TERENA Trans-European Research and Education Networking Association

Compendium

of National Research and Education Networks in Europe

> 2006 Edition

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Introduction

Since the publication of the first edition of the Compendium in 2001, it has grown into a sought-after and authoritative source of reference for all those who take an interest in the development of research and education networking. The information contained in the Compendium has continued to grow in variety and dependability, even though caution in interpreting the data remains essential.

This year's edition is the second that has been published as part of the GN2 (GÉANT2) project and that has benefited from the input from activity leaders in that project. Like last year, an attempt was made to aggregate data for groups of NRENs and to look at and partially explain multi-year trends. This year, summarised information is provided in a number of 'overview' sections at the start of each chapter, whilst the more analytical and explanatory texts are at the end of each chapter. Throughout the Compendium, analytical or explanatory text has been highlighted.

Some of the trends have again been summarised in the 'Summary of Key Findings.'

The production of the 2006 edition was overseen by a Review Panel composed of the following people: Marko Bonač (Slovenia), Sabine Jaume-Rajaonia (France), Mike Norris (Ireland), Esther Robles (Spain) and Lars Skogan (Norway). Input was also received from a number of Activity Leaders in the GN2 project, from the TERENA Technical Staff, the Secretary General and the Executive Committee. Maarten de Jong, who was recruited for this project as a Data Analyst, was responsible for reminding NRENs, handling requests for information and clarification and for preparing the tables and graphs.

Collecting data of this type typically requires the involvement of a number of people from each NREN, as well as careful checking by NREN staff. TERENA wishes to express its gratitude to all those in the NREN community who contributed to the gathering, submitting, clarifying and double-checking of the data contained in this publication.

The Compendium consists of two parts: the basic information as submitted by the individual NRENs (available on the Web at http://www.terena.nl/compendium) and this publication.

Most tables and graphs first show the EU and EFTA[1] countries and then other countries in Europe and North Africa. A list of all those countries is given in section 1.0. Data are usually presented in alphabetical order by the English-language name of each country. An alphabetical list of NRENs included in the Compendium is in Appendix 2. This year, for the first time, countries from outside of Europe were asked to provide some basic data, in the form of responses to a mini-questionnaire. In a few cases, information from these questionnaires has been included for illustrative purposes. The full data can be found on the Web. Note that unless otherwise specified, the data describe the situation at or close to the 31 January, 2006.

It is hoped that this sixth edition of the Compendium will prove to be at least as valuable as the previous ones. Feedback is again invited and is key to the future development of the Compendium!

Bert van Pinxteren
TERENA Chief Administrative Officer

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

In a number of places in this document, reference is made to the SERENATE studies. The SERENATE project was an Accompanying Measure in the Information Society Technologies programme of the Fifth Framework Programme and was supported as such by the European Union. The summary report, 'Networks for Knowledge and Innovation', ISBN 90-77559-01-9 is available from the TERENA Secretariat and on the Web, at http://www.serenate.org/publications/d21-serenate.pdf.

The SERENATE studies have been succeeded by EARNEST. The EARNEST studies run from March 2006 to August 2007 (see http://www.terena.nl/activities/earnest/).

Summary of Key Findings

Unless otherwise specified, all NRENs have been asked to provide data that describe the situation at or close to the 31 January, 2006.

Legal Form

The most common model in the EU and EFTA countries is an NREN which is a separate legal entity. This separate legal entity is controlled by the research and education community which itself is (largely) government funded. It is important to note, however, that several other models exist. In the other countries, there is a greater variety.

NREN development requires the commitment of all major stakeholders, such as funders and users. A governing model that allows the participation of these stakeholders would seem to be the most appropriate; such a situation can be achieved a number of different ways.

NRENs that can operate with a certain amount of independence from their respective governments may have certain advantages, such as easier decision-making procedures and the ability to offer staff attractive terms of employment. This may help to explain why this model is more common in countries where research networking has developed over many years and is now well established.

