.

Graph 4.5.1 – Congestion index, EU/EFTA countries, n=28



Graph 4.5.2 – Congestion index, other countries, n=11



[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.

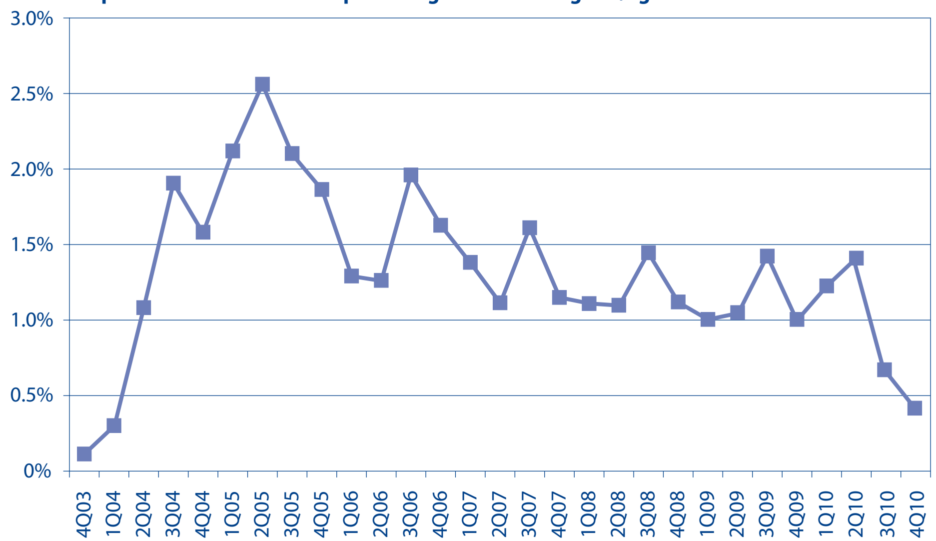
4.6 IPv6

The 2008 *Compendium* reported that the proportion of IPv6 traffic across the NREN/GÉANT gateways was far lower than IPv4 traffic and that IPv6 traffic was growing more slowly than IPv4 traffic.[2] Evidently, many connected user groups and institutions see few compelling reasons to migrate to IPv6, even though IPv4 address space is likely to run out soon; some predict that this will happen as soon as in early 2011.[3]

As indicated in previous editions of the *Compendium*, most European NRENs were early to adopt IPv6 and have supported native IPv6 for several years.

Based on available statistics for the ingress and egress points of the GÉANT network, Graph 4.6.1 (below) shows that the general trend continued into 2009: IPv6 traffic as a proportion of the total IP traffic remained low, hovering around 1.0-1.5%.[4]

Graph 4.6.1 – IPv6 traffic as a percentage of total IP ingress/egress traffic on GÉANT



Graph 4.6.1 shows a saw-tooth variation with a period of approximately 12 months. The explanation for this phenomenon that was given last year still holds: the variation in the percentage is not so much due to variations in IPv6 traffic as to variations in IPv4 traffic that are related to the summer period. The most likely cause is that when human-user traffic drops during the summer, the automated traffic between servers that continues regardless of season becomes proportionately higher, and these servers are more likely to be using IPv6 than a human user. This finding suggests that the adoption of IPv6 by end-users is lower than that of centrally provided services.

For this edition of the *Compendium*, we asked NRENs what percentage of their traffic is IPv6 traffic. Only a handful of NRENs responded. The highest percentage reported was 2.5%, but in most cases the IPv6 traffic was below 0.4%.

The IPv6 situation does not seem to have changed with respect to the 2009 *Compendium*. In general, connected institutions do not yet feel the need to migrate to IPv6. Since there are real costs for institutions in migrating to IPv6 and no apparent functional improvements for the end-user, it is hardly surprising that the migration is slow.

Nevertheless, it seems inevitable that IPv4 address space will be exhausted in the near future. Thereafter, all new addresses issued can only be IPv6. Thus, there is a risk that existing hosts that are exclusively IPv4 will become unreachable from hosts that only have IPv6 addresses. All institutions connected to the NREN networks should therefore be actively encouraged to migrate to IPv6 support and be made fully aware of the necessary timescales and the consequences of not doing so.

[2] 2008 *Compendium*, p. 58.
[3] See, for example, the IPv4 exhaustion counter at www.inetcore.com/project/ipv4ec/index_en.html
[4] Data supplied by GÉANT.

4.7 Lambda traffic

Eighteen of the EU/EFTA NRENs who responded to our questionnaire currently offer dedicated wavelengths (lambdas) to their customers. Most lambdas are used continuously. Measuring the traffic on these 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 2009 ranges from one to 64 (CESNET). In the US, Internet2 reports having provisioned 99 lambdas in 2009. Clearly, there is still a considerable growth potential in this area.

Of the 18 NRENs mentioned above, nine indicate that they do not measure lambda traffic, whereas four report that they plan to measure such traffic, and five have some form of measurement in place. Three of those five report using SNMP[5] as the measurement method. This protocol is only suitable for IP-based traffic. GARR (Italy) has router counters, but only for lambdas that are terminated on routers managed by GARR itself. SWITCH (Switzerland) only measures the EoMPLS[6] circuits. Thus, not the amount of traffic but the amount of circuits is being measured. This may be an appropriate alternative way of measuring and documenting the evolution of lambda traffic. An indirect measure of usage is any recurrent charge for lambdas. Where such charges exist, they indicate an ongoing commitment by the client to use the lambda.

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[5] Simple Network Management Protocol. For more information, see, for example: en.wikipedia.org/wiki/Simple_Network_Management_Protocol

[6] Ethernet over MPLS. For more information, see, for example: en.wikipedia.org/wiki/Multiprotocol_Label_Switching

5 OTHER SERVICES

Almost all NRENs are involved in providing 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 hierarchy[1]:

1. Network & connectivity services;
2. Security services;
3. Authentication & mobility service;
4. Housing – storage – hosting – content delivery services;
5. Network collaboration tools & conferencing;
6. Network computing resources;
7. E-learning / distance teaching & learning: e-research;
8. User interaction – knowledge dissemination;
9. NREN side activities/services (not NREN user-specific).

In this *Compendium*, network and connectivity services are covered in Section 3. The *Compendium* survey does not cover all of the other services each year. Thus, security services are not covered in this edition. (For more information, see, for example: **www.terena.org/activities/tf-csirt**)

Section 5.2 provides information on authentication and related services. Section 5.3 examines housing, storage, hosting and content-delivery services. Section 5.4 deals with network collaboration tools and includes subsections on IP telephony, video conferencing and multimedia repositories. Section 5.5 looks at network computing resources. Please note that e-learning and NREN side activities are not covered by this edition of the *Compendium*; as always, though, for each NREN all the data for these activities can be found on the TERENA website: **www.terena.org/compendium**. Finally, Section 5.6, considers user interaction and knowledge dissemination.

[1] Developed by Koen Schelkens, BELNET.

5.1 Overview

Access to a service is becoming increasingly independent of the physical location of the user or service. As a result, there is a growing need for identity federations and certification services; indeed, both are becoming more common. In 2010, the user population of federations operating in higher education passed the 15-million mark. In October 2010, 16,332,026 federated identities were active, while approximately 2,000 operational federated services were available for use through the 27 federations participating in the REFEDS (Research and Education Federations) community. Federation technology is still being rolled out to new users. The number of actual certificates issued by NRENs in the EU/EFTA area continues to grow. The most advanced service of this type is provided in Germany, where the experience indicates that further growth can be expected in the rest of Europe over the next few years.

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.

Over the past year, there has been significant growth in VoIP. Just under one-third of the EU/EFTA NRENs currently offer a centrally-administered VoIP service, while a further 40% are planning to introduce it in the near future. Twenty-four of the EU/EFTA NRENs already offer or plan to offer a centrally managed video-conferencing service. Almost half of the NRENs already offer a web-based multimedia content repository for storage and retrieval of audio/video recordings created by research and higher-education communities. Many of them also feature or plan to introduce video-sharing functionality that enables direct content management by the end-user.

Grid services have become an important area for NRENs. The data show that almost 80% of the EU/EFTA NRENs currently provide or are planning to provide Grid services. This is similar to last year's figure, whereas four years ago the figure was 56%. Cloud services are not yet as common as Grid services. Seven of the EU/EFTA NRENs currently offer virtualisation services; six more are planning to introduce this. Outside the EU/EFTA area, Croatia also offers such service.

NRENs generally provide a range of user-support services, mostly in the form of training. Many NRENs also host national user-conferences and provide support to specific user-groups. The most popular broker service seems to be joint software licensing. This is an area in which NRENs will probably be able to achieve considerable savings for their customers and in which there is potential for expansion, especially given the current economic climate.

5.2 Authorisation and mobility services[2]

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 increasingly independent of 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 is who and who is entitled to what. This means that authorisation and mobility services must go hand in hand. It also means that the development of these services can either constrain or encourage the way other services are developed and delivered to users.

In Europe, a pioneering mobility service is eduroam®, which was established in 2003 under the TERENA umbrella and has developed into a secure, world-wide roaming access service for the international research and education community. This service is currently offered by all the NRENs that participate in the GN3 (GÉANT) project and by NRENs in a growing number of countries in other continents. However, this does not mean that eduroam® is available in every institution or at all locations within a given institution. For further information on eduroam and its deployment, see **www.eduroam.org**.

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

[2] This section includes contributions by Ingrid Melve, UNINETT and Licia Florio, TERENA.

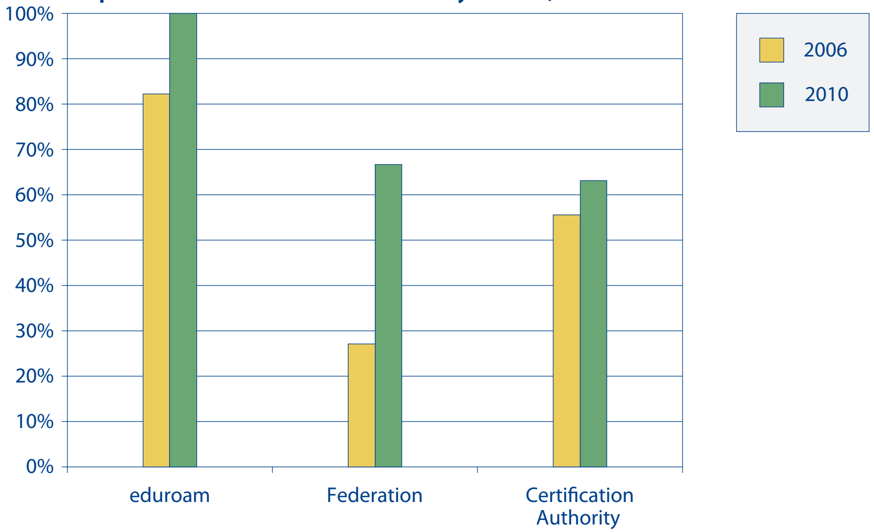
5.2.1 Identity federations

Identity management systems can be used to accredit users so that they may gain access to a variety of services through one authentication mechanism. These systems originated in the NREN community. Like NRENs, federations have a variety of organisational forms (e.g. project within a NREN, consortium, separate entity, collaboration with primary education, etc.). Normally, there is one federation for higher education and research in each country. NRENs either operate the research and education federation themselves or have close organizational ties to 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 login and attribute information.

Identity federations offer 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; and e-learning tools and portals. In addition, there are services such as: video- and web-conferencing; MCU booking systems; streaming video portals; software licensing, and webshops for a range of academic services. Service providers can use federated access to identify and authorise a particular set of users; for example, students who may be entitled to special terms for travel, mobile phones, etc.

As reported in the *Compendium* since 2006, the number of identity federations has been growing constantly. In order to foster collaboration in this area, TERENA has facilitated the formation of REFEDS, in which most federations collaborate. The information provided in this section combines some of the answers from the *Compendium* survey with an analysis of answers from a more detailed REFEDS survey. For further information, see **www.refeds.org**.

