TERENA

« networking the networkers »

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of National Research and Education Networks in Europe

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INTRODUCTION

Since the first edition of the *Compendium* was published in 2001, it has grown into a much sought-after and authoritative reference source for all who take an interest 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 caution in interpreting the data remains essential.

This year's edition, the first to be published as part of the GN3 (GÉANT) project, has been enhanced with input from activity leaders in that project. As last year (2008), we have attempted to aggregate data for groups of NRENs and to examine and partially explain multi-year trends. Summaries and analyses of the most important information are presented in a number of 'overview' subsections at the start of each section.

Some of the major trends are summarised in the 'Summary of key findings' that follows this introduction.

Production of this 2009 edition was overseen by the Review Panel: Lars Fischer (NORDUnet), Sabine Jaume-Rajaonia (RENATER), Steve Hogger (JANET UK), Simon Leinen (SWITCH), Mike Norris (HEAnet) and Milan Sova (CESNET).

In response to a request from various NRENs, this year we attempted to simplify the survey questions, to weed out unnecessary questions and to make data entry easier. In addition, NRENs from outside Europe were invited to submit their data. This brought responses from an unprecedented 76 NRENs in 75 countries. It also resulted in a new Table 1.2.1, detailing NRENs and their initiatives all over the world. This year's edition includes several other new features, such as statistics showing the average level of traffic per inhabitant.

Collecting data of this type typically requires contributions from, and careful checking by, various staff members of each NREN. TERENA wishes to express its gratitude to 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 **http://www.terena.org/activities/compendium**) and this publication.

Most of the tables and graphs present data on the EU[1] and EFTA[2] countries first and then on other countries in Europe and North Africa. The data are usually presented in alphabetical order, sorted on the English name of each country. All the countries 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 from countries outside Europe is included for illustrative purposes. The full data is available at **http://www.terena.org/activities/compendium**.

Please note that, unless otherwise specified, the data indicate the situation at or close to 31 January **2009**.

We hope that this ninth 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

In several instances in this document, reference is made to the EARNEST studies. These are foresight studies into research and education networking that were conducted within the framework of the GN2 project and, as such, were supported by the European Union. The studies ran from March 2006 to October 2007 (see **http://www.terena.org/activities/earnest**). The summary report, *Innovation, Integration and Deployment: Challenges for European Research and Education Networking Innovation* (ISBN 978-90-77559-18-5), is available from the TERENA Secretariat and at **http://www.terena.org/publications/files/EARNEST-Summary-Report.pdf**

[1] On 1 January 2007, Bulgaria and Romania joined the EU. Wherever the *Compendium* presents data on EU/EFTA countries from 2006 and earlier, Bulgaria and Romania are **not** included. From 2007 onwards, data on EU/EFTA countries **do** include Bulgaria and Romania.

[2] The EFTA countries are Iceland, Norway, Switzerland and Liechtenstein. Liechtenstein is serviced by SWITCH (Switzerland) and not counted separately in this *Compendium*.

SUMMARY OF KEY FINDINGS

Unless otherwise specified, all NRENs were asked to provide data indicating the situation at or close to 31 January **2009**.

The most common model in the EU and EFTA countries is an NREN that is a separate legal entity controlled by the research and education community, which itself is entirely or largely funded by government. It is important to note, however, that several other models exist; indeed, there is a greater variety of models in non-EU/EFTA countries.

For NRENs to develop, the commitment of all major stakeholders, such as funders and users, is required. A governing model that allows the participation of these stakeholders would seem to be the most appropriate.

NRENs that can operate with a certain degree of independence from their respective governments may have certain 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.

The environment is a relatively new area of concern for NRENs; currently, only two NRENs have specific environmental policies in place. Work in this area is progressing in the context of the GN3 (GÉANT) project.

Users/clients

All NRENs can and do connect universities, research institutes and, with a few exceptions, institutes of higher education. For other institutions, NRENs differ greatly in connection policy.

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 a MAN (Metropolitan Area Network) or RAN (Regional Area Network).

Network and connectivity services

NRENs differ in many ways, which means that there are considerable differences in network architecture. This is evident, for example, in the widely ranging numbers of points of presence (PoPs) in the various networks.

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, which is potentially able to handle high capacities, so they can increase capacity easily and cheaply whenever required.

In the other countries, the trend that was already visible last year continues: they have profited from the introduction of affordable Gigabit Ethernet technology.

Network capacity growth is not linear. Comparing the growth in core capacity with the growth in traffic reveals that, roughly speaking, these two trends keep pace with each other. In addition, many NRENs now also offer several point-to-point circuits and lightpaths, which provide additional capacity that is often not measured in normal traffic statistics.

According to NREN respondents, the expected developments include:

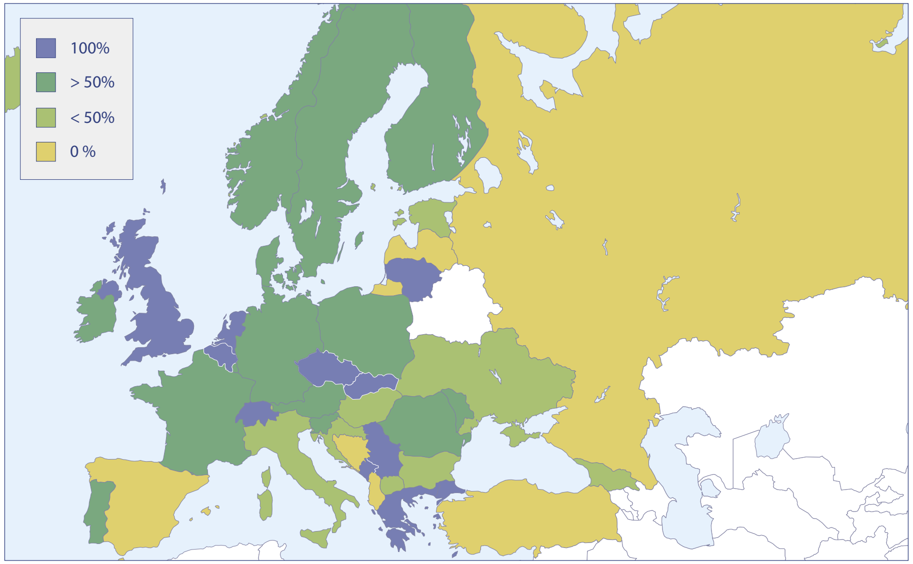
- Preparation for 100 Gb/s, reported by various NRENs. Several NRENs also report the advent of DWDM;
- Acquisition of dark fibre by countries outside Europe, which seems to be the

way forward if NRENs there want to make quick progress on a manageable upgrade path;
- In many developing countries, the expansion of the NREN to areas outside the capital, which is one of the greatest challenges they face.

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. For NRENs with relatively low external capacities (totalling less than 10 Gb/s), the connection to GÉANT is the most important. For those NRENs with the highest external capacities (≥ 50 Gb/s), GÉANT capacity is often not the largest fraction of the total, while cross-border dark fibre provides a relatively high percentage of the external capacity.

The maps in Sections 3.3, 3.7 and 3.8 illustrate the rapid developments that have occurred in the area of dark fibre in recent years.

Dark fibre on NREN backbones, 2009



The data in Section 4 shows that, over the past five years, growth has fluctuated from year to year with an average growth rate of just under 40% per annum.

Traffic per inhabitant is proposed as a reasonable way of comparing NRENs in all but the smallest countries. The analysis shows that there is still a substantial 'digital divide' in Europe: Bulgaria, Moldova, Romania, Serbia and Turkey still have considerably lower volumes of traffic per inhabitant than the rest of Europe. This is further borne out by the 2009 Congestion Index, which shows far higher congestion levels outside the EU/EFTA area than within.

IPv4 address space is likely to run out soon; some predict that this will happen as soon as late 2011. Most Europeans NRENs have been early 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. The respondent NRENs also cite this as the major barrier to IPv6 adoption. As a result, IPv6 traffic remains only a small fraction of the total traffic, hovering around 1.0-1.5%.

Other services

In the EU/EFTA area, twelve NRENs (43% of respondents) provide optical capabilities on all their PoPs, twelve provide optical capabilities on some of their PoPs, and only four (14% of respondents) provide zero optical support on their PoPs. Eighty-five percent of NRENs state that they either prefer to over-provision their networks or see no need for QoS traffic engineering. All other reasons account for 15%. Generally, the lower the congestion index score on the backbone of the NREN network, the more likely the NREN is to be adopting over-provisioning as the approach to managing QoS.

Access to a service is becoming increasingly independent of the physical location of the user or service. The research and education community is at the forefront of this development. In this area, security is an important issue, which means that authorisation and mobility services go hand in hand. In Europe, a pioneering mobility service is eduroam®, which has been developed into a secure, world-wide roaming access service for the international research and education community. eduroam is currently provided by NRENs in all 30 EU/EFTA countries and is also available in over 10 non-EU/EFTA countries worldwide. However, this does not mean that eduroam is available in every institution or at all locations within a given institution.

In the EU/EFTA countries, accreditation for users who are not at their own institutions has been made possible by identity federations, which, with a few exceptions, are operated as a service of the NREN. As reported in the *Compendium* since 2006, the number of identity federations has grown continuously. However, it is clear that currently the actual number of users is still only a fraction of the potential number.

Many NRENs run a Certification Authority. The 2009 survey shows that the number of certificates issued has almost doubled compared to 2008, rising to 31,000. The predicted growth for the coming year is 65%.

Currently 16 EU/EFTA NRENs (53%) offer some form of video service and seven more (23%) are planning to introduce this. Twenty-one of the EU/EFTA NRENs provide or plan to provide a centrally managed video conferencing service.

Compared with last year, growth in the area of IP telephony has been marginal.

Twenty-five (89%) of the EU/EFTA NRENs already provide, or are planning to provide, Grid services. (Four years ago, the figure was 56%.)

NRENs are providing an increasing range of support services. In most NRENs, these take the form of training; however, many NRENs also host national user conferences and provide support to specific user groups.

Funding and staffing

It is almost impossible to compare NRENs by staff or budget size. This is because NREN budgets differ in structure, tasks performed and source of funding.

NREN budgets tend to be relatively stable; any year-to-year fluctuations depend on whether an important investment is made in a particular year. Each year, NRENs are able to deliver more bandwidth and more services for roughly the same amount of money as the previous year. Over the past year, however, there have been signs from various NRENs that budget cuts are being proposed or implemented; several NRENs have reported that, with reduced funding levels, they are finding it very challenging to continue delivering the service that their users have come to expect.

Among the least developed NRENs, the situation is not as clear. There, new possibilities for significantly upgrading international bandwidth could act as a catalyst for increased national network budgets. In such countries, the data suggest that, in many cases, a modest budgetary increase leads to a significant increase in traffic.

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


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

1 BASIC INFORMATION

The TERENA *Compendium* provides an authoritative reference source on the development of research and education networking in Europe and beyond. This section starts with information, in Section 1.1 on the European NRENs that responded to the questionnaire. Section 1.2 includes a comprehensive list of NRENs in other continents. Section 1.3 covers their legal standing and their relationship with government. Section 1.4 contains the major changes within the NREN, its services or users and Section 1.5 looks at environmental policies.

1.1 European NRENs that responded to the questionnaire

There are 54 countries in the area covered by this 2009 edition of the *Compendium* (basically, Europe and nearby countries in the Middle East and North Africa). In three of those countries, there are either no NRENs or we have no knowledge of NREN work there. A total of 45 NRENs from 44 countries responded to the questionnaire. Many, though not all, of the NRENs answered all the questions. The map and Tables 1.1.1 (right), 1.1.2 and 1.2.1 give an overview of the NRENs that submitted responses and an impression of their completeness. Please note that in most of the tables and graphs included in this edition of the *Compendium*, the names of NRENs appear as abbreviations of the 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. Table 1.1.2 lists several European and Mediterranean countries where, to our knowledge, research and education networking exists but from which no responses were received. Table 1.2.1 lists NRENs in other continents that submitted responses for the *Compendium* which are available at **http://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 which connect research communities across the globe, listed at **http://www.geant.net/Network/GlobalConnectivity**

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

Further information on NRENs in the Asia/Pacific region can be obtained from APAN, **http://www.apan.net**; for Latin America, see CLARA, **http://www.redclara.net**; for Eastern and Southern Africa, see the UbuntuNet Alliance, **http://www.ubuntunet.net**. For Canada, see **http://www.canarie.ca**; for the United States of America, see Internet2, **http://www.internet2.edu** and the National Regional Networks Consortium **http://www.thequilt.net**. Worldwide co-ordination is managed through the Coordinating Committee for Intercontinental Research Networking (CCIRN), **http://www.ccirn.org**.

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

Country	NREN	URL
EU/EFTA countries		
Austria	**ACOnet**	www.aco.net
Belgium	**BELNET**	www.belnet.be
Bulgaria	**BREN**	www.bren.bg
Cyprus	**CYNET**	www.cynet.ac.cy
Czech Rep.	**CESNET**	www.cesnet.cz, www.ces.net
Denmark	**UNI-C**	www.forskningsnettet.dk/eng/
Estonia	**EENet**	www.eenet.ee
Finland	**Funet**	www.funet.fi (http://www.csc.fi/funet)
France	**RENATER**	www.renater.fr
Germany	**DFN**	www.dfn.de
Greece	**GRNET S.A.**	www.grnet.gr/default.asp?pid=1&la=2
Hungary	**NIIF/HUNGARNET**	www.niif.hu
Iceland	**RHnet**	www.rhnet.is

Table 1.1.1 - continued

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

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
(light grey)	Beyond the scope of the *Compendium*

Table 1.1.1 - continued

Country	NREN	URL
Other European and Mediterranean countries		
Russian Fed.	RBNet/RUNNet	www.ripn.net, www.runnet.ru
Serbia	**AMRES**	www.amres.ac.rs
Turkey	**ULAKBIM**	www.ulakbim.gov.tr
Ukraine	UARNet	www.uar.net
Ukraine	URAN	www.uran.ua

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

Country	NREN	URL
Albania		
Armenia	ARENA	www.arena.am
Azerbaijan	ANAS	www.ict.az/en
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
Syria	SHERN	www.shern.net
Tunisia	TUREN	www.rnu.tn

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 is 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 **http://alice2.redclara.net/index.php/en/documents/compendium**

Table 1.2.1 – NRENs known to be operating in other continents

Country	NREN	URL
Afghanistan	AfRENA	
Argentina	INNOVA|RED	www.innova-red.net
Australia	AARNet	www.aarnet.edu.au
Bangladesh	BdREN	www.bdren.net.bd
Bhutan	RUB	www.rub.edu.bt
Bolivia	BOLNET	www.adsib.gob.bo/adsibnueva
Brazil	RNP	www.rnp.br
Brunei Darussalam	Brunet	
Cambodia	ITC	
Canada	CANARIE	www.canarie.ca
Chile	REUNA	www.reuna.cl
China	CERNET	www.edu.cn
China	CSTNet	www.cstnet.net.cn
Colombia	RENATA	www.renata.edu.co
Congo DR	eb@le	www.ebale.cd
Costa Rica	CRNet	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

Table 1.2.1 – continued

Country	NREN	URL
Ethiopia	EthERNet	
Ghana	GARNET	www.garnet.edu.gh
Guatemala	RAGIE	www.ragie.org.gt
Honduras	UNITEC	www.unitec.edu
Hong Kong	HARNET	www.harnet.hk
India	ERNET	www.eis.ernet.in
Indonesia	ITB	www.itb.ac.id
Iran	IRANET/IPM	www.iranet.ir
Japan	NII	www.nii.ac.jp/index.shtml.en
Japan	NiCT	www.nict.go.jp/about/index-e.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.krena.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
Namibia	NAMREN	
Nepal	NREN	www.nren.net.np
New Zealand	REANNZ	www.karen.net.nz
Nicaragua	RENIA	
Nigeria	NgNER	
Pakistan	PERN	www.pern.edu.pk
Panama	RedCyT	www.redcyt.org.pa
Papua New Guinea	PNGARNet	www.pngarnet.ac.pg
Paraguay	Arandu	www.arandu.net.py
Peru	RAAP	www.raap.org.pe
Philippines	PREGINET	www.pregi.net

Table 1.2.1 – continued

Country	NREN	URL
Qatar	Qatar Foundation	www.qf.org.qa
Rwanda	RwEdNet	
Saudi Arabia	KAUST	www.kaust.edu.sa
Senegal	RENER	
Singapore	SingAREN	www.singaren.net.sg
South Africa	TENET	www.tenet.ac.za
Sri Lanka	LEARN	www.learn.ac.lk
Sudan	SUIN	www.suin.edu.sd
Taiwan	NCHC	www.nchc.org.tw/en/, www.twaren.net/english/
Tajikistan	TARENA	www.tarena.tj
Tanzania	TERNET	www.ternet.or.tz
Thailand	ThaiREN	www.thairen.net.th
Turkmenistan	TuRENA	www.science.gov.tm
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. 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 Table 1.3.1.

Separate legal entity

Many NRENs operate as separate legal entities; many others form part of a larger organisation (often a ministry, a university or a research institution). Until recently, a few NRENs had a special status, operating neither as a separate legal body nor as part of a larger organisation; typically, these were 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 reasonable 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. In Table 1.3.1, those NRENs are indicated by the word 'appoints'. Many NRENs have a mixed model, being governed by representatives both of government and of the research and education community.

In Table 1.3.1, 'indirect' implies an indirect relationship with government. 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 Table 1.3.1, the most common model in the EU/EFTA countries is an NREN that is a separate legal entity controlled by the research and education community, which itself is entirely or largely funded by government. It should be noted, however, that several other models exist; indeed, there is a greater variety of models in non-EU/EFTA 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.

Table 1.3.1 – Legal form and relationship with government

Country	NREN	Separate legal entity?	Relationship with government	Remarks / Parent organisation
EU/EFTA countries				
Austria	ACOnet	no	indirect	University of Vienna
Belgium	BELNET	no	direct	Belgian Ministry of Science Policy
Bulgaria	BREN	yes	indirect	—
Cyprus	CYNET	yes	appoints	Our governing body consists of representatives of education, research and government agencies.
Czech Republic	CESNET	yes	indirect	—
Denmark	UNI-C	no	direct	The Danish ministry of Science, Technology and Innovation has overall political responsibility. It has nominated a committee, named Styregruppen ('steering group'), which is the management team of the NREN. The committee has members from a number of the largest user organisations on the net.
Estonia	EENet	yes	direct	Operates as a state agency administered by the Estonian Ministry of Education and Research. Decisions about policy have to be accepted by the Supervisory Board of EENet.
Finland	Funet	no	appoints	Funet is a service provided by CSC - IT Center for Science Ltd.CSC is a not-for-profit company 100% owned and governed by the Finnish Ministry of Education.
France	RENATER	yes	indirect	—
Germany	DFN	yes	indirect	—
Greece	GRNET S.A.	yes	other	Owned by the Ministry of Development; under the supervision of the General Secretariat of Research and Technology. The Ministry of Development appoints the members of the Board of Directors.
Hungary	NIIF/HUNGARNET	yes	other	Joint NREN operation by HUNGARNET (independent) and NIIFI (government supervised).
Iceland	RHnet	yes	indirect	—
Ireland	HEAnet	yes	indirect	—
Italy	GARR	yes	indirect	—
Latvia	SigmaNet	no	indirect	The Head of SigmaNet reports to the director of the Institute of Mathematics and Computer Science, University of Latvia.
Lithuania	LITNET	no	indirect	The structure and regulations of the LITNET Board are approved by the Ministry of Science and Education.
Luxembourg	RESTENA	yes	indirect	—
Malta	UoM/RicerkaNet	no		University of Malta.
Netherlands	SURFnet	yes	indirect	—
Norway	UNINETT	yes	other	A public limited company, 100% owned by the Norwegian Ministry of Education and Research.
Poland	PIONIER	yes	indirect	—
Portugal	FCCN	yes	indirect	—
Romania	RoEduNet	yes	direct	—

Table 1.3.1 – continued

Country	NREN	Separate legal entity?	Relationship with government	Remarks / Parent organisation
EU/EFTA countries				
Slovakia	SANET	yes	indirect	—
Slovenia	ARNES	yes	appoints	—
Spain	RedIRIS	no	direct	Since April 2008, the Ministry of Science and Innovation is in charge of funding RedIRIS and setting its basic strategy, but its operational and technical management has been entrusted to RED.ES until at least 2011. RED.ES is a state-owned entity with its own legal character, but it belongs to the Ministry of Industry, Tourism and Trade, through its State Department for Telecommunications and Information Society.
Sweden	SUNET	no	direct	The SUNET board is appointed by the Swedish Research Council after nomination by the Association of Swedish Higher Education.
Switzerland	SWITCH	yes	indirect	—
United Kingdom	JANET(UK)	yes	indirect	—
Other countries				
Algeria	CERIST	no	other	Ministry of Higher Education and Scientific Research.
Belarus	BASNET	no	indirect	—
Croatia	CARNet	yes	appoints	—
Georgia	GRENA	yes	indirect	—
Israel	IUCC	yes	indirect	—
Jordan	JUNet	yes	other	—
Macedonia	MARNet	no	indirect	—
Moldova	RENAM	yes	indirect	Most RENAM Council Members are appointed by research and education institutions and some are representatives of ministries and state agencies.
Montenegro	MREN	no	appoints	—
Morocco	MARWAN	other	appoints	National Scientific and Technical Research Centre (CNRST).
Russian Federation	RBNet/RUNNet	yes	indirect	
Serbia	AMRES	no	indirect	Project set up by the Ministry of Science.
Turkey	ULAKBIM	no	other	An institute of TUBITAK, an agency advising the Turkish Government on science and research issues.
Ukraine	UARNet	yes	none	State enterprise of the National Academy of Sciences.
Ukraine	URAN	yes	indirect	Self-governed, non-profit-making association of universities and scientific institutions.

1.4 Major changes in NRENs

All the NRENs covered by this edition of the *Compendium* were requested to briefly describe major changes that occurred in their mandate or remit, user base or technology and services over the past year or that are expected in the coming year. Table 1.4.1 (below) presents the submitted responses, lightly edited 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, Network, Table 3.4.1.

Table 1.4.1 clearly shows that many NRENs either have recently changed over to dark fibre infrastructures or are in the process of doing so. The advantage of such infrastructures is that their capacity can be increased fairly easily as required.

Table 1.4.1 – Major changes in NRENs

NREN	Changes in services
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 (http://www.aco.net/aconet07.html?&L=1). The migration to the fibre optic backbone was successfully completed in January 2009 (http://www.aco.net/technologie.html?&L=1).
Belgium, BELNET	In 2008, we put the new network into production and migrated our customers to it. It is based on a 15-year IRU. Next year, we expect the implementation of new services based on real user needs.
Bulgaria, BREN	A major achievement was accomplished during 2009. The national backbone of the network was upgraded to 1Gbit/s capacity. The topology was also changed to form a ring across the country, allowing for failover. Similar development was accomplished on a smaller scale in the backbone within the metro area of Sofia — the capital of Bulgaria. In Sofia, dark fibrefibre was leased, creating another network ring which connects 7 large state universities. Currently, the network backbone is entirely based on Gigabit Ethernet.
Cyprus, CYNET	As the EUMEDCONNECT project has come to completion, CyNet maintains its two GEANT2 connections for international connectivity while providing transit services to the Syrian NREN for connection to GEANT2 via CyNet and the EUMEDCONNECT PoP hosted at CyNet. Major changes have been made at the connection with the Syrian NREN (HIAST), which changed to 34Mbps, and the bandwidth upgrade of our second PoP in Limassol to 60Gbps. Some of the institutions have also upgraded their connections.
Czech Republic, CESNET	The major changes during the past year were: - CESNET Czechlight (CL) DWDM deployment on the new optical lines (one/two fibre lines); - new terabit router deployment (CRS-1/16) in the CESNET2 IP/MPLS network core; - network redundancy and reliability enhancement (splitting Prague PoP into two locations, on both DWDM and IP/MPLS network layers). The main changes planned for the coming year are: - CRS-1/16 deployment on Brno PoP; - Brno PoP splitting.
Denmark, UNI-C	The expected upgrade to DWDM infrastructure has been delayed by about a year, but the major Danish universities are now connected via DWDM. Exploitation of the infrastructure is yet to be seen.
Finland, Funet	The Finnish university system is currently undergoing the largest restructuring process in decades, merging several universities to create larger and more diverse institutions. The change has already 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 currently covers over 50% of the network and will replace almost all remaining leased circuits by 2010. The DWDM network will make connections of up to 40 Gbps possible. The ongoing router upgrade will increase the IP network backbone bandwidth to 10 Gbps and provide better availability of faster customer connections (up to 10 Gbps) by 2010.
France, RENATER	GIP RENATER welcomed two new members in Feb 2009 : ONERA and CPU (Conférence des Présidents d'Université, representing universities).
Germany, DFN	The number of fibres for the X-WiN has been extended. Additional CBF links have been implemented.

Table 1.4.1 – continued

NREN	Changes in services
EU/EFTA countries	
Greece, GRNET S.A.	GRNET S.A. has already acquired 15-year IRUs for dark fibre (DF) links. GRNET currently owns 8410 km of dark fibre pairs and plans to extend them this year. Alcatel DWDM equipment is 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. The recently created GRNET node in Athens is operational and hosts the new node of GEANT and the GReek Internet eXchange (GRIX). Finally, Carrier Ethernet equipment has been acquired to develop an experimental network for research and design purposes, towards the new generation of the GRNET network. The installation of this equipment will be completed in 2009. 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 previously operated under the umbrella of the Ministry of Communication and Informatics, and later under the Ministry of Economy and Transport for several years. In April-May 2008, the structure of the Hungarian Government changed. Since then, NIIFI has been operating under the umbrella of the Prime Minister's Office. 2. The research network in Hungary has been continuously developing over the past several years (backbone and access network extensions and upgrades + international connectivity upgrade to GEANT+). No major changes in organisational structure and mandate are expected for 2008-2009. No significant change in the user base is forecast.
Iceland, RHnet	Two new sites were connected recently, one of them a university in the northern part of the country. Now all formal universities in Iceland are connected to RHnet. International connectivity: As hinted in last year's *Compendium*, we would have been in trouble if our international connectivity had not been upgraded before autumn 2008. Unfortunately, the government did not provide the support we were hoping for that summer. But in October 2008, with the help of NORDUnet, we were able to procure an additional 155 Mb/s line (STM-1), this time to the USA, to ease the excessive load. In the summer of 2009, a new submarine optical cable between Iceland and Denmark came into operation. NORDUnet was able to procure connectivity on this new cable and in September installed their first PoP in Iceland (Reykjavik) with 10 Gb/s connectivity to Denmark. It is hoped that before the end of 2009 a further two connections to this PoP will be made: a 2.5 Gb/s connection to London and a 4 Gb/s to New York. At present (October 2009), RHnet connects to this NORDUnet PoP with 1 Gb/s.
Ireland, HEAnet	• Procedures will be put in place to determine how to handle the consequences of IPv4 address depletions for HEAnet's services. Furthermore, in 2009 project plans will be made for a) a stand-aloneIPv6 network and b) how to stimulate clients to adopt IPv6 (business plans). These plans will be implemented in the coming years. (We aim to make a firm decision on IPv4/6 in 2013.) • Technical dialogues will be held to compose a CfT (call for tender) for replacement of the present optical/Ethernet network (backbone and MANs). • A 10 Gbit/s point-to-point inter-institute network will be created for use in the e-INIS project, to be used by the National Grid Initiative of Ireland. • Roll out of videoconferencing units is progressing and will be extended. • Licenses are being sought for regional wireless networks and an investigation has been carried out for an educational & research broadcast channel (DVB-IPTC- Digital Video Broadcast- Cable, DVB-C – Digital Video Broadcast Cable, DVB-T – Digital Video Broadcast - Terrestrial).
Latvia, SigmaNet	No major changes have happened to SigmaNet in the past year. The GEANT connectivity was upgraded to 2.5Gb/s, but due to the poor economic situation in the country, it had to be reduced to 1.25Gb/s in 2009.
Lithuania, LITNET	Over the past few years, we have made these major changes to our network: - Installed our own optics in backbone links; - Upgraded our backbone devices to support 10Gbit connectivity; - In some parts of our backbone network, installed DWDM equipment; - Offered IPv4 multicast service to users; - Offered IPv6 service to users.
Netherlands, SURFnet	The launch of dynamic lightpaths as a new pilot service was an important result in 2008. A dynamic lightpath is a network connection that can be established by the user himself, either manually through a web interface, or fully automated through an application, for any duration and as often as necessary. SURFnet provides dynamic lightpaths to 1 Gbit/s and static lightpaths of 150 Mbit/s to 10 Gbit/s.

Table 1.4.1 – continued

NREN	Changes in services
EU/EFTA countries	
Norway, UNINETT	In 2008, UNINETT continued to deploy optical equipment to offer lambda services to our customers. Meanwhile, the general capacity and redundancy in our network were continuously improved. One important event in 2008 was that UNINETT joined a company to build fibre infrastructure in the remotest part of Norway (Finnmark county). This gives us the opportunity to reach the goal of providing gigabit connectivity to all university colleges in Norway in 2009. Finnmark county is also a strategically important region in terms of various research projects and potential collaboration with north-western Russia.
Poland, PIONIER	In the past year, we established Gigabit Ethernet connectivity using CBF to URAN and Uarnet networks in Ukraine via Hrebenne.
Portugal, FCCN	During 2008, the main effort of FCCN was directed at extending our optical fibre infrastructure internally as well as to Spain over the northern and eastern borders. Both cross-border fibres were completed on the Portuguese side. The east-west cable serves three new institutions.
Romania, RoEduNet	Done: - RoEduNet2 project deployed using dark fibre and DWDM technology; new structure connects RoEduNet NOCs with 10 Gbps links; - GEANT2 PoP in Bucharest operational starting 2008 Q3, with a 10 Gbps link to RoEduNet; - new connection to Telia for DWS 2009 Q2; - RoEduNet administrative re-organization in 2008 Q4.
Slovakia, SANET	All backbone links upgraded to 10 GE.
Slovenia, ARNES	All PoPs connected with dark fibre.
Spain, RedIRIS	Red.es/RedIRIS IRIS launched a 138 M€ project, RedIRIS NOVA, for the provision of a dark fibre network (including optical equipment) for the next 10-15 years. Red.es also launched a 130 M€ call for tenders (through competitive dialogue) in November 2008. 23 companies presented valid offers and participated in the competitive dialogue. A final decision is expected by approx. September 2009. Additional, smaller tenders might be called afterwards. The winning bidder will have to deploy the requested optical equipment and network before October 2011, when the current RedIRIS-10 contract expires.
Sweden, SUNET	Some core links were upgraded to 40 Gbit/sec; smaller customers were upgraded from FE to GE. Several new 10G customers were connected.
Switzerland, SWITCH	Upgrades to 10Gbps according to needs.
Other countries	
Algeria, CERIST	A plan has been prepared for another upgrade of capacities of ARN PoPs, universities and research centres for 2010. In terms of service, many events have used videoconferencing and streaming facilities on the network.
Australia, AARNet	2010 will continue with a number of technological changes in AARNet's network: - Trial 40Gbps DWDM transmission; - Enable Dynamic Lightpath capability on the AARNet optical network; - Implement VPLS capability as an alternative technology to the Optical Private Networks built on a mesh of PtP circuits currently in use for customer campus interconnectivity.
Bangladesh, BdREN	BdREN is not operational yet; it is in the process of development.
Belarus, BASNET	In 2008, BASNET became a full member of TERENA. Also in 2008, the Belarusian research network BASNET received an invitation to participate in the GN3 (GEANT3) initiative with the status of 'Associate Member'.