Users/Clients

In the period 2003 – 2006, NRENs in the EU states have shown a steady increase in the number of universities connected at **Gigabit speeds**.

The SERENATE study [2] recommended the promotion of Gigabit networking services. Gigabit connections can be seen as a necessary, though by no means sufficient, condition for a university to engage in high-end research and learning programmes.

The Compendium data suggest that the SERENATE recommendations on Gigabit networking are being followed in many countries. It seems that fibre optic technology is allowing NRENs to leap-frog immediately to much higher capacities. Gigabit Ethernet is being introduced by many less developed NRENs and thus seems to make it possible, for the first time, to quickly address an important aspect of what was termed the 'digital divide' in Europe in the SERENATE study.

There is clear evidence that the connection of **secondary and primary schools** to the Internet via NRENs and also the provision of support and application services to schools is high on the agenda in many countries. The commitment by EU heads of government in Lisbon in 2000 to making Europe 'the most dynamic and competitive knowledge-based economy in the world' by 2010 is a common factor underlying these activities.

In a number of countries, the percentage of coverage of connected schools is either 100% or close to it. In many countries, connections to schools are funded centrally through ministries of education. The percentage of connections is expected to rise sharply in some countries because implementation of schemes to connect most or all schools has just started.

Network

The overall trend is that there is considerable **growth** year on year. In 2006, all but three of the EU/EFTA NRENs have a capacity of at least 1 Gb/s; the most common capacity is 10 Gb/s or a multiple of this and eleven NRENs operate at this capacity.

We have data from nineteen additional NRENs. In 2006, seven of these operated at 1 Gb/s and one had a capacity of 2.5 Gb/s. What is interesting to note here is that these NRENs have made a larger jump than the EU/EFTA NRENs, thus skipping one or more of the network development stages that the EU/EFTA NRENs experienced.

[2] SERENATE summary report, p.5

The Compendium shows that for most NRENs that are part of the GN2 project, the **external link** to GÉANT is by far the most important in terms of capacity. Often NRENs also have peering arrangements at neutral Internet exchanges and many also have connections to commercial ISPs, but these do not have the same capacity as those to GÉANT. The situation is obviously different in the countries that are not part of GN2 project.

There are indications that more and more NRENs are switching over to **dark fibre**. There is a steady increase in the number of NRENs that currently have at least two-thirds of their backbone as dark fibre. This seems to be the technology of choice for NRENs that are planning to upgrade their networks now or in the near future.

As a new development, a number of countries already have or are planning to install **cross-border dark fibre links** directly from one NREN to a neighbouring NREN. The Compendium provides an overview of these links.