Graph 5.2.1.1 – Authorisation and mobility services, EU/EFTA countries



With the growth of identity federations and federated services, a need to inter-federate them has arisen. As yet, there is only one operational confederation, Kalmar2, which links the Nordic federations, though tests are underway for a pan-European confederation called eduGAIN, which is scheduled to become operational in 2011. For more information on eduGAIN, see **www.edugain.org**. Both eduroam® and eduGAIN are supported by the EU through the GN3 project.

The user population of federations operating in higher education passed the 15-million mark in 2010. In October 2010, 16,332,026 federated identities were active, while approximately 2,000 operational federated services were available for use through the 27 federations participating in the REFEDS community. Federation technology is still being rolled out to new users, even as some communities cover over 90% of their user-base. The largest federation in terms of number of enabled users is WAYF of Denmark; in terms of number of identity providers, the UK federation is the largest.

Table 5.2.1.2 – Identity Federations according to the REFEDS survey

Country	NREN	Name of federation	Status	No. of identity providers	No. of service providers	No. of enabled users
EU/EFTA countries						
Austria	ACOnet	ACOnet-AAI	Pilot	24	16	
Belgium	BELNET	BELNET	Production			
Czech Republic	CESNET	eduID.cz				
Denmark		WAYF	Production	72	26	3,500,000
Finland	FUNET	Haka	Production	43	97	270,000
France	RENATER	Federation Education Recherche	Production	86	123	1,113,000
Germany	DFN	DFN-AAI	Production	60	60	
Greece	GRNET	GRNET	Production	19	4	30,000
Hungary	NIIF/ HUNGARNET	eduID	Pilot	10	50	
Ireland	HEAnet	Edugate	Production	3	4	60,000
Italy	GARR	IDEM	Production	29	16	1,300,000
Latvia	LANET	LAIFE	Production	4	2	60,000
Netherlands	SURFnet	SURFnet	Production	64	28	699,026
Norway	UNINETT	Feide	Production	65	80	390,000
Portugal	FCCN	RCTSaii	Production	50	8	
Slovenia	ARNES	ArnesAAI	Production	11	11	
Spain	RedIRIS	SIR	Production	69	132	1,250,000
Sweden	SUNET	Swamid	Production			
Switzerland	SWITCH	SWITCHaai	Production	43	455	300,000
UK	JANET(UK)	Ukfed	Production	651	527	3,000,000
Other countries						
Croatia		AAI@EduHr	Production	226	60	660,000
Australia		AAF	Production	40	88	300,000
Brazil	RNP	CAFe				

Table 5.2.1.2 – continued

Country	NREN	Name of federation	Status	No. of identity providers	No. of service providers	No. of enabled users
Other countries						
Canada	CANARIE	CAF	Production	19	14	800,000
Japan	NII	GakuNin	Production	15	17	300,000
New Zealand		Tuakiri New Zealand Access Federation	Pilot	4	–	–
US	Internet2	InCommon	Production	79	140	2,200,000
Global		IGTF	Production	86	2,500	100,000

The scope of the federations is related to the NRENs, but not necessarily limited to the same user-groups. For example, some federations cover primary and secondary schools even if the NREN operating the federation does not provide service to schools, or the federation may cover only universities, even if the NREN provides services to research institutes and other customer groups. Almost all federations operate on a country basis. There is a large variety of organisational solutions, both in relation to the user groups and to the NREN in the country.

Most federations support multiple federation protocols and technologies. The preferred federation protocol is SAML2, for which either support is now in place or there are plans to migrate to it from older protocols. Federation protocols include the previously introduced national systems (e.g. PAPI, OpenAthens, A-Select, etc), as well as emerging technology such as oAuth. In contrast to the situation a few years ago, when certain software was mandatory, most federations are now using several different software solutions. This reflects the growing maturity of protocols and operational experience.

5.2.2 Certification Authorities

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 they are required whenever a secure connection between servers, or between a client and server, is needed.

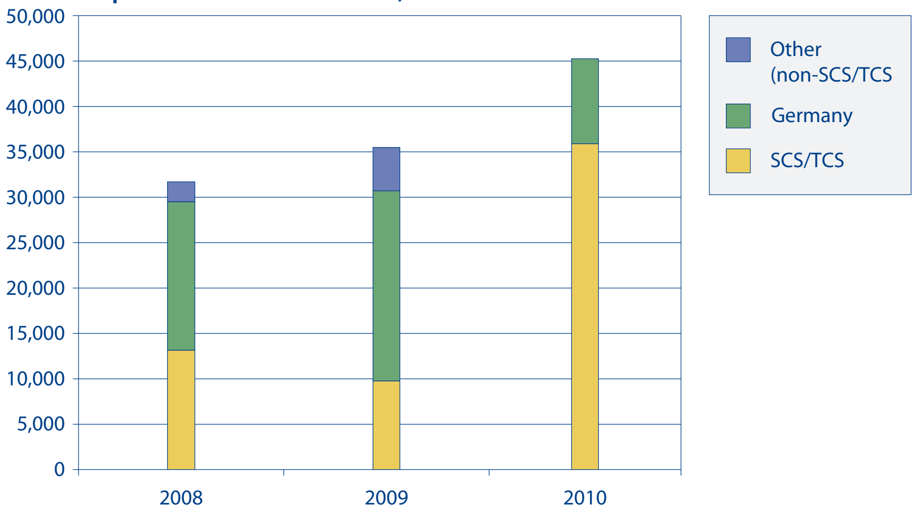
In order to support the user community (for example, in eScience) in deploying services in a secure manner, many NRENs run a Certification Authority. However, certificates issued by these authorities are not automatically trusted outside the NREN's own domain. Therefore, NRENs have requested that TERENA offer a Certificate Service. The first instance of this service, named the Server Certificate Service (SCS), was launched in 2006 and ended in January 2010. In 2009, a new provider was selected and more certificate types were added. The service was renamed as the TERENA Certificate Service (TCS). In January 2011, it supported 25 NRENs for server certificates, 20 for personal certificates and 9 for code-signing certificates.

Not all NRENs rely solely on the TCS in this area. Eleven EU/EFTA NRENs operate certification authorities in addition to, or independent of, the TCS. By far the largest of these is in Germany. In ten cases, the CA is operated by the NREN itself; one NREN (SWITCH) uses a commercial certification authority. Outside the EU/EFTA area, many NRENs also operate their own CA. These CAs usually issue server certificates; most issue personal certificates as well.

In the 2008 edition of the *Compendium*, it was reported that 16,000 server certificates had been issued by NRENs in the EU/EFTA countries. By the end of 2008, this figure had risen to 31,000, over half of which were issued by DFN in Germany (not a participant in the TCS).

In January 2010, the old service (SCS) was discontinued. The new service (TCS) was introduced gradually during 2009 and not simultaneously in all countries.[3] Therefore, the number of server certificates issued under the TCS in 2009 was lower than the number issued under the SCS in 2008. The 2010 statistics[4] show a rapid growth of the TCS, to over 35,000 server certificates issued in calendar year 2010. As clearly shown by Graph 5.2.2.1 (below), the number of server certificates that were issued in Germany declined. It should be noted that these certificates are valid for several years. As the service is launched, most certificates issued will be to servers that did not previously have such a certificate. Gradually, though, this is likely to change to a situation in which most certificates will replace existing certificates that have expired.

Graph 5.2.2.1 – Server Certificates, 2008 - 2010[5]



[3] Under the TCS, server certificates could be issued from 1 July 2009, personal and eScience personal certificates from 5 February 2010, code-signing certificates from 1 June 2010, and eScience server certificates from 1 October 2010.

As of 1 October 2010, the TCS also offers eScience Server Certificates, which are designed specifically for authenticating Grid hosts' and services' eScience Server certificates. These certificates are accredited by the EUGridPMA. Only 30 of these certificates were issued in 2010.

The growth in TCS personal certificates was even larger, from 244 issued in 2009 to 1,472 in 2010, though in absolute terms this is still a modest number. In 2009 in Germany alone, 132,000 personal certificates were issued.

5.3 Housing, storage, hosting and content-delivery services

NREN users need 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.

The survey focused on six areas in this category:

1. Distributed storage specifically for Grid users;
2. Distributed storage for any NREN users;
3. Dedicated/special high-level connectivity to commercial-content servers or commercial content;
4. Hosting of commercial-content servers or appropriate commercial content on the NREN network;
5. Video servers for use by NREN sites;
6. 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 interest in it. The results are summarised in Table 5.3.1. Mirroring is the service that seems most popular in the EU/EFTA area, having grown from 16 NRENs in 2008 to 21 NRENs in 2010.

[4] TCS statistics compiled by Kevin Meynell of TERENA from data supplied by Comodo CA, Ltd.
[5] 2010 statistics from non-TCS countries except Germany are not yet available.

Table 5.3.1 – Storage and related services

	Grid storage	Data storage	Peered commercial	Hosting commercial	Video service	Mirroring
EU/EFTA countries	31%	17%	21%	28%	45%	72%
Other European and Mediterranean countries	50%	8%	25%	0%	42%	33%

Thirteen EU/EFTA NRENs (45%) currently offer a video service and eight more are planning to introduce one. This is just one example of a range of real-time and synchronous collaboration services that are currently being investigated by NRENs.

Table 5.3.2 – Storage and related services

Country, NREN	Grid storage	Data storage	Peered commercial	Hosted commercial	Video service	Mirroring
EU/EFTA countries						
Austria, ACOnet	no	no	planned	no	no	yes
Belgium, BELNET	no	planned	planned	no	no	yes
Bulgaria, BREN	yes	planned	planned	no	planned	planned
Cyprus, CYNET	no	planned	no	no	planned	planned
Czech Rep., CESNET	yes	planned	no	no	yes	no
Denmark, UNI•C	no	no	no	no	yes	no
Estonia, EENet	yes	planned	no	no	yes	yes
Finland, Funet	yes	planned	yes	yes	yes	yes
France, RENATER	no	no	no	yes	no	no
Germany, DFN	no	no	no	no	planned	no
Greece, GRNET S.A.	no	no	planned	no	planned	planned
Hungary, NIIF/HUNGARNET	yes	yes	no	no	planned	no
Iceland, RHnet	planned	planned	planned	yes	yes	yes
Ireland, HEAnet	no	yes	no	no	yes	yes
Italy, GARR	no	no	no	no	yes	yes
Latvia, SigmaNet	yes	yes	no	yes	planned	yes
Lithuania, LITNET	no	no	no	no	no	yes

Table 5.3.2 – continued

Country, NREN	Grid storage	Data storage	Peered commercial	Hosted commercial	Video service	Mirroring
EU/EFTA countries						
Luxembourg, RESTENA	no	planned	yes	yes	no	yes
Netherlands, SURFnet	planned	planned	yes	yes	yes	yes
Norway, UNINETT	yes	planned	yes	yes	yes	yes
Poland, PIONIER	planned	planned	yes	yes	planned	yes
Portugal, FCCN	planned	planned	no	no	yes	yes
Romania, RoEduNet	no	no	planned	no	planned	yes
Slovakia, SANET	no	no	no	no	no	yes
Slovenia, ARNES	yes	yes	no	no	yes	yes
Spain, RedIRIS	no	no	no	no	no	yes
Sweden, SUNET	no	no	no	yes	no	yes
Switzerland, SWITCH	no	no	no	yes	yes	yes
UK, JANET(UK)	yes	yes	yes	yes	yes	yes
Other countries						
Australia, AARNet	planned	planned	yes	yes	planned	yes
Belarus, BASNET	planned	no	no	no	no	no
Croatia, CARNet	planned	planned	planned	no	yes	planned
Georgia, GRENA	yes	yes	no	no	planned	yes
Israel, IUCC	no	no	no	no	yes	no
Jordan, JUNet	planned	planned	no	no	planned	no
Macedonia, MARNet	yes	no	yes	no	yes	no
Moldova, RENAM	yes	planned	no	no	yes	planned
Montenegro, MREN	yes	no	no	no	planned	no
Morocco, MARWAN	yes	planned	yes	no	planned	planned
New-Zealand, REANNZ	no	no	no	no	no	no
Russian Fed., e-ARENA	yes	planned	no	no	yes	yes
Serbia, AMRES	no	planned	yes	yes	no	yes
Taiwan, NCHC	yes	yes	no	no	yes	yes
Turkey, ULAKBIM	yes	planned	planned	planned	planned	yes
United States, Internet2	no	no	yes	no	no	no

5.4 Network collaboration tools[6]

Over the past decade, NREN-supported network-based collaboration of research groups and higher-education staff has developed considerably in terms of infrastructure and service. Collaboration techniques are playing a key role in making project 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.