Table 1.4.1 – continued

NREN	Changes in services
Other countries	
Canada, CANARIE	CANARIE's mandate was renewed in March 2007. Its mandate is for five years ending 31 March 2012. Under this mandate, CANARIE will: Network operations: continue to operate CANARIE's Network as essential research infrastructure and to the extent resources permit; expand the provision of advanced network capabilities to Canada's research and education community; upgrade the capacity of the network in keeping with demand; increase access to and use of the network by real and virtual organizations consistent with the network's Acceptable Use Policy (AUP); and enhance Canada's involvement in international networking and networking-focused collaborations. Technology innovation: develop, demonstrate and implement next-generation technologies to advance CANARIE's network as a leading-edge research network, and, to the extent that resources permit, develop service-oriented, architecture-based software interfaces and tools that facilitate the flexible use of network resources; develop service-oriented, architecture-based software interfaces, applications and tools that facilitate flexible and integrated use of distributed equipment and resources; and reinforce Canada's position as a recognized leader in the development and use of advanced research networks.
Colombia, RENATA	The RENATA Corporation has been created as an independent legal institution. Our NREN is constituted by regional (local) networks: RUANA, RUMBA, RUMBO, RUAV, RUP, RADAR, RIESCAR and UNIRED.
Croatia, CARNet	CARNet is implementing a major project to connect all primary and secondary schools to the network. Also, extensive work is being done to implement the E-Islands project.
Ecuador, CEDIA	We hope to have two new members. And we are looking for Ecuadorian government cooperation in the international connection to RedCLARA.
Georgia, GRENA	GRENA is actively participating in a Georgian secondary school connectivity program, 'Deer Leap Georgia'. Under this program, all 2300 schools in Georgia will receive Internet services via a virtual private network (VPN), and GRENA is acting as a Network Operation Centre for this network. In April 2009, GRENA established connectivity to GEANT according to the EC Black Sea Interconnection project.
Guatemala, RAGIE	Our link to RedCLARA has changed to an STM-1, which will allow for immediate and future growth in bandwidth. Currently, because of the prohibitive costs, we are only using 18 Mbps. One way we are hoping to increase the bandwidth is to also provide, through the STM-1, commodity internet for our members. This will provide some overhead which will allow us to acquire a higher bandwidth to RedCLARA. The university system in Guatemala is different from most countries in that all universities are based in the capital city. However, most of them also have campuses elsewhere in the country. At this time, only the campuses in the capital city are connected and we hope that in 2010 we will start the process of linking the other campuses, particularly in the most populated areas. For this reason, we are looking into acquiring Dark Fibre as this promises to be much more cost effective.
Japan, NiCT	We upgraded our JP-SG-TH circuit to 622Mbps, and also upgraded some of the circuits inside Japan. We also started our virtual storage service, DCN, PerfSONAR, etc.
Kazakhstan, KazRENA	In March 2009 KazRENA switched from satellite to fibre-optics.
Kyrgyzstan, KRENA-AKNET	1) Shifted from satellite to optical fibre; 2) Number of users has increased.
Macedonia, MARNet	MARNet become a GEANT member and is participating in the GN3 project. From February 2009, MARNet upgraded its international link to 155 Mbps, using a connection to GEANT through the Budapest PoP. It is expected that at the beginning of next year (i.e. 2010), MARNet will change its legal status and become an independent legal entity.
Malawi, MAREN	After registration and setting up a Network Operations Centre, we envisage that our user base will increase.
Malaysia, MYREN	MYREN is embarking on total infrastructure changes by early next year. We are moving to MYREN2 with our backbone of 622Mbps. We are moving away from the existing telco-managed network to a self-managed network.
Mexico, CUDI	Integration of CUDI videoconference system in 2008 with a central MCU for university service.

Table 1.4.1 – continued

NREN	Changes in services
Other countries	
Moldova, RENAM	One new DF link was realized in Chisinau MAN, allowing widening of our own optical infrastructure to 35 km. The capacity of radio-relay channel Chisinau (RENAM, Moldova) and Iasi (RoEduNet, Romania) was upgraded in February 2002 to 2x155 Mbps. The second external back-up channel was upgraded to 100 Mbps and is provided by local IDSP StarNet. From February 2009, the summarized external channels capacity (excluding local IX peering) achieved 300 + 100 Mbps. In 2009, development of the DF backbone in Chisinau continued. Four new RENAM nodes were connected by fibre optic links that allowed improved connectivity for campuses of the Technical University of Moldova, the State University of Medicine and Pharmaceutics, and the State Pedagogical University. In the second half of 2008, the elaboration of the technical solution of the DF link Chisinau-Iasi construction was finalized and in April 2009, practical realization of DF connection was started. RENAM CERT operation was promoted and appropriate services to the NREN community were deployed in production mode.
Montenegro, MREN	During the past year, there have been no major changes in our network topology, except relocation of the network core. In the coming year, we plan to replace the core router with a better performing router. The new router should have enough capacity to support full bgp routing tables; it must be a modular router with IDS and IPS capabilities.
Morocco, MARWAN	In April 2009, we put out a tender to the three national telecom operators. A new operator has been chosen and the new network will start in January 2010. This telecom operator will provide much greater bandwidths to the universities and institutes connected to Marwan, with better prices.
New Zealand, REANNZ	- Establishment of physically diverse Upper South Island path - Christchurch - Lower Hutt (2009); - Trial of National Education Network to 10% of schools (2008-2010); - Implementation of a permanent video-conferencing service (2009); - Procurement of national & international connectivity (2009/10).
Russian Federation, RBNet/ RUNNet	2006 - New SDH-based infrastructure of network backbone in Russia; 2006 – 2.5 Gb/s GEANT connectivity; 2007 - Moscow-Amsterdam channel (GLORIAD project); 2007 - 10Gb/s Moscow–St. Petersburg-Stockholm channel; 2009 - Dark cross-border fibre.
Sri Lanka, LEARN	Previously, the LEARN Project was an undertaking of the University Grants Commission of Sri Lanka. In 2009, it was registered as an association limited by guarantee, under the companies act of Sri Lanka.
Turkey, ULAKBIM	Access and backbone capacity upgrades were made. The capacity of GEANT connectivity has increased from 622 Mbps to 2x2.5 Gbps. Backbone router procurements have been done.
Turkmenistan, TuRENA	There have been no structural changes in the TuRENA network. Previously, the Supreme Council of Science and Technology supervised the TuRENA network. Now, the newly founded Academy of Sciences is responsible for the Project in Turkmenistan.
Ukraine, UARNet	Links upgraded to 10GE, all uplinks to Nx10GE, switches to Nx10GE ports.
Ukraine, URAN	In 2009, URAN implemented 1/10 Gbps connections to peers and users. An ACB DF connection to PIONIER (Poland) was established. Total IP traffic has increased by a factor of 8.
United Arab Emirates, ANKABUT	The Ankabut project is the NREN in the UAE. Ankabut's function is to link up universities, schools and public institutions with telecoms and data communication over fibre and IP. The network has connected 25 campuses and is rapidly expanding in the areas of networking and service provision. Ankabut works in partnership with universities and operators to provide the network infrastructure. It provides a selection of services that include, but are not limited to: voice and video conferencing, national federated SSO, inter-library systems, cloud computing and offsite disaster recovery.

Table 1.4.1 – continued

NREN	Changes in services
Other countries	
United States, 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. 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: http://www.internet2.edu/government/stimulus
Uzbekistan, UzSciNet	Educational projects have been expanded. The ECDL test centre is open. Regional CISCO Academy and Microsoft IT-Academy.
Vietnam, VinaREN	In 2009, we connected 9 more members; completion of the project is targeting 50 members of VinaREN.

1.5 Environmental policies

Recently, environment protection – including the issue of climate protection – has increasingly been at the focal point of public attention. Part of the GN3 (GÉANT) project is to evaluate how to establish and operate 'greener' (more environment friendly) networks and services. The first step is to take inventory of the current situation. This can be done in a standard-compliant manner (e.g. according to ISO 14064), so that the audit of the GHG (greenhouse gas) emissions of the participating NRENs can be validated and used constructively. The next step is to collect best practices, followed by the formulation of proposals and recommendations.

For this *Compendium*, NRENs were asked whether they have an environmental policy for efficient power use, recycling, etc. Currently, most NRENs do not have such a policy. Of course, that does not necessarily mean that they do nothing in this area. Only EENet of Estonia and JANET(UK) actually have a policy. The UK policy is available at
http://www.ja.net/documents/company/environmental-policy.pdf

Outside Europe, the CANARIE Green IT Program is noteworthy:
http://www.canarie.ca/en/green-program/pilot/about

2 USERS/CLIENTS

This section starts with information, in Section 2.1, 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 looks at the typical bandwidths and Section 2.5 at typical connection methods.

2.1 Overview

As shown by Graph 2.2.1 (right), all NRENs 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 NRENs are also allowed to connect secondary schools, primary schools, hospitals and government departments. There are great differences between NRENs: some are allowed to operate as national networks for a full 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 always 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.

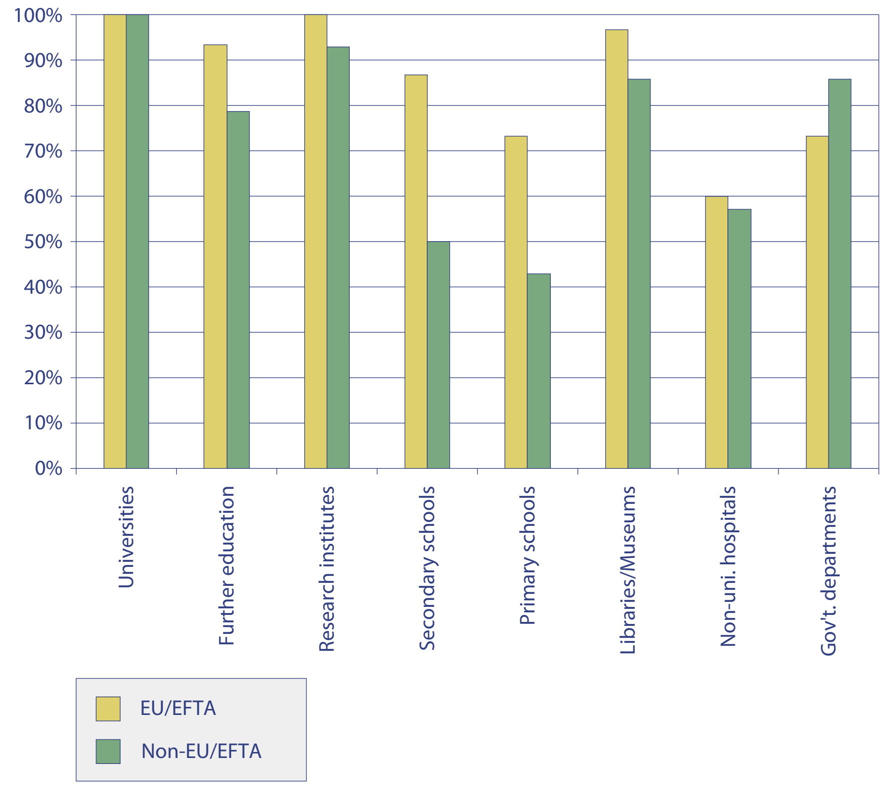
For universities within the EU/EFTA area, the typical connection capacity is now gigabit or greater — a tremendous difference compared with the situation a few years ago. Capacities exceeding 10 Gb/s are currently being introduced. Other categories of users have significantly lower capacities. Outside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

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

2.2 Connection policies

Graph 2.2.1 (below) summarises the NREN connection policies. As before, all NRENs are allowed to connect universities and almost all are allowed to connect research institutes. Many NRENs may also connect libraries, museums and archives, as well as institutes of further education. Note, however, that the fact that an NREN is allowed to connect a certain category of users does not necessarily mean that it does this in practice. As shown in Section 2.3, 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 tends to vary greatly between countries due to differing 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 (below) provides an overview of the number of institutions in each user category, as well as an indication of the percentage that are serviced by each NREN. Only approximate percentages were obtained from *Compendium* respondents.

NRENs that operate in a strong hierarchy of Metropolitan or Regional Area/Aggregation Networks (MAN/RAN) often cannot provide connection figures but do service high percentages of the community. The *Compendium* website (**http://www.terena.org/compendium**) contains additional information on individual NRENs.

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	TOTAL
EU/EFTA countries									
Austria, ACOnet	30 (≈100%)	1 (≈100%)	25 (≈<50%)	+ (≈100%)	+ (≈>50%)	9 (≈<50%)	4 (≈<50%)	25 (≈<50%)	94
Belgium, BELNET	67 (≈100%)	4 (≈0%)	40 (≈100%)	5 (≈0%)	+	12 (≈0%)	13 (≈0%)	50 (≈<50%)	191
Cyprus, CYNET	8 (≈100%)	1 (≈0%)	3 (≈<50%)	1 (≈0%)	-	-	-	-	13
Czech Republic, CESNET	26 (≈100%)	10 (≈<50%)	23 (≈<50%)	131 (≈<50%)	23 (≈0%)	34 (≈<50%)	33 (≈<50%)	44 (≈<50%)	324
Denmark, UNI-C	7 (≈100%)	10 (≈<50%)	10 (≈<50%)	5 (≈0%)	-	5 (≈0%)	1 (≈0%)	2 (≈0%)	40
Estonia, EENet	26 (≈100%)	8 (≈<50%)	15 (≈50%)	54 (≈>50%)	36 (≈>50%)	83 (≈<50%)	+	3 (≈0%)	225
Finland, Funet	55 (≈100%)	-	12 (≈50%)	-	-	4 (≈0%)	-	8 (≈0%)	79
France, RENATER	420 (≈100%)	340 (≈>50%)	350 (≈100%)	120	+	10 (≈<50%)	5 (≈0%)	25 (≈0%)	1270
Germany, DFN	+ (≈100%)	+ (≈100%)	+ (≈>50%)	+	+	+	+	+	
Greece, GRNET S.A.	40 (≈100%)	143 (≈100%)	24 (≈100%)	4150 (≈100%)	9956 (≈100%)	10 (≈<50%)	-	753 (≈<50%)	15076
Hungary, NIIF/HUNGARNET	+ (≈100%)	+ (≈100%)	+ (≈100%)	+ (≈<50%)	+	+ (≈100%)	+ (≈<50%)	+ (≈<50%)	
Iceland, RHnet	8 (≈100%)	1 (≈0%)	8 (≈>50%)	+	-	1 (≈0%)	-	-	18
Ireland, HEAnet	8 (≈100%)	30 (≈100%)	10 (≈>50%)	800 (≈100%)	3200 (≈100%)	+	-	5 (≈0%)	4053
Italy, GARR	118 (≈100%)	+	188 (≈100%)	+	+	29 (≈<50%)	40 (≈<50%)	-	375
Latvia, SigmaNet	22 (≈<50%)	4 (≈0%)	12 (≈<50%)	6 (≈0%)	-	7 (≈0%)	2 (≈0%)	-	53
Lithuania, LITNET	43 (≈100%)	138 (≈100%)	67 (≈>50%)	758 (≈<50%)	51 (≈<50%)	109 (≈<50%)	11 (≈0%)	48 (≈0%)	1225
Luxembourg, RESTENA	4 (≈100%)	4 (≈100%)	20 (≈100%)	58 (≈100%)	198 (≈100%)	31 (≈>50%)	+	1 (≈<50%)	316

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	TOTAL
EU/EFTA countries									
Malta, UoM/RicerkaNet	1 (≈100%)	2 (≈50%)	3 (≈50%)	+	+	+	-	-	6
Netherlands, SURFnet	37 (≈100%)	79 (≈100%)	46 (≈>50%)	-	-	24 (≈0%)	3 (≈<50%)	-	189
Norway, UNINETT	7 (≈100%)	38 (≈100%)	86 (≈50%)	6 (≈0%)	2 (≈0%)	13 (≈<50%)	-	-	152
Poland, PIONIER	165 (≈100%)	13 (≈0%)	198 (≈100%)	115 (≈0%)	11 (≈0%)	134 (≈<50%)	38 (≈<50%)	105 (≈<50%)	779
Portugal, FCCN	30 (≈100%)	+	6 (≈100%)	2700 (≈>50%)	+	3 (≈0%)	-	8 (≈<50%)	2747
Romania, RoEduNet	50 (≈100%)	10 (≈>50%)	50 (≈>50%)	400 (≈50%)	150 (≈<50%)	35 (≈50%)	-	25 (≈<50%)	720
Slovakia, SANET	38 (≈100%)	7 (≈<50%)	20 (≈50%)	130 (≈<50%)	100 (≈<50%)	6 (≈<50%)	+	+	301
Slovenia, ARNES	4 (≈100%)	17 (≈100%)	54 (≈100%)	150 (≈100%)	493 (≈100%)	197 (≈100%)	-	20 (≈0%)	935
Spain, RedIRIS	73 (≈100%)	-	108 (≈100%)	-	-	27 (≈0%)	46 (≈<50%)	39 (≈0%)	293
Sweden, SUNET	30 (≈100%)	9 (≈>50%)	4 (≈>50%)	-	-	18 (≈>50%)	-	19 (≈0%)	80
Switzerland, SWITCH	34 (≈100%)	2 (≈0%)	6 (≈<50%)	2 (≈0%)	+	+	+ (≈<50%)	3 (≈<50%)	47
United Kingdom, JANET(UK)	187 (≈100%)	605 (≈100%)	44 (≈100%)	+ (≈100%)	+ (≈100%)	8 (≈<50%)	-	38 (≈<50%)	882
Other countries									
Algeria, CERIST	42 (≈100%)	15 (≈100%)	18 (≈100%)	-	-	-	-	7 (≈<50%)	82
Australia, AARNet	38 (≈100%)	12 (≈<50%)	23 (≈<50%)	147 (≈0%)	142 (≈0%)	8 (≈<50%)	+	1 (≈0%)	371
Bangladesh, BdREN	+	-	-	-	-	-	-	-	
Belarus, BASNET	9 (≈<50%)	+	60 (≈<50%)	+	+	15 (≈<50%)	4 (≈0%)	14 (≈0%)	102
Canada, CANARIE	+ (≈100%)	+ (≈100%)	+ (≈50%)	+ (≈<50%)	+ (≈<50%)	+ (≈<50%)	+	+ (≈<50%)	
Chile, REUNA	+ (≈100%)	-	+ (≈<50%)	-	-	-	+	+	
Croatia, CARNet	200 (≈100%)	47 (≈100%)	46 (≈100%)	397 (≈>50%)	874 (≈<50%)	7 (≈<50%)	25 (≈<50%)	23 (≈<50%)	1619
Georgia, GRENA	9 (≈50%)	10 (≈50%)	40 (≈100%)	70 (≈<50%)	+	8 (≈0%)	4 (≈0%)	5 (≈0%)	146
Guatemala, RAGIE	6 (≈50%)	+	+	+	+	+	+	+	6
Israel, IUCC	11 (≈<50%)	-	5	-	-	+	+	-	16
Japan, NiCT	50 (≈<50%)	10 (≈<50%)	30 (≈<50%)	5 (≈0%)	5 (≈0%)	5 (≈0%)	5 (≈0%)	30 (≈<50%)	140
Jordan, JUNet	10 (≈100%)	-	-	-	-	-	-	-	10
Kazakhstan, KazRENA	+ (≈>50%)	+	+	+	+	+	+	+	
Kyrgyzstan, KRENA-AKNET	21 (≈50%)	3 (≈<50%)	16 (≈<50%)	5 (≈<50%)	+	1 (≈0%)	1 (≈0%)	1 (≈0%)	48
Macedonia, FYR, MARNet	20 (≈<50%)	-	38 (≈50%)	-	-	+ (≈50%)	-	+	

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	TOTAL
Other countries									
Malaysia, MYREN	15 (≈<50%)	+	2	-	-	-	-	-	17
Moldova, RENAM	9 (≈100%)	2 (≈0%)	35 (≈>50%)	+	+	14 (≈<50%)	3 (≈0%)	5 (≈0%)	68
Montenegro, MREN	20 (≈0%)	2 (≈0%)	2 (≈0%)	-	-	2 (≈0%)	-	1 (≈0%)	27
Morocco, MARWAN	14 (≈100%)	77 (≈100%)	7 (≈50%)	-	-	2 (≈<50%)	-	2 (≈<50%)	102
Nepal, NREN	3 (≈50%)	8 (≈<50%)	4 (≈<50%)	-	-	1 (≈0%)	5 (≈<50%)	1 (≈0%)	22
New Zealand, REANNZ	8 (≈100%)	5 (≈<50%)	15 (≈100%)	15 (≈0%)	8 (≈0%)	5 (≈<50%)	-	-	56
Russian Federation, RBNet/RUNNet	252 (≈>50%)	+ (≈<50%)	248 (≈<50%)	+	+	+	+	+	500
Serbia, AMRES	80 (≈100%)	5 (≈<50%)	40 (≈>50%)	5 (≈0%)	+	15 (≈0%)	5 (≈0%)	3 (≈0%)	153
Singapore, SingAREN	4 (≈>50%)	3 (≈>50%)	2 (≈<50%)	+	+	+	+	+	9
Sri Lanka, LEARN	32 (≈100%)	2 (≈<50%)	6 (≈<50%)	-	-	+	+	2 (≈0%)	42
Sudan, SUIN	30 (≈100%)	+	+	-	-	+	+	+	30
Taiwan, NCHC	180 (≈100%)	20 (≈100%)	30 (≈50%)	240 (≈100%)	20 (≈100%)	20 (≈0%)	10 (≈<50%)	5 (≈0%)	525
Turkey, ULAKBIM	704 (≈100%)	+ (≈100%)	14 (≈100%)	-	-	3 (≈0%)	-	9 (≈0%)	730
Turkmenistan, TuRENA	207 (≈>50%)	+ (≈50%)	+ (≈50%)	+ (≈<50%)	+	+	+ (≈<50%)	+	207
Ukraine, URAN	60 (≈>50%)	5 (≈0%)	15 (≈<50%)	2 (≈0%)	-	4 (≈0%)	2 (≈0%)	1 (≈0%)	89
United Arab Emirates, ANKABUT	25 (≈<50%)	+	+	+	+	+	+	+	25
Uzbekistan, UzSciNet	62 (≈100%)	23 (≈100%)	47 (≈>50%)	5 (≈0%)	-	28 (≈>50%)	9 (≈<50%)	33 (≈<50%)	207

2.4 Typical bandwidths

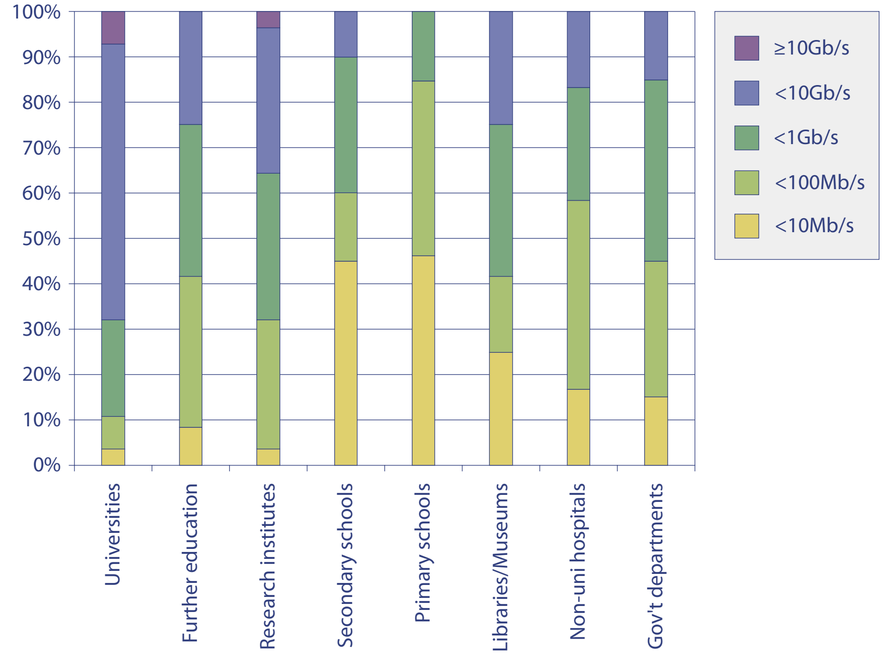
From the previous edition of the *Compendium*:

> *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 gigabit or greater. 10 Gb/s is now becoming increasingly common. 40 Gb/s is only available to a limited number of institutions. All other user categories have much lower connection speeds.

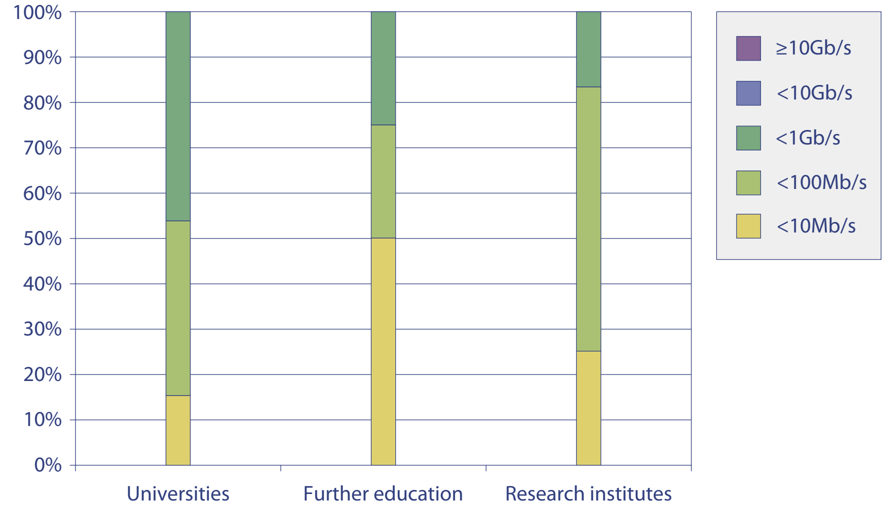
Graph 2.4.1 (below) gives an overview of the distribution of typical bandwidths available to NREN users. Note that not all NRENs provided information relevant to this overview, so the set of countries is not entirely the same for each user category.

Graph 2.4.1 – Typical bandwidth, EU/EFTA countries



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

Graph 2.4.2 – Typical bandwidth, other countries



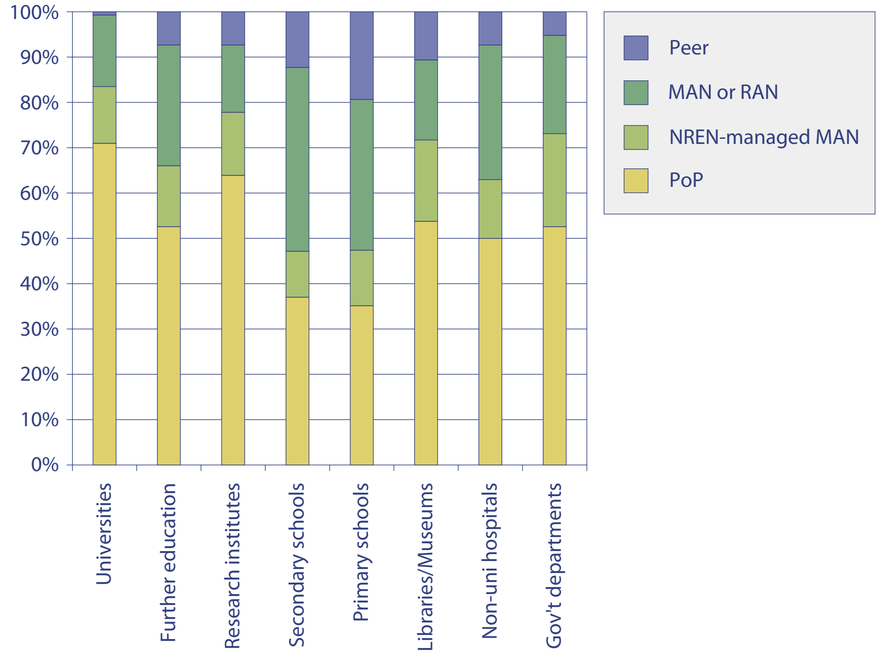
2.5 Connection methods

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.

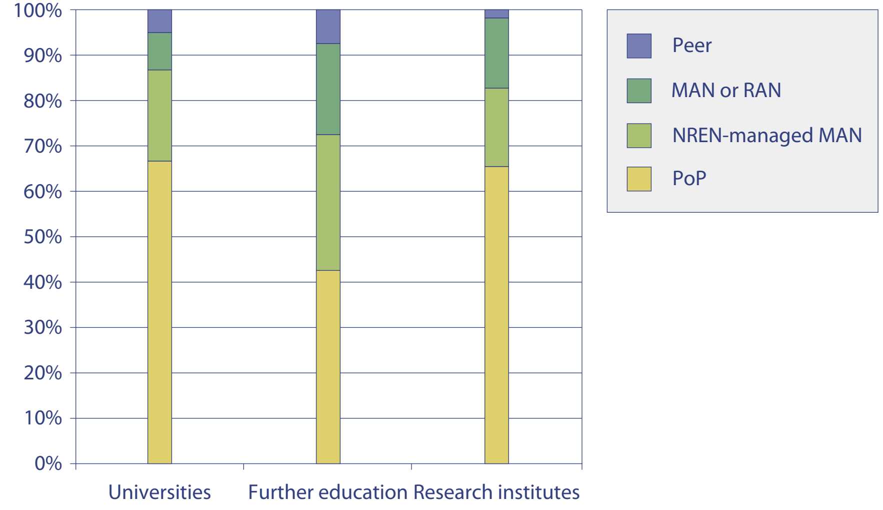
Graphs 2.5.1 and 2.5.2 indicate the prevalence of those connection methods among the various user categories. The graphs show how NRENs, on average, connect institutions.

Graph 2.5.1 – Typical connection methods, 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 much variation in the range of services provided.

Graph 2.5.2 – Typical connection methods, other countries



3 NETWORK AND CONNECTIVITY SERVICES

This section provides insights into a number of important network characteristics. Section 3.2 starts with information on PoPs (points of presence), optical PoPs, locations where core routing is undertaken and numbers of managed circuits and sites. Section 3.3 provides information about core capacity on the networks. Section 3.4 contains a new table listing network developments as expected or foreseen by NRENs. Section 3.5 is about the external links of NRENs. Section 3.6 summarizes existing and planned national and international point-to-point circuits. Section 3.7 documents recent developments in the area of dark fibre. Finally, Section 3.8 gives information on cross-border dark fibre links.

3.1 Overview

NRENs differ from one another in many respects, including network architecture. The number of PoPs on the network is one indicator of the amount of resources that the NREN needs to maintain its network. Section 3.2 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 cheaply whenever required.

In the other countries, the trend that was already visible last year continues: they have profited from the introduction of affordable Gigabit Ethernet technology.

Network capacity growth is not linear. 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, as Section 3.6 indicates, many NRENs now also offer several point-to-point circuits and lightpaths, which provide additional capacity that is often not included in normal traffic statistics.