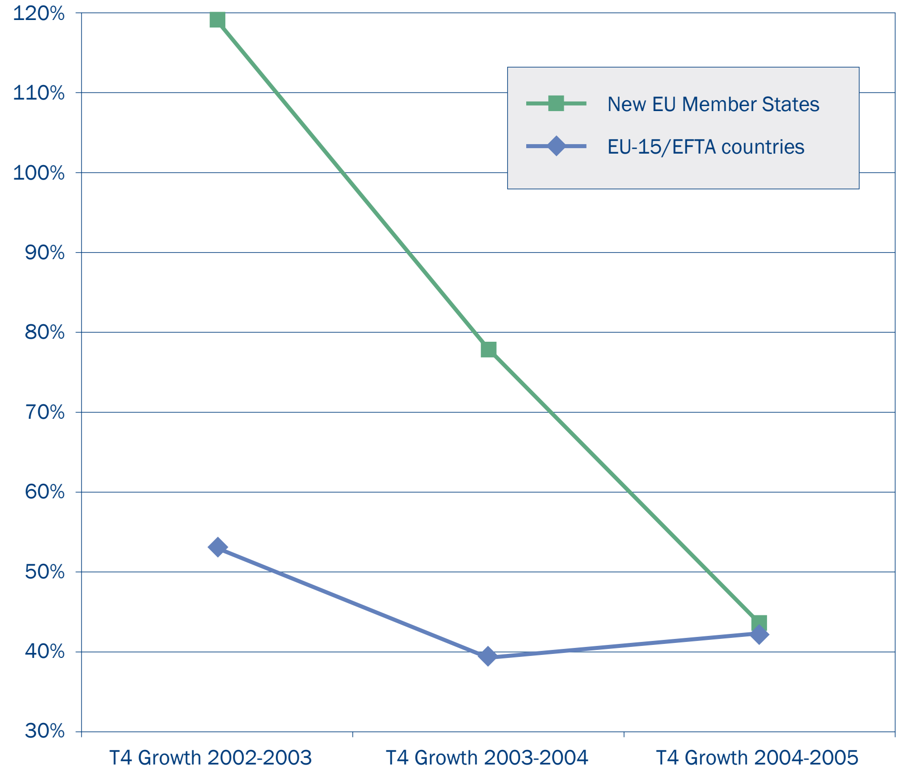
Traffic

The 2005 edition of the Compendium showed a significant distinction between the growth rates in the new EU member states and in non-EU/EFTA countries. The growth rates in the 'new' member states were clearly higher than those in the 'old' EU member states. As is clear from the new data, the growth rates have now converged.

As stated last year, it seems that in the EU, traffic is now determined more by (changes in) user demand, than by limitations in network capacity. In the 'Other' group of countries, this is probably not yet the case.

The lower growth rate for the EU/EFTA countries that was evident when comparing 2002/2003 to 2004/2005 now seems to have stabilised. It is difficult, if not impossible, to predict what the future will bring – new Grid applications, for example, may change the picture. However, in that case,

Inbound External Traffic (T4) Growth in the 'Old' and 'New' EU Member States, 2002 – 2005



growth will be driven by demand rather than by changes in network capacities. In addition, changes in technology may change the picture.

The level of **NREN traffic with the general Internet**, as distinct from inter-NREN traffic, is quite uniformly high. The overall average proportion across all NRENs in the survey is approximately 75%. However, the spread between NRENs is considerable, ranging from just under 30% for RHnet (Iceland) to more than 90%, for example, for ULAKBIM (Turkey).

A single metric was derived for the level of congestion in each network element from the subjective levels reported by NRENs. The overall picture is the same as in 2005: in EU/EFTA countries, NRENs report relatively little congestion in those parts of the network within their domain of responsibility. Uniformly, they see no serious congestion on external circuits, virtually none in their core networks and little in the MAN or regional network. Any serious congestion, they report, is largely confined to access networks or, to the campus LANs of connected institutions.

The 'Other' NRENs report that most congestion is on their external connections. In those countries, the restrictions imposed by low-capacity external connections mean that constraints at the campus and other levels are less apparent. It is to be expected that these constraints will surface as soon as the problems at other levels have been solved.

The uptake of **IPv6** seems to be slowing down. On the one hand, the proportion of universities that have some form of IPv6 connectivity has increased, at least in the EU/EFTA area. The growth in IPv6 traffic on the GÉANT backbone has peaked, at least for the time being. It seems that institutions are adopting the connection, but are not using it.

Services

Services are receiving more attention from NRENs. There are a few trends that can be noted from the data:

- More users have come to expect reliable, high-capacity Internet connections. NRENs are doing more to provide such connections and to provide assistance in case of problems. One way of doing this is through the 'PERTs'. These now exist in roughly half of the NRENs. In cases where a PERT does not exist, an NREN is able to call upon the central GÉANT PERT.

- There is an increased need for an authorisation and authentication infrastructure (AAI) in the NREN environment and many NRENs are working to develop such an infrastructure. However, the work is by no means complete. Currently deployed AAI's have very different capabilities, ranging from simple username/password-based authentication systems to sophisticated middleware for granting or denying access to resources.