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

5.4.1 IP telephony

Compared to 2009, growth in VoIP was greater in 2010. The situation in the EU/EFTA countries is summarised below.

Just under one-third of the EU/EFTA NRENs currently offer a centrally-administered VoIP service. A further 45% are planning to introduce such a service.

Of all the countries outside the EU/EFTA region, Croatia and Turkey have progressed furthest with this type of service. A number of other non-EU/EFTA countries are planning to introduce it in the near future.

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.[7] Far fewer also provide a VoIP-to-PSTN[8] 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. Table 5.4.1.2 gives the full picture.

Graph 5.4.1.1 – IP telephony, EU/EFTA countries

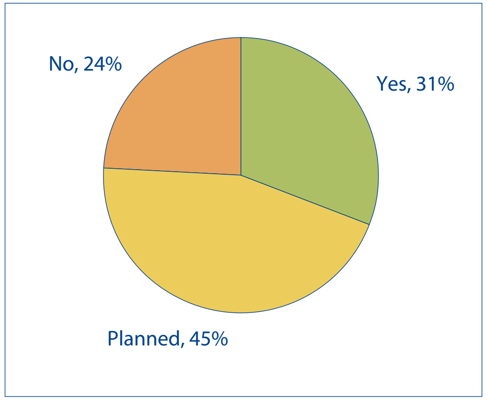


Table 5.4.1.2 – IP telephony

Country, NREN	Centrally managed	PSTN services	Inter-organisational	ENUM/ NRENUM.net	Individual users
EU/EFTA countries					
Austria, ACOnet	no				
Belgium, BELNET	planned				
Bulgaria, BREN	planned				
Cyprus, CYNET	planned				
Czech Rep., CESNET	yes	no	yes	yes	no
Denmark, UNI•C	no				
Estonia, EENet	no				
Finland, Funet	no				
France, RENATER	yes	planned	yes	no	no
Germany, DFN	yes	yes	yes	yes	no
Greece, GRNET S.A.	yes	no	yes		yes
Hungary,NIIF/HUNGARNET	yes	yes	yes	yes	
Iceland, RHnet	no				

[6] This section includes contributions by András Kovács, NIIF/HUNGARNET.
[7] 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.
[8] Public Switched Telephone Network.

Table 5.4.1.2 – continued

Country, NREN	Centrally managed	PSTN services	Inter-organisational	ENUM/ NRENUM.net	Individual users
EU/EFTA countries					
Ireland, HEAnet	no				
Italy, GARR	yes	no	planned	yes	yes
Latvia, SigmaNet	planned				
Lithuania, LITNET	no				
Luxembourg, RESTENA	planned				
Netherlands, SURFnet	no				
Norway, UNINETT	planned	planned	yes	yes	planned
Poland, PIONIER	yes	yes	yes	yes	no
Portugal, FCCN	yes	no	yes	yes	no
Romania, RoEduNet	planned				
Slovakia , SANET	yes	no	yes	yes	no
Slovenia, ARNES	no				
Spain, RedIRIS	no				
Sweden, SUNET	no				
Switzerland, SWITCH	no				
UK, JANET(UK)	no				
Other countries					
Belarus, BASNET	no				
Croatia, CARNet	yes	planned	yes	planned	yes
Georgia, GRENA	no				
Israel, IUCC	no				
Jordan, JUNet	planned				
Macedonia, MARNet	planned				
Moldova, RENAM	planned				
Montenegro, MREN	planned				
Morocco, MARWAN	planned				
Russian Fed., e-ARENA	planned				
Serbia, AMRES	planned				
Turkey, ULAKBIM	yes	no	yes	no	no

5.4.2 Video-conferencing

As shown by Table 5.4.2.1 (right), twenty-four of the EU/EFTA NRENs provide or plan to offer a centrally managed video-conferencing service, which is usually complemented by deployment of a multipoint conferencing unit (MCU) and availability of a central user-support team. The old ITU-T H.323 communication protocol is still the most widely deployed. The more recent Session Initiation Protocol (SIP) continues to play a secondary role. An indicator of the importance of SIP is the number of NRENs that are planning to introduce SIP as vendor implementations are getting better is an indicator of its importance (four in the EU/EFTA area, three more in the other countries). The H.323 protocol is still used in conjunction with the Global Dialling Scheme (GDS), a virtual numbering scheme that is supported by 18 NRENs within the EU/EFTA area; H.323 is also utilised by many countries outside the EU/EFTA area.

MCU services universally offer standard definition (TV) quality conferencing. Two-thirds of the NRENs that offer video-conferencing have already made high definition available, or are planning to introduce it. Approximately half of the NRENs provide an online booking system that allows MCU access. Recording and streaming of video-conferences is also available, or will be available in the near future, in many countries. Only 11 NRENs currently offer a complementary web-conferencing service to allow easy collaboration and document sharing from the desktop.

Table 5.4.2.1 – Video-conferencing service deployment and planning

Country	NREN	Centrally managed	Central user support	H.323 support	SIP support	GDS	Standard definition	High definition	Online booking	Recording/ streaming	Web conferencing
EU/EFTA countries											
Austria	ACOnet	planned									
Belgium	BELNET	yes	yes	yes	yes	yes	yes	planned	yes	planned	yes
Bulgaria	BREN	planned									
Cyprus	CYNET	planned									
Czech Rep.	CESNET	yes	planned	yes	yes	yes	yes	yes	yes	yes	yes
Denmark	UNI•C	yes	yes	no	no	yes	yes	yes	no	yes	yes
Estonia	EENet	yes	no	yes	no	no	no	no	no	yes	no
Finland	Funet	planned	planned			yes	planned	planned	planned		
France	RENATER	planned									
Germany	DFN	yes	yes	yes	yes	yes	yes	yes	no	yes	yes
Greece	GRNET S.A.	yes	yes	yes	planned	yes	yes	planned	yes	no	planned
Hungary	NIIF/HUNGARNET	yes	yes	yes	planned	yes	yes	yes	yes	yes	yes
Iceland	RHnet	yes	yes	yes	no	yes	yes	no	yes	no	no
Ireland	HEAnet	yes	no	yes	yes	yes	yes	yes	planned	yes	planned
Italy	GARR	yes	yes	yes	yes	yes	yes	planned	yes	planned	no
Latvia	SigmaNet	no									
Lithuania	LITNET	no									
Luxembourg	RESTENA	no									
Netherlands	SURFnet	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Norway	UNINETT	yes	planned	yes	planned	yes	yes	planned	planned	planned	planned
Poland	PIONIER	yes	no	yes	yes	yes	yes	yes	yes	yes	no
Portugal	FCCN	yes	yes	yes	planned	yes	yes	yes	yes	yes	yes
Romania	RoEduNet	planned									
Slovakia	SANET	no									
Slovenia	ARNES	yes	yes	yes	yes	yes	yes	planned	planned	yes	yes
Spain	RedIRIS	yes	planned	yes	yes	yes	yes	planned	planned	planned	planned
Sweden	SUNET	no	yes				no	no	yes		
Switzerland	SWITCH	yes	yes	yes	no	yes	yes	no	yes	no	yes
UK	JANET(UK)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

Table 5.4.2.1 – continued

Country	NREN	Centrally managed	Central user support	H.323 support	SIP support	GDS	Standard definition	High definition	Online booking	Recording/ streaming	Web conferencing
Other countries											
Belarus	BASNET	no									
Croatia	CARNet	yes	yes	yes	yes	yes	yes	planned	yes	yes	yes
Georgia	GRENA	no									
Israel	IUCC	yes	yes	yes	planned	no	yes	no	no	yes	no
Jordan	JUNet	yes	yes				yes	planned	planned	no	planned
Macedonia	MARNet	yes	planned	yes	yes	planned	yes		planned	yes	planned
Moldova	RENAM	planned									
Montenegro	MREN	yes	yes	planned	planned	no	planned	no	no	planned	planned
Morocco	MARWAN	planned									
Russian Fed.	e-ARENA	yes	yes	yes	planned	planned	yes	planned	planned	planned	planned
Serbia	AMRES	yes	planned	yes	yes	planned	planned	planned	planned	planned	no
Turkey	ULAKBIM	planned									

5.4.3 Multimedia repositories and streaming

This year, we asked some new questions about the use of multimedia repositories (video archives) and streaming services offered by NRENs. There have been many developments in this area recently. As shown by Table 5.4.3.1 (right), 18 NRENs currently offer a multimedia content repository and several more are planning to establish one. Thirteen NRENs also feature or are planning to introduce video-sharing functionality, which enables the user community to publish and manage the content they themselves have created. Fewer repository providers are able to exchange metadata with other content aggregators, but many of them plan to implement this capability in the near future. Similarly, user-initiated live streaming support is not yet a common functionality, but this is being planned by five NRENs.

Table 5.4.3.1 – Multimedia repository services

Country, NREN	Multimedia repository	URL	Video sharing	Metadata exchange	Live streaming
EU/EFTA countries					
Austria, ACOnet	planned				
Belgium, BELNET	no				
Bulgaria, BREN	no				
Cyprus, CYNET	planned				
Czech Rep., CESNET	yes	videoserver.cesnet.cz	no	planned	yes
Denmark, UNI•C	yes	www.edumedia.dk	yes	no	no
Estonia, EENet	planned				
Finland, Funet	yes	tv.funet.fi/medar	planned	yes	planned
France, RENATER	no				
Germany, DFN	no				
Greece, GRNET S.A.	yes	vod.grnet.gr	planned	planned	planned
Hungary, NIIF/HUNGARNET	yes	videotorium.hu	yes	planned	planned
Iceland, RHnet	no				
Ireland, HEAnet	planned		planned	no	yes
Italy, GARR	yes	www.garr.tv	yes	planned	planned
Latvia, SigmaNet	no				
Lithuania, LITNET	no				
Luxembourg, RESTENA	no				
Netherlands, SURFnet	yes	www.surfmedia.nl	yes	planned	yes
Norway, UNINETT	planned		planned	planned	planned
Poland, PIONIER	yes	fbc.pionier.net.pl	planned	yes	yes
Portugal, FCCN	yes	www.zappiens.pt	no	yes	yes
Romania, RoEduNet	planned				
Slovenia, ARNES	yes	www.arnes.si/storitve/multimedijske-storitve/videoarhiv.html	yes	planned	yes
Spain, RedIRIS	yes	arca.rediris.es	no	yes	no

Table 5.4.3.1 – continued

Country, NREN	Multimedia repository	URL	Video sharing	Metadata exchange	Live streaming
EU/EFTA countries					
Sweden, SUNET	planned				
Switzerland, SWITCH	yes	cast.switch.ch	yes	yes	no
UK, JANET(UK)	yes				
Other countries					
Belarus, BASNET	no				
Croatia, CARNet	yes	mod.carnet.hr	yes	planned	yes
Georgia, GRENA	planned				
Israel, IUCC	yes	maor.iucc.ac.il/english.php	no	no	yes
Jordan, JUNet	no				
Macedonia, MARNet	no				
Moldova, RENAM	planned				
Montenegro, MREN	planned				
Morocco, MARWAN	planned				
Russian Fed., e-ARENA	yes	www.fcior.edu.ru			
Serbia, AMRES	yes	media.amres.ac.rs	yes	no	yes
Turkey, ULAKBIM	yes		no	no	yes

5.5 Network computing resources

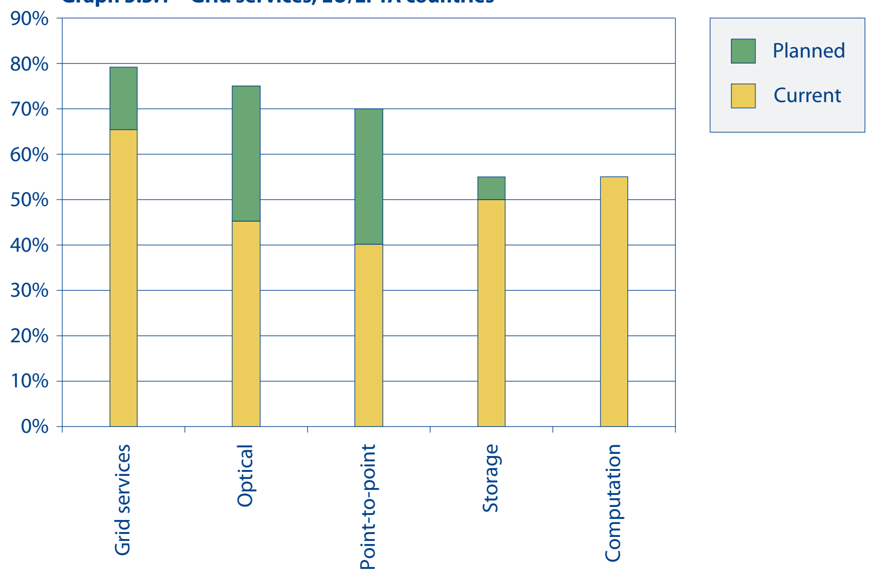
5.5.1 Grid services

Grid services have become an important area for NRENs. Projects and organisations such as the new European Grid Infrastructure (**www.egi.eu**) aim to introduce a production Grid service for scientific research purposes, using distributed computing services. In many cases, the NRENs provide the networking infrastructure for such services and are expanding into the offering of additional services to the Grid community. In almost all cases, these services are international in geographical scope.