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, the expansion of the NREN to areas outside the capital, which is one of the greatest challenges they face.

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 more than 60% of the total external connectivity. The remaining 40% 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. For NRENs with relatively low external capacities (totalling less than 10 Gb/s), the connection to GÉANT is the most important. For those NRENs with the highest external capacities (≥ 50 Gb/s), GÉANT capacity is often not the largest fraction of the total, while cross-border dark fibre provides a relatively high percentage of the external capacity.

The maps in Section 3.7 illustrate the rapid developments in the area of 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 2011.

A continuing development is the implementation of cross-border dark fibre links between NRENs. Section 3.8 presents current and planned links of this type both in map and table format.

3.2 PoPs and routing

The number of PoPs on the network is one indicator of the amount of resources that the NREN needs 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 on the number of PoPs. Thus, Germany's (i.e. DFN's) network with 55 optical PoPs and 55 locations where core routing is undertaken has an architecture that is quite different from the Netherlands' (i.e. SURFnet's) architecture, with 308 optical PoPs but only two locations where core routing is undertaken. (Further information on optical PoPs is given in Section 5.4.) For this reason, statistics indicating the total number of PoPs in Europe are not as meaningful as might be imagined.

In Table 3.2.1 (right), NRENs in which all PoPs are optical and offer Layer 3 routing are highlighted in colour.

Table 3.2.1 – Numbers of PoPs

Country	NREN	No. of PoPs	No. of locations offering optical PoPs	No. of optical PoPs where L3 routing is provided	No. of locations where core routing is undertaken
EU/EFTA countries					
Austria	ACOnet	20	20	12	
Belgium	BELNET	21	21	21	2
Bulgaria	BREN	14	0		1
Cyprus	CYNET	3	0	0	2
Czech Republic	CESNET	40	18	12	14
Denmark	UNI-C	9	5	2	7
Estonia	EENet	16	4	4	16
Finland	Funet	41	39	12	6
France	RENATER	40	> 30	> 30	
Germany	DFN	55	55	55	55
Greece	GRNET S.A.	38	56	38	38
Hungary	NIIF/HUNGARNET	43	43	43	43
Iceland	RHnet	14	0	14	14
Ireland	HEAnet	11	2	2	2
Italy	GARR	47	17	9	14
Latvia	SigmaNet	5	1	1	5
Lithuania	LITNET	48	6	5	5
Luxembourg	RESTENA	13	2	2	13
Malta	UoM/RicerkaNet	2			2
Netherlands	SURFnet	308	308	2	2
Norway	UNINETT	40	4	4	40
Poland	PIONIER	35	71	3	3
Portugal	FCCN	2	15	0	2
Romania	RoEduNet	41	33		8
Slovakia	SANET	26	26	26	26
Slovenia	ARNES	45	45	45	45

Table 3.2.1 – continued

Country	NREN	No. of PoPs	No. of locations offering optical PoPs	No. of optical PoPs where L3 routing is provided	No. of locations where core routing is undertaken
EU/EFTA countries					
Spain	RedIRIS	20	0		19
Sweden	SUNET	23	21	4	3
Switzerland	SWITCH	33	33	33	33
United Kingdom	JANET(UK)	18	44	18	8
Other countries					
Algeria	CERIST	4	4		4
Belarus	BASNET	22	22	5	2
Croatia	CARNet	677	480	400	130
Georgia	GRENA	13	9	9	12
Israel	IUCC	2	0	0	9
Macedonia	MARNet	1	1		
Moldova	RENAM	42	20	5	2
Montenegro	MREN	13	25	25	1
Morocco	MARWAN	15	12	15	0
Russian Federation	RBNet/RUNNet	12	4		10
Serbia	AMRES	54	54	54	54
Turkey	ULAKBIM	3	0		3
Ukraine	UARNet	280	140	0	5
Ukraine	URAN	25	25		4

For the first time, the *Compendium* questionnaire collected data on the number of NREN-managed circuits that carry production traffic. This is one indicator of the overall size and complexity of the network. As in previous years, information was collected on the number of managed sites, i.e. where the NREN manages routing or switching equipment. Information from both these data sets is represented in Table 3.2.2 (below).

As can be seen from Table 3.2.2, NRENs differ considerably in these areas. The differences in the number of managed circuits reflect differences in network architecture. 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, increases in the number of managed sites by at least 25% are highlighted in colour.

Table 3.2.2 – Managed circuits and sites

Country	NREN	No. of client institutions	No. of managed circuits	No. of managed sites 2009	No. of managed sites 2008	No. of managed sites 2007
EU/EFTA countries						
Austria	ACOnet	94	24	21	15	15
Belgium	BELNET	191	126	21	21	16
Bulgaria	BREN		30	14	10	10
Cyprus	CYNET	13	0	2	3	3
Czech Republic	CESNET	324	56	40	39	29
Denmark	UNI-C	40	23	20	20	20
Estonia	EENet	225	20	16	16	16
Finland	Funet	79	120	25	18	16
France	RENATER	1270		50	50	50
Germany	DFN		129	55	54	49
Greece	GRNET S.A.	15076	78	79	79	63
Hungary	NIIF/ HUNGARNET		48	43	42	40
Iceland	RHnet	18	18	14	14	14

Table 3.2.2 – continued

Country	NREN	No. of client institutions	No. of managed circuits	No. of managed sites 2009	No. of managed sites 2008	No. of managed sites 2007
EU/EFTA countries						
Ireland	HEAnet	4053	504	63	12	10
Italy	GARR	375	64	47	42	38
Latvia	SigmaNet	53	40	5	10	1590
Lithuania	LITNET	1225	200	458	200	200
Luxembourg	RESTENA	316	59	57	57	57
Malta	UoM/ RicerkaNet	6	17	4	2	1
Netherlands	SURFnet	189	336	308	256	262
Norway	UNINETT	152	240	385	385	385
Poland	PIONIER	779	31	25	25	23
Portugal	FCCN	2747	2	30	9	9
Romania	RoEduNet	720	53	80	40	40
Slovakia	SANET	301	30	26	26	26
Slovenia	ARNES	935	1054	946	1190	1107
Spain	RedIRIS	293	67	20	20	20
Sweden	SUNET	80	200	5	3	60
Switzerland	SWITCH	47	50	34	35	34
United Kingdom	JANET(UK)	882	1500	504	742	742
Other countries						
Algeria	CERIST	82	3	4		
Belarus	BASNET	102	43	42	38	
Croatia	CARNet	1619	677	677	613	570
Georgia	GRENA	146	10	13	13	13
Israel	IUCC	16	16	10	10	10
Macedonia	MARNet	10	25			
Moldova	RENAM	68	50	58	51	51

Table 3.2.2 – continued

Country	NREN	No. of client institutions	No. of managed circuits	No. of managed sites 2009	No. of managed sites 2008	No. of managed sites 2007
Other countries						
Montenegro	MREN	27	30	25	31	31
Morocco	MARWAN	102	34	1		
Russian Federation	RBNet/RUNNet	500		56	12	12
Serbia	AMRES	153	153	54	52	40
Turkey	ULAKBIM	730	150	3	3	3
Ukraine	UARNet		1370	29	850	
Ukraine	URAN	89	160	35		

3.3 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 which case we requested data on the **usable** IP capacity.

Graphs 3.3.1 and 3.3.2 give an impression of how network capacities evolved from 2005 to 2008. The information is presented in one graph for the EU/EFTA countries and one for the other countries. Note that the vertical scales are logarithmic.

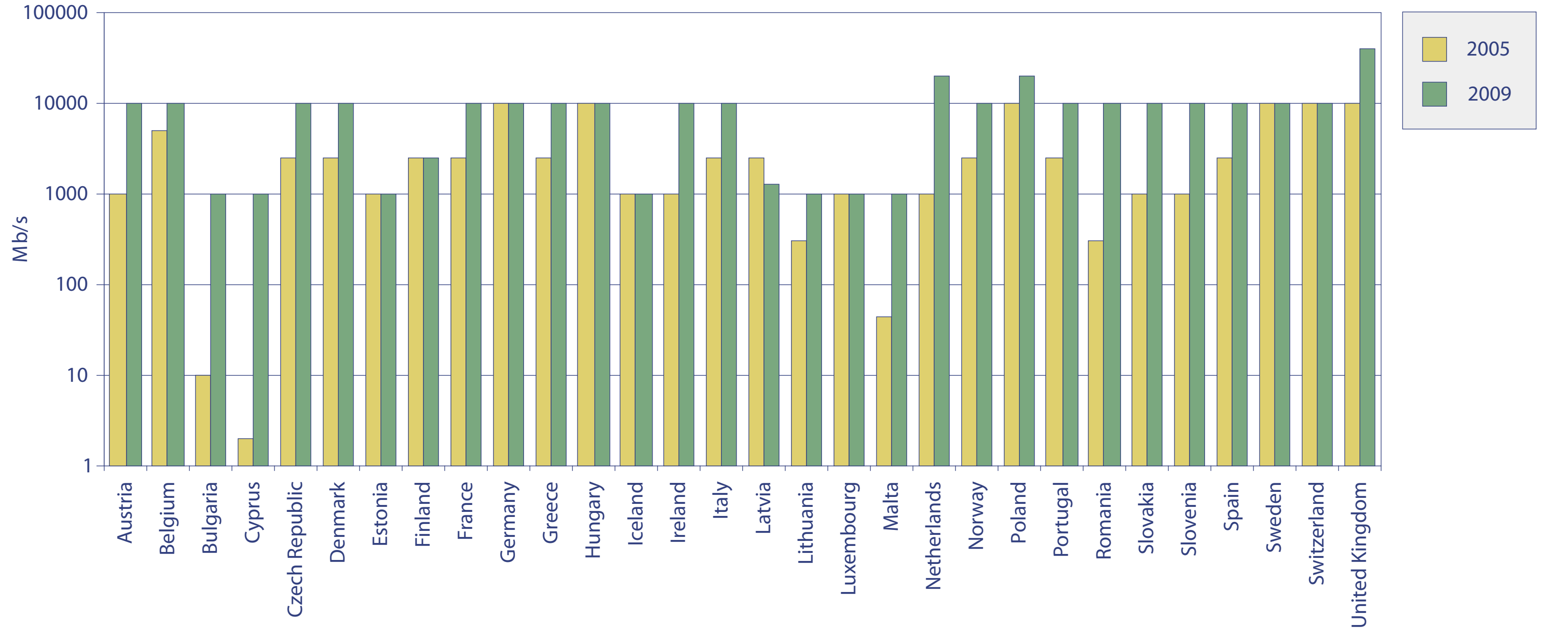
In most EU/EFTA countries, the typical core capacity is now 10 Gb/s. This is also the median capacity, up from 2.5 Gb/s in 2005. This capacity is no longer a hard limit: many NRENs have access to dark fibre (see Section 3.7 below), which is potentially able to handle high capacities, so they can increase capacity easily and cheaply whenever required. Thus, CANARIE in Canada already deploys 50 Gb/s on the backbone; in Europe, the UK currently deploys the highest capacity:

40 Gb/s. Five years ago, such capacities were not yet common, nor had the transition to dark fibre taken place. In 2005, 2.5 Gb was the most common capacity.

In the other countries, the trend that was already visible last year continues: they have profited from the introduction of affordable Gigabit Ethernet technology. Network capacity growth is not linear. 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 2005-2009, average growth of core capacity in the EU/EFTA countries was 29%. Over the same period, average growth of traffic on the GÉANT backbone was 36%.

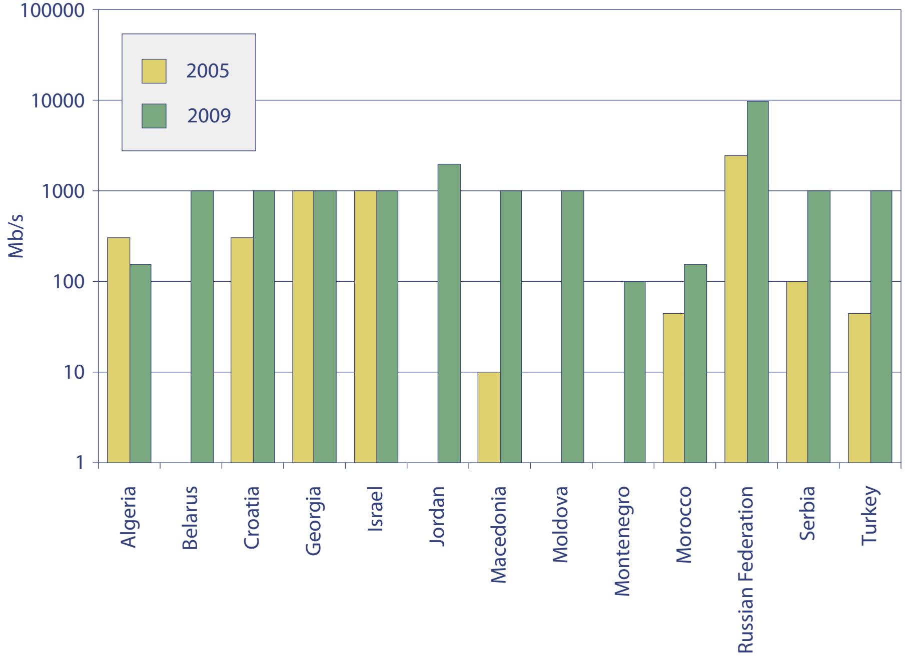
The growth of core capacity is not the whole story: the number and capacity of links on the backbones have grown as well. This is illustrated by Maps 3.3.3 and 3.3.4, produced by the GÉANT project and showing the extent of 10 Gb/s links in 2004 and 2009. In addition, as Section 3.6 shows, many NRENs now have several point-to-point circuits and lightpaths. These offer additional capacity that is often not included in normal traffic statistics.

Graph 3.3.1 – Core capacity on the networks, 2005-2009, EU/EFTA countries
(N.B. Logarithmic vertical scale)

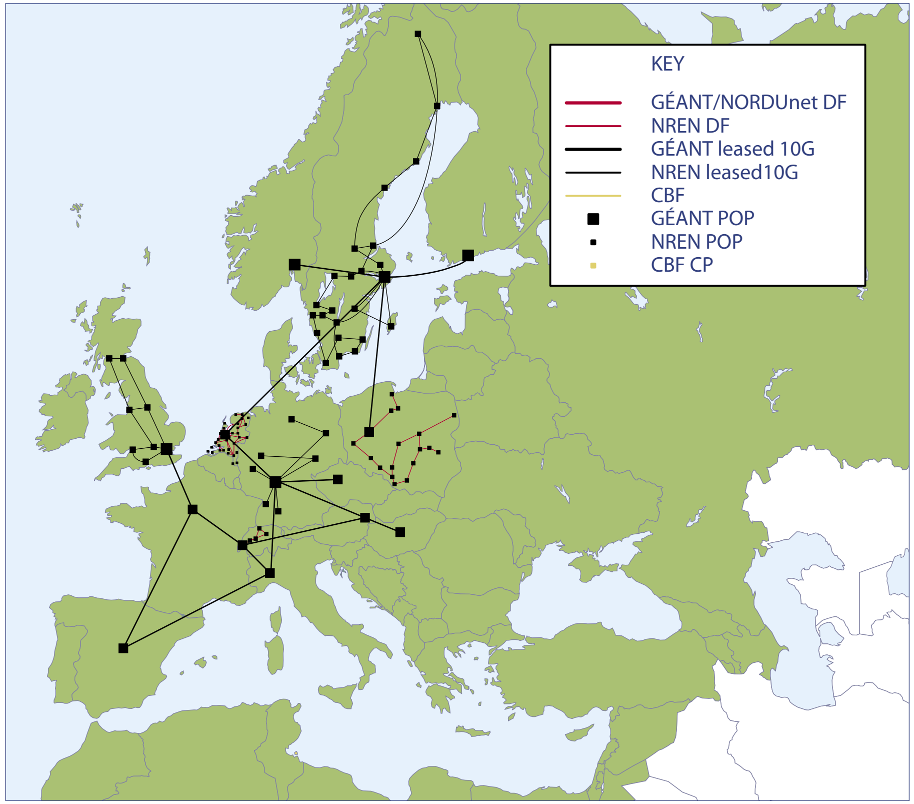


Graph 3.3.2 – Core capacity on the networks, 2005-2009, other countries

(N.B. Logarithmic vertical scale)

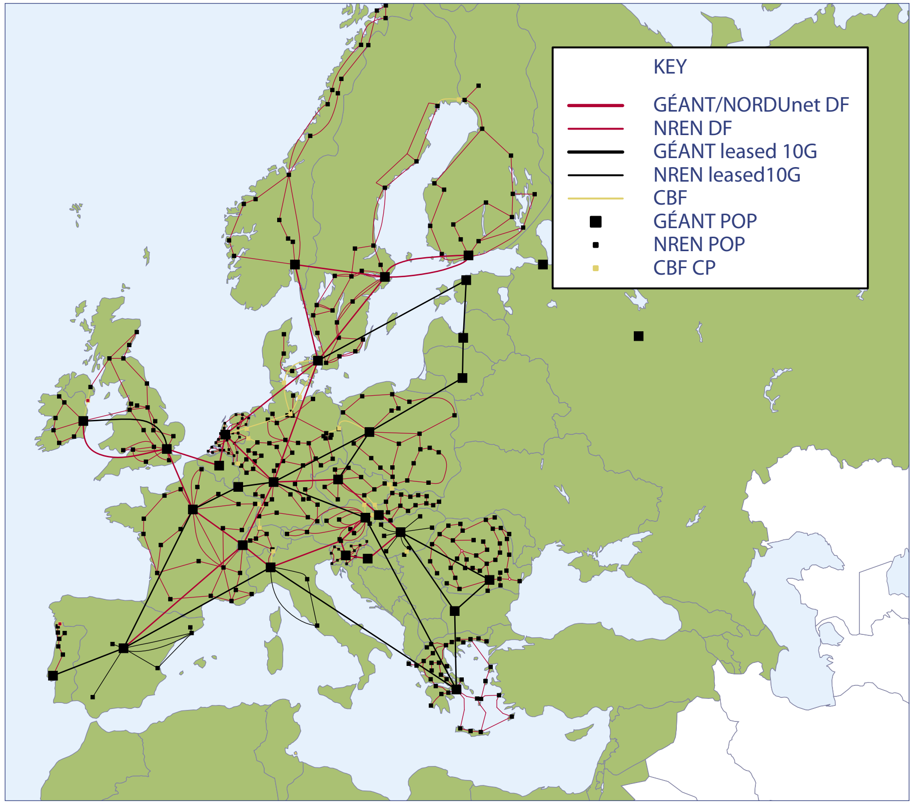


Map 3.3.3 – 10 Gb/s links, 2004



Compiled by DANTE, from network information provided courtesy of NREN and DANTE operations teams.

Map 3.3.4 – 10 Gb/s links, 2009



Compiled by DANTE, from network information provided courtesy of NREN and DANTE operations teams.

3.4 Major expected network developments

The NRENs covered by this edition of the *Compendium* were requested to descriptively outline major initiatives relating to development of their underlying network that they expect to realise within the next 2 to 5 years. Several NRENs that did not respond to this question did provide more general answers; these are listed in Section 1.4.

Table 3.4.1 provides a general insight into expected major network developments 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 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 for transmitting data;
- 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.

Table 3.4.1 – Major expected network developments

Country	NREN	Developments	Time-frame	Certainty
EU/EFTA countries				
Belgium	BELNET	Further extend the fibre network by implementing regional fibre rings.	2010-2011	Quite likely
		Shift the demarcation line from BELNET PoPs into the customers' network.	2010-2011	Quite likely
Bulgaria	BREN	SEELIGHT Project gives the prospect of providing cross-border dark fibre links, as well as dark fibre to at least part of the national backbone.	3 yrs.	Likely
Cyprus	CYNET	Upgrade the GÉANT connection to 2.5 Gb/s.	< 1yr.	Quite likely
Czech Republic	CESNET	Pilot 40 Gbit/s IP/MPLS line Prague-Brno over DWDM network.	1 yr.	
Denmark	UNI•C	DWDM Metro Networks.	1 yr.	Quite likely
Finland	Funet	Extend the coverage of the DWDM optical network.	2 yrs.	Quite likely
		Expand the availability and usage of backup customer connections.	3 yrs.	Quite likely
Greece	GRNET	Online services over cloud computing infrastructure. e.g. storage, VMs access.	3 yrs.	Quite likely
		40 Gbps Internal links.	3 yrs.	Quite likely
		Cross-border fibre to FYRoMacedonia, Albania and Turkey.	3 yrs.	Uncertain
Hungary	NIIF/HUNGARNET	Reconstruct and upgrade the internal network.	1 yr.	
Iceland	RHnet	General build-up of 10 GE to the connected institutions.	2 yrs.	Quite likely
		10 Gb/s connectivity to NORDUnet. Could be as early as in Sept. 2009.	1 yr.	Quite likely

Table 3.4.1 – continued

Country	NREN	Developments	Time-frame	Certainty
EU/EFTA countries				
Ireland	HEAnet	Possible support of WiMAX networks on campus networks.	1-5 yrs.	Uncertain
		Work on the integration of virtualisation of network and services (combination of IaaS, PaaS [Platform] and SaaS [Software]).	2-5 yrs.	Uncertain
		Virtualisation of network resources using IaaS (Infrastructure as a Service) framework. This can incorporate BoD).	2-5 yrs.	Uncertain
		Upgrading of existing DWDM network to ROADM.	2 yrs.	Quite likely
		A three-stream strategy on IPv4/IPv6 environment:		
		a. IPv4 depletion processes;	1 yr.	Certain
		b. Fully standalone IPv6 network;	1-3 yrs.	Certain
		c. clients on IPv6;	4-5 yrs.	Likely
		No 40G, will use nx10G instead. Wait for 100G.	1-2 yrs.	Quite likely
		Possible connection of large number of sensor devices onto our network.	2-5 yrs.	Uncertain
		Service (path, PoP, Power, Equipment) resilience to clients.	1 yr.	Certain
Latvia	SigmaNEt	Build new academic network based on dark fibre of leased lambdas.	4 yrs.	Likely

Table 3.4.1 – continued

Country	NREN	Developments	Time-frame	Certainty
EU/EFTA countries				
Lithuania	LITNET	Vilnius University Grid cluster becomes CERN TIER1 data centre.	4 yrs.	Uncertain
		Cross-border fibre with PIONIER (PL).	4 yrs.	Likely
		Cross-border fibre with SigmaNet (LV).	5 yrs.	Uncertain
Luxembourg	RESTENA	The network is converging to a network based entirely on optical dark fibres within the next 2 years. DWDM technology is being deployed to provide 10G pt-2-pt circuits to research and Grid projects.	2 yrs.	
Malta	UoM/RicerkaNet	Connectivity to GÉANT at 1 Gbps.	1 yr.	Quite likely
Norway	UNINETT	More redundancy.	5 yrs.	Quite likely
		Promote and demonstrate use of wavelengths.	5 yrs.	Quite likely
		Upgrade core network: 10 Gbit/s → 40 Gbit/s for universities; 1 Gbit/s → 10 Gbit/s for university colleges.	3 yrs.	Quite likely
Poland	PIONIER	Increase capacity to BasNet to 622 Mb/s.	2009	Quite likely
Portugal	FCCN	Complete the national fibre ring.	2 yrs.	Quite likely
Romania	RoEduNet	PoPs to be connected to NOCs using the new DWDM structure with 1 Gbps links.		
		Cross-border connection to RENAM using dark-fibre and CWDM or DWDM.	1 yr.	
Slovakia	SANET	100 Gbit Ethernet.	5 yrs.	Quite likely

Table 3.4.1 – continued

Country	NREN	Developments	Time-frame	Certainty
EU/EFTA countries				
Spain	RedIRIS	National dark fibre deployment; national coverage, including Canary Islands.	3 yrs.	Quite likely
Switzerland	SWITCH	Upgrade of some backbone trunks to 2*10GE.	2 yrs.	Quite likely
		Upgrade of main backbone trunk to 100GE.	5 yrs.	Likely
		Setup of 10GE lightpaths between major data centres and GÉANT PoP.	2 yrs.	Likely
Other countries				
Algeria	CERIST	Upgrade connectivity to commercial Internet.	Current	Quite likely
		Upgrade connectivity to GÉANT.	2011	Quite likely
Australia	AARNet	Upgrade backbone to 100 Gb/s.	5 yrs.	Likely
		Upgrade backbone 10 to 40 Gb/s.	2 yrs.	Quite likely
		Extend optical network to Perth, Geraldton, Murchison Radio-Astronomy Observatory.	2 yrs.	Quite likely
		Extend optical network to Tasmania.	3 yrs.	Uncertain
		Enable G.MPLS across network.	4 yrs.	Likely
		Enable 10G access for all customers.	1 yr.	Quite likely
Bangladesh	BdREN	The Government has a project to implement an NREN in Bangladesh. It has received credit from the World Bank for this.	2 yrs.	Quite likely

Table 3.4.1 – continued

Country	NREN	Developments	Time-frame	Certainty
Other countries				
Belarus	BASNET	Increase the capacity of the link to PIONIER to 622 Mbps.	2009	Quite likely
Chile	REUNA	Upgrade the northern part of the backbone to at least 1 Gb/s using one DWDM lambda.	2010	Quite likely
		Upgrade the southern part of the backbone to at least 1 Gb/s using one DWDM lambda.	2011	Quite likely
Croatia	CARNet	QoS.	2011	Quite likely
		Optical switching.	2012	Likely
Ecuador	CEDIA	Upgrade network capacity to 45 Mbps; upgrade last-mile connections to 2 Mbps.	1 yr.	
El Salvador	RAICES	Change network topology, moving from a star topology with 2 MB links to a ring topology among members, with 100 MB links between each one.	1 yr.	
Guatemala	RAGIE	Increase our bandwidth to CLARA to 34 Mb/s.	2 yrs.	Quite likely
		Currently, only campuses in the capital city are connected. Initiate the process of extension into rural areas.	1 yr.	Quite likely
Japan	NiCT	Cloud computing.	1 yr.	Quite likely
		Over 40G.	1 yr.	Quite likely
		Optical switching.	1 yr.	Quite likely
Kyrgyzstan	KRENA/AKNET	Upgrade channel (core bandwidth) from 7 Mb/s to 45 Mb/s.	2011	Quite likely
		Connect other regions.	2015	Quite likely
Malaysia	MYREN	MYREN2 network commissioning.	1 yr.	Quite likely

Table 3.4.1 – continued

Country	NREN	Developments	Time-frame	Certainty
Other countries				
Mexico	CUDI	Upgrade backbone from 155 Mb/s to 1 Gb/s.	1 yr.	
		One new cross-border link between Mexico and USA.	1 yr.	
Moldova	RENAM	CBF (DF) connection to Romania.	Current	Quite likely
		Transferring RENAM-RoEduNet-GÉANT connection to 10 Gb/s Ethernet technology; new routing equipment to organize operation of CBF connection to RoEduNet.	2010 Q1	Quite likely
		Upgrade internal network equipment in Chisinau MAN for processing and distribution of 10 Gb/s traffic in 5 main nodes of RENAM.	2010 Q1/Q2	Quite likely
		Elaborate detailed technical project for Eastern external connection to Ukraine.	2010 Q3	Quite likely
		GÉANT PoP in Chisinau organization.	2011	Quite likely
		Implement cross-border connection to Ukrainian NREN (and to possible GÉANT PoP in Kiev).	2012	Quite likely
Montenegro	MREN	Develop Grid service.	4 yrs.	Quite likely
		Develop E-Learning services and platforms.	2 yrs.	Likely
Morocco	MARWAN	New Internet link 2x155 Mbps.	1 yr.	Quite likely
New Zealand	REANNZ	Deployment of 40 or 100G technologies.	4 yrs.	Quite likely
		Move to dark fibre.	4 yrs.	Likely
Russian Federation	RBNet/RUNNet	DWDM international connectivity.	2009	Quite likely

Table 3.4.1 – continued

Country	NREN	Developments	Time-frame	Certainty
Other countries				
Serbia	AMRES	Upgrade the NREN backbone to 10 Gb/s and to DWDM equipment, to be provided through the SEELight project.	3 yrs.	Quite likely
Singapore	SingAREN	High bandwidth connectivity to DCN as part of the Gloriad Taj NSF project.	2-3 yrs.	Likely
		Connectivity to South Asia to be more pervasive as part of TEIN4.	1-2 yrs.	Quite likely
		Re-examine our PoP connectivity, given the Singapore government's Next Generation Broadband Network, with the possible setup of Singapore Gigabit Internet Exchange.	1-2 yrs.	Quite likely
Taiwan	NCHC	Implement next generation optical network technologies (NG-SDH, DWDM and ROADM).	2 yrs.	
Turkey	ULAKBIM	Install dark fibre in metropolitan areas.	2 yrs.	Quite likely
		Dark fibre leasing for backbone connections.	2 yrs.	Quite likely
Turkmenistan	TURENA	Extend the network, especially to connect new centres in Ashgabat and other regions.	1-2 yrs.	Quite likely
		Upgrade VSH system in Turkmenistan; install terminal and network equipment.	2-5 yrs.	Likely
Ukraine	URAN	Implement IPv6.	2010	Likely
		Typical 1G user connection.	2010 – 2011	Likely
USA	Internet2	http://www.internet2.edu/network		
Uzbekistan	UzSciNet	CAREN project.	2010	Quite likely

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 2009.

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 education and research traffic, while peerings and other connections convey traffic to and from the general Internet. The former category of traffic may be highly specialised data, 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. In other words, 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.

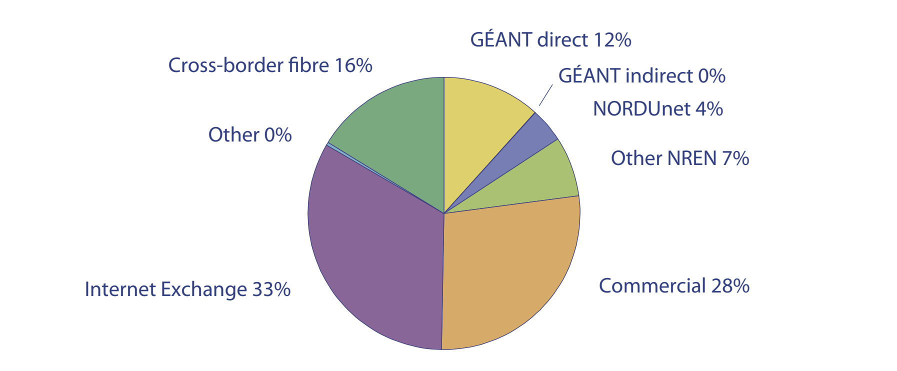
In contrast, traffic to and from the general Internet tends to be aggregated and smoothly varying. It comprises a large number of small-to-medium data flows, which combine to produce a fairly predictable traffic pattern. Therefore, the required capacity of the link can reliably be related to the average flow of data.

In Graphs 3.5.1 to 3.5.4, these two distinct categories of traffic are, however, 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 of crucial importance to NRENs. Graph 3.5.1, which presents the average situation for all EU/EFTA NRENs, illustrates that connections to Internet Exchanges and to commercial Internet providers together account for more than 60% of the total external connectivity. The remaining 40% is divided between connections to

GÉANT and NORDUnet, cross-border fibre connections (see Section 3.8) and direct NREN-to-NREN connections.