- There is a renewed and increasing interest in the Public Key Infrastructure (PKI) area.

- Many NRENs are now introducing or have introduced eduroam, a facility that provides roaming access for users to wireless networks.[3]

- A related area is that of security incident response. The figures indicate that in this area, there is still a large gap between the EU/EFTA countries and the other countries in the region.

- Approximately 25% of the NRENs are currently offering a bandwidth on demand service; approximately the same percentage is planning to introduce it in the next two years, with a significant percentage of NRENs still in doubt.

- Grid services are currently running in most NRENs – several others are planning to introduce such a service. There has been a clear increase of interest over the past year. A striking element in the responses is that the adoption of Grid technology has widened beyond the initial high-energy physics and biomedical communities. All disciplines seem to be well represented.

- Several NRENs have introduced IP Telephony services on their network; however, the scale and types of implementation vary widely, depending on different national situations.

[3] eduroam is a registered trademark of TERENA. See also http://www.eduroam.org.

- Videoconferencing is now part of the day-to-day collaboration activities in universities and research centres. 85% of the NRENs in the EU/EFTA countries currently offer such a service.

Funding

NREN budgets may fluctuate from year to year, because investments can vary considerably. NRENs have many different tasks and are organised in different ways. Some NRENs provide services only to the research or education communities in their country. Others provide additional services, for example, they administer the country-code top-level domain or they connect others who are clearly outside of the research or education communities. There are also other reasons why comparisons are difficult:

- Funding for regional and/or metropolitan area networks is handled differently in different countries;
- In some countries, clients pay for their line to the nearest NREN PoP, in others the NREN pays for this;
- Some spend a large part of their budget on connecting primary and secondary schools, while others do not.

When comparing current budget data with data from previous editions of the Compendium, it becomes clear that NREN budgets tend to be stable over time. There are fluctuations from year to year, depending on whether or not an important investment takes place during that year. But on the whole, the trend is that budgets stay relatively stable and that NRENs are able to deliver more bandwidth and more services for roughly the same amount of money.

The situation is different for the less developed NRENs. New possibilities for significantly upgrading international bandwidth (for example under the GN2, EUMEDCONNECT or SEEREN projects) seem to act as a catalyst for increased national NREN budgets. A case in point is CERIST of Algeria. For 2005, it has received extra funding for a major upgrade of its backbone and of the access network. It could be that this increase has, in fact, been stimulated in part by the improved international connectivity that has become available to CERIST through the EUMEDCONNECT project.

However, in these countries, a modest increase in budget leads, in many cases, to a great leap in traffic. Often there is not yet a commensurate increase in services.


Answers obtained
NREN not fully functional or only partial answers obtained
No answers obtained
No NREN or no knowledge of NREN work in this country available
Outside the scope of the Compendium
Iceland 20
Norway 33
Sweden 42
Finland 14
Estonia 13
Latvia 25
Lithuania 26
Denmark 11
Ireland 21
United Kingdom 47
Netherlands 32
Belgium 6
Luxembourg 27
Germany 17
Poland 34
Belarus 5
Russian Federation 37
Czech Republic 10
Slovakia 39
Ukraine 46
France 15
Switzerland 43
Austria 3
Hungary 19
Moldova 30
Slovenia 40
Romania 36
Croatia 8
Serbia & Montenegro 38
Italy 23
Bulgaria 7
FYR Macedonia 28
Albania 1
Greece 18
Georgia 16
Azerbaijan 4
Turkey 45
Portugal 35
Spain 41
Malta 29
Cyprus 9
Syria 44
Morocco 31
Algeria 2
Egypt 12
Israel 22
Jordan 24

1 Basic Information

1.0 NRENs that have Responded to the Questionnaire

There are 53 countries in the area that have been considered for this edition of the Compendium (basically, Europe and the surrounding countries in the Middle East and North Africa). In three countries, there are no NRENs or we do not have knowledge of NREN work in those countries. 47 NRENs responded to the survey, from 46 different countries. Not all NRENs were able to answer all of the questions, but many were; two NRENs only answered the mini-version of the questionnaire. The following map and table give an overview of the NRENs that sent their replies and an impression of the completeness of those replies.