The data show that, similarly to the situation in 2009, almost 80% of the EU/EFTA NRENs already provide, or are planning to provide, Grid services.

There are various types of Grid services. For this edition of the *Compendium*, NRENs were asked whether they offer Grid users dedicated optical paths, dedicated point-to-point IP circuits, storage facilities or computation power (CPUs). Graph 5.5.1 (below) summarizes the situation in the EU/EFTA countries.

Graph 5.5.1 – Grid services, EU/EFTA countries



5.5.2 Cloud services

Cloud services are not yet as common as Grid services. Seven of the EU/EFTA NRENs currently offer virtualisation services; six more are planning to introduce them. Outside the EU/EFTA area, Croatia offers such services, while several NRENs are planning to do so. Cloud services are usually managed through some kind of virtual management interface.

Graph 5.5.2.1 – Cloud services, EU/EFTA countries

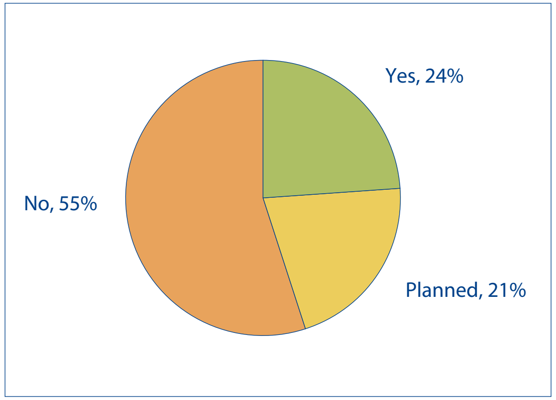


Table 5.5.2.2 (below) shows who has access to these services, whether permanent storage is offered outside the virtual machines, whether distributed computational frameworks (such as Hadoop) are offered to the users, and whether the capability of migrating live virtual instances to end-users is offered.

Table 5.5.2.2 – Cloud service details

Country, NREN	Current	To whom?	Storage outside virtual machines?	Distributed frameworks?	Instance migration?
EU/EFTA countries					
Belgium, BELNET	planned				
Czech Republic, CESNET	yes	End-users, laboratories	yes	no	no
Denmark, UNI•C	planned				
Estonia, EENet	yes	End-users	yes	yes	yes
Finland, Funet	yes	Laboratories, publicly funded institutions	yes	yes	no

Table 5.5.2.2 – continued

Country, NREN	Current	To whom?	Storage outside virtual machines?	Distributed frameworks?	Instance migration?
EU/EFTA countries					
Greece, GRNET	yes	NOCs, Labs, projects	yes	no	yes
Hungary, NIIF/HUNGARNET	planned				
Ireland, HEAnet	planned				
Latvia, SigmaNet 3	yes	End-users	no	no	no
Luxembourg, RESTENA	planned				
Netherlands, SURFnet	planned				
Poland, PIONIER	yes	R&D community	yes	yes	no
Slovenia, ARNES	yes	Research, educational and cultural organizations	no	no	no
Other European and Mediterranean countries					
Algeria, ARN/CERIST	planned				
Azerbaijan, AzScienceNet	planned				
Croatia, CARNet	yes	Our member institutions (universities, schools, research institutes, etc.)	no	no	no
Moldova, RENAM	planned				
Other countries					
Australia, AARNet	planned				
New Zealand, REANNZ	planned				
US, Internet2	planned				
Venezuela, REACCIUN	yes	Only NREN end-users	no	no	no

5.6 User interaction / knowledge dissemination

As in previous years, almost all NRENs provide some form of training courses to their users, and most organise national user-conferences. 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**.

NRENs function as centres of excellence, in service of their clients. This year's *Compendium* survey has identified a number of new services being provided by NRENs under the general heading of 'brokerage', i.e. when a NREN uses 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. Probably, this is an area in which NRENs can achieve considerable savings for their customers and in which there is 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 own 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.

Not all the NRENs that are known to be active in these areas answered the corresponding questions. Table 5.6.1 gives an overview of the answers that were provided.

Table 5.6.1 – Special NREN services

Country	NREN	Premium services?	Broker or proxy services?
EU/EFTA countries			
Belgium	BELNET	No, but we have started an experiment for a charged training course for our Vulnerability Scanner Service	No, not yet, but we are investigating the possibilities. For about 10 years, we have been operating open-source software.
Czech Republic	CESNET	No	No
Denmark	UNI•C	No	No
Estonia	EENet	No	Planned
Finland	Funet	Case-by-case consultancy on national ICT projects outside the NREN scope.	Email reputation service (Funet Black List) by Trend Micro, video conferencing service (Funet Virtual Office) by Videra Ltd
Ireland	HEAnet	Security audits	Software licence negotiation, contract management for national frameworks, organising framework tenders
Latvia	SigmaNet	Consultancy regarding network planning, design, and addressing schemes.	Not yet.
Norway	UNINETT	Security audits in connection with security policy work; advice on campus network infrastructure; a suite of technical recommendations	Software licensing, PCs, Macs, printers, storage equipment, telephony, audio/visual equipment, ADSL
Poland	PIONIER	Security audits	Software licensing
Portugal	FCCN	Technical consultancy, security audits, technical advisories	Digital libraries content licensing and federated search, software licensing
Slovenia	ARNES	No	No
Spain	RedIRIS	Yes - technical advice	Support for tendering of software for specific services, quality evaluation and assessment

Table 5.6.1 – continued

Country	NREN	Premium services?	Broker or proxy services?
EU/EFTA countries			
United Kingdom	JANET(UK)	No	Telecommunications circuit framework; router and switches purchase and maintenance framework; video-conferencing equipment purchase and maintenance framework.
Other countries			
Algeria	ARN/CERIST	Consultancy for networks and services for E&R institutions.	
Azerbaijan	AzScienceNet	No	No
Croatia	CARNet	Our CARNet CERT and our National CERT (NCERT) provide security penetration tests to our member institutions (free of charge).	No
Georgia	GRENA	GRENA is providing consultancy for the Ministry of Education and Science in IT.	
Israel	IUCC		We provide software licensing services for Microsoft, Adobe, Matlab, Exceed, Mathematica, Novell, Origin and other packages
Jordan	JUNET	Networking design and implementation	Microsoft licensing
Moldova	RENAM	No	No

6 FUNDING AND STAFFING

It should be noted that some NRENs provide services only to the research and/or education communities in their country. Some provide additional services; for example, they administer the country-code top-level domain, or they connect companies and/or institutions that are not part of the research or education communities. To enable comparison, we asked the NRENs covered by this 2010 edition of the *Compendium* to provide information only about their activities for national research or education communities. We refer to such activities simply as 'NREN activities'.

Below, Section 6.1 gives an overview, Section 6.2 provides information on various aspects of NREN staffing, and Section 6.3 deals with NREN budgets. Sections 6.4 and 6.5 give further information on income sources and expenditure categories, respectively. Finally, Section 6.6 indicates how network levels are funded.

6.1 Overview

It is almost impossible to compare NRENs by staff or budget size, because their budgets are structured in various ways, depending on their tasks, and their funding also differs greatly.

Section 6.2 gives details of the considerable differences in the number and types of staff that NRENs employ and attempts to explain some of these differences.

Section 6.3 provides information on, and explains the variety of, NREN budgets, which may fluctuate from year to year and differ from country to country because activities are funded in various ways.

Comparing 2010 budget data with those from past editions of the *Compendium* reveals that NREN budgets tend to be relatively stable; any year-to-year fluctuations depend on whether an important investment is made in a particular year. 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.

Although the overall budget figures show that NRENs are not (yet) significantly affected by the current economic crisis, in 2010 four EU/EFTA NRENs were confronted with budget cuts of 20% or more with respect to 2009 levels. Also in 2010, total staff size generally declined with respect to 2009 levels; in three EU/EFTA countries, staff sizes were cut by 25% or more.

It is impossible to discern a trend for the situation in the other (i.e. non-EU/EFTA) countries, because they submitted insufficient data. New possibilities for significantly upgrading international bandwidth could lead to increased national network budgets. In such countries, the data indicate that, in many cases, a modest budgetary increase leads to a significant increase in traffic.

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.

6.2 Staffing

Graphs 6.2.1 and 6.2.3 (right) give an overview of the staff that are directly employed in NREN activities, plus subcontracted staff, in full-time equivalents (FTE). Graph 6.2.4 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 that is available to an NREN.

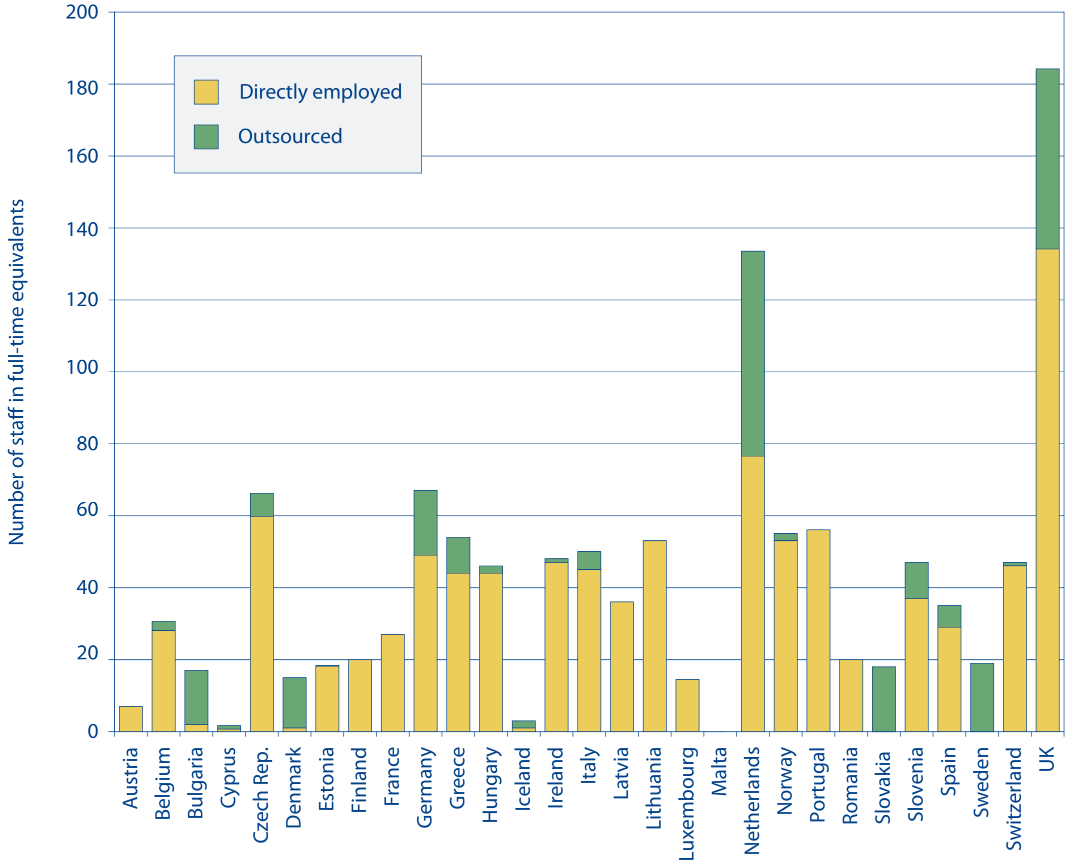
As in previous years, there are considerable differences in the number of staff employed by NRENs and their set of skills. One explanation for this variety is that, in some NRENs, the research network is a service provided by a parent organisation; thus, it is not possible for all those NRENs to specifically estimate the non-technical staff time (e.g. in accounting, human resources, etc.) devoted to NREN activities. This helps to explain why some NRENs have a high ratio of technical to total staff.