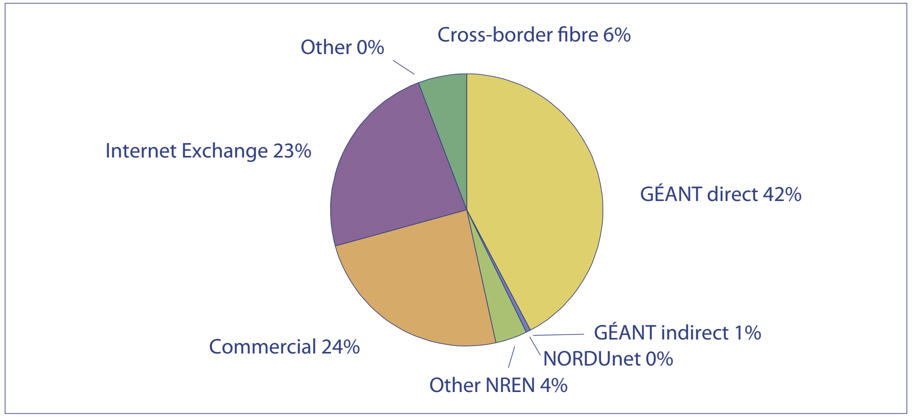
Graph 3.5.1 – NREN external connections, EU/EFTA countries



It should be noted that there are large differences between NRENs, as is illustrated by Graphs 3.5.2 to 3.5.4. Graph 3.5.2 shows the combined external capacities of 13 European (EU/EFTA and non-EU/EFTA) NRENs, each with total external connections of under 10 Gb/s.

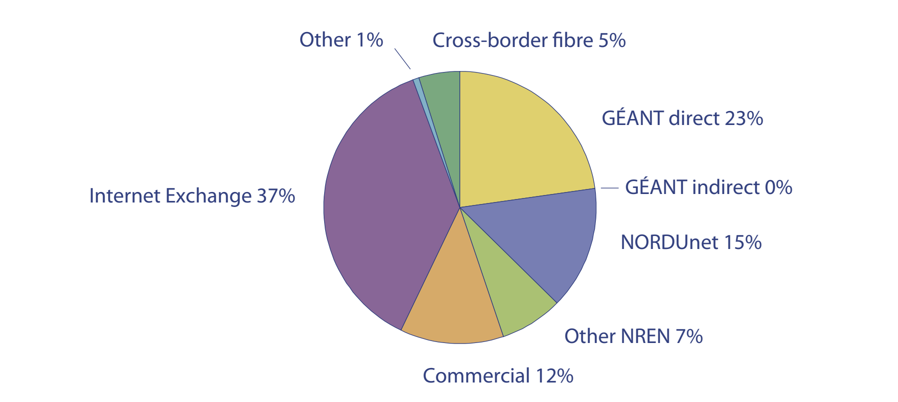
The pattern revealed by Graph 3.5.2 is that connections to GÉANT, NORDUnet and other NRENs jointly account for nearly half of the total external capacity, i.e. more than twice the average for the EU/EFTA countries as a whole. Most of the remaining capacity is divided between commercial Internet connections and connections to Internet Exchanges. Cross-border fibre is responsible for only 6% of the total capacity for these NRENs.

Graph 3.5.2 – European NRENs with external connections < 10 Gb/s



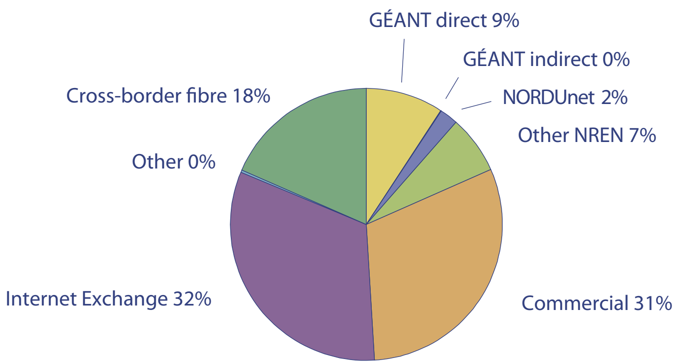
As Graph 3.5.3 (below) illustrates, the pattern is quite different for those 14 European NRENs with total external connections of between 10 and 50 Gb/s. Their connections to Internet Exchanges account for a much larger portion of the total than is the case for the NRENs included in Graph 3.5.2 (above).

Graph 3.5.3 – European NRENs with external connections of 10-50 Gb/s



As Graph 3.5.4 (below) shows, the situation is again quite different for those 11 European NRENs with total external connections of 50 Gb/s or greater. Their connections to GÉANT, NORDUnet and other NRENs jointly account for only 18% of the total capacity. Connections to commercial providers and to peerings each account for just under one-third of the total. Cross-border fibre connections are more important for this group of NRENs than for those included in Graphs 3.5.2 and 3.5.3 (above), accounting for 19% of the total external connection capacity. Unsurprisingly, it is generally true that the greater the number of external connections, the more diverse they are.

Graph 3.5.4 – European NRENs with external connections ≥ 50 Gb/s



Please note that Graphs 3.5.1 to 3.5.4 do not include the additional international point-to-point circuits (other than the IP circuits already covered) that some NRENs have, mostly for specific projects. For details of such circuits, see Section 3.6 (right).

3.6 Point-to-point circuits

The NRENs covered by this edition of the *Compendium* were asked to list point-to-point circuits within their networks, or starting in their networks and ending elsewhere, such as p2p circuits across GÉANT. The responses, listed in Table 3.6.1 (below) show that many NRENs have such circuits.

Please note that most of the European circuits included in Table 3.6.1 are listed twice (i.e. by NRENs at either end of the circuit). Also, there may be some overlap with the cross-border dark fibres shown on Map 3.8.2.

Table 3.6.1 – Point-to-point circuit

National point-to-point circuits			
Country	**Number**	**Purpose**	**Total capacity**
EU/EFTA countries			
Belgium	2	Backup	2 Gb/s
	28	Production	44.2 Gb/s
Germany	33	Production	144 Gb/s
Ireland	1	Project	1 Gb/s
Luxembourg	4	Production	4 Gb/s
Netherlands	Several	Mostly production	169.8 Gb/s
Portugal	1	Production	3 Gb/s
Spain	> 30	Project	1 Gb/s
	1	Testing	10 Gb/s
Slovenia	1	Production	1 Gb/s
Sweden	Several	Production	40 Gb/s
Switzerland	5	Production	13.1 Gb/s
UK	14		21.2 Gb/s
Other countries			
Algeria	3	Production	344 Mb/s
Israel	6	Backup	1200 Mb/s
	7	Production	13.5 Gb/s

Table 3.6.1 – continued

International point-to-point circuits			
Country	**Number**	**Purpose**	**Total capacity**
EU/EFTA countries			
Czech Republic	2	Production, Europe	2 Gb/s
	5	Project, Europe	14 Gb/s
	1	Production, Taipei	622 Mb/s
	3	Project, US	3 Gb/s
Finland	2	Project, Europe	20 Gb/s
France	2	Production, Europe	20 Gb/s
	2	Project, Europe	20 Gb/s
	2	Project, International	3 Gb/s
Germany	11	Production, Europe	83 Gb/s
Greece	1	Experimental, Europe	1 Gb/s
	1	Project, Europe	3 Gb/s
Hungary	2	Project, Europe	2 Gb/s
Ireland	5	Project, Europe	5 Gb/s
	1	Testing, Europe	1 Gb/s
Italy	7	Project, Europe	25 Gb/s
Netherlands	8	Production, Europe	34.3 Gb/s
	3	Project, Europe	3 Gb/s
	1	Testing, Europe	1 Gb/s
	6	Production, International	15 Gb/s
	3	Testing, International	12 Gb/s
Norway	1	Testing, Europe	1 Gb/s
	1	Project, International	1 Gb/s
Poland	7	Project, Europe	7 Gb/s
	1	Project, International	1 Gb/s
Portugal	2	Testing, Europe	2 Gb/s
Slovenia	1	Production, Europe	1 Gb/s
Spain	6	Project, Europe	33 Gb/s

Table 3.6.1 – continued

International point-to-point circuits			
Country	**Number**	**Purpose**	**Total capacity**
EU/EFTA countries			
Sweden	Several	Production, Europe	32 Gb/s
Switzerland	3	Production, Europe	3 Gb/s
UK	7	Europe	37 Gb/s
	1	International	155 Mb/s
Other countries			
Algeria	1	Production, Europe	155 Mb/s
Israel	1	Production, Europe	2.5 Gb/s

3.7 Dark fibre

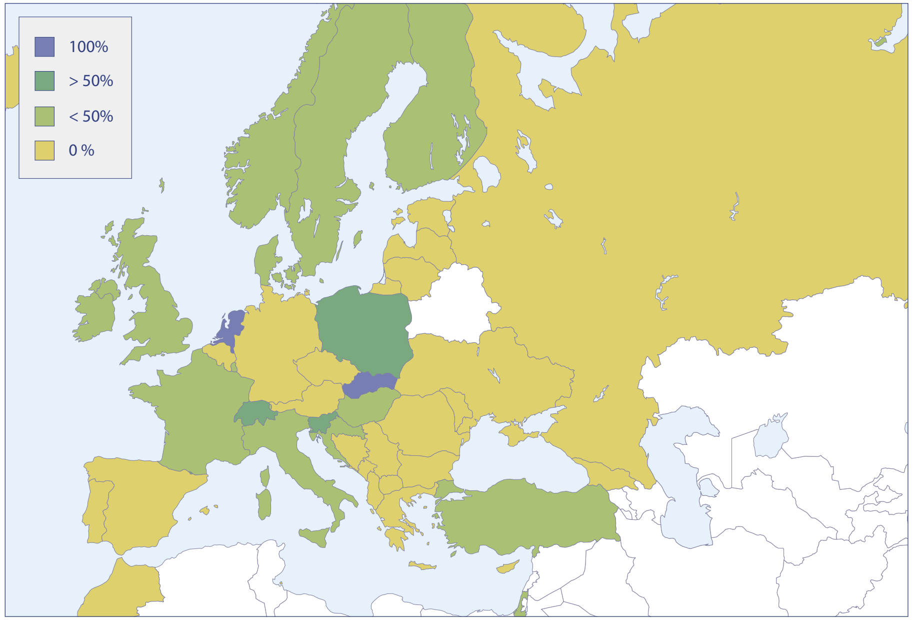
Some NRENs own dark fibre, have IRUs[1] or lease dark fibre, and can therefore decide what technology and speeds to use on it. The NRENs covered by this edition of the *Compendium* were asked whether they currently own dark fibre or have IRUs, or plan to acquire it within the coming two years. The NRENs were also asked to state approximately what percentage of their backbone is dark fibre.

Maps 3.7.1 and 3.7.2 (opposite)[2] illustrate the rapid developments in this area in recent years. Many, though not all, NRENs predict a further increase in the percentage of their network accounted for by dark fibre by 2011.

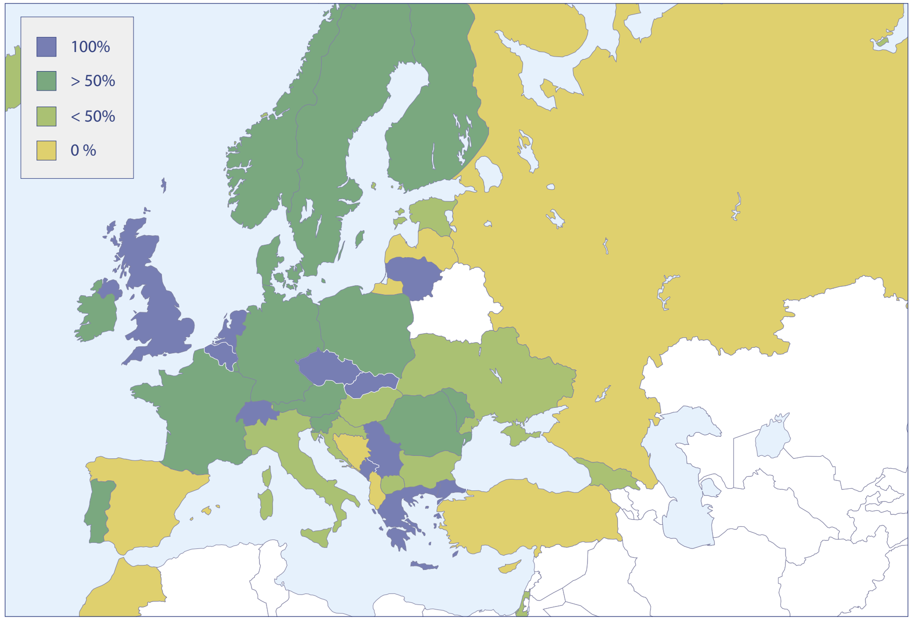
Legend: dark blue indicates 100% dark fibre; yellow indicates either no dark fibre or no information from that country for that year. Note that for 2009, 2008 data has been used for some countries that did not answer this year.

[1] 'Indefeasible Right of Use', the effective long-term lease (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.
[2] Concept developed by RedIRIS, Spain.

Map 3.7.1 – Dark fibre on NREN backbones, 2005



Map 3.7.2 – Dark fibre on NREN backbones, 2009



3.8 Cross-border dark fibre

A number of countries have or are planning to install cross-border dark fibre links, i.e. connecting neighbouring NRENs. Cross-border dark fibre "is optical fibre dedicated to use by a single organisation — where the organisation is responsible for attaching the transmission equipment to 'light' the fibre".[3] Table 3.8.1 provides an overview of current and planned cross-border dark fibre links. Links which entered service relating to this edition of the *Compendium* are highlighted in colour.

Map 3.8.2 presents the same information schematically: note that the links shown do not correspond to the actual geographical routes.

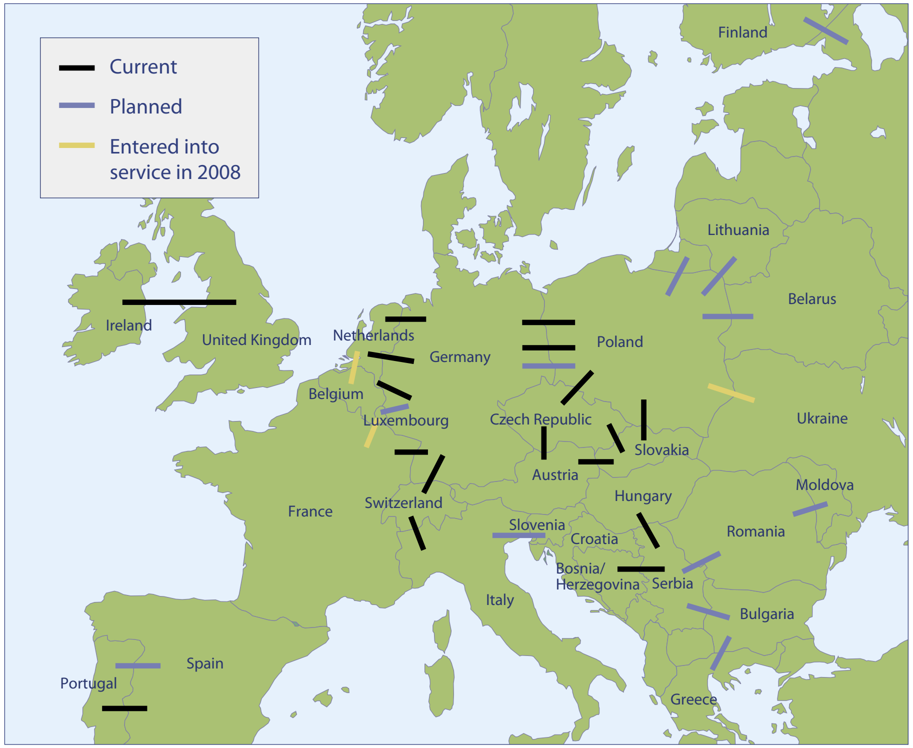
[3] *Networks for Knowledge and Innovation: A strategic study of European research and education networking*, SERENATE Summary Report, IST-2001-34925, p. 28, http://www.serenate.org/publications/d21-serenate.pdf

As Table 3.8.1 and Map 3.8.2 reveal, the majority of the cross-border links are concentrated in central Europe. As indicated in Section 3.5 (above), cross-border dark fibre is becoming an increasingly important component of the total external connection capacity of many NRENs.

Table 3.8.1 – Cross-border dark fibre

NREN to NREN	Current	Start date
ACOnet - SANET	Vienna, Austria - Bratislava, Slovakia	Aug. 2002
ACOnet - CESNET	Brno, Czech Republic - Vienna, Austria	2006
AMRES - University of Banja Luka	Sabac, Serbia - Doboj, Bosnia/Herzegowina	
AMRES - NIIF/HUNGARNET	Subotica, Serbia - Szeged, Hungary	2006
BELNET-SURFnet		2009 Q4
CESNET - PIONIER	Ostrava, Czech Republic - Cieszyn, Poland	2005
CESNET - SANET	Brno, Czech Republic - Bratislava, Slovakia	Apr. 2003
DFN - PIONIER	Gubin, Poland - Guben, Germany	May 2006
DFN – PIONIER	Frankfurt (Oder), Germany – Słubice, Poland	Oct. 2007
DFN - RENATER	Kehl, Germany - Strasbourg, France	Jun. 2006
DFN - SURFnet	Muenster, Germany - Enschede, Netherlands	
DFN - SURFnet	Aachen, Germany - Maastricht, Netherlands	2007 Q2
DFN - SURFnet	Hamburg, Germany - Amsterdam, Netherlands	2007 Q2
DFN - SWITCH	Lorrach, Germany (BelWu) - Basel, Switzerland	Jun. 2006
FCCN-RedIRIS	Lisbon-Badajoz	2009 Q4
GARR - SWITCH	Milano, Italy - Manno, Switzerland	2006
HEAnet - JANET(UK)	Dublin, Ireland - Belfast, UK	Nov. 2006
PIONIER - SANET	Zwardoń-Skalite , Poland - Žilina, Slovakia	Oct. 2007
PIONIER - URAN	Hrebenne, Poland – Rava Ruska, Ukraine	Dec. 2008
RESTENA – RENATER	Nancy, France - Esch/Alzette, Luxembourg	2009
	Planned	
AMRES – RoEduNet		2011
AMRES-Bulgaria		2011
ARNES - GARR	Sežana - Trieste	2010
BASNET – PIONIER	Kuznica, Poland – Grodno, Belarus	2010
BELNET – RESTENA		2010
FCCN - RedIRIS	Porto, Portugal - Vigo, Spain	2010
GRNET – Bulgaria	Atherns, Greece – Sofia, Bulgaria	2011
LITNET - PIONIER	Kaunas, Lithuania - Ogrodniki, Poland	2010
PIONIER-DFN	Kołbaskowo, Poland – Prenzlau, Germany	2011
PIONIER – RBNet/RUNnet	Granowo, Poland – Mamonovo, Russia	2010
RBNet/RUNNet - FUNET	St. Petersburg, Russia – Helsinki, Finland	
RENAM-RoEduNET	Chisinau, Moldova – Iasi, Romania	2010

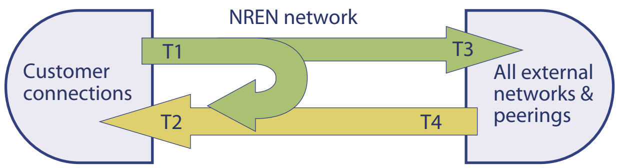
Map 3.8.2 – Cross-border dark fibre



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 provide are defined in Diagram 4.0.1 (below).

Diagram 4.0.1 – Types of traffic flow



T1	All IP traffic **originating from** NREN customer sites entering the NREN network.
T2	All IP traffic **flowing into** customer sites from the NREN network.
T3	All traffic **to** external networks including GÉANT, direct connections to other NRENs or commercial networks.
T4	All traffic **from** external networks including GÉANT, direct connections to other NRENs or commercial networks onto the NREN backbone.

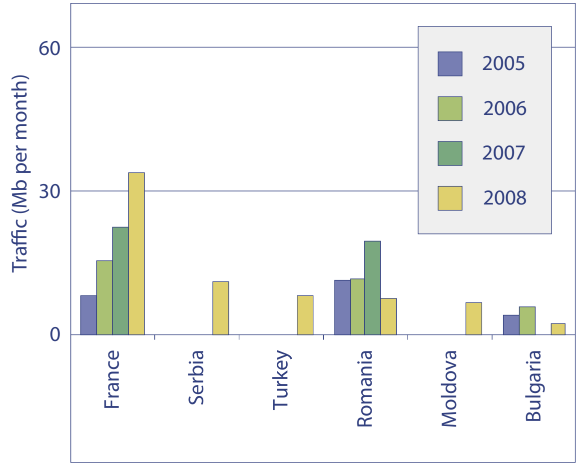
Section 4.1 gives an overview. Section 4.2 looks at traffic in 2008, whereas Section 4.3 analyses traffic trends over the past five years. Section 4.4 gives information on NREN traffic per inhabitant. Section 4.5 looks at congestion and Section 4.6 focuses on IPv6 traffic.

4.1 Overview

Most NRENs report the level of annual traffic flows at the point where they exchange traffic with external networks (T3 & T4); however, only half of the NRENs that responded to the 2009 *Compendium* questionnaire reported the level of the 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 places on the network to monitor. The graphs included in Section 4.2 represent the full national responses submitted in 2009. Comparison with data from previous years reveals that traffic continues to grow. Over the past five years, the annual rate of growth has fluctuated, averaging just under 40%.

This year's *Compendium* attempts to identify an indicator that allows some form of comparison between NRENs. The chosen metric is traffic per inhabitant, which gives a reasonably reliable comparative indication, though not for countries with very small populations.

Graph 4.1.1 – Traffic per inhabitant and the digital divide



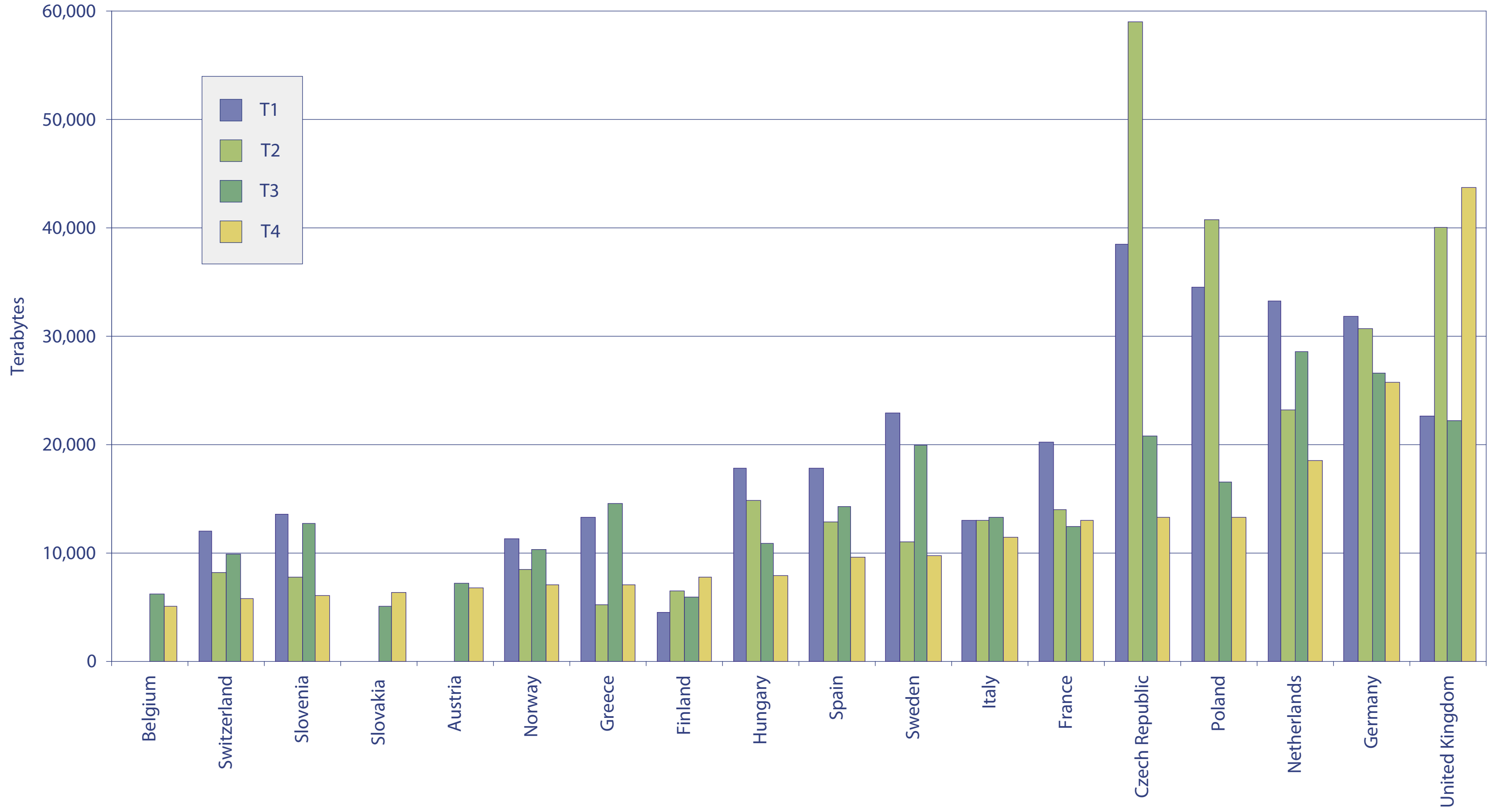
Analysis of the available data shows that there is still a substantial 'digital divide' in Europe: Bulgaria, Moldova, Romania, Serbia and Turkey still lag considerably behind the other countries. This is further borne out by the 2009 congestion index, which also shows far higher congestion levels outside the EU/EFTA area than within it.

IPv4 address space is likely to run out soon; some predict that this will happen as soon as in late 2011. Most Europeans NRENs have been early 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. The respondent NRENs cite this as the major barrier to IPv6 adoption. As a result, IPv6 traffic remains only a small fraction of the total traffic, hovering around 1.0-1.5%.

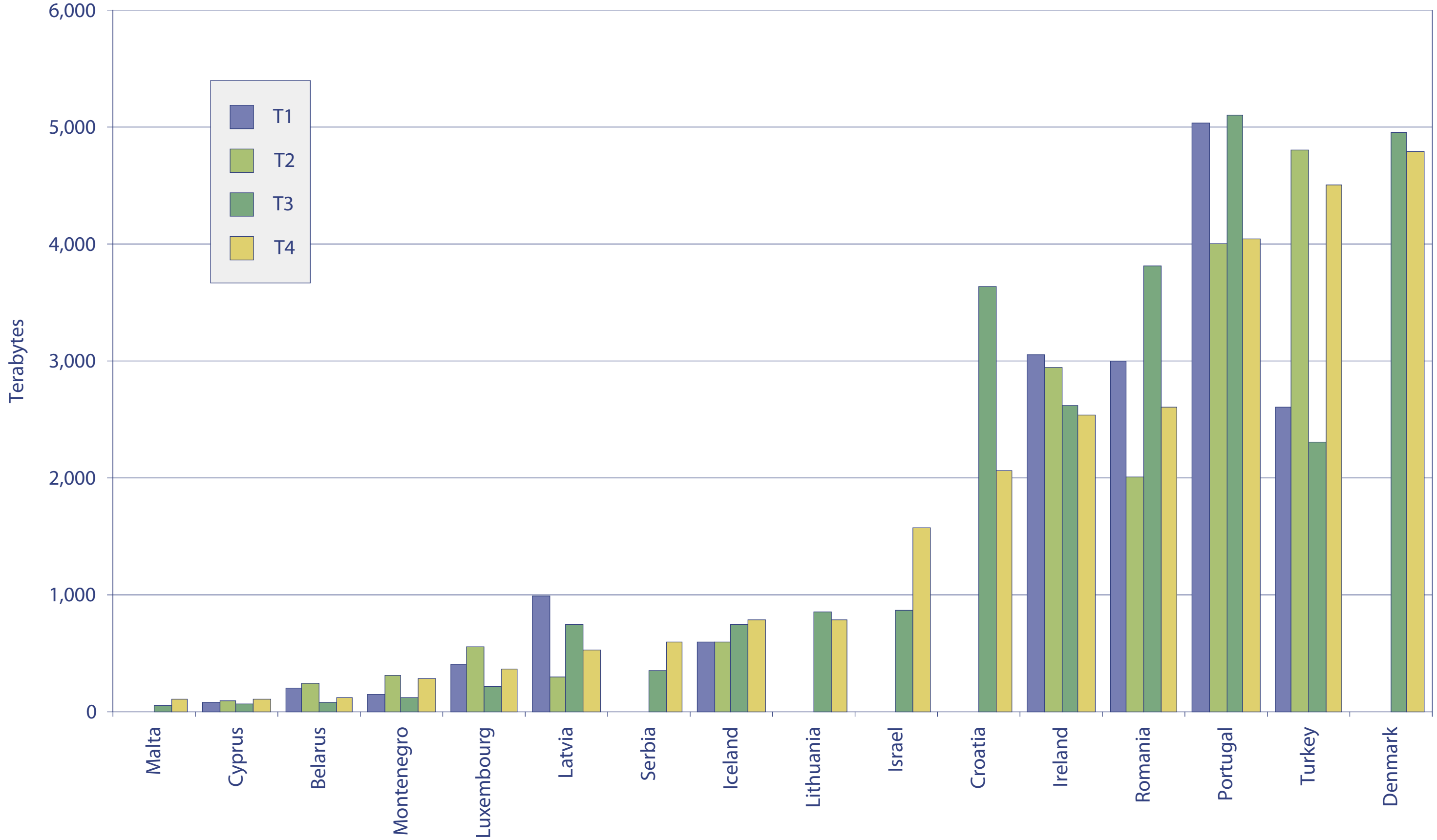
4.2 Traffic in 2008

Graph 4.2.1 (below) represents the data submitted by those NRENs with T4 traffic exceeding 5000 terabytes per year; Graph 4.2.2 represents the data submitted by NRENs with lower levels of T4 traffic. These graphs show clearly how the division of total traffic between the four categories (T1 to T4) differs from NREN to NREN.