In most of the tables and graphs, the English-language abbreviation of the NREN's name has been used in order to denote the NREN. Table 1.0.1 provides a list of countries and the abbreviations of the NREN(s) from those countries that submitted information. Table 1.0.2 provides a list of countries where we know that research networking exists, but from which no replies were received. Table 1.0.3 provides a list of other NRENs that provided information for the Compendium, as found on the Compendium website.

NRENs were asked to double-check and update their replies.

Two projects are relevant in this context: the EUMEDCONNECT project focusing on the Mediterranean region (see http://www.dante.net/eumedconnect/) and the Virtual Silk Highway focusing on the Central Asian countries (see http://www.silkproject.org/). In addition, CEENet (http://www.ceenet.org/) maintains contacts and provides support to many NRENs in Central and Eastern Europe and the former Soviet Union.

More information about NRENs from 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/index.htm. Worldwide co-ordination is performed through the CCIRN, http://www.ccirn.org.

Table 1.0.1 NRENs and urls. NRENs in bold are TERENA members.

#	Country	NREN	URL
1	Albania	ANA	http://www.inima.al
2	Algeria	CERIST	http://www.cerist.dz
3	Austria	**ACOnet**	http://www.aco.net
4	Azerbaijan	AzNET	http://www.aznet.org
	Azerbaijan	AzRENA	http://www.azrena.org
5	Belarus	BASNET	http://www.basnet.by
6	Belgium	**BELNET**	http://www.belnet.be
7	Bulgaria	IST Foundation	http://www.ist.bg
8	Croatia	**CARNet**	http://www.carnet.hr
9	Cyprus	**CyNet**	http://www.cynet.ac.cy
10	Czech Republic	**CESNET**	http://www.ces.net
11	Denmark	**UNI•C**	http://www.denet.dk
12	Egypt	EUN	http://www.frcu.eun.eg
13	Estonia	**EENet**	http://www.eenet.ee
14	Finland	**Funet**	http://www.nic.funet.fi
15	France	**RENATER**	http://www.renater.fr
16	Georgia	GRENA	http://www.grena.ge
17	Germany	**DFN**	http://www.dfn.de
18	Greece	**GRNET**	http://www.grnet.gr
19	Hungary	**NIIF/HUNGARNET**	http://www.niif.hu
20	Iceland	**RHnet**	http://www.rhnet.is
21	Ireland	**HEAnet**	http://www.heanet.ie
22	Israel	**IUCC**	http://www.iucc.ac.il
23	Italy	**GARR**	http://www.garr.it
24	Jordan	JUNet	http://www.junet.edu.jo
25	Latvia	**LATNET**	http://www.latnet.lv
26	Lithuania	**LITNET**	http://www.litnet.lt

Table 1.0.1 - continued

#	Country	NREN	URL
27	Luxembourg	**RESTENA**	http://www.restena.lu
28	Macedonia, FYRo	**MARNet**	http://www.ukim.edu.mk
29	Malta	**CSC**	http://www.um.edu.mt
30	Moldova	RENAM	http://www.renam.md
31	Morocco	MARWAN	http://www.marwan.ma
32	Netherlands	**SURFnet**	http://www.surfnet.nl
33	Norway	**UNINETT**	http://www.uninett.no
34	Poland	**PIONIER**	http://www.pionier.gov.pl
35	Portugal	**FCCN**	htttp://www.fccn.pt
36	Romania	RoEduNet	http://www.iasi.roedu.net/
37	Russian Federation	RBNet/RUNNet	http://www.ripn.