It should be noted that NRENs differ considerably in the tasks that 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 (see Section 2.2) 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 6.2.1 and 6.2.3 (right).

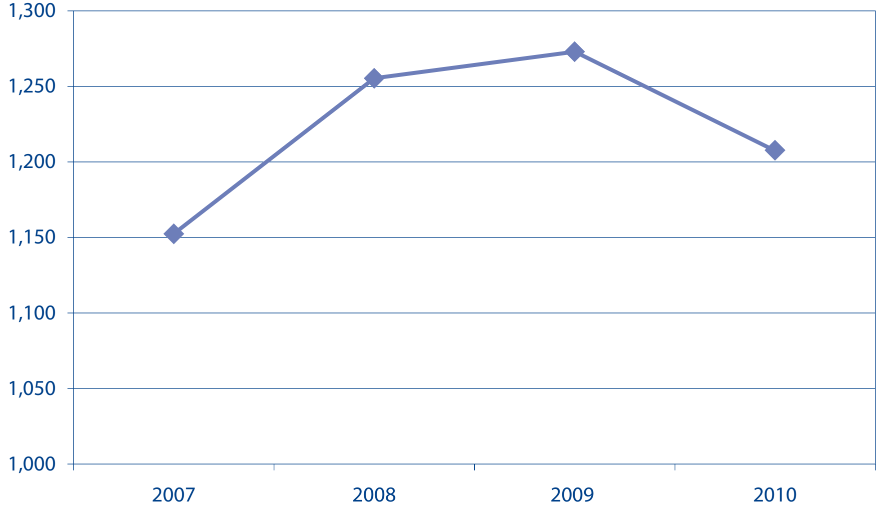
Finally, some NRENs provide support to individual end-users at institutions, some provide limited customer support, and many have service levels that are somewhere in between. This can have a significant effect on staff levels.

Graphs 6.2.1 and 6.2.2 appear to indicate that the economic crisis has had some impact: in the EU/EFTA countries, the total number of NREN-employed staff increased in the period 2007-2008, levelled off in 2009 and then decreased in 2010. Staff levels were reduced by more than 25% in Denmark and Lithuania. The only significant staff increase was in Luxembourg, which doubled its staff.

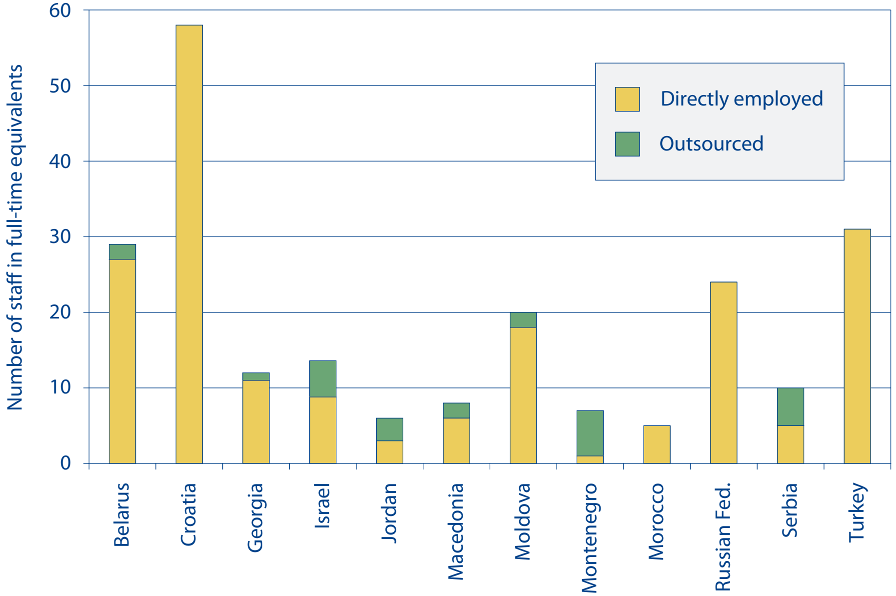
Graph 6.2.1 – Total NREN staff in FTE, EU/EFTA countries



Graph 6.2.2 – Total NREN staff in EU/EFTA countries, 2007- 2010

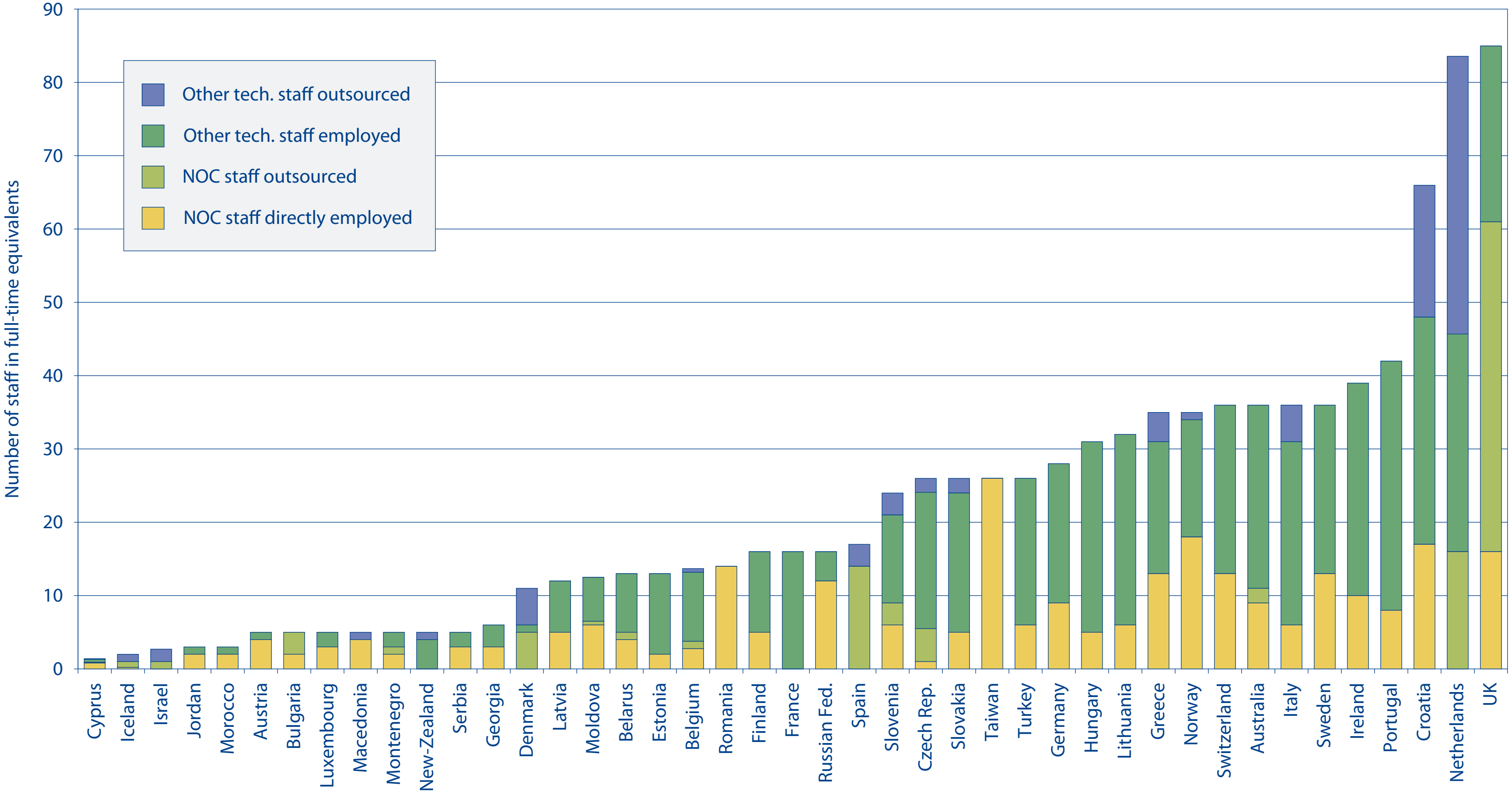


Graph 6.2.3 – Total NREN staff in FTE, other countries



It is impossible to discern a trend for the situation in the other (i.e. non-EU/EFTA) countries, because they submitted insufficient data.

Graph 6.2.4 – NREN technical staff in FTE



6.3 Total budgets, 2005-2007 and 2008-2010

NREN budgets may fluctuate due to annually fluctuating investment levels. In order to filter out as much of this effect as possible, in Graphs 6.3.1 and 6.3.2 (for the EU/EFTA countries) we compared the total NREN budgets for two three-year periods: 2005-2007 and 2008-2010. Note that for JANET(UK) the financial year is from August to July; thus, its 2010 budget is actually its 2009/2010 figure.

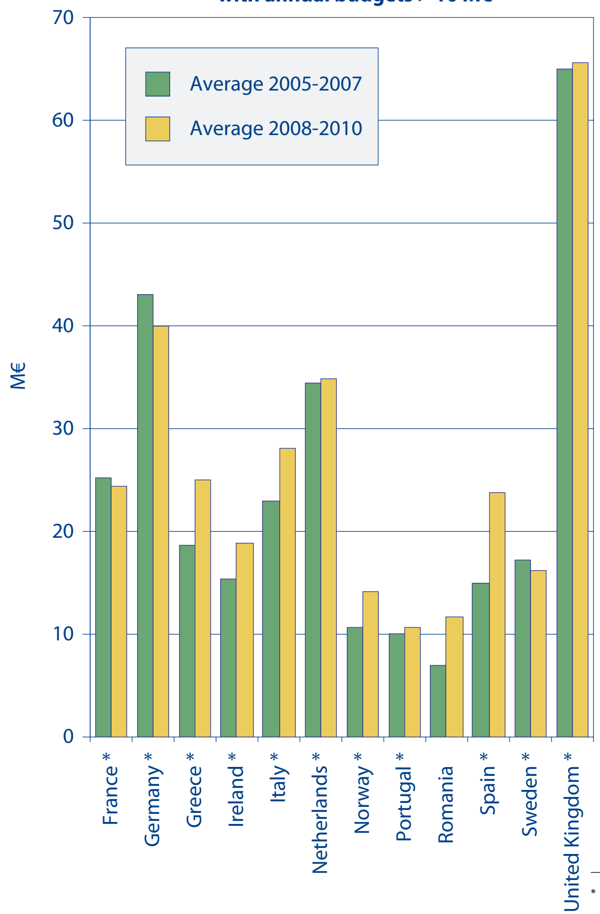
The annual total budgets are shown in Graph 6.3.3, together with the growth in GÉANT traffic.

As explained in Section 6.2, NRENs differ from one another in terms of their remit and how they are organised. Some NRENs provide services only to the research and/or education communities in their country, while others provide additional services; for example, they administer the country code top-level domain or they connect companies and/or institutes that are not part of the research or education communities. To enable comparison, we asked the NRENs to provide information only about their budget in relation to activities for national research and education communities.