Graph 4.2.1 – 2008 traffic, T4 > 5000 TB



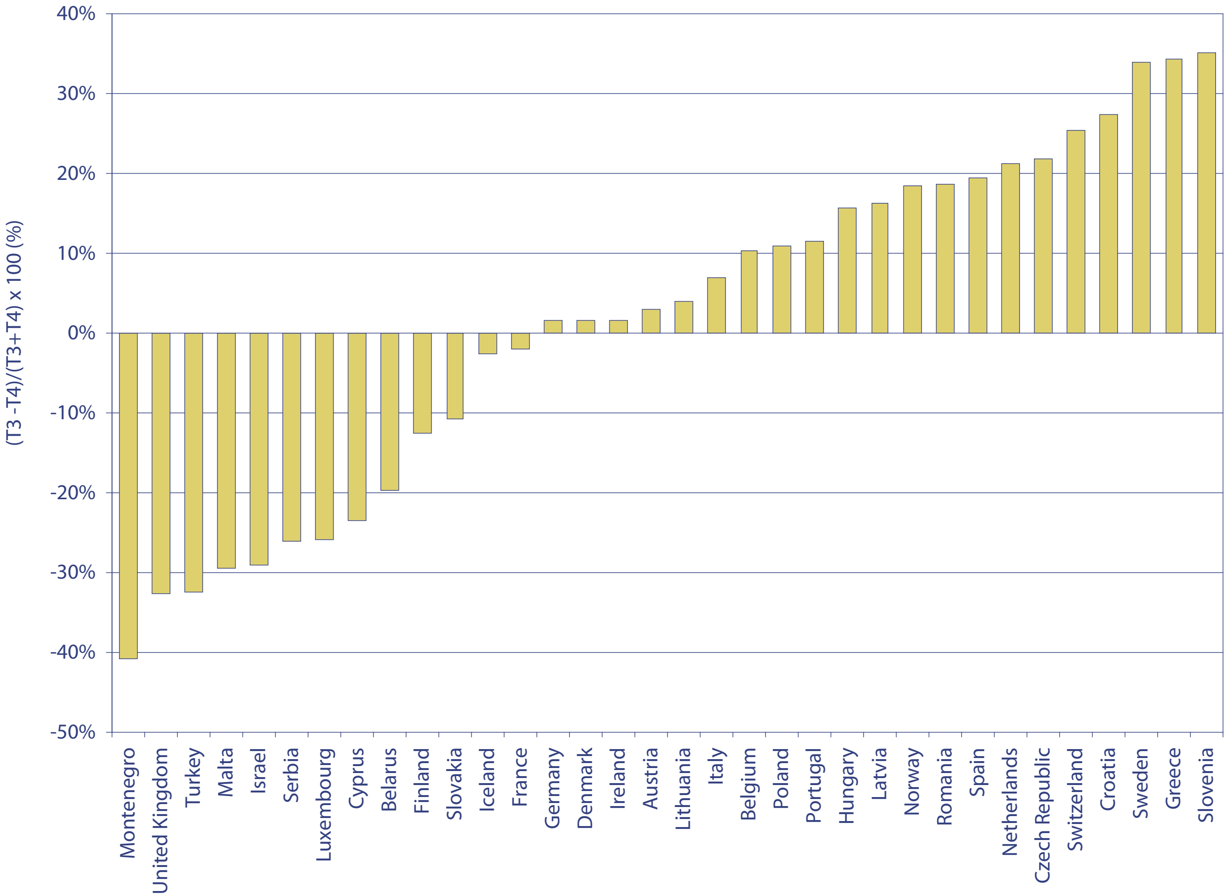
Graph 4.2.2 –2008 traffic, T4 < 5000 TB



There are various possible reasons why some NRENs (such as the Czech Republic, Poland and Turkey) have a T2 value greater than T4; one is that these NRENs have relatively large traffic flows between their connected institutions. In the case of the Czech Republic, the main reason is that the NREN backbone hosts a number of major data sources that provide streaming services and Grid data storage, etc.

Those NRENs with T3 greater than T4 (such as Sweden, the Czech Republic, Poland and the Netherlands) are net exporters of data. The inverse situation (such as in the UK) represents a net import of data. This is represented in Graph 4.2.3: the NRENs to the right are net data exporters; those to the left are net data importers.

Graph 4.2.3 – Data import/export

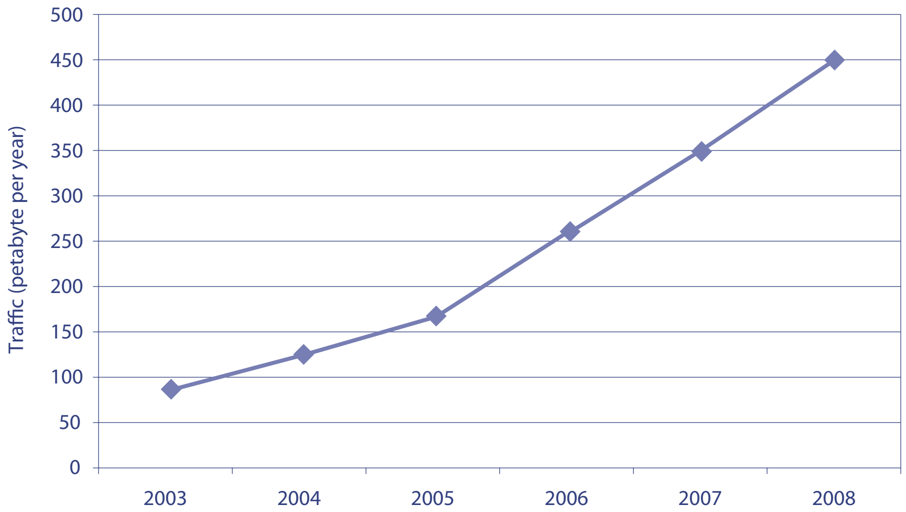


4.3 Traffic growth, 2003-2008

The 2008 *Compendium*'s analysis of traffic growth was based on the average of all four flows illustrated above, as this was thought to most closely represent the actual volume of traffic on the networks. Few NRENs have reported all four values consistently over the past five or more years, which is why the 2008 graphs were based on a sample of only 13 NRENs.

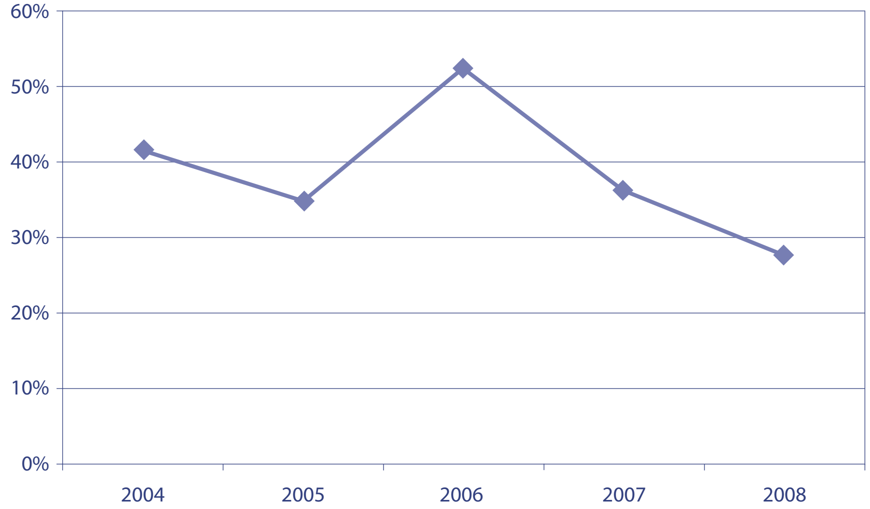
For this 2009 *Compendium*, we have used only the T3+T4 values, resulting in a sample of 23 NRENs that have consistently submitted complete data for five or more years. For those NRENs that have provided the relevant data, comparing the T3+T4 data set represented by Graph 4.3.1 (below) with the T1 to T4 data set represented by Graphs 4.2.1 and 4.2.2 reveals a very similar growth pattern.

Graph 4.3.1 – NREN average annual traffic flows (T3+T4), 2003-2008, n=23 NRENs



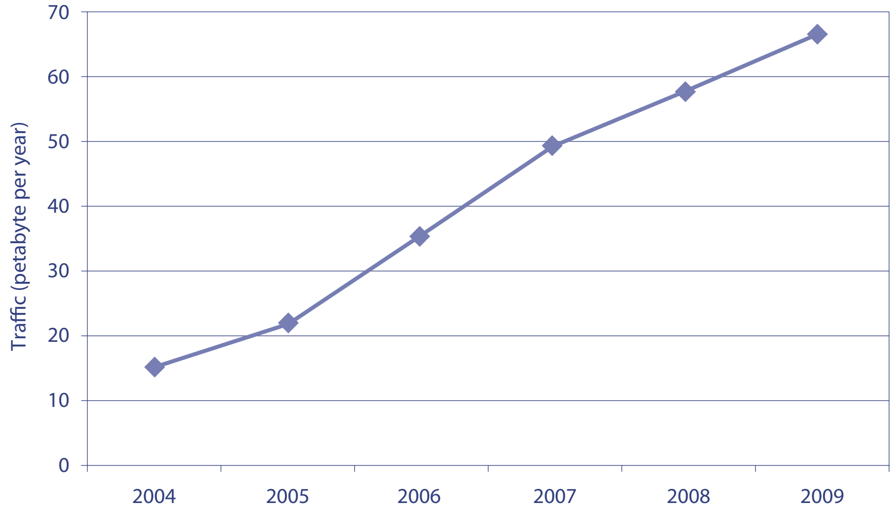
Clearly, traffic has continued to grow at an average annual rate of just under 40% over the five-year period (2003-2008). Graph 4.3.2 (right) shows how the growth rate has varied over the same period.

Graph 4.3.2 – NREN traffic growth rate, 2004-2008



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

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; for some NRENs, the transition is still proceeding. That such a 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 from 2007 to 2009, their number increased from 29 to 69. Unfortunately, we do not have data on the traffic volumes in those circuits.

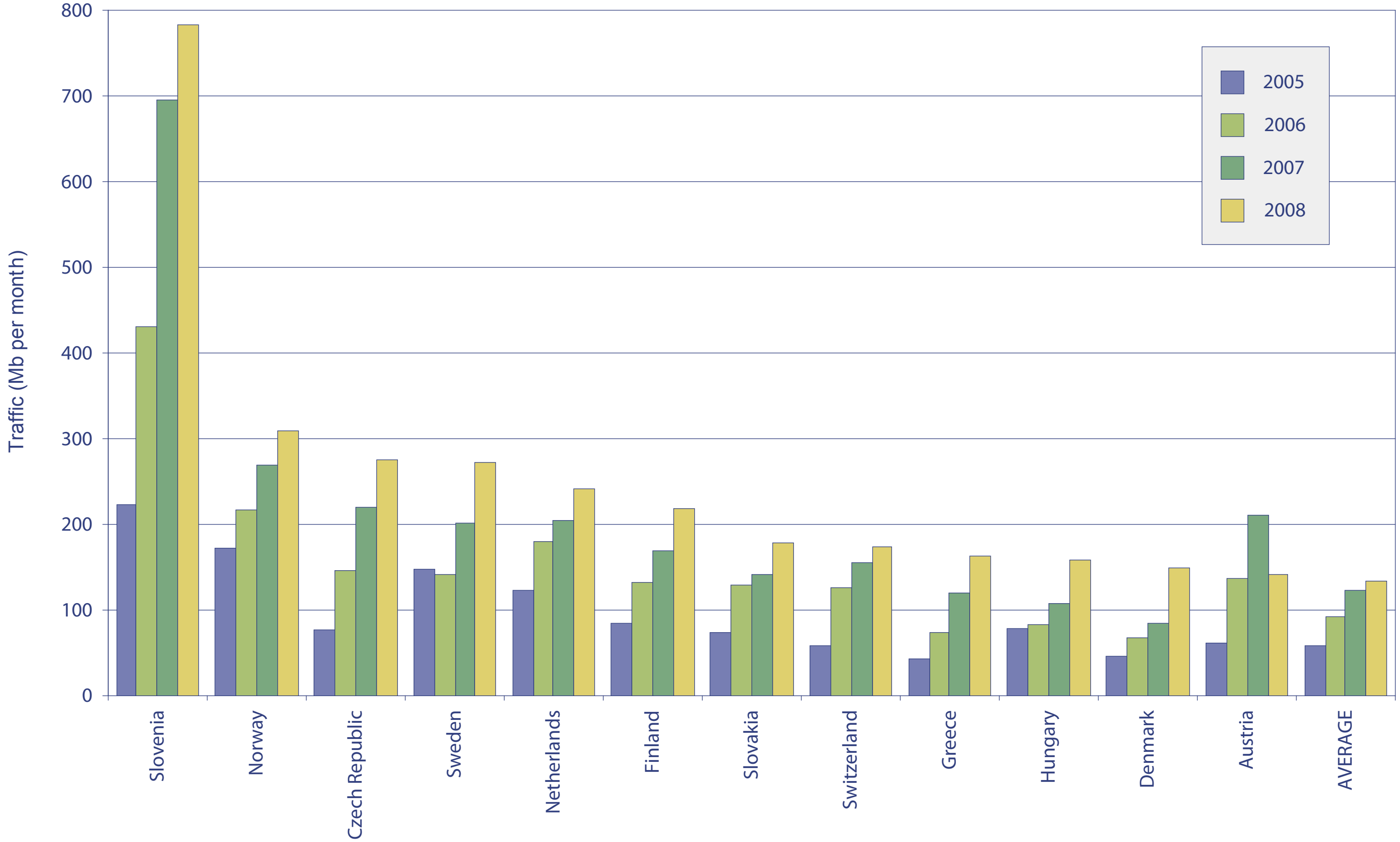
4.4 Traffic per inhabitant

We have attempted to identify an indicator that allows some form of comparison between NRENs. Clearly, absolute traffic figures alone are poor indicators, due to differences in national population size and other demographic factors.

Some NRENs connect only tertiary educational and research institutes; some include secondary schools, others primary schools as well. We tried to reflect these differences by incorporating them into the analysis. We then compared the result of that analysis to a simple metric showing the NREN traffic per inhabitant. The overall results were not significantly different, except for countries with very small populations. However, in order to take account of national differences in user groups, we were forced to make various 'guesstimates', which, unfortunately, did not result in a better indicator. Therefore, for this edition of the *Compendium* only the traffic-per-inhabitant metric is shown and only for countries with a population of at least one million.

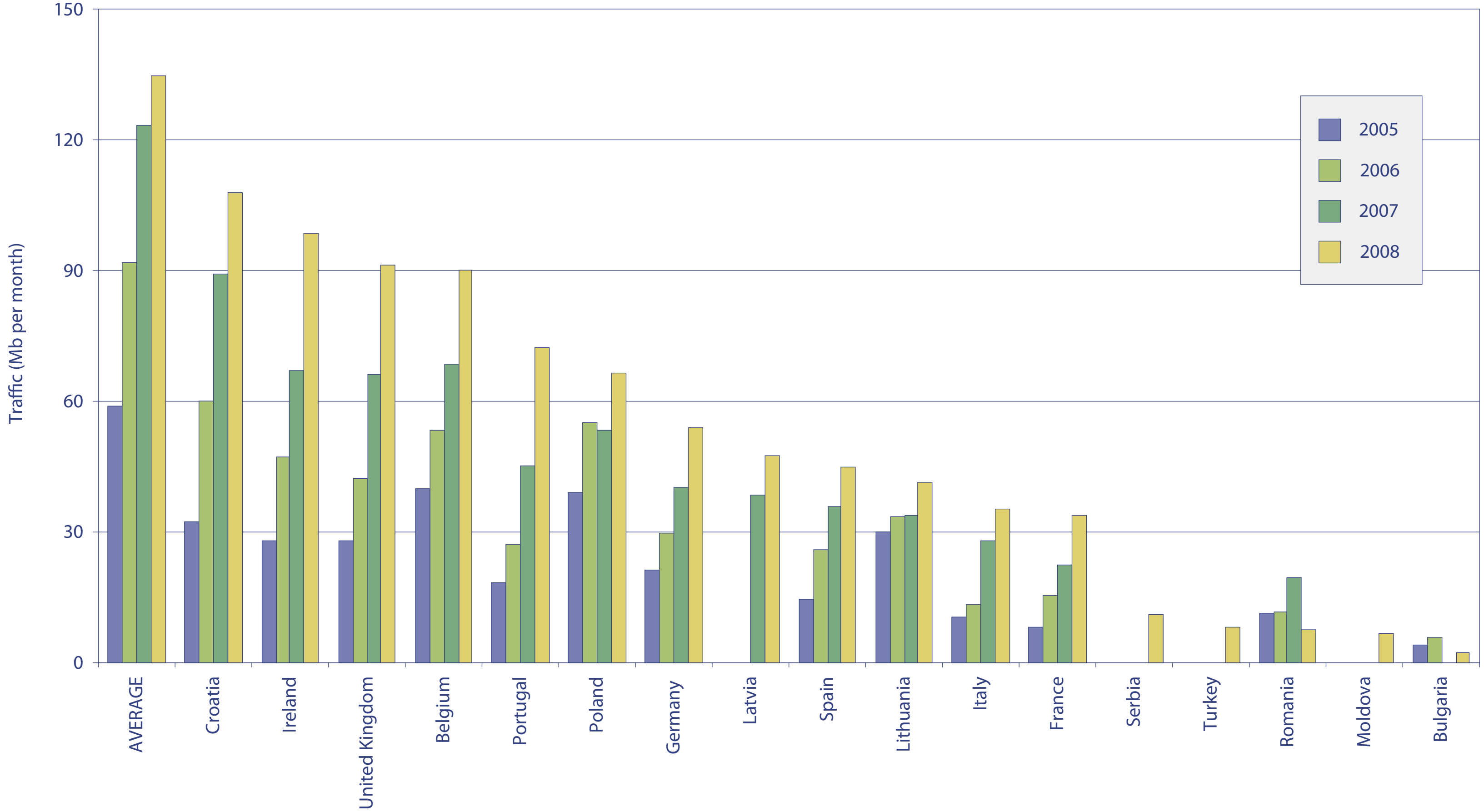
Graphs 4.4.1 and 4.4.2 (opposite) show NREN annual T3+T4 traffic in 29 countries over the period from 2005 to 2008, normalised according to the total national population in each corresponding year. This is certainly not a direct indicator of the network traffic generated by a typical member of the population. In most cases, 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. This seems to be a consistent metric over the years covered.

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



At the left is Slovenia with consistently high nominal traffic (per inhabitant) over the four year period. 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: there are more than 1000 schools connected to the ARNES backbone and just a few universities. Some of the schools are connected with gigabit capacities. Therefore, the proportion of the population that is connected by the NREN is 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, Romania, Serbia and Turkey lag considerably behind the rest of Europe.

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 single metric was derived for the level of congestion in each network element, using the following formula:[1]

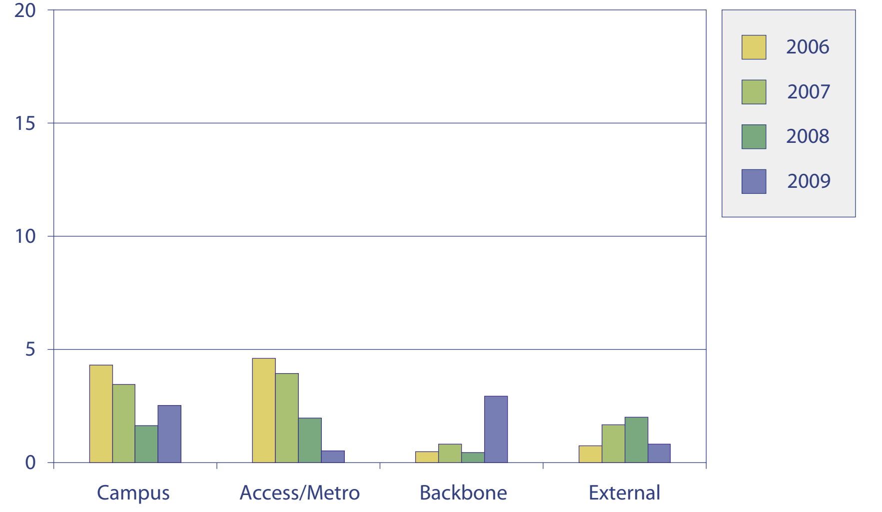
congestion index = (0.05*little + 0.2*some + 0.5*serious) - 5

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.

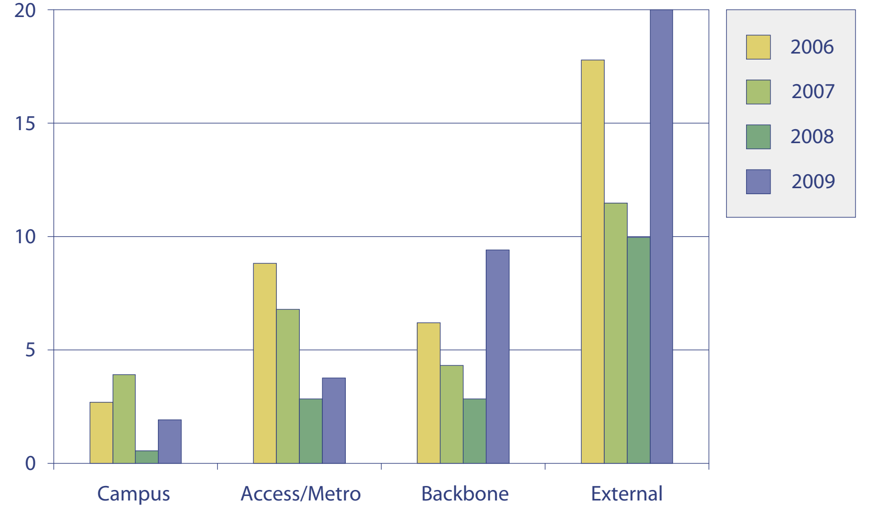
As Graph 4.5.1 shows, for the EU and EFTA countries, the average estimated congestion at campus level has increased marginally, after decreasing over the previous two years. It has also increased at the backbone level. In contrast, congestion has decreased at the level of access networks and external connections. To some extent, the latter is a logical phenomenon: many NRENs have recently invested in external connection upgrades, thus reducing congestion. However, further traffic increases at campus levels can be expected ahead of the next round of investments.

As Graph 4.5.2 shows, for the other (i.e. non-EU/EFTA) countries, the greatest difficulties seem to be at the backbone and external connection levels. Note that the reliability of these figures is questionable: the set of countries is smaller than in Graph 4.5.1 and varies from year to year.

Graph 4.5.1 – Congestion index, EU/EFTA countries, n=27



Graph 4.5.2 – Congestion index, other countries, n=6



[1] This index was developed for the *Compendium* by Mike Norris of HEAnet. The index was modified in 2009 so that the minimum value is now zero instead of 5.

4.6 IPv6

The 2008 *Compendium* reported that the proportion of IPv6 traffic across the NREN/GÉANT gateways was low in comparison to IPv4 traffic and that the growth in IPv6 traffic was slower than the growth in 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 late 2011.[3]

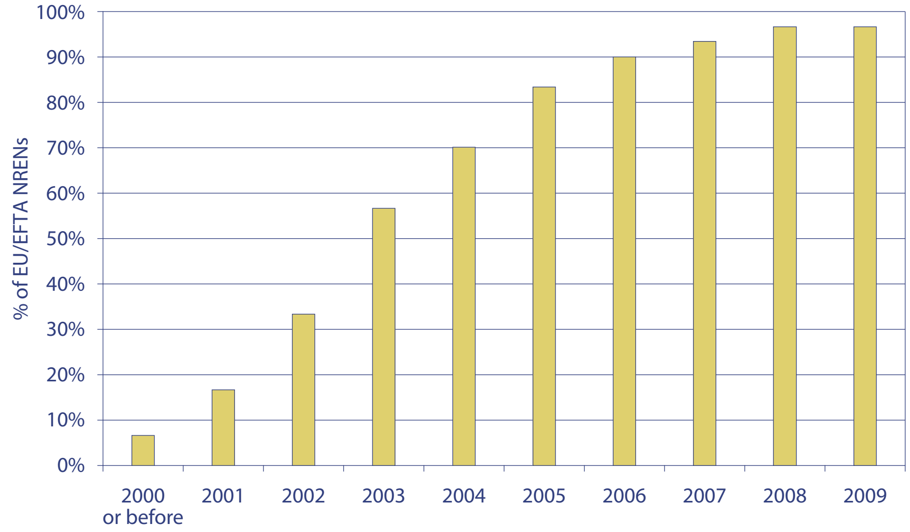
How prepared is the European NREN community?

As Graph 4.6.1 shows, most European NRENs were early to adopt IPv6 and have supported native IPv6 for several years. At the time of writing this *Compendium*, the one remaining EU/EFTA NREN not to have adopted IPv6 expects to have IPv6 capability in place within the next 12 months. In this context, 'support' means that the NREN allocates IPv6 addresses to its client institutions, that it routes IPv6 traffic over its network and that it has IPv6 external peerings wherever possible, notably with other European NRENs through the GÉANT network; in other words, the NREN treats IPv6 as an operational service on a par with IPv4.

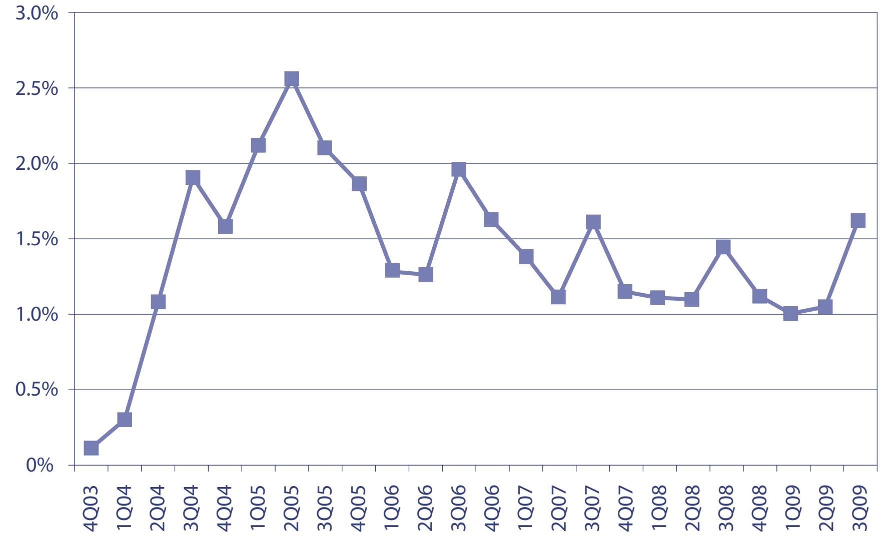
IPv6 utilisation

As reported in the 2008 *Compendium*, statistics are available for the ingress and egress points of the GÉANT network. As Graph 4.6.2 (right) shows, the general trend continued into 2009: IPv6 traffic as a proportion of the total IP traffic remained low, hovering around 1.0-1.5%. GÉANT is gratefully acknowledged for supplying the necessary data from its monthly service reports.

Graph 4.6.1 – IPv6 implementation, EU/EFTA countries



Graph 4.6.2 – IPv6 traffic as a percentage of total IP ingress/egress traffic on GÉANT



[2] 2008 *Compendium*, p. 58.
[3] See, for example, the IPv4 exhaustion counter at http://inetcore.com/project/ipv4ec/index_en.html

Graph 4.6.2 shows a saw-tooth variation with a periodicity of approximately 12 months. Detailed analysis reveals that this 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.

In order to understand the disparity between NREN readiness to migrate to IPv6 and the apparent lack of adoption by end-users, NRENs were asked what they believed to be the main obstacles to migration to IPv6. Around half the NRENs cited as the main reason that users are simply not ready for such a migration. Lack of technical skills and problems with upstream providers were also cited as important reasons. Slightly more than 25% of the NRENs consulted stated that they saw no real obstacles.

Conclusions

It appears that the NRENs themselves are generally ready for the migration from IPv4 to IPv6; however, the transition does not appear to be happening in practice. The likely cause is that, generally, the connected institutions do not sense the urgency of the situation.

Since there are real costs for institutions in migrating to IPv6 and no apparent functional improvements for the end-user, it is little wonder that the migration is slow.

Nevertheless, it seems inevitable that IPv4 address space will become exhausted, after which new addresses issued can only be IPv6. Therefore, 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 be actively encouraged to migrate to IPv6 support and should be made fully aware of the timescales and the consequences of not doing so.

5 OTHER SERVICES

Almost all NRENs are involved in providing a range of important services to their customers which are layered upon the connectivity service. This section provides brief information on NREN services in the following areas:

- 5.2 Network Operations Centres
- 5.3 Performance monitoring and management
- 5.4 Optical services
- 5.5 Quality of service
- 5.6 Incident response
- 5.7 Authorisation and mobility services
- 5.8 Housing, storage and content-delivery services
- 5.9 Network communication tools
- 5.10 Grid services
- 5.11 User and client support

5.1 Overview

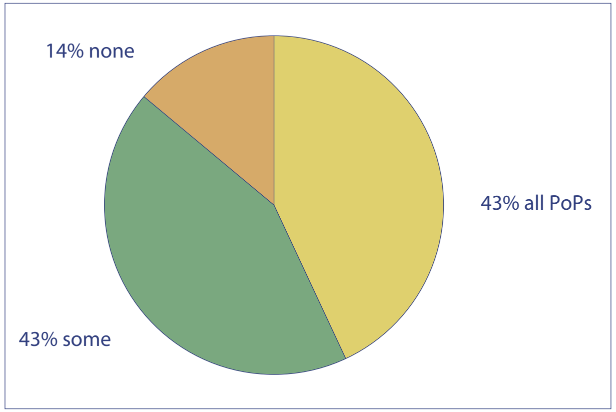
Network Operations Centres are a vital element in the delivery of connectivity services to NREN users. In the EU/EFTA countries, slightly over half the NRENs directly employ NOC staff. The other NRENs either outsource this service or use a combination of their own and outsourced staff. NOC staff size varies considerably, from 0.6 FTE in Cyprus to 61 in the UK. This variation is due not only to network size, but also to differences in the functions performed by the NOCs.

Currently, 12 of the 30 EU/EFTA countries have Performance Emergency Response Teams (PERTs), a drop from 16 in 2008. However, a further 15 NRENs are planning to establish such PERTs within the next three years. Many NRENs in other countries either have a PERT or are planning to establish one. Many NRENs offer a range of monitoring tools, an overview of which is given in Section 5.3.

In many parts of Europe, the increasing availability of an affordable optical networking infrastructure is making near-limitless capacity a real possibility.

In the EU/EFTA area, twelve NRENs (43% of respondents) provide optical capabilities on all their PoPs, twelve provide optical capabilities on some of their PoPs, and only four (14% of respondents) reported zero optical support on their PoPs.

5.1.1 – Percentage of optical PoPs, EU/EFTA countries



A similar pattern is evident for NREN respondents in countries outside the EU/EFTA area.

To prevent performance problems in a network, two approaches can be taken: over-provisioning or providing quality of service (QoS) options. As in 2008, most NRENs prefer over-provisioning.

As in previous years, incident response teams are more common in the EU/EFTA area than elsewhere. The level of accreditation is also higher, which is important because trusted international collaboration is a key factor that determines the success of such teams.

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, both of which are becoming more common. The number of actual certificates issued by NRENs in the EU/EFTA area rose spectacularly from 16,000 in 2008 to 31,000 in 2009. Continued growth is expected in the next few years.

Many NRENs already provide or are planning to provide some kind of housing or storage service. The service currently offered by the largest number of NRENs is mirroring.

Compared with 2008, growth in the area of VoIP has been marginal. Twenty-one of the EU/EFTA NRENs already offer or plan to offer a centrally managed video conferencing service.

Grid services have become an important area for NRENs. The data show that twenty-five (89%) of the EU/EFTA NRENs currently provide or are planning to provide such services. (Four years ago, the figure was 56%.) In EU/EFTA countries, grid services have seen the largest growth in the disciplines of chemistry, computational chemistry and biomedical science.

NRENs provide an increasing 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.

5.2 Network Operations Centres

Network Operations Centres (NOCs) are responsible for operating and monitoring the NREN's network and associated services. In some cases, there are separate centres for the various categories of users or services that the NREN operates.

NOCs are a vital element in the delivery of a mission-critical service such as an NREN network, dealing with an extensive range of services including physical infrastructure, network administration and network monitoring. NOCs usually 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 challenge and, as a consequence, different NRENs take different approaches to staffing, as can be seen in Tables 5.2.1 and 5.2.2.

Table 5.2.1 – NOC staff, EU/EFTA countries

	NOC staff employed by NREN in-house[1]	NOC staff outsourced by NREN	Total NOC staff
NRENs directly employing NOC staff - 57% of the 23 respondent NRENs			
Estonia, EENet	2.0		2.0
Luxembourg, RESTENA	3.0		3.0
Slovenia, ARNES	3.0		3.0
Austria, ACOnet	4.0		4.0
Hungary, NIIF/HUNGARNET	5.0		5.0
Latvia, SigmaNet	5.0		5.0
Portugal, FCCN	6.0		6.0
Germany, DFN	9.0		9.0
Greece, GRNET S.A.	10.0		10.0
Ireland, HEAnet	10.0		10.0
Switzerland, SWITCH	10.0		10.0
Finland, Funet	14.0		14.0
Romania, RoEduNet	16.0		16.0
NRENs outsourcing NOC staff - 13% of the 23 respondent NRENs			
Denmark, UNI-C		3.0	3.0
Sweden, SUNET		14.0	14.0
Netherlands, SURFnet		16.0	16.0
NRENs using a combination of direct/outsourced staff - 30% of the 23 respondent NRENs			
Cyprus, CYNET	0.4	0.2	0.6
Iceland, RHnet	0.3	0.7	1.0
Belgium, BELNET	2.7	1.0	3.7
Czech Republic, CESNET	1.0	4.5	5.5
Spain, RedIRIS	6.0	3.0	9.0
Norway, UNINETT	17.0	1.0	18.0
United Kingdom, JANET(UK)	16.0	45.0	61.0[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 5.2.2 – NOC staff, other countries

	NOC staff employed by NREN in-house	NOC staff outsourced by NREN	Total NOC staff
NRENs directly employing NOC staff - 50% of the 18 respondent NRENs			
Sri Lanka, LEARN	1.0		1.0
Montenegro, MREN	2.0		2.0
Morocco, MARWAN	2.0		2.0
Georgia, GRENA	3.0		3.0
Chile, REUNA	5.0		5.0
Uzbekistan, UzSciNet	5.0		5.0
Turkey, ULAKBIM	6.0		6.0
Algeria, CERIST	10.0		10.0
Russian Federation, RBNet/ RUNNet	12.0		12.0
NRENs outsourcing NOC staff - 17% of the 18 respondent NRENs			
Singapore, SingAREN		0.3	0.3
Israel, IUCC		0.5	0.5
Turkmenistan, TuRENA		3.0	3.0
NRENs using a combination of direct/outsourced staff - 33% of the 18 respondent NRENs			
Belarus, BASNET	4.0	1.0	5.0
Ukraine, URAN	4.0	2.0	6.0
Moldova, RENAM	7.0	0.5	7.5
Australia, AARNet	9.0	1.0	10.0
Taiwan, NCHC	12.0	5.0	17.0
Serbia, AMRES	18.0	4.0	22.0

5.3 Performance monitoring and management

Performance monitoring and management mostly depends on the work of the Network Operations Centres (NOCs). A number of tools facilitate this work, such as network 'weathermaps' that show traffic load in real time, making network performance and traffic statistics more transparent.

In order to deal with performance issues, many NRENs have set up separate Performance Enhancement and Response Teams (PERTs). These are coordinated within the GN2 and GN3 projects. In the 30 EU/EFTA countries, the number of PERTs has dropped from 16 in 2008 to 12 in 2009. In contrast, the number of NRENs planning to establish a PERT within the next three years has increased from 10 last year to 15 now. This will lead to PERTs in at least 27 out of the 30 EU/EFTA NRENs.

Many NRENs in other countries also have a PERT or are planning to establish one.

Graph 5.3.1 – PERT and performance, statistics and monitoring tools, EU/EFTA countries

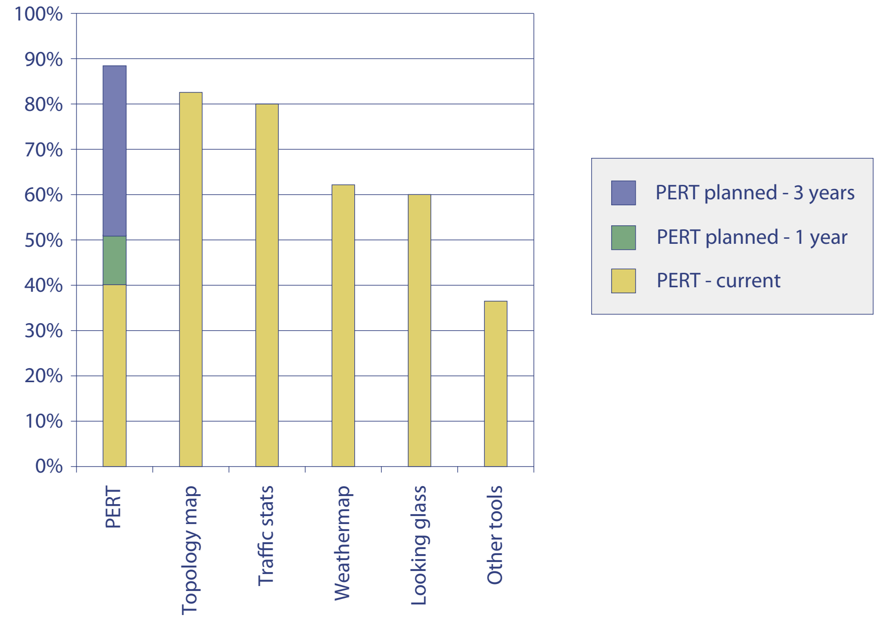


Table 5.3.2 (below) shows where PERT services are currently being deployed and where they are being planned. The *Compendium* website contains URLs to publicly visible traffic monitoring and analysis tools deployed within NRENs. In addition, several NRENs provide websites that are password protected or available only to a particular NREN's constituency.

Table 5.3.2 – PERT deployment

NREN	PERT?	Plan to deploy
EU/EFTA countries		
Czech Republic, CESNET	yes	
Finland, Funet	yes	
France, RENATER	yes	
Germany, DFN	yes	
Hungary, NIIF/HUNGARNET	yes	
Lithuania, LITNET	yes	
Luxembourg, RESTENA	yes	
Poland, PIONIER	yes	
Portugal, FCCN	yes	
Slovakia, SANET	yes	
Slovenia, ARNES	yes	
Switzerland, SWITCH	yes	
Austria, ACOnet	no	within 3 years
Belgium, BELNET	no	within 3 years
Bulgaria, BREN	no	within 3 years
Cyprus, CYNET	no	within 3 years
Denmark, UNI-C	no	within 1 year
Estonia, EENet	no	within 3 years
Greece, GRNET S.A.	no	within 3 years
Iceland, RHnet	no	within 3 years
Ireland, HEAnet	no	within 3 years
Italy, GARR	no	within 1 year

Table 5.3.2 – continued

NREN	PERT?	Plan to deploy
EU/EFTA countries		
Latvia, SigmaNet	no	within 3 years
Malta, UoM/RicerkaNet	no	within 3 years
Netherlands, SURFnet	no	within 3 years
Norway, UNINETT	no	within 3 years
Romania, RoEduNet	no	within 1 year
Spain, RedIRIS	no	within 1 year
Sweden, SUNET	no	never
United Kingdom, JANET(UK)	no	
Other countries		
Belarus, BASNET	yes	
Georgia, GRENA	yes	
Russian Federation, RBNet/RUNNet	yes	
Serbia, AMRES	yes	
Ukraine, URAN	yes	
Algeria, CERIST	no	within 3 years
Croatia, CARNet	no	within 1 year
Israel, IUCC	no	within 3 years
Moldova, RENAM	no	within 3 years
Montenegro, MREN	no	within 3 years
Morocco, MARWAN	no	within 3 years
Turkey, ULAKBIM	no	within 3 years
Ukraine, UARNet	no	

5.4 Optical services

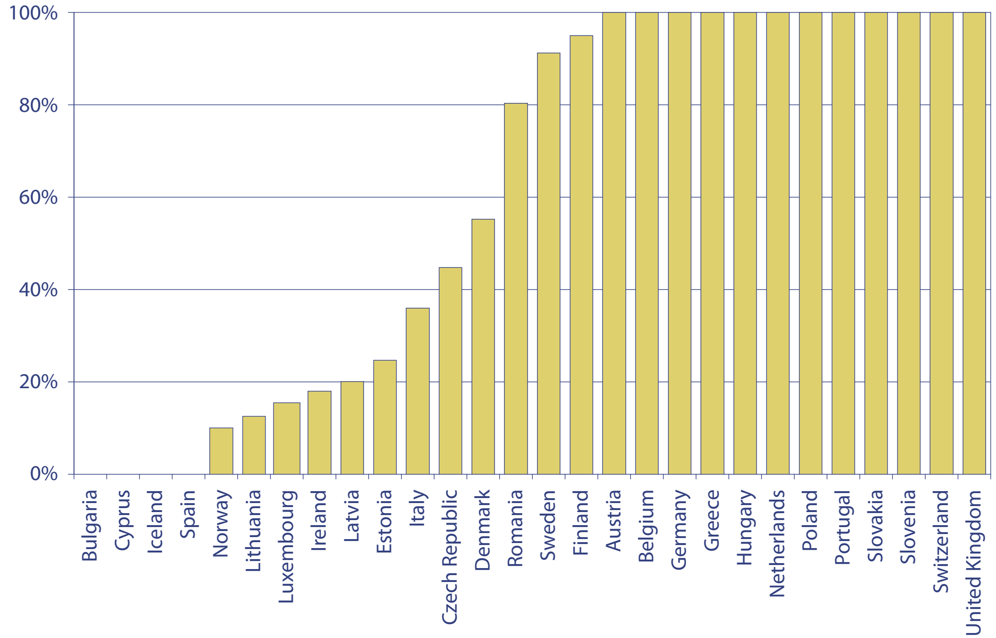
The increasing availability of affordable optical networking infrastructure is making near-limitless capacity a real possibility in many parts of Europe, though there are some notable exceptions[3]. New cables containing many fibre pairs are continually being deployed. Each of these fibre pairs is potentially capable of carrying many different circuits (wavelengths, lambdas or just 'λ').

In order to determine the extent of optical services, NRENs were asked:

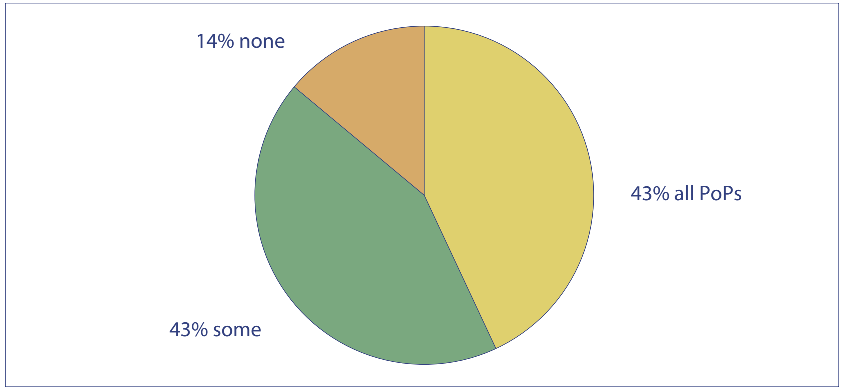
- *What is the number of PoPs on your network?*
- *At how many places do you offer optical PoPs?*

In the EU/EFTA area, twelve NRENs (43% of respondents) provide optical capabilities on all their PoPs, twelve provide optical capabilities on some of their PoPs, and only 4 (14% of respondents) reported zero optical support on their PoPs.

Graph 5.4.1 – Percentage of optical PoPs for EU/EFTA countries



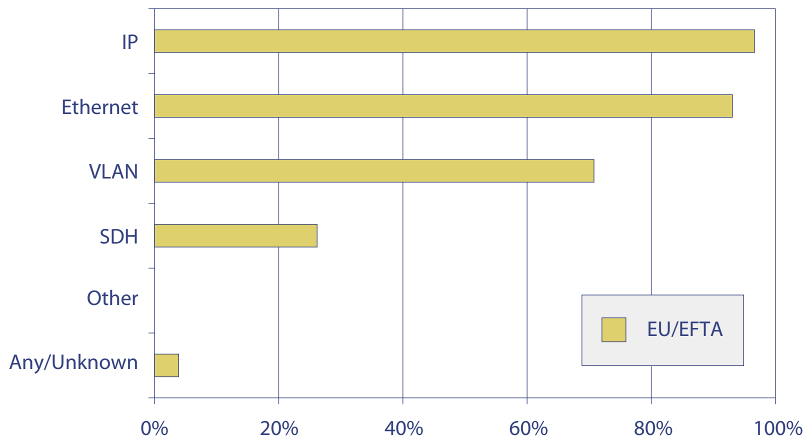
Graph 5.4.2 – Percentage of optical PoPs, EU/EFTA countries



A similar pattern is evident for NREN respondents in countries outside the EU/EFTA area.

The survey also asked what types of traffic are carried on the optical networks. The majority of the optical links are used to transport IP, Ethernet, VLAN traffic and SDH for infrastructure purposes.

Graph 5.4.3 – Types of traffic carried via optical networks



[3] For more information, see the EARNEST study, Report on Geographic Issues, April 2008, http://www.terena.org/activities/earnest/docs/20090604-Geographic-Issues.pdf

5.5 Quality of service (QoS)

When networks become heavily used (i.e. congested) user traffic can experience various unwanted effects: packets may be dropped and need retransmission; there may be some delay; or the packet-to-packet interval may vary (i.e. jitter). These effects can have unacceptable impacts on the operation of real-time applications such as voice traffic carried over an IP network (VoIP). At the same time, the onset of congestion can be seen as an incentive to improving the design and dimensioning of a network as well as the services layered upon it. There will always be congestion at some point in a network, whether it be at the core, on the access layer, or even at end-points such as PCs. It may not be possible to entirely eliminate congestion, in which case the challenge is to manage it.

5.5.1 Approaches to QoS

In wide-area networks such as NRENs, there are two approaches to managing this problem for the highest priority traffic so that a good QoS is maintained for the most important applications.

Over-provisioning

In this approach, the capacity provided on the links is sufficient to prevent congestion altogether or, at least, to ensure that there is no noticeable effect on application traffic. In this context, 'noticeable' may be defined as including the results of monitoring application-level parameters, such as Mean Opinion Score (MOS) to determine end-to-end voice quality. Over-provisioning provides the same QoS to all traffic on the network, not just a few select applications.

QoS traffic engineering

In this approach, the utilization of the link is optimized so that real-time traffic can be given priority transit through the network and is not affected by any congestion that may occur. This is achieved by defining a number of traffic classes, each differentiated by a tag indicating the level of priority it should be afforded. Typically, these classes are:

- PIP = Priority IP: delay and packet loss are kept to a minimum;
- BE = Best Effort IP: normal IP service;
- LBE = Less than Best Effort: packets are the first to be discarded when congestion occurs; it uses any bandwidth available after PIP and BE have been serviced.

In the case of QoS traffic engineering, the development, debugging and maintenance of complex policing configurations that ensure the QoS all have their costs. Additional costs may be incurred by obtaining devices that support QoS mechanisms and ensuring that these mechanisms work as they should, without adversely affecting other functions. It may be difficult to incorporate such 'hidden costs' in the overall charges passed on to users.

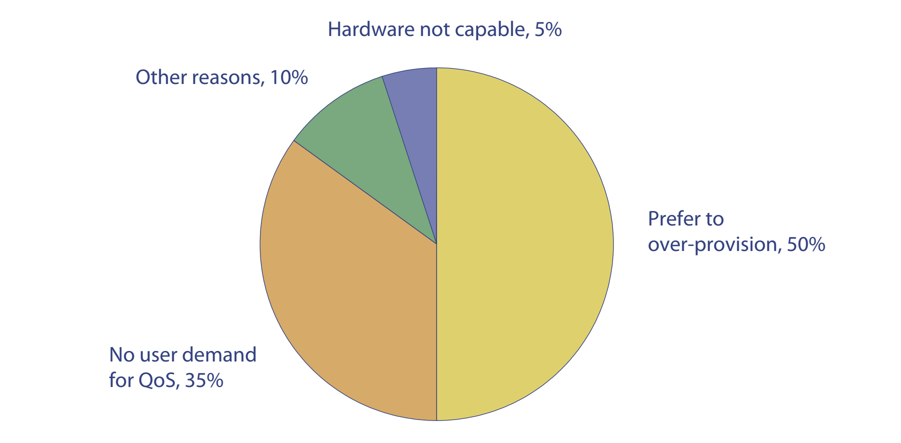
In contrast, users experience an over-provisioned network as a generally faster service - something tangible for which they are willing to pay. Many NRENs find over-provisioning a cost-effective approach to providing their users with the quality of service that they need.

NRENs were asked which of these approaches they adopt and, if they adopt over-provisioning, why they did not choose to implement QoS traffic engineering. As in 2008, the majority of NRENs report that they have chosen over-provisioning.

Several factors contribute to the use of over-provisioning as a solution, including:

- Hardware not capable;
- No user-demand;
- Not physically possible unless all domains in path participate;
- Not economically viable;
- Prefer to over-provision network;
- Other.

Graph 5.5.1.1 – Reasons for over-provisioning, EU/EFTA countries



As shown by Graph 5.5.1.1 (above), 85% of NRENs in EU/EFTA countries stated that they either prefer to over-provision their networks or see no need for QoS traffic engineering. All the other reasons together account for no more than 15% of the NRENs.

The increasing capacity to over-provision networks results from the improved availability and reduced costs of links brought about by new technologies (optical, DWDM, etc.), market conditions and the revision of regulatory environments to encourage competition. In areas where these factors are not the case, the level of over-provisioning is much reduced.

The closed nature of NRENs may also be an advantageous factor. In the commercial sector, such over-capacity could not be sustained for long and would soon be either scaled back or used to generate more customers and/or a richer mix of services.

5.5.2 Relationship between perceived congestion and QoS implementation

We set out to determine whether there is a correlation between the perceived congestion on the network and the adoption of over-provisioning or QoS traffic engineering.

For each NREN, the congestion index (CI) was calculated (see Section 4.5) and then compared with the answers to the survey question: "Does your NREN offer GEANT level of QoS?" By ranking all 30 NRENs on congestion index and then dividing them into three equally sized groups of 10, a pattern did emerge.

Table 5.5.2.1 – Groups of NRENs divided according to congestion index (CI)

NREN groups	CI range	Percentage of NRENs preferring to over-provision	Percentage of NRENs already adopted QoS traffic engineering	Percentage of NRENs planning to adopted QoS traffic engineering
Top third (1-10)	All zero	80%	10%	10%
Middle third (11-20)	0 – 2.5	50%	40%	10%
Bottom third (21-30)	2.55 – 31.35	30%	20%	50%

The lower the CI-score on the backbone of the NREN network, generally the more likely the NREN is to be adopting over-provisioning as the approach to managing QoS. Those NRENs achieving higher CI-scores were generally most likely to be planning QoS traffic engineering, but have not yet implemented it.

5.6 Incident response

Computer security incidents require fast and effective responses from the organisations concerned. Computer Security Incident Response Teams (CSIRTs), which are either internal or outsourced, are responsible for receiving, reviewing and responding to computer security incidents.

International collaboration is essential to CSIRTs and depends on their willingness to trust one another. To facilitate these trust relationships, there are accreditation processes such as the Trusted Introducer (TI) scheme (**www.trusted-introducer.org**) and the Forum of Incident Response Teams (**www.first.org**). TF-CSIRT is a task force that promotes collaboration between CSIRTs at the European level and liaises with similar groups in other areas. For more information, see **www.terena.org/activities/tf-csirt**.

Within the EU/EFTA area, all CSIRTs that are members of FIRST are also members of the Trusted Introducer scheme, while in the other countries there is no overlap between FIRST and TI-accredited members.

Table 5.6.1 – Incident response teams

	Incident response team	In-house	Outsourced
EU/EFTA countries	96%	82%	15%
(n=28[4])	Accredited: 78% (TI: 78% First: 41%)		
Other countries	57%	94%	6%
(n=28)	Accredited: 38% (TI: 13% First: 25%)		

Although the percentage of NRENs that have a CSIRT is much higher in EU/EFTA countries than in other countries, 29% of non-EU/EFTA NRENs are planning to create such an incident response team.

It should be noted that JANET-CERT is effectively counted twice, as it provides the CSIRT services for HEAnet (Ireland) in addition to JANET(UK).

[4] Bulgaria and Malta did not provide CSIRT information for 2009.

5.7 Authorisation and mobility services[5]

The Internet is being increasingly used as a mechanism for delivering a range of services to specific groups of users that need access to such services. 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. This has developed into a secure, world-wide roaming access service developed for the international research and education community. eduroam is currently offered by NRENs in all 30 EU/EFTA countries and is available in over 40 countries worldwide. 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 **http://www.eduroam.org**.

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

[5] With contributions by Licia Florio, TERENA.

5.7.1 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. In most European countries, such authentication mechanisms are provided by educational or research institutions. Exceptions are FEIDE, which operates a national identity management system for the educational sector in Norway, and an outsourced identity provider connected to the UK Access Management Federation, which supports over 500 institutions.

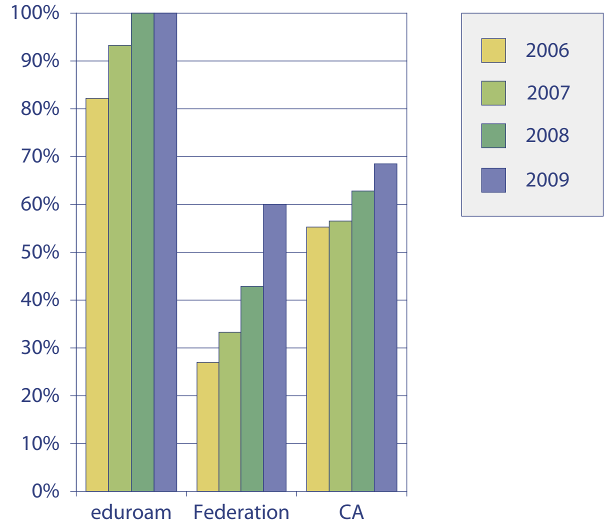
In the EU/EFTA countries, accreditation for users who are not at their own institutions has been made possible by identity federations which, with a few exceptions, have been operated as an NREN service. This is not a universal model. Thus, the Australian Access Federation, the Canadian Access Federation and InCommon (US) are not run by a NREN.

Identity federations offer access to a variety of services, these 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 conferencing gatekeeper and MCU booking systems, streaming video and software licensing and webshops for a range of academic services.

As reported in the *Compendium* since 2006, the number of identity federations has grown constantly. Many NRENs were unable to answer the Compendium survey question about the number of users per federation. However, it is clear that currently the actual number of users is still only a fraction of the potential number. Up-to-date information on research and education federations can be found at **https://refeds.terena.org**.

The growth of identity federations and federated services has led to a need to interfederate these federations. Within Europe, this is supported by eduGAIN. For more information on eduGAIN, see **http://www.edugain.org**. Both eduroam and eduGAIN are supported by the EU through the GN3 project.

Graph 5.7.1.1 – Authorisation and mobility services, EU/EFTA countries



5.7.2 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:

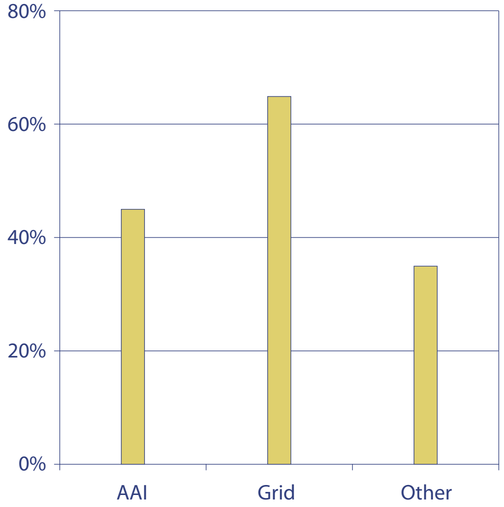
- a user securely connecting to a Web server using a web browser;
- a user authenticating with a server using a digital certificate;
- two users exchanging encrypted emails.

For example, the Grid community requires secure authentication for users to login to Grid resources; this requirement is met by using personal certificates. In general, 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 develop the TERENA Certificate Service (TCS), which currently supports 22 NRENs for server certificates and 15 for personal certificates.

In the 2008 edition of the *Compendium*, it was reported that 16,000 certificates had been issued by NRENs in the EU/EFTA countries. This figure was expected to rise to 23,000 in 2009. However, the 2009 survey shows that the number of certificates issued has almost doubled, rising to 31,000. The predicted growth for the coming year is 65%.

Graph 5.7.2.1 – Certificate use, EU/EFTA countries



Twenty NRENs in EU/EFTA countries expect to issue user certificates in the near future; fifteen of them will use the TCS. In the first year, more than 50,000 user certificates are expected to be issued; in subsequent years, the figure should double annually.

Denmark has the government-run OCES certificate service. FCCN in Portugal plans to use Portuguese citizen card certificates. In addition, agreements similar to the TCS arrangement may be used to procure certificates from commercial suppliers.

5.8 Housing, storage, hosting and content-delivery services

NREN users want 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 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 5.8.1 (below).

Mirroring is the service that seems most popular in the EU/EFTA area, having grown from 16 NRENs in 2008 to 22 NRENs in 2009.

Table 5.8.1 – Storage and related services

	1 Grid storage	2 Any storage	3 Peered commercial	4 Hosting commercial	5 Video	6 Mirroring
EU/EFTA countries	33%	17%	23%	37%	53%	73%
Other countries	32%	7%	36%	7%	29%	21%

Sixteen EU/EFTA NRENs (53%) currently offer a video service and seven more are planning to introduce it. This is just one of a range of real-time and synchronous collaboration services that are currently being investigated by NRENs. This development warrants further investigation in future years.

Table 5.8.2 – Storage and related services

	Grid storage	Storage service	Peered commercial	Hosted commercial	Video service	Mirroring
EU/EFTA countries						
Austria, ACOnet	no	no	planned	no	no	yes
Belgium, BELNET	no	planned	planned	planned	planned	yes
Bulgaria, BREN	yes	planned	planned	no	planned	planned
Cyprus, CYNET	no	planned	no	no	planned	planned
Czech Republic, CESNET	yes	planned	no	no	yes	no
Denmark, UNI-C	no	no	no	no	yes	yes
Estonia, EENet	yes	planned	no	no	yes	yes
Finland, Funet	yes	planned	yes	yes	yes	yes
France, RENATER	no	no	no	no	no	no
Germany, DFN	no	no	no	no	planned	no
Greece, GRNET S.A.	yes	yes	planned	no	yes	yes
Hungary, NIIF/ HUNGARNET	yes	yes	no	yes	yes	yes
Iceland, RHnet	planned	planned	no	yes	yes	yes
Ireland, HEAnet	planned	planned	planned	planned	yes	yes
Italy, GARR	no	no	no	no	yes	yes
Latvia, SigmaNet	yes	yes	no	yes	planned	planned
Lithuania, LITNET	planned	no	no	no	no	no
Luxembourg, RESTENA	no	planned	yes	yes	no	yes
Malta, UoM	no	no	no	no	no	no
Netherlands, SURFnet	planned	yes	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	planned	no	no	no	yes	yes
Spain, RedIRIS	planned	planned	no	planned	no	yes

Table 5.8.2 – continued

	Grid storage	Storage service	Peered commercial	Hosted commercial	Video service	Mirroring
EU/EFTA countries						
Sweden, SUNET	yes	no	yes	yes	yes	yes
Switzerland, SWITCH	no	planned	no	yes	yes	yes
United Kingdom, JANET(UK)	yes	yes	yes	yes	yes	yes
Other countries						
Algeria, CERIST	yes	planned	yes	no	planned	no
Belarus, BASNET	planned	no	no	no	no	no
Croatia, CARNet	no	planned	no	no	yes	no
Georgia, GRENA	yes	yes	no	no	planned	yes
Israel, IUCC	yes	no	no	no	yes	no
FYR Macedonia, MARNet	yes	no	yes	no	planned	no
Moldova, RENAM	yes	planned	no	no	yes	planned
Montenegro, MREN	planned	no	no	no	planned	no
Morocco, MARWAN	yes	planned	yes	planned	planned	planned
Russian Federation, RBNet/RUNNet	yes	planned	no	no	yes	yes
Serbia, AMRES	yes	planned	no	no	planned	no
Turkey, ULAKBIM	yes	planned	planned	planned	planned	yes
Ukraine, UARNet	planned	planned	yes	yes	planned	planned
Ukraine, URAN	planned	planned	yes	no	planned	no

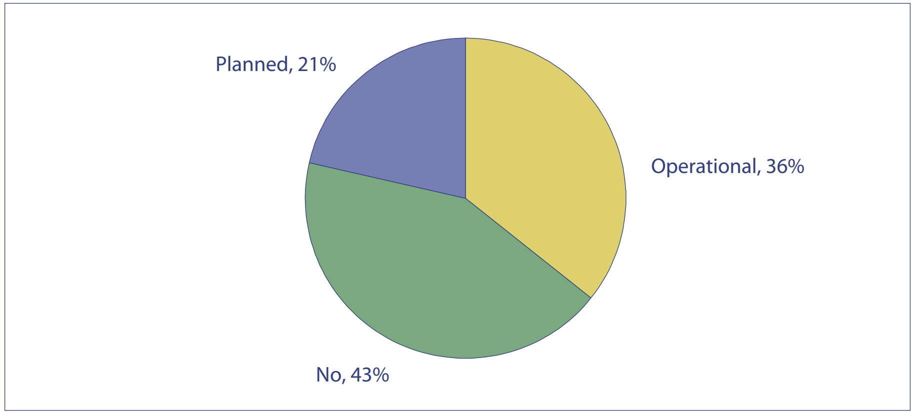
5.9 Network communication tools

5.9.1 IP telephony

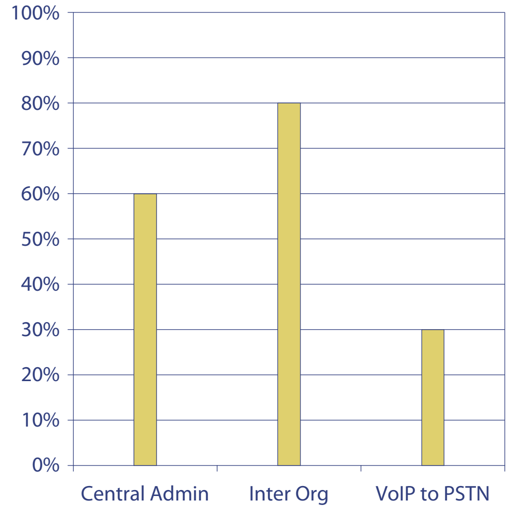
As in 2008, there has only been marginal growth in the area of VoIP. The situation in the EU/EFTA countries is summarised below.