Nevertheless, 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 6.3.1 and 6.3.2 (below), the NRENs that include the GÉANT subsidy in their budget figure are marked with an asterisk (*). As shown in Section 6.4, the proportion of funds received from the EU (though not always exclusively for GÉANT) differs considerably. There are more reasons why comparison is difficult:

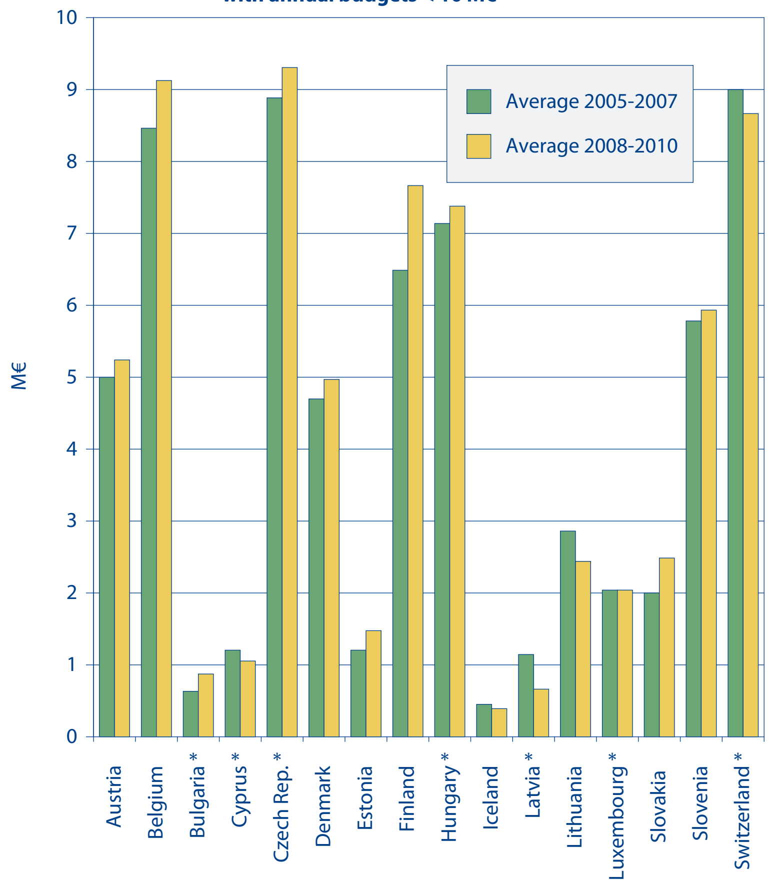
- Regional and/or metropolitan area networks (RANs/MANs) are funded differently in different countries;
- In some countries, clients pay for their link to the nearest NREN point of presence; in others, the NREN pays for this;
- Some NRENs spend a large part of their budget on connecting primary and secondary schools; others do not, or may take this separately into account;
- There are large differences in how staff are paid. In the EU/EFTA area, one NREN spends only 2% of its budget on staff, whereas another spends 58% of its budget on this. In this context, it should be noted that some NRENs have staff who are not paid from the NREN budget. There may be differences in other expenditure categories as well.

Graph 6.3.1 – Total budgets, 2005-2010 averages, EU/EFTA countries with annual budgets > 10 M€



* Budget includes GÉANT subsidy.

Graph 6.3.2 – Total budgets, 2005-2010 averages, EU/EFTA countries with annual budgets < 10 M€

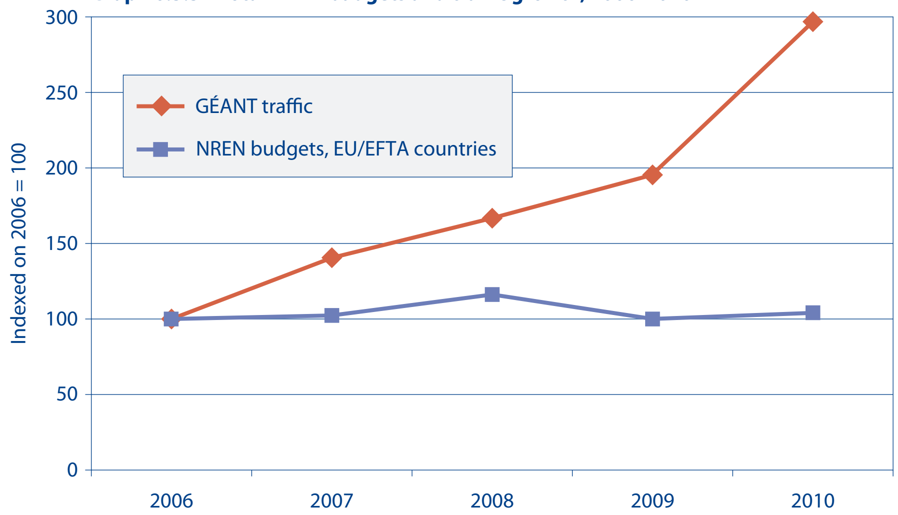


As is clear from Graphs 6.3.1 and 6.3.2, most NREN budgets have remained fairly stable over the past few years. Notable exceptions are the relatively large budget decreases in Latvia and Lithuania and the relatively large increases in Greece, Italy, Romania and Spain. In the latter cases, the increases are related mainly to major one-off investments in dark-fibre infrastructure.

The overall trend is also illustrated by Graph 6.3.3 (below), which confirms that the total budget for the 30 EU/EFTA countries[1] has remained stable over the past five years, at approximately 375 million euro. The notable exception, the peak in 2008, was due to major investments in network infrastructure in Greece, Italy and Romania. Similar budget increases took place in Belgium, Cyprus and Spain. Major budget reductions (of at least 20% with respect to the 2009 level) occurred in 2010 in the Czech Republic, Greece, Hungary and Lithuania.

Traffic trebled over the same five-year period, as illustrated by the figures for traffic on the GÉANT backbone, which are also plotted in Graph 6.3.3.

Graph 6.3.3 – Total NREN budgets and traffic growth, 2006-2010



As Graph 6.3.3 clearly shows, the general trend of improvement in value for money has been sustained: each year, NRENs are able to deliver more bandwidth and more services for roughly the same amount of money as in the previous year.

* Budget includes GÉANT subsidy.

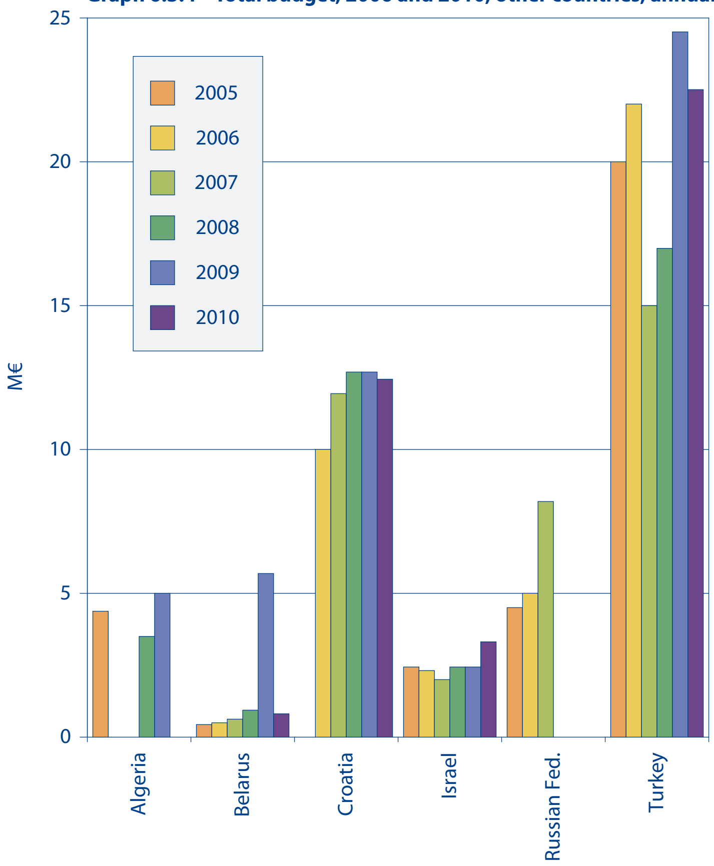
[1] Excluding data from Poland.

The data from the other countries is not sufficiently consistent over time to allow the same type of presentation as that for the EU/EFTA countries. Therefore, Graphs 6.3.4 and 6.3.5 (below) represent annual budgets and confirm the points made above for the EU/EFTA region:

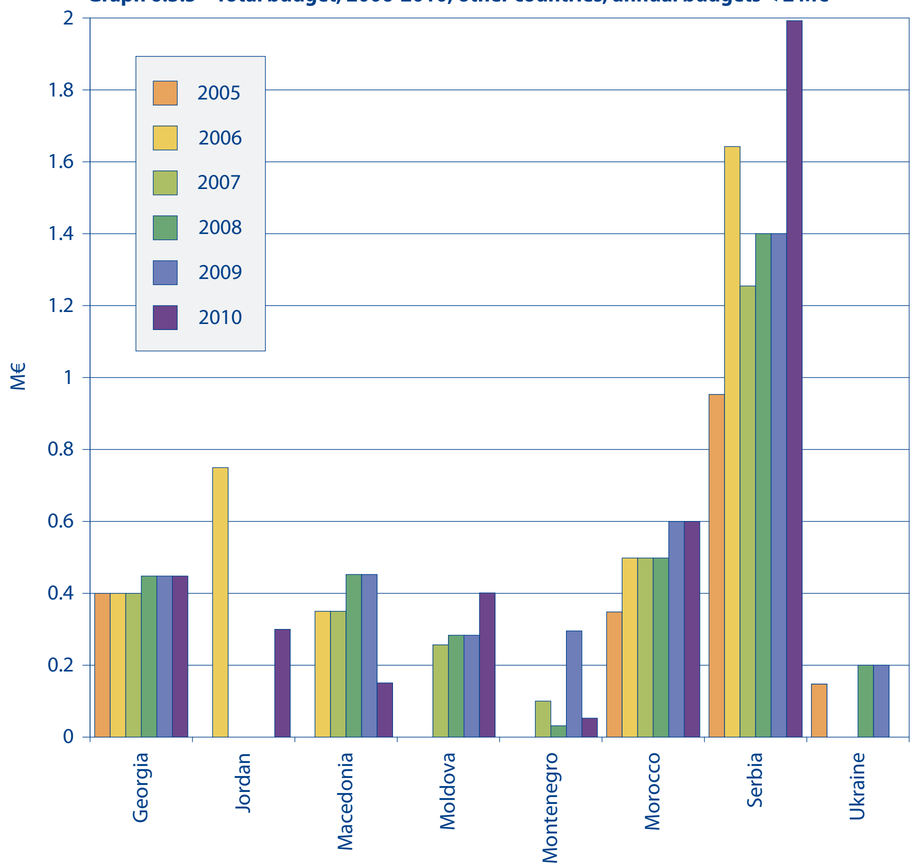
- Budgets may fluctuate significantly from year to year; however,
- Generally, over a longer period of time, budgets tend to be relatively stable.

For the non-EU/EFTA countries, this may be cause for concern: if they are to bridge the 'digital divide', it is probably necessary to increase NREN funding rather than remain at previous levels.

Graph 6.3.4 – Total budget, 2006 and 2010, other countries, annual budgets > 2 M€



Graph 6.3.5 – Total budget, 2006-2010, other countries, annual budgets < 2 M€



6.4 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 6.4.2 and 6.4.3 indicate what percentage of NREN funds comes from which source. Note that in many cases (see also Graphs 6.3.1 and 6.3.3) the amount of funding received from the EU is not shown.

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.