Most NRENs that offer VoIP also provide central administration of the service. In addition, a majority provide VoIP between institutions served by the same NREN. However, only a minority also provide VoIP to PSTN[6] service, probably due to issues with billing and cost recovery. Also, the declining cost of national phone calls means that this is an area in which NRENs do not add significant value to their community beyond the offerings of commercial PSTN providers and market forces. Graph 5.9.1.2 summarises the situation.

Graph 5.9.1.1 – IP telephony, EU/EFTA countries



Graph 5.9.1.2 – VoIP service deployment



[6] Public Switched Telephone Network.

5.9.2 Video conferencing

As shown by Table 5.9.2.1, twenty-one of the EU/EFTA NRENs provide or plan to offer a centrally managed video conferencing service, which is usually defined by the deployment of a central multipoint conferencing unit (MCU). These 21 NRENs currently deploy 28 such units.

This MCU service universally offers standard definition (TV quality) conferencing. In addition, eight EU/EFTA NRENs provide a high definition MCU service.

The Global Dialling Scheme (GDS) is supported by 14 NRENs within the EU/EFTA area; it is also utilised in Australia and Croatia.

Table 5.9.2.1 – Video conferencing service deployment and planning

NREN	Centrally managed?	SD MCU	HD MCU	External MCU use	Central archiving	Online booking	Central support	GDS
EU/EFTA countries								
Austria, ACOnet	no							
Belgium, BELNET	now	now	planned	-	planned	now	now	now
Cyprus, CYNET	planned							
Czech Republic, CESNET	now	now	now	-	-	now	-	now
Denmark, UNI-C	now	now	now	now	now	-	-	-
Estonia, EENet	now	-	-	-	now	-	-	-
Finland, Funet	now	planned	planned	planned	planned	planned	planned	now
Germany, DFN	now	now	now	-	now	-	now	now
Greece, GRNET S.A.	now	-	-	now	planned	now	now	now
Hungary, NIIF/HUNGARNET	now	now	planned	now	now	now	now	now
Iceland, RHnet	now	now	-	now	-	now	now	-
Ireland, HEAnet	now	now	now	now	now	planned	now	now
Italy, GARR	now	now	-	-	-	now	now	now
Latvia, SigmaNet	no	-	-	-	-	-	-	-
Lithuania, LITNET	no							
Luxembourg, RESTENA	no							
Netherlands, SURFnet	now	now	now	now	now	now	now	now
Norway, UNINETT	planned	planned		-	planned	planned	-	planned
Poland, PIONIER	no							
Portugal, FCCN	now	now	now	now	now	now	now	now
Romania, RoEduNet	planned							
Slovakia, SANET	no							
Slovenia, ARNES	now	now	planned	planned	now	planned	now	now
Spain, RedIRIS	now	now	planned	-	planned	planned	planned	now
Sweden, SUNET	now	-	-		now	now	now	
Switzerland, SWITCH	now	now	now	-	-	now	now	now
United Kingdom, JANET(UK)	now	now	now	-	now	now	now	now

Table 5.9.2.1 – continued

NREN	Centrally managed?	SD MCU	HD MCU	External MCU use	Central archiving	Online booking	Central support	GDS
Other countries								
Algeria, CERIST	now	now	planned	-	now	planned	now	-
Belarus, BASNET	no							
Croatia, CARNet	now	now	planned	now	now	now	now	now
Georgia, GRENA	no							
Israel, IUCC	now	now	-	-	-	-	now	-
FYR Macedonia, MARNet	planned							
Moldova, RENAM	planned							
Montenegro, MREN	now	planned	-	-	-	-	now	-
Morocco, MARWAN	planned							
Russian Federation, RBNet/RUNNet	now	now	planned	-	now	planned	now	-
Serbia, AMRES	now	-	-	-	planned	-	planned	-
Turkey, ULAKBIM	planned							
Ukraine, UARNet	planned							
Ukraine, URAN	now	now	-	-	planned	-	planned	-

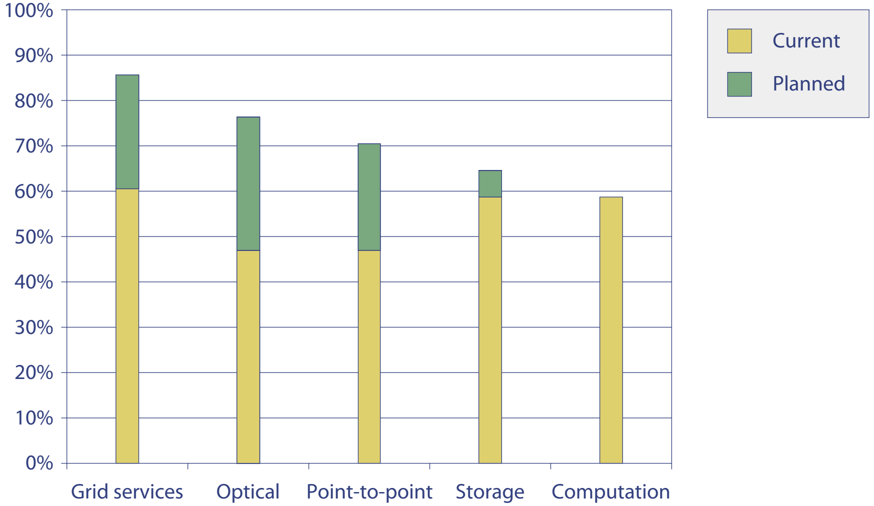
5.10 Grid services

Grid services have become an important area for NRENs. Projects and organisations such as the new European Grid Initiative (**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 offering additional services to the Grid community. In almost all cases, the geographical extent of these services is international.

The data show that 25 (89%) of the EU/EFTA NRENs already provide, or are planning to provide, Grid services. (Four years ago, the figure was 56%.)

There are different types of Grid services. For the *Compendium*, NRENs were asked whether they offer dedicated **optical paths** for Grid users, dedicated **point-to-point** IP circuits, **storage** facilities or **computation** power (CPUs). Graph 5.10.1 summarizes the situation in the EU/EFTA countries.

Graph 5.10.1 – Grid services, EU/EFTA countries

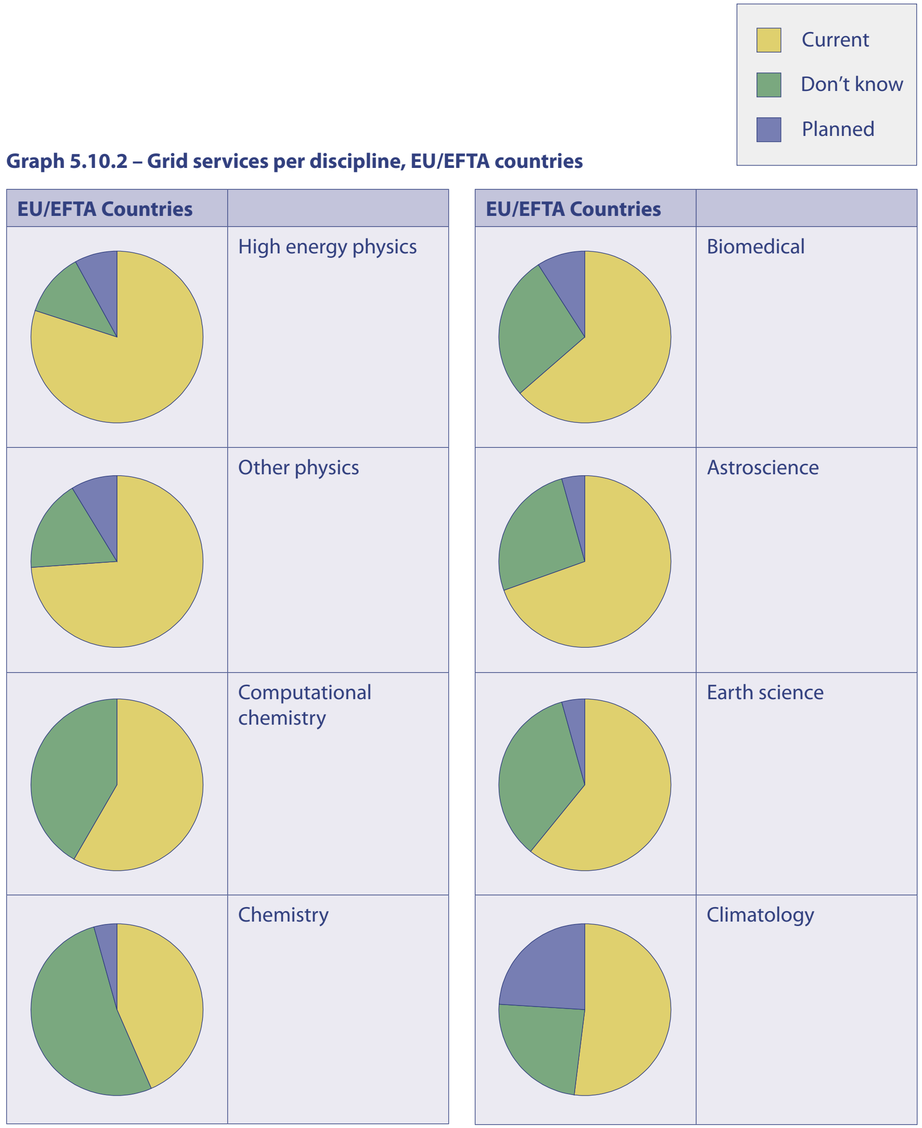


The NRENs were also asked **which disciplines** are using these services in the various countries. Graph 5.10.2 (below) indicates which disciplines are currently using Grid services and which are planning to use them in the next few years. Possible answers were 'now' (i.e. service is currently running), 'planned', 'no' or 'don't know'. It should be noted that the responses given do not present the full picture: even though NRENs indicate that they are unaware of Grid services in certain disciplines, this does not necessarily mean that such services do not exist.

Several NRENs provided information about additional disciplines using Grid services, including: arts and humanities; semantic language research; education; business and economics; and computer science.

In EU/EFTA countries, grid services have seen the largest growth in the disciplines of chemistry, computational chemistry and biomedical science.

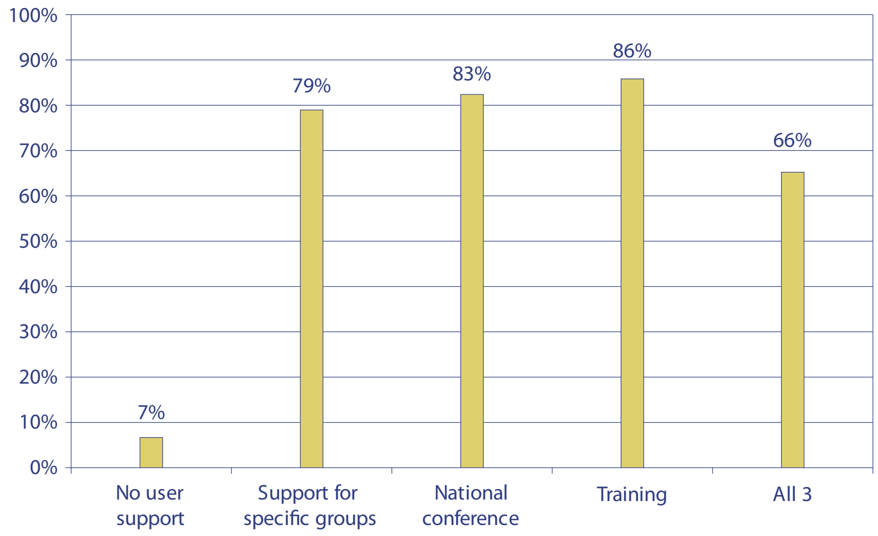
Graph 5.10.2 – Grid services per discipline, EU/EFTA countries



5.11 User and client support

As shown by Graph 5.11.1, NRENs are providing an increasing range of support services. In most NRENs, these take the form of training; however, many NRENs also host national user conferences and provide support to specific user groups.

Graph 5.11.1 – User/client support, EU/EFTA countries



In comparison with the 2008 *Compendium* data, Bulgaria, Cyprus, Portugal and Serbia have added training to their support repertoire. Seven EU/EFTA NRENs offer two support services; the remaining 19 offer all support services.

Only Estonia, Slovakia and Israel report that they offer no user or client support in the three categories surveyed. This does not necessarily mean that this support is unavailable in these countries; for example, it could mean that such support is provided by universities instead.

Staffing

The data included in Table 5.11.2 (below) show that staffing levels within NRENs differ considerably. JANET and SURFnet have more than 20 FTE in this area. Several NRENs are able to provide services even though they have no dedicated staff in this area; they clearly rely on other staff to take on this role.

Table 5.11.2 shows reported staffing in the area of use support and training. This is further broken down into NREN-employed staff vs. outsourced staff. Only five of the respondent NRENs have support and training staff located outside their organisation.

Table 5.11.2 – Support services offered to users

NREN	Support for specific groups?	National conference?	Training courses?	Staffing (in-house/ outsourced)
EU/EFTA countries				
Austria, ACOnet	no	yes	yes	0.5
Belgium, BELNET	yes	yes	yes	5.6 (4.7/0.9)
Bulgaria, BREN	no	yes	yes	
Cyprus, CYNET	no	no	yes	0.3
Czech Republic, CESNET	yes	yes	yes	1
Denmark, UNI-C	yes	yes	no	0
Estonia, EENet	no	no	no	6.1
Finland, Funet	yes	yes	yes	
France, RENATER	yes	yes	yes	4
Germany, DFN	yes	yes	yes	5
Greece, GRNET S.A.	yes	yes	yes	5 (1/4)
Hungary, NIIF/HUNGARNET	yes	yes	yes	2
Iceland, RHnet	yes	yes	yes	0.2 (0/0.2)
Ireland, HEAnet	yes	yes	yes	
Italy, GARR	yes	yes	yes	
Latvia, SigmaNet	yes	no	yes	11
Lithuania, LITNET	yes	yes	yes	

Table 5.11.2 – continued

NREN	Support for specific groups?	National conference?	Training courses?	Staffing (in-house/ outsourced)
EU/EFTA countries				
Luxembourg, RESTENA	yes	yes	no	1
Netherlands, SURFnet	yes	yes	yes	27.9 (24.9/3)
Norway, UNINETT	yes	yes	yes	6
Poland, PIONIER	yes	no	yes	
Portugal, FCCN	yes	yes	yes	
Romania, RoEduNet	yes	yes	yes	
Slovakia, SANET	no	no	no	
Slovenia, ARNES	yes	yes	yes	17 (7/10)
Spain, RedIRIS	yes	yes	yes	
Sweden, SUNET	no	yes	yes	
Switzerland, SWITCH	yes	yes	yes	4
United Kingdom, JANET(UK)	yes	yes	yes	22
Other countries				
Algeria, CERIST	yes	no	yes	5
Belarus, BASNET	yes	no	no	2
Croatia, CARNet	yes	yes	yes	
Georgia, GRENA	yes	no	yes	2
Israel, IUCC	no	no	no	0
FYRo Macedonia, MARNet	yes	no	yes	
Moldova, RENAM	yes	yes	yes	2.5 (1/1.5)
Montenegro, MREN	yes	yes	yes	1
Morocco, MARWAN	yes	yes	yes	1
Russian Federation, RBNet/RUNNet	yes	yes	yes	3
Serbia, AMRES	yes	no	yes	
Turkey, ULAKBIM	yes	yes	yes	2
Ukraine, UARNet	no	yes	no	
Ukraine, URAN	no	yes	yes	2

6 FUNDING AND STAFFING

Note 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. For the sake of comparability, we asked the NRENs that are covered by this edition of the *Compendium* to provide information only about their activities for the research or education communities. We refer to such activities simply as 'NREN activities'.

Section 6.1 gives an overview. Section 6.2 provides information on various aspects of NREN staffing. 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 provides information about how network levels are funded.

6.1 Overview

It is almost impossible to compare NRENs by staff or budget size. This is because NREN budgets are structured in various ways, depending on their tasks, which are also funded in a variety of ways.

Section 6.2 gives details on 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 significantly from year to year because of activities that are funded differ from country to country.

Comparing current budget data with those from past editions of the *Compendium* shows 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. Over the past year, however, there have been signs from various NRENs that budget cuts are being proposed or implemented; several NRENs have reported that, with reduced funding levels, they are finding it very challenging to continue delivering the service that their users have come to expect.

Among the least developed NRENs, the situation is not as clear. There, new possibilities for significantly upgrading international bandwidth could act as a catalyst for increased national network budgets. In such countries, the data suggest that, in many cases, a modest budgetary increase leads to a significant increase in traffic.

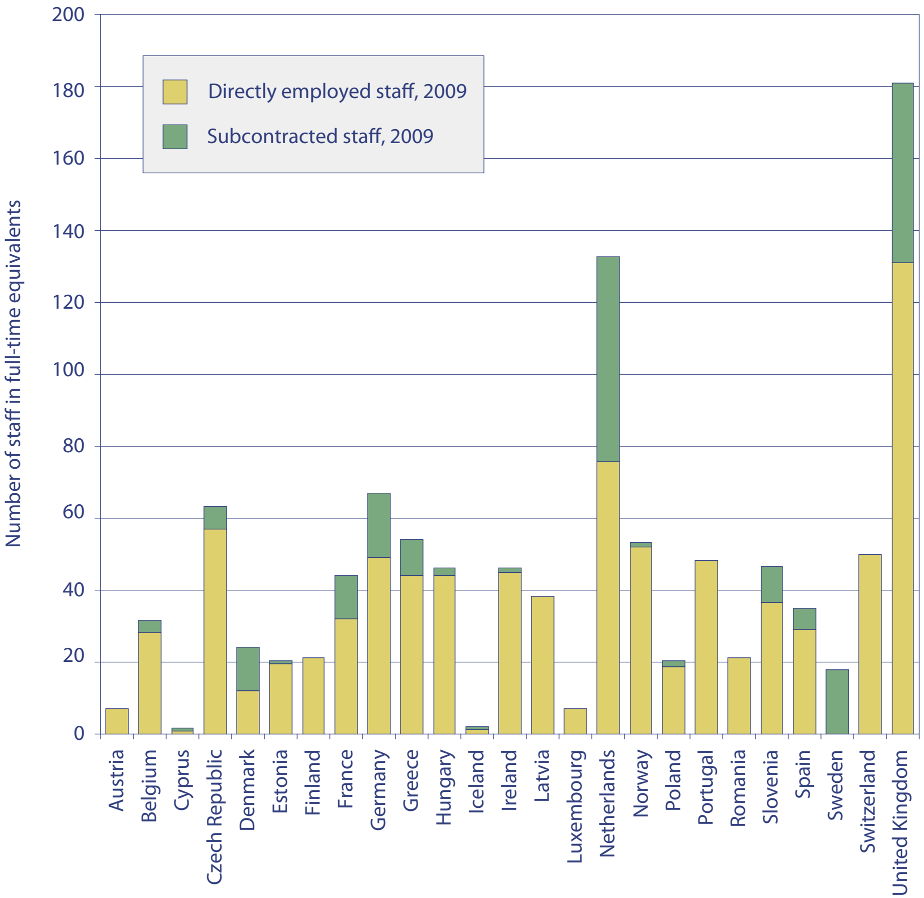
Although it is impossible to make general recommendations for NREN funding mechanisms, it would seem that a model that in some way involves the various stakeholders in an NREN provides the best guarantees for its continued success. It should be noted that many NRENs are involved in innovative developments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

6.2 Staffing

Since many NRENs use subcontractors, staff size is not a reliable indicator of the total amount of person-power that is available to an NREN. Graphs 6.2.1 and 6.2.2 give an overview of the staff that are directly employed in NREN activities, plus subcontracted staff, in full-time equivalents (FTE). Graph 6.2.3 provides such information specifically for technical staff.

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 provided as a service by a parent organisation; thus, it is not possible for all these 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 proportion of technical staff to total staff.

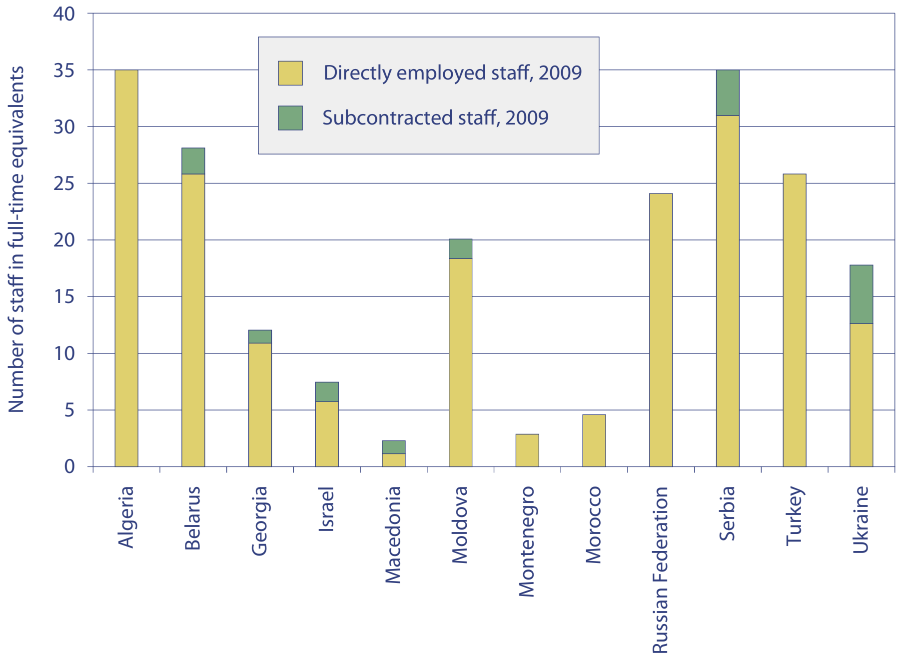
Graph 6.2.1 – Total NREN staff in FTE, EU/EFTA countries



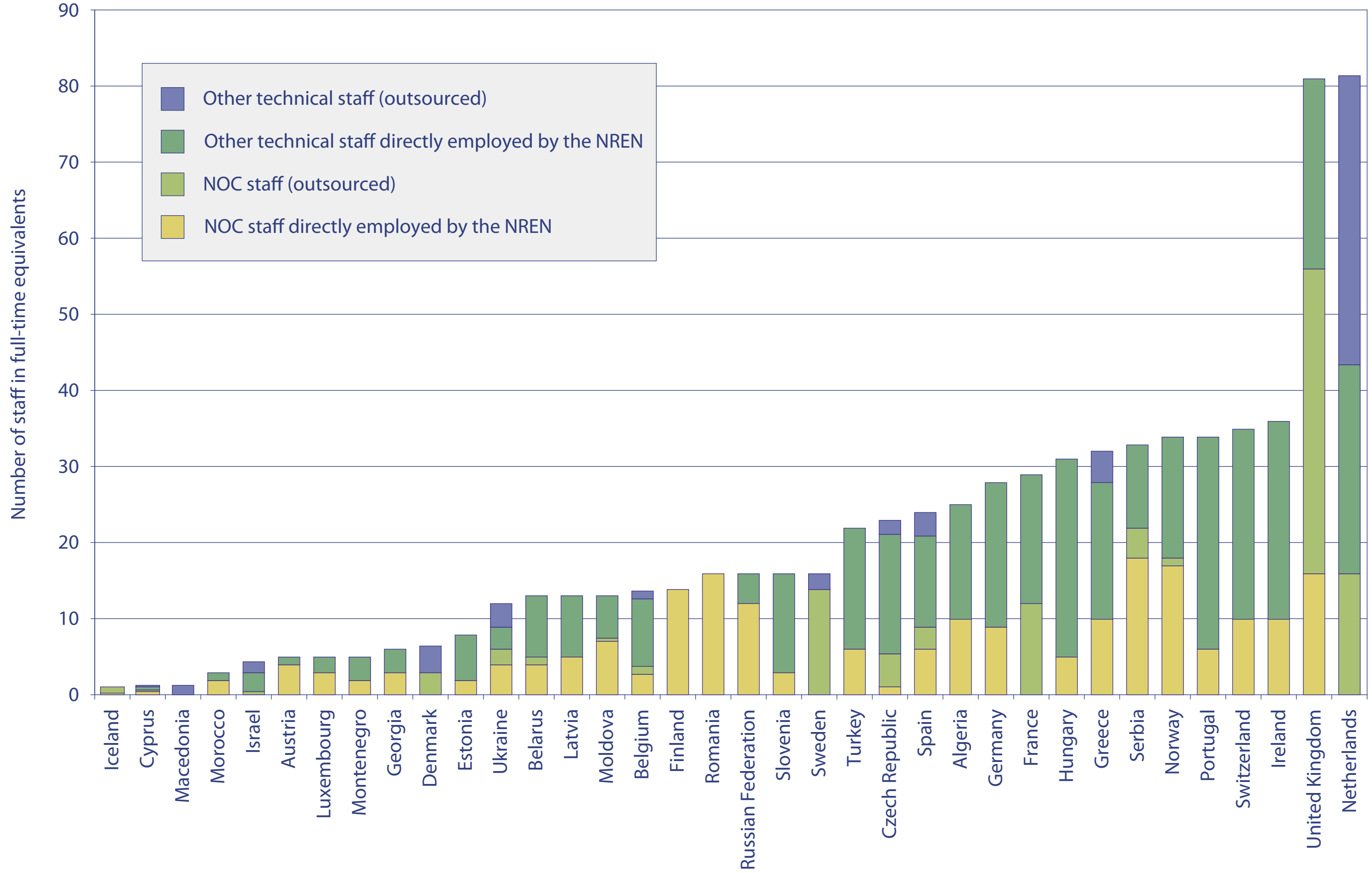
It should be noted that NRENs differ considerably in the tasks they perform: for example, some provide connection to metropolitan area networks or to access networks, which in turn connect the institutions. Other NRENs connect institutions directly and some manage metropolitan area networks themselves. The connection policies of NRENs (see Section 2.2 above) differ, for example, with respect to secondary and primary schools. This affects the remit of the NRENs and explains some of the differences seen in staff numbers in the graphs below.

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.

Graph 6.2.2 – Total NREN staff in FTE, other countries



Graph 6.2.3 – NREN technical staff in FTE



6.3 Total budgets, 2005 and 2009

Graphs 6.3.1 and 6.3.2 (below) show total NREN budgets for 2005 and 2009.

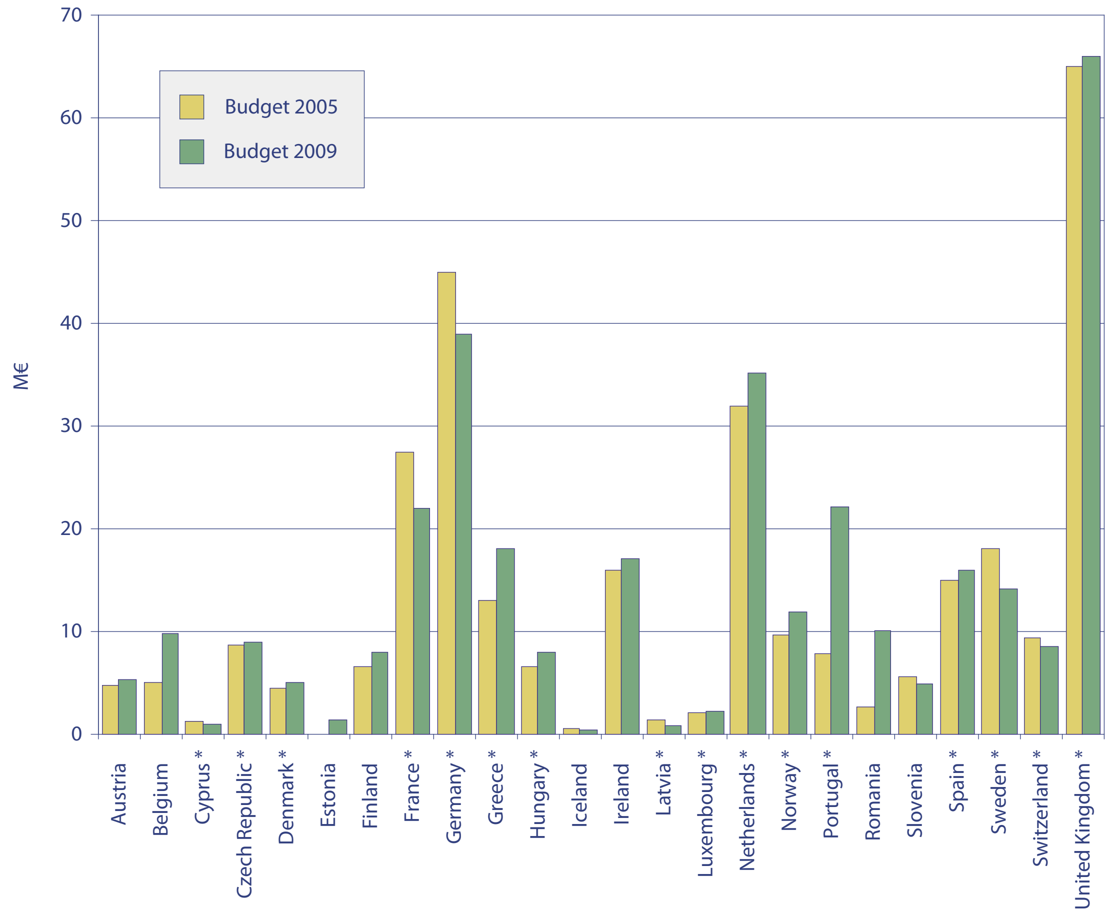
NREN budgets may fluctuate from year to year, as investments can vary considerably. Note that the financial year for JANET(UK) runs from August to July; thus, its 2009 budget is actually the 2008/2009 figure.

As explained in Section 6.2 (above), 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. For the sake of comparability, we asked the NRENs to provide information only about their budget in relation to activities for national research and education communities.

Even so, for several reasons (see list below) it is difficult to directly compare budgets. We asked the NRENs whether the budget figure that they have submitted includes the EU grant for GÉANT activity. For some NRENs, this grant is shown as part of their budget; for others, it 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 are marked with an asterisk. As can be seen in Section 6.4 (below), the proportion of funds received from the EU (though not always exclusively for GÉANT) differs considerably. There are other reasons why comparisons are difficult:

- Regional and/or metropolitan area networks 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;
- As Section 6.4 (below) indicates, some NRENs do not spend money on salaries: even though they have staff, they are not paid from the NREN budget. There may be differences in other expenditure categories as well.

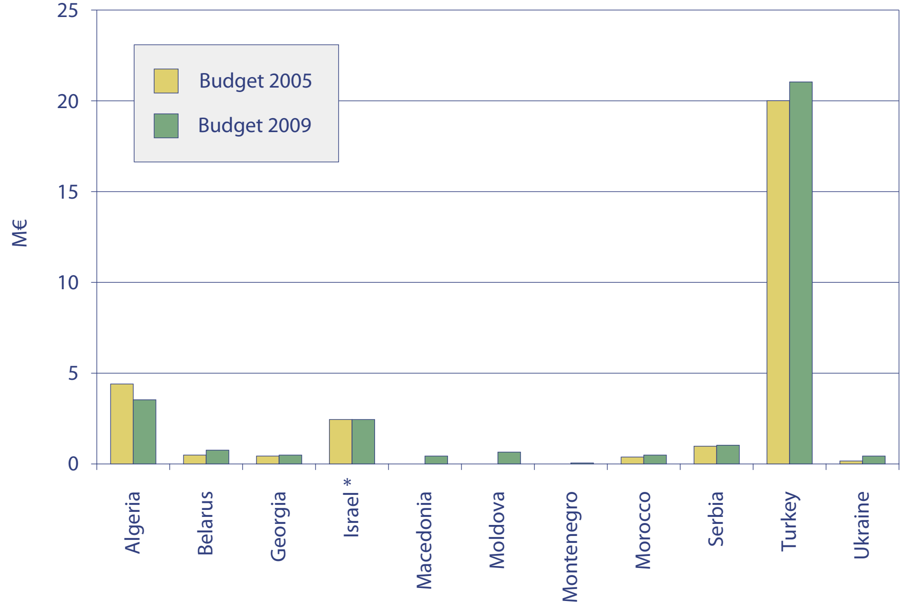
Graph 6.3.1 – Total budget, 2005 and 2009, EU/EFTA countries



* budget includes GÉANT subsidy.

Comparing 2005 with 2009 budget data shows that the situation has been relatively stable over that period. In the EU/EFTA countries, the average annual budget increase has been 2.2%, matching or marginally exceeding inflation. 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.

Graph 6.3.2 – Total budget, 2005 and 2009, other countries



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 (below) indicate what percentage of NREN funds comes from which source. Note that in many cases (see also Graphs 6.3.1 and 6.3.2 above) the amount of funding received from the EU is not shown.

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

Relevant in this context is the September 2007 EARNEST *Report on Organisational and Governance Issues*, by Robin Arak.[1] In the EARNEST Summary Report,[2] a number of recommendations (highlighted) from that study are summarised:

"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

* budget includes GÉANT subsidy.
[1] TERENA, Amsterdam, 2007, ISBN 978-90 -77559-11- 6, http://www.terena.org/publications/files/EARNEST-Organisation.pdf

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

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 2009 *Compendium* questionnaire, NRENs were asked whether they can make use of multi-annual budgeting. Of the non-EU/EFTA NRENs that responded, only CERIST of Algeria responded that it has some form of multi-annual funding in place: in relation to NREN activities, its budget is evaluated for a two-year period and an allocation made on this basis. Of the 24 EU/EFTA NRENs that responded, 62.5% reported that multi-annual budgeting was possible; the remaining NRENs cannot make use of it. A full overview is given in Table 6.4.1 (below).

Table 6.4.1 – Multi-annual budgeting

Country	NREN	Multi-year?	Description
Austria	ACOnet	YES	–
Belgium	BELNET	YES	BELNET develops multi-annual budgets via accountancy software which takes into account our multi-annual financial contractual engagements;Positive amounts are automatically reported to the following year
Cyprus	CYNET	NO	–
Czech Rep.	CESNET	NO	–

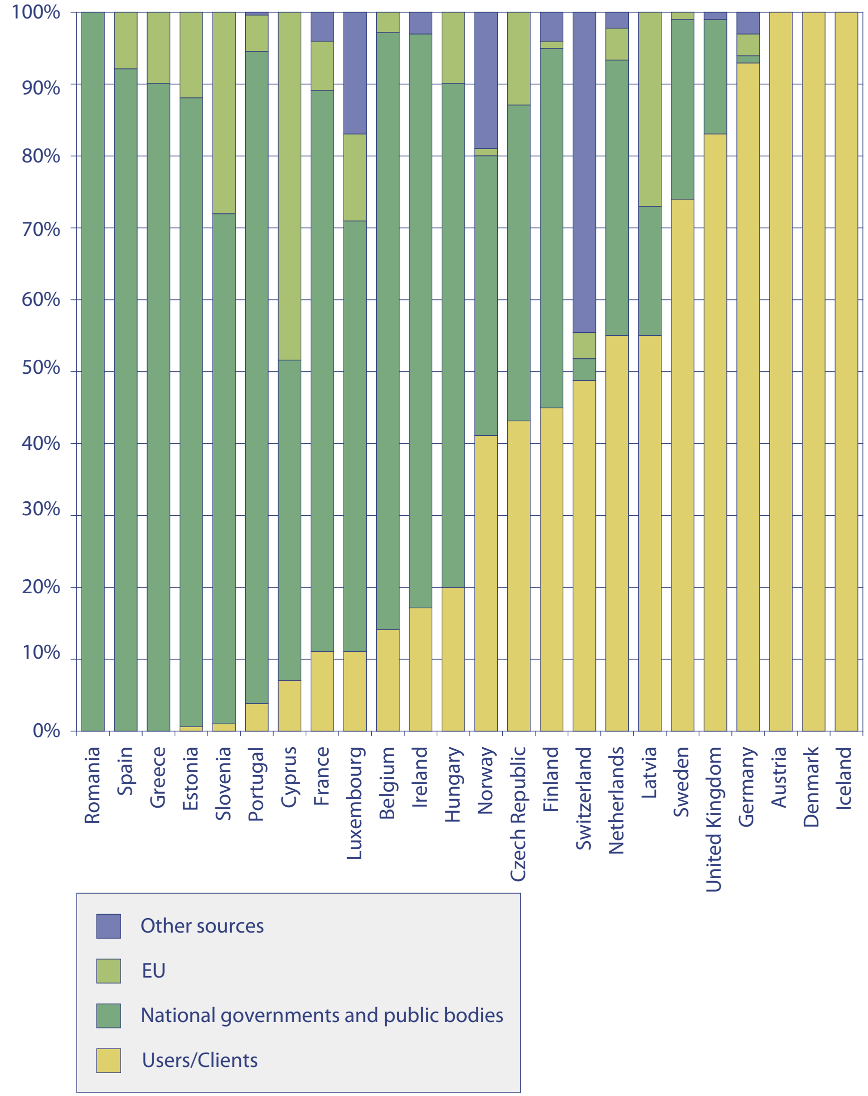
Table 6.4.1 – continued

Country	NREN	Multi-year?	Description
Denmark	UNI-C	YES	The NREN is economically self-contained, with special government grants for special acquisitions. Those acquisitions are not included in the figures.The special grant to be spent in 2008 was approximately €5 million. However one was deposited to be used in 2009 instead.
Estonia	EENet	NO	–
Finland	Funet	YES	Limited possibility for multi-annual plans in major investments like network upgrades, together with Ministry of Education (utilizing ministry strategies etc.).
France	RENATER	YES	–
Germany	DFN	YES	It is an extrapolation of existing plans.
Greece	GRNET S.A.	NO	–
Hungary	NIIF/HUNGARNET	YES	Multi-annual plans (strategic plans) are prepared and regularly revisited. The annual plans are derived, with due modifications, from these strategic plans. However, multi-annual budgeting is not possible, except for multi-annual projects (national or international).
Iceland	RHnet	YES	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	–
Latvia	SigmaNet	NO	–
Luxembourg	RESTENA	NO	–
Netherlands	SURFnet	YES	Each year a budget is made for a period of four years.
Norway	UNINETT	YES	UNINETT has a long-term policy of non-profit, but may run a surplus or a deficit from year to year. Funds for multi-year projects may be allocated over a number of years.

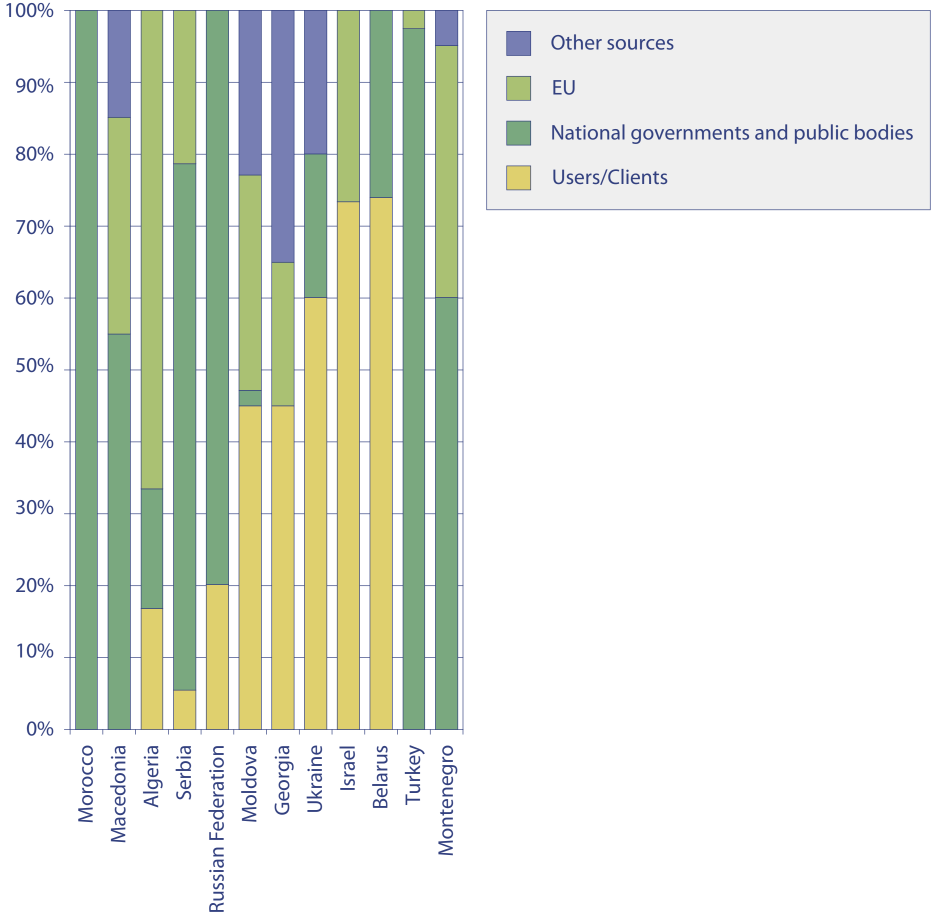
Table 6.4.1 – continued

Country	NREN	Multi-year?	Description
Portugal	FCCN	YES	An investment plan for four years was prepared by the managers, according to the guidelines of the Board of Directors. The operating budget was prepared using a growth rate.
Romania	RoEduNet	NO	–
Slovenia	ARNES	YES	Planning new services, with estimation of costs.
Spain	RedIRIS	YES	The Ministry of Science and Innovation, which activity funds most of RedIRIS and directly pays the backbone contract, can develop multi-annual plans following procedures established in the budget legislation. Multi-annual plans have been approved to ensure funding for connectivity contracts, which last for several years.
Sweden	SUNET	NO	–
Switzerland	SWITCH	YES	There is a financial plan that is filled out by the heads of the business units, who estimate for the next 7 years.
UK	JANET(UK)	NO	–

Graph 6.4.2 – Income sources, EU/EFTA countries



Graph 6.4.3 – Income sources, other countries

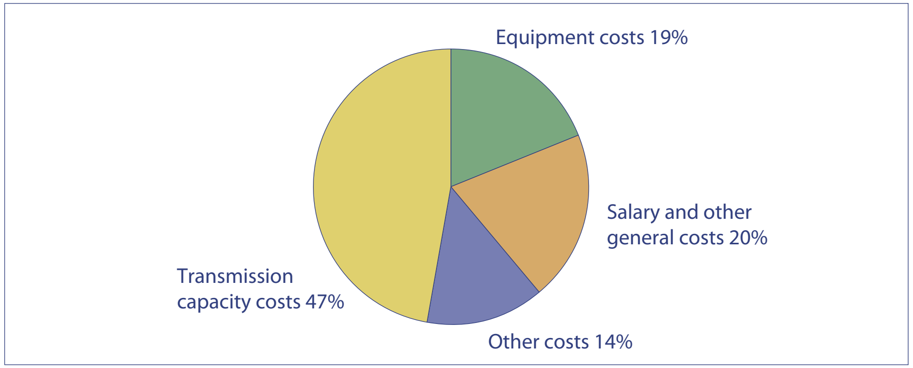


6.5 Expenditure by category

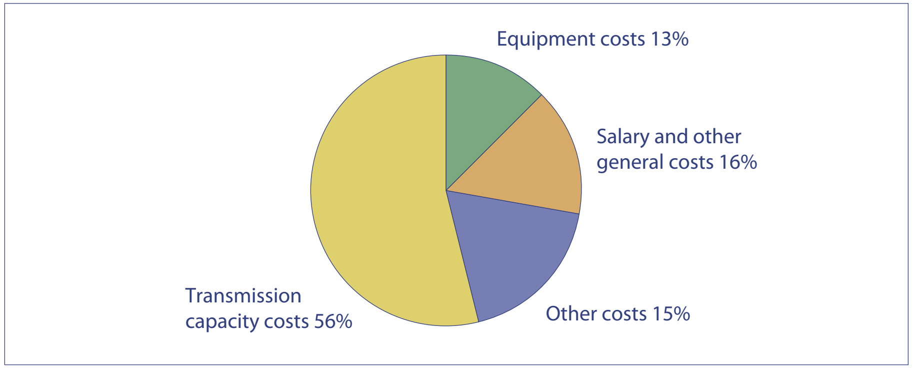
Graphs 6.5.1 and 6.5.2 (below) show the average percentage of NREN income spent on various categories of costs. Note that there are considerable differences between NRENs in this respect.

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.

Graph 6.5.1 – Expenditure by category, 2009, EU/EFTA countries



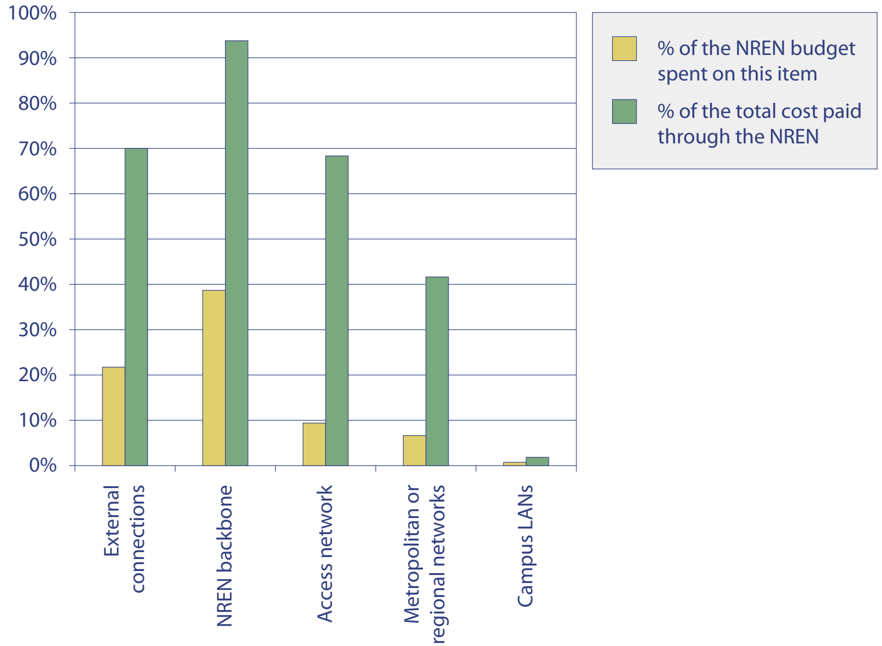
Graph 6.5.2 – Expenditure by category, 2009, other countries



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 70% of their budget. Others, such as SigmaNet (Latvia) do not pay for this at all. Similarly, UNINETT (Norway) spends 42% of its budget on metropolitan or regional networks. Metropolitan networks also exist in other countries (though they may have different functions from those in Norway), but they are not paid for through the NREN budgets. Most NRENs do not concern themselves with campus local area networks, but in Latvia they do. 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 Lists of NRENs

Note that the country entries at **http://www.terena.org/compendium** contain additional information.

NREN Acronym	NREN Name	Country
AARNet	Australian Academic and Research Network	Australia
ACOnet	Austrian Academic Computer Network Österreichisches akademisches Computernetz	Austria
AfRENA		Afghanistan
AMRES	Academic And Research Network of Serbia Akademska Mreza Srbije	Serbia
ANA (RASH)	Albanian Academic NetworkRjeti Akademik Shqiptar	Albania
ANKABUT	United Arab Emirates Research and Education Network	United Arab Emirates
Arandu	Arandú	Paraguay
ARENA	Armenian Research and Education Networking Association (ARENA) Foundation	Armenia
ARNES	Academic and Research Network of Slovenia Akademska in raziskovalna mreža Slovenije	Slovenia
AzRENA	Azerbaijan Research and Educational Networking Association Azerbaycan Elmi-Tedqiqat ve Tehsil Şebekeleri Assosiasiyası	Azerbaijan
BASNET	Belarussian Academy of Sciences Network Setka Natsianalnai Akademii Nauk Belarusi	Belarus
BdREN	Bangladesh Education and Research Network	Bangladesh
BELNET	BELNET, The Belgian National Research Network (NL): Het Belgische telematicaonderzoeksnetwerk, BELNET (FR): BELNET, Réseau télématique belge de la recherche	Belgium
BREN (BIOM)	Bulgarian Research and Education Network Association Sdruzhenie Bulgarska Izsledovatelska i Obrazovatelna Mrezha	Bulgaria
CANARIE	CANARIE Inc.	Canada
CARNet	Croatian Academic and Research Network – CARNet Hrvatska akademska i istraživačka mreža – CARNet	Croatia
CEDIA	Ecuadorian Consortium for Advance Internet Development Consorcio Ecuatoriano para el Desarrollo de Internet Avanzado	Ecuador
CERIST	Research Centre on Scientific and Technical Information Centre de Recherche sur l'Information Scientifique et Technique	Algeria
CERNET	China Education and Research Network	China
CESNET	CESNET, Association of Legal Entities CESNET, zájmové sdružení právnických osob	Czech Republic
CNRS	National Council for Scientific Research	Lebanon
CoNARE	Consejo Nacional de Rectores	Costa Rica
CSTNet	China Science and Technology Network	China
CUDI	University Corporation for Internet Development Corporación Universitaria para el Desarrollo de Internet	Mexico
CYNET (KEAD)	Cyprus Research and Academic Network KYPRIAKO EREVNITIKO KAI AKADIMAIKO DIKTIO	Cyprus
DFN	DFN-Verein e.V.	Germany
eb@le	eb@le or ebale	Congo, D.R.
EENet	Estonian Educational and Research Network Eesti Hariduse ja Teaduse Andmesidevork	Estonia
ERNET	Education and Research Network	India
EUN	The Egyptian Universities Network Shabaket El Gamaat ElMasria	Egypt
FCCN	Foundation for National Scientific Computing Fundação para a Computação Científica Nacional	Portugal
FREEnet	Academic and Research Network FREEnet Nauchno-obrazovatel naya set FREEnet	Russian Federation
Funet	Finnish University and Research Network	Finland
GARNET	Ghana Academic Research Network	Ghana
GARR	Consortium GARR	Italy
GCC	Palestinian Government Computer Center Markaz Al Hasoub Al Hokomi	Palestine
GRENA	Georgian Research and Educational Networking Association	Georgia
GRNET S.A. (ΕΔΕΤ Α.Ε.)	Greek Research & Technology Network S.A. Ethniko Diktio Ereynas & Technologias	Greece
HARNET	Hong Kong Academic and Research Network	Hong Kong
HEAnet	HEAnet Ltd.	Ireland
INNOVA|RED	Red Nacional de Investigación y Educación de Argentina	Argentina
Internet2	Internet2	United States
IRANET	Iranian Research and Academic NETwork Markaze Tahghiqaate Fizike Nazari va Riaaziaat, IRANET	Iran
ITB	Institut Teknologi Bandung	Indonesia
ITC	Institut de Technologie du Cambodge	Cambodia

NREN Acronym	NREN Name	Country
IUCC (MACHBA)	Israel Interuniversity Computer Center Merkaz Hachishuvim haBain Universitai	Israel
JANET(UK)	The JNT Association trading as JANET(UK)	United Kingdom
JUNet	The Jordanian Universities Network Shabakat Aljamiat Al Urduniyeh	Jordan
KazRENA	Kazakhstan Research and Education Networking Association Qazaqstannyn' bilim beru zhane gylymi kompyuter zhelisin koldanushylar kauymdastygy / Asociaciya polzovateley nauchno obrazovatrlnoi kompyuternoi seti Kazakhstana	Kazakhstan
KENET	Kenya Education Network Trust	Kenya
KOREN	Korea Advanced Research Network	Korea, Republic of
KRENA-AKNET (KNOKS-AKNET)	Kyrgyz Research and Education Network Association- AKNET Kyrgyzskaya Nauchnaya i Obrazovatel'naya Kompyuternaya Set-AKNET	Kyrgyzstan
KREONET	Korea Research Environment Open Network	Korea, Republic of
LEARN	Lanka Education and Research Network	Sri Lanka
LERNET	Lao Education and Research Network	Laos
LITNET	Lithuanian Academic and Research Network Lietuvos mokslo ir studiju instituciju kompiuteriu tinklas	Lithuania
MAREN	Malawi Research and Education Network	Malawi
MARNet	Macedonian Academic and Research Network Makedonska akademska nauchno-istrazhuvachka mrezha	Macedonia, FYR
MARWAN	Moroccan Academic and Research Wide Area Network MARWAN- Réseau informatique national pour l'éducation, la formation et la recherché	Morocco
MoRENet	Mozambique Research and Education Network	Mozambique
MREN	Montenegro Research and Education Network Crnogorska mreza za razvoj i nauku	Montenegro
MYREN	Malaysian Research & Education Network Rangkaian Pendidikan & Penyelidikan Malaysia	Malaysia
NCHC	National Center for High-performance Computing	Taiwan
NiCT	National Institute of Information and Communications Technology Dokuritu Gyousei Houjin Jyouhou Tuusin Kenkyuu Kikou	Japan

NREN Acronym	NREN Name	Country
NIIF/ HUNGARNET	National Information Infrastructure Development Institute / Hungarian Academic and Research Networking Association Nemzeti Informacios Infrastruktura Fejlesztesi Intezet / Magyar Kutatasi es Oktatasi Halozati Egyesulet	Hungary
NITC	National Information Technology Center	Jordan
NREN	Nepal Research and Education Network	Nepal
PADI2	Palestinian Association for the Development of Internet2 Al-Jameja Al-Falastinieh letatweer Al-Jeel Al-Thany min Al-Internet	Palestine
PERN	Pakistan Education & Research Network	Pakistan
PIONIER	The Polish Optical Internet Poznańskie Centrum Superkomputerowo-Sieciowe	Poland
PNGARNet	Papua New Guinea Academic and Research Network	Papua New Guinea
PREGINET	Philippine Research Education and Government Information Network	Philippines
RAAP	Peruvian Academic Network Red Académica Peruana	Peru
RAGIE	Guatemalan Advanced Network for Research and Education Red Avanzada Guatemalteca para la Investigación y Educación	Guatemala
RAICES	Advanced Salvadorean Research, Science and Education Network Red Avanzada de Investigación, Ciencia y Educación Salvadoreña	El Salvador
RAU	Uruguayan Research Network Red Académica Uruguaya	Uruguay
RBNet/RUNNet	Russian Backbone Network / Russian Universities Network Rossiski NII Razviyia Obshestvennih Setei/Gosudarstvenni NII Informacionnih Tehnologi i Telecommunicaci	Russian Federation
REACCIUN	Reacciun2, high performance and education network for universities and research centers Red Académica de Centros de Investigación y Universidades Nacionales de Alta Velocidad	Venezuela
REANNZ	Research and Education Advanced Network New Zealand Limited	New Zealand
RedCyT	Red Cientifica y Tecnologica	Panama
RedIRIS	RedIRIS	Spain
RedUNIV	REDUNIV Red Universitaria de la Repùblica de Cuba	Cuba
RENAM (ARSEM)	Research and Educational Networking Association of Moldova Asociatia Obsteasca RENAM	Moldova

NREN Acronym	NREN Name	Country
RENATA	National Academic Advanced Technology Network Corporation - RENATA Corporación Red Nacional Académica de Tecnología Avanzada – RENATA	Colombia
RENATER	GIP RENATER National Telecommunication network for Technology, Education and Research Réseau national de télécommunications pour la technologie, l'enseignement et la recherché	France
RENU	Research and Education Network of Uganda (RENU)	Uganda
RESTENA	Fondation RESTENA, Réseau Téléinformatique de l'Education Nationale et de la Recherche	Luxembourg
REUNA	National University Network Red Universitaria Nacional	Chile
RHnet	Icelandic University and Research Network Ltd. (RHnet) Rannsókna- og háskólanet Íslands hf (RHnet)	Iceland
RNP	Rede Nacional de Ensino e Pesquisa	Brazil
RNRT	Secretariat of State for Scientific Research and Technology responsible for the National R&D Network Reseau National de la Recherche Scientifique et la Technologie	Tunisia
RoEduNet (AARNIEC)	The Agency for Adminsitration of the National Network for Education and Research "RoEduNet" Agentia de Administrare a Retelei Nationale de Informatica pentru Educatie si Cercetare - "RoEduNet"	Romania
RUB	Royal University of Bhutan	Bhutan
RwEdNet	Rwanda Education Network	Rwanda
SANET	SANET - Slovak Academic Network Association Združenie používateľov slovenskej akademickej dátovej siete – SANET	Slovakia
SANReN	South African National Research Network	South Africa
SHERN	Syrian Higher Education and Research Network Shabaket Altaalim Alaali wa Albahheth Alelmee	Syria
SigmaNet	SigmaNet, Academic Network laboratory of Institute of Mathematics and Computer Science, University of Latvia SigmaNet, Latvijas Universitates Matematikas un Informatikas instituta Akadēmiskā tīkla laboratorija	Latvia
SingAREN	Singapore Advanced Research and Education Network (SingAREN)	Singapore
SUIN	The Sudanese Universities Information Network	Sudan

NREN Acronym	NREN Name	Country
SUNET	Swedish University Computer Network Det svenska universitetsdatornätet SUNET	Sweden
SURFnet	SURFnet B.V.	Netherlands
SWITCH	SWITCH - The Swiss Education & Research Network SWITCH - Teleinformatikdienste für Lehre und Forschung / Services de téléinformatique pour l'enseignement et la recherche	Switzerland
TARENA	Tajik Academic, Research and Educational Network Association	Tajikistan
TENET	Tertiary Education and Research Network of South Africa	South Africa
TERNET	Tanzania Education and Research Network	Tanzania
ThaiREN	Thai Research and Education Network	Thailand
TUREN	Tunisian University Research Network	Tunisia
TuRENA (TMYBT)	Turkmen Research Educational Network Association Türkmenistanyň milli ylym-bilim tory	Turkmenistan
UARNet	Ukrainian Academic and Research Network Derzavne pidpryemstvo naukovo-telekomunikacijnyj centr "Ukrainska akademichna i doslidnytska mereza" IFKS NAN Ukrainy	Ukraine
ULAKBIM	Turkish Academic Network and Information Center Ulusal Akademik Ag ve Bilgi Merkezi	Turkey
UNI-C	UNI-C, Forskningsnettet	Denmark
UNINETT	UNINETT AS	Norway
UNITEC	Universidad Tecnológica Centroamericana	Honduras
UNREN (NOMU)	Ukrainian National Research and Education Network Assotsiatsiya Natsionalna naukovo-doslidna ta osvitnya merezha Ukrainy	Ukraine
UoM/ RiċerkaNet	University of Malta IT Services/RicerkaNet Servizzi tat-Teknoloġija ta' l-Informazzjoni, L-Università ta Malta/RiċerkaNet	Malta
URAN	Association of Users of Ukraine Research and Academic Network Asociacija Korystuvachiv Ukrainskoji Naukovo-Osvitnioji Telekomunikacijnoji Merezhi	Ukraine
UzSciNet	Scientific and educational network of Uzbekistan O'zbek ilmiy va o'quv tamog'i	Uzbekistan
VinaREN	National Centre for Scientific and Technological Information	Vietnam
ZAMREN	Zambia Research and Education Network	Zambia

2 Glossary of Terms

Terms not listed in this glossary are either explained in the text or presumed to be of common understanding.

AAI	Authentication and Authorisation Infrastructure is a term used for systems supporting both the process of determining whether someone is who they declared to be (authentication) and they have the appropriate rights or privileges necessary to access a resource (authorisation).
APAN	Asia-Pacific Advanced Network is 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, see http://www.apan.net/ for more information.
AUP	Acceptable Use Policy.
Bit or b	Binary digit - the smallest unit of data in a computer – in the compendium: kilobit (kb), Megabit (Mb), Gigabit (Gb).
Byte or B	8 bits – in the compendium: TB (Terabyte), PB (Petabyte).
CA	Certification (or Certificate) Authority.
CCIRN	Coordinating Committee for Intercontinental Research Networking. See http://www.ccirn.org for more information.
CERT	Computer Emergency Response Team is an historic term used for Computer Security Incident Response Team.
CLARA	CLARA (*Cooperación Latino Americana de Redes Avanzadas*) is an international organisation whose aim is to connect Latin America's academic computer networks. See http://www.redclara.net for more information.
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 are 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	DANTE (Delivery of Advanced Network Technology to Europe) is 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 ('lit') by the NREN or the client institution.
DWDM	In fiber-optic communications, dense wavelength-division multiplexing (DWDM) is a technology that uses multiple wavelength of light to multiplexes multiple signals in a single optical fibre.
eduroam ®	A **edu**cation **roam**ing service that provides secure international roaming service for users in the international research and education community allowing users visiting another institution connected to eduroam to log on to the WLAN using the same credentials the user would use if he or she were at his or her home institution.
EARNEST	The Education And Research Networking Evolution Study - activity coordinated by TERENA in the framework of the GN2 project, see http://www.terena.org/activities/earnest
EFTA	European Free Trade Association
EC	European Commission
EU	European Union
EUMEDCONNECT	A project to connect NRENs in the Mediterranean region to the GÉANT network. Succeeded by the EUMEDCONNECT2 project.
FEIDE	National federated identity management system for the education sector in Norway, see http://feide.no/
FTE	Full-Time Equivalent
GDS	Global Dialling Scheme is a hierarchy of videoconference 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). Succeed 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 by which data, in the form of packets, is sent over a network.
IPv4	Internet Protocol version 4 is the fourth iteration and first widely deployed implementation of IP. 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 http://www.ipv6actnow.org/
IRU	Indefeasible Right to Use is 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 in place of RAN for covering a wider geographic area.
MCU	Multi-point Conferencing Unit used to connect multiple video conferencing (VC) end-points together. An MCU is also able to translate between different video formats, including SD (standard definition) and HD (high definition), to provide an optimized viewing experience for each VC unit connected.
NOC	Network Operations Centre is 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 and 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 is the location of an access point to the Internet.
PSTN	Public Switched Telephone Network is the traditional circuit-switched telephony service using dedicated circuits for the duration of a call.
RAN	Regional Area Network covering a wider geographic area than a MAN.
RedCLARA	Latin American advanced network, managed by CLARA.

SAML	Security Assertion Markup Language is a fundamental component of federated identity and access management systems.
Shibboleth	An Internet2 supported and open-source and standards-based software which uses SAML to provide Web Single Sign On (SSO) across or within organisational boundaries. See http://shibboleth.internet2.edu/
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 education institutions served by participating National Research and Education Networks. Previously called the Server Certificate Service (SCS).
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, consult http://www.uis.unesco.org
VoIP	Voice-over-Internet Protocol: a protocol for the transmission of 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*.

TERENA

« 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 include not only NREN organisations (or NRENs) but also 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 in those decades, 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 co-operation 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.

GÉANT