In this context, it is still relevant to cite the September 2007 EARNEST Report on Organisational and Governance Issues, by Robin Arak.[2] The EARNEST Summary Report,[3] includes the following summarised recommendations from that study:

> *Partial funding by connected institutions is a viable model, but it needs to be treated carefully. For upgrades of the network and for the development and deployment of innovative services, a certain amount of central funding is often indispensable.*
>
> *If connected institutions are charged for the connectivity and services provided by NRENs, this should be done in such a way that it is not a disincentive for innovation.*
>
> *In a changing economic environment, it is important that the development and enhancement of research and education networks is planned on an appropriate time scale and that forward budget planning over several years is carried out, so that the necessary resources, both human and financial, are available when required. EARNEST found that many national research and education networking organisations only plan budgets on an annual basis. That is not sufficient for planning major network and service infrastructure developments. Involving major users of research and education networks in the planning is also important, particularly when some of them may need additional dedicated connections or services, or significant enhancements to existing infrastructure, to achieve their research and education objectives.*
>
> *NRENs should reassess their planning and budgeting periods. They should plan and budget over a period of several years, in line with best practice in the planning of major infrastructure projects.*

In the 2010 *Compendium* questionnaire, NRENs were asked whether they can make use of multi-annual budgeting. Of the 28 EU/EFTA NRENs that responded, 64% confirmed that they can; the remaining NRENs cannot make use of it. A full overview is given in Table 6.4.1 (right).

[2] TERENA, Amsterdam, 2007, ISBN 978-0-77559-11-6, www.terena.org/publications/files/EARNEST-organisation.pdf

[3] TERENA, *Innovation, Integration and Deployment: Challenges for European Research and Education Networking Innovation* (Amsterdam: 2008), ISBN 978-90-77559-18-5, www.terena.org/publications/files/EARNEST-Summary-Report.pdf, p. 31.

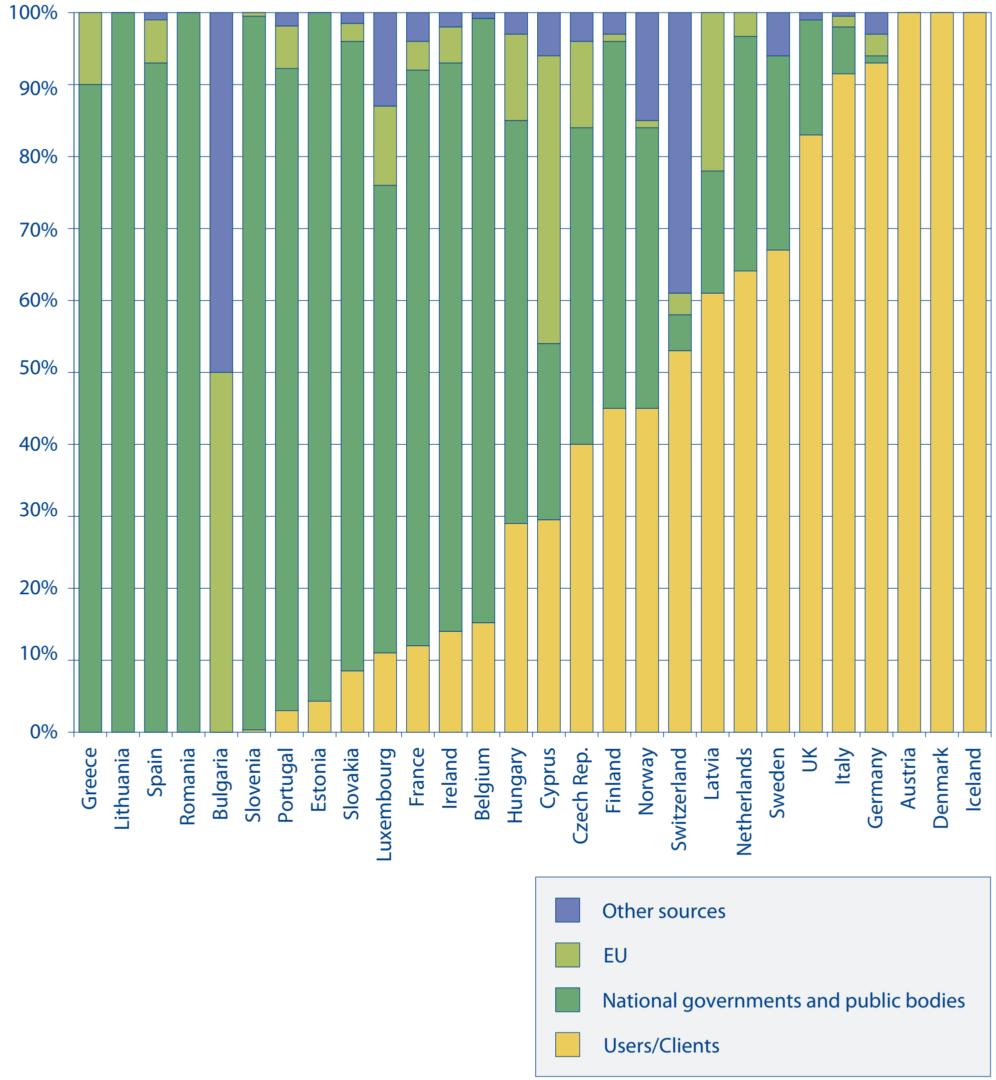
Table 6.4.1 – Multi-annual budgeting

Country	NREN	Multi-year?	Description
EU/EFTA countries			
Austria	ACOnet	YES	
Belgium	BELNET	YES	
Bulgaria	BREN	NO	
Cyprus	CYNET	YES	We make 1-year plans and an extra 2-year projection within the Central State Budget.
Czech Rep.	CESNET	NO	
Denmark	UNI•C	YES	Multi-annual budgets are made possible by public long-term project subsidy, which represents the main source of incomes.
Estonia	EENet	NO	
Finland	Funet	YES	Limited possibility for multi-annual plans in major investments such as network upgrades, together with Ministry of Education (utilizing ministry strategies, etc.).
France	RENATER	YES	
Germany	DFN	YES	An extrapolation of existing plans.
Greece	GRNET S.A.	NO	
Hungary	NIIF/ HUNGARNET	YES	NIIFI has a running 3-year Strategy Plan. In national and international projects, the plans may span multiple years.
Iceland	RHnet	YES	It is possible when deemed necessary or to get a better overview of the estimated cash flow. It is mostly done in connection with relatively large investments.
Ireland	HEAnet	YES	Multi-annual plans are discussed with the Board of Directors and the grant providers. From the outcome, an annual budget is allocated.
Italy	GARR	NO	
Latvia	SigmaNet	NO	
Lithuania	LITNET	YES	LITNET experts prepare a 4-5-year programme that is then approved by the LITNET board and submitted to the Ministry of Education.
Luxembourg	RESTENA	NO	
Netherlands	SURFnet	YES	Each year a budget is made for a period of 4 years. Long-term agreements are made with 'customers'.

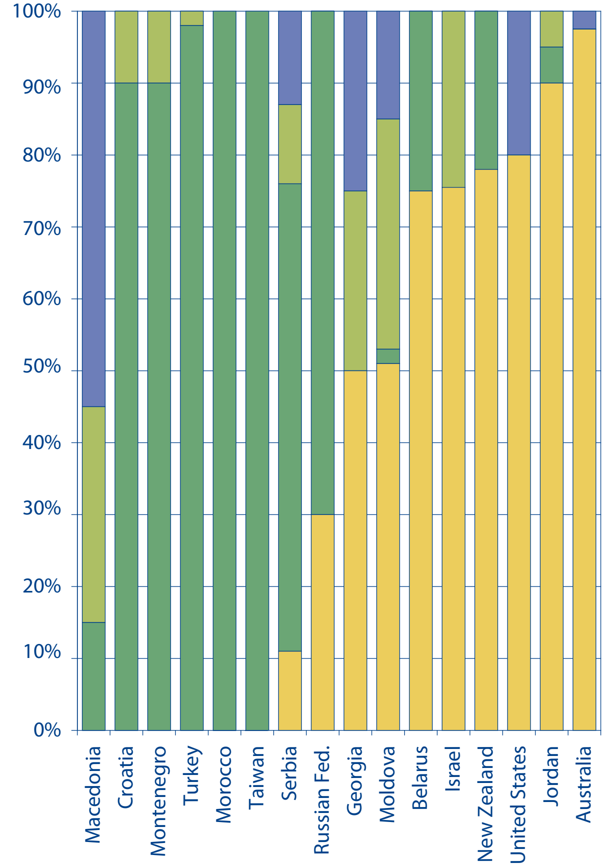
Table 6.4.1 – continued

Country	NREN	Multi-year?	Description
EU/EFTA countries			
Norway	UNINETT	YES	UNINETT is a limited company and is subject to Norwegian rules and regulations on companies. UNINETT has a long-term policy of non-profit but may run a surplus or a deficit from year to year. Multi-annual plans are typically used for larger programmes (GigaCampus, eCampus) or procurement of infrastructure.
Portugal	FCCN	YES	The activity plan and budget for each year is prepared by the Executive Board and approved by a Founders Board. Daily operation is managed by the Executive Board.
Romania	RoEduNet	NO	
Slovakia	SANET	NO	
Slovenia	ARNES	YES	Planning new services and estimating costs
Spain	RedIRIS	YES	The Council of Ministers approved the RedIRIS-NOVA project in 2009, with a budget of 138 M€ between 2009 and 2013 for the deployment of a new dark fibre network and optical equipment.
Sweden	SUNET	NO	
Switzerland	SWITCH	YES	The budgeting is done by the SWITCH management. The budget must be approved by the Foundation Council. Customers are also represented in the Foundation Council, whose responsibility is to assure that the foundation's mission is accomplished.
UK	JANET(UK)	NO	

Graph 6.4.2 – Income sources, EU/EFTA countries



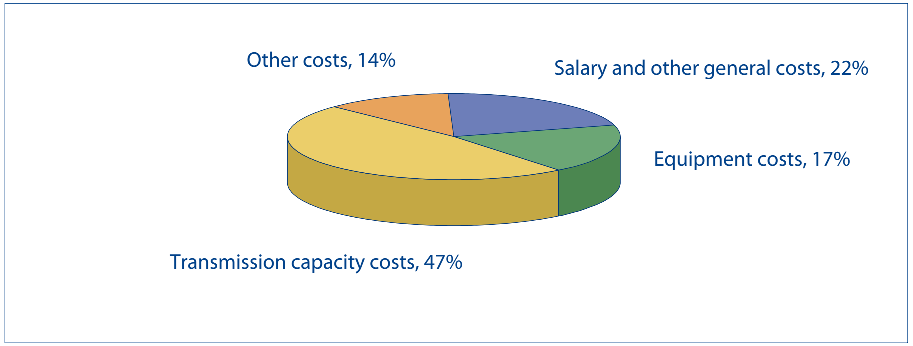
Graph 6.4.3 – Income sources, other countries



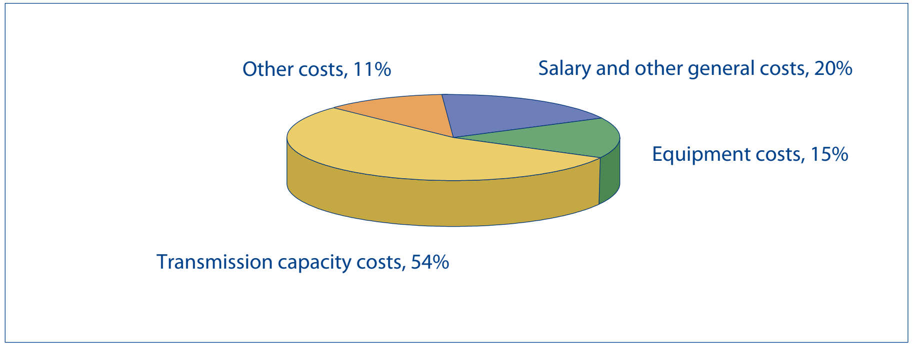
6.5 Expenditure by category

Graphs 6.5.1 and 6.5.2 (below) show the average percentage of NREN income spent on various categories of costs. Note that, in this respect, there are considerable differences between NRENs. Compared to 2008, the proportion of transmission capacity costs has decreased somewhat in the EU/EFTA countries, while the proportion of salary and other general costs has increased (although this does not necessarily mean that salaries have increased in absolute terms).

Graph 6.5.1 – Expenditure by category, 2010, EU/EFTA countries



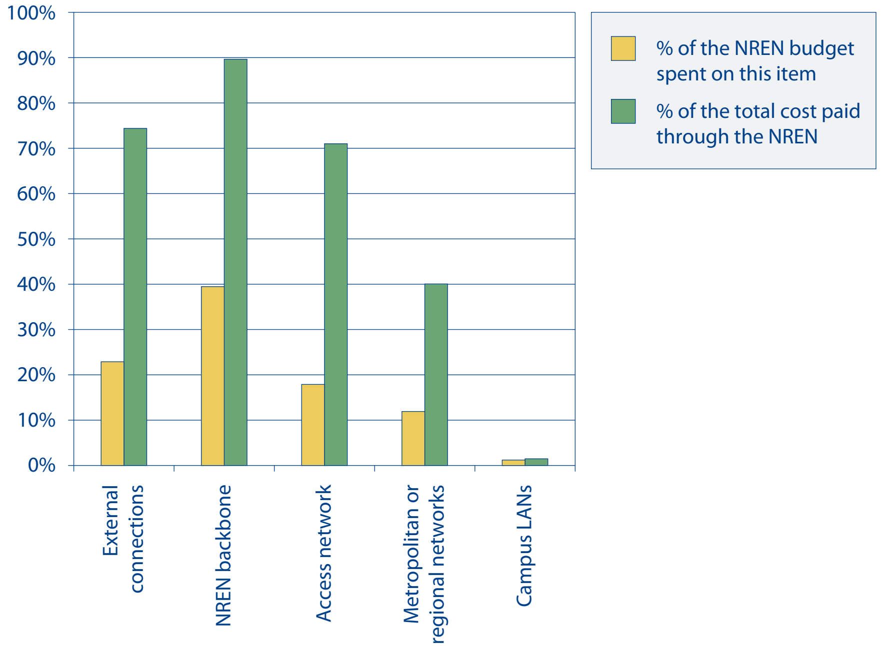
Graph 6.5.2 – Expenditure by category, 2010, other countries



6.6 Expenditure by network level

There are important differences between NRENs in terms of what parts of the network are funded specifically through the NREN budget. As Graph 6.6.1 (below) shows, on average, NRENs spend 20% of their annual budget on external connectivity and pay for 70% of its total cost. However, in this respect there are considerable differences between NRENs. Most NRENs pay for their external connections and this may consume as much as 60% of their budget. For others, such as HEAnet (Ireland) this portion can be as little as 7%. Similarly, several countries pay for metropolitan or regional area networks through their NREN budget, but many do not. Metropolitan area networks also exist in other countries, which do not pay for them through NREN budgets. Most NRENs do not concern themselves with campus local area networks, but in a few countries they do. Some NRENs have expenditures on lambda provisioning, though it is not always clear where they include this in their statistics. Such differences make it extremely difficult to compare NREN budgets.

Graph 6.6.1 – NREN expenditure per network level, EU/EFTA averages



APPENDICES

1 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	Australian Academic and Research Network	Australia
ACOnet	Österreichisches akademisches Computernetz	Austria
AfREN	Afghan Research and Education Network	Afghanistan
AMRES	Akademska Mreza Srbije	Serbia
ANKABUT		United Arab Emirates
Arandu		Paraguay
ARENA	Armenian Research and Education Networking Association Foundation	Armenia
ARNES	Akademska in raziskovalna mreža Slovenije	Slovenia
AzScienceNet	Azerbaycan Milli Elmler Akademiyası Şebekesi	Azerbaijan
BASNET	Setka Natsianalnai Akademii Nauk Belarusi	Belarus
BdREN	Bangladesh Research and Education network	Bangladesh
BELNET	(NL): Het Belgische telematicaonderzoeksnetwerk, BELNET (FR): BELNET, Réseau télématique belge de la recherche	Belgium
BOLNET		Bolivia
BREN	Sdruzhenie Bulgarska Izsledovatelska i Obrazovatelna Mrezha	Bulgaria
Brunet		Brunei Darussalam
CANARIE	CANARIE inc.	Canada
CARNet	Hrvatska akademska i istraživačka mreža - CARNet	Croatia
RNU	Réseau National Universitaire	Tunisia
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 Rep.
CNRS		Lebanon
CRNet		Costa Rica

NREN acronym	NREN name	Country
CSTNet		China
CUDI	Corporación Universitaria para el desarrollo de Internet	Mexico
CYNET	KYPRIAKO EREVNITIKO KAI AKADIMAIKO DIKTIO	Cyprus
DFN	DFN-Verein e.V.	Germany
e-ARENA	Nacionalnaia Associacia issledovatelskih i nauchno-obrazovatelnih electronnih infrastructur 'e-ARENA'	Russian Fed.
eb@le	ebale	Congo DR
EENet	Eesti Hariduse ja Teaduse Andmesidevork	Estonia
ERNET	Education and Research Network)	India
EthERNet	Ethiopian Education and Research Network	Ethiopia
EUN	Shabaket El Gamaat ElMasria	Egypt
FCCN	Fundação para a Computação Científica Nacional	Portugal
Funet	Funet	Finland
GARNET		Ghana
GARR	Associazione Consortium GARR	Italy
GRENA	Saqartvelos samecniero-saganmanatleblo kompiuteruli qselebis asociacia	Georgia
GRNET S.A.	Ethniko Diktio Ereynas & Technologias	Greece
HARNET		Hong Kong
HEAnet		Ireland
HIAST		Syria
INNOVA|RED		Argentina
Internet2		United States
IRANET/IPM	Markaze Tahghiqaate Fizike Nazari va Riaaziaat, IRANET	Iran
ITB	Institut Teknologi Bandung	Indonesia
ITC		Cambodia
IUCC	Merkaz Hachishuvim haBain Universitai	Israel
JANET(UK)	The JNT Association trading as JANET(UK)	UK
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

NREN acronym	NREN name	Country
KOREN		Korea, South
KRENA-AKNET	Kyrgyzskaya Nauchnaya i Obrazovatel'naya Kompyuternaya Set-AKNET	Kyrgyzstan
KREONET		Korea, South
LEARN	Lanka Education And Research Network	Sri Lanka
LERNET		Laos
LITNET	Lietuvos mokslo ir studiju instituciju kompiuteriu tinklas	Lithuania
MAREN	Malawi Research and Education Network	Malawi
MARNet	Makedonska akademska nauchno-istrazhuvachka mrezha	Macedonia
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
NAMREN		Namibia
NCHC	National Center for High-performance Computing	Taiwan
NgNER		Nigeria
NiCT	Dokuritu Gyousei Houjin Jyouhou Tuusin Kenkyuu Kikou	Japan
NII	National Institute of Informatics	Japan
NIIF/ HUNGARNET	Nemzeti Informacios Infrastruktura Fejlesztesi Intezet / Magyar Kutatasi es Oktatasi Halozati Egyesulet	Hungary
NREN	Nepalese Research and Education Network	Nepal
PADI2		Palestinian Territory
PERN	Pakistan Education & Research Network	Pakistan
PIONIER	Polski Internet Optyczny - Konsorcjum Akademickich Sieci Komputerowych i Centrów Komputerów Dużej Mocy	Poland
PNGARNet	Red Académica Peruana	Papua New Guinea
PREGINET	Philippine Research, Education, and Government Information Network	Philippines
Qatar Foundation		Qatar
RAAP	Red Académica Peruana	Peru

NREN acronym	NREN name	Country
RAGIE	Red Avanzada Guatemalteca para la Investigación y Educación	Guatemala
RAICES	Red Avanzada de Investigación, Ciencia y Educación Salvadoreña	El Salvador
RAU	Red Académica Uruguaya	Uruguay
REACCIUN	REACCIUN: Red Académica de Centros de Investigación y Universidades Nacionales	Venezuela
REANNZ	Research and Education Advanced Network New Zealand Limited	New Zealand
RedCyT	Red Científica y Tecnológica - Panamá	Panama
RedIRIS	RedIRIS	Spain
RedUNIV		Cuba
RENAM	Asociatia Obsteasca RENAM	Moldova
RENATA	Corporación Red Nacional Académica de Tecnología Avanzada - RENATA	Colombia
RENATER	Réseau national de télécommunications pour la technologie, l'enseignement et la recherche	France
RENER		Senegal
RENIA		Nicaragua
RENU	Research and Education Network of Uganda (RENU)	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 Nacional de Ensino e Pesquisa	Brazil
RoEduNet	Agentia de Administrare a Retelei Nationale de Informatica pentru Educatie si Cercetare - 'RoEduNet'	Romania
RUB		Bhutan
RwEdNet		Rwanda
SANET	Združenie používateľov slovenskej akademickej dátovej siete - SANET	Slovakia
SigmaNet	SigmaNet, Latvijas Universitātes Matemātikas un Informātikas institūta Akadēmiskā tīkla laboratorija	Latvia
SingAREN		Singapore
SUIN		Sudan

NREN acronym	NREN name	Country
SUNET	Det svenska universitetsdatornätet SUNET	Sweden
SURFnet		Netherlands
SWITCH		Switzerland
TARENA		Tajikistan
TENET	Tertiary Education and Research Network of South Africa	South Africa
TERNET		Tanzania
ThaiREN		Thailand
TuRENA	Türkmenistanyň milli ylym-bilim tory	Turkmenistan
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	Forskningsnettet, UNI•C	Denmark
UNINETT	UNINETT AS	Norway
UNITEC		Honduras
UoM/ RicerkaNet	Servizzi tat-Teknoloġija ta' l-Informazzjoni, 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 Đào tao Viêt Nam	Vietnam
ZAMREN		Zambia

2 Glossary of Terms

Terms not listed in this glossary are either explained in the 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.
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).
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) is an international organisation whose aim is to interconnect Latin America's academic computer networks. For more information, see www.redclara.net.
Confederation	A federation formed by multiple independent federations with a common purpose. An example in the NREN community is the European eduroam Confederation, which unites country-level eduroam federations.
Congestion index	A measure of congestion at different levels of network access. Developed by Mike Norris 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.
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.
EFTA	European Free Trade Association
EC	European Commission
EU	European Union
EUGridPMA	The international organisation to coordinate the trust fabric for e-Science grid authentication in Europe
EUMEDCONNECT2	A project to connect NRENs in the Mediterranean region to the GÉANT network.
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.

Identity Management System	A system that combines technologies and policies to allow institutions to store users' personal information and keep it up to date. An IdM is the first step to providing AAI for a local or federated environment.
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. Defined in 1998, it has yet to achieve widespread adoption and usage. See www.ipv6actnow.org.
IRU	Indefeasible Right to Use: the granting of temporary ownership of a fibre-optic cable, allowing the unencumbered use of DWDM technology to maximize the capacity of the link.
Lightpath	A dedicated point-to-point optical connection created via the use of wavelengths in an optical network, to provide guaranteed service levels for demanding applications bypassing the shared IP network.
MAN	A Metropolitan Area Network covers a geographic 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.
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 these networks with the world-wide network for research and education as well as the general purpose Internet.
NREN	National Research and Education Network (can also refer to the operator of such a network).
PERT	Performance Enhancement and Response Team.
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 access point to the Internet.
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).
RedCLARA	Latin American advanced network, managed by CLARA.
SAML	Security Assertion Markup Language: a fundamental component of federated identity and access management systems.
TCP	Transmission Control Protocol: one of the core protocols of the Internet Protocol suite.
TCS	TERENA Certificate Service: offers a variety of digital certificates for server, personal and e-Science use at research and educational institutions served by participating National Research and Education Networks (NRENs).
UbuntuNet Alliance	A not-for-profit association of NRENs that aims to provide a research and education backbone network for Africa.
University	Institution providing 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.

« *networking the networkers* »

What is TERENA?

TERENA, the Trans-European Research and Education Networking Association, fosters the development of computer network technology, infrastructure and services to be used by the research and education community. TERENA offers 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 and 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, 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 documents areas that require further work, which, to some extent, 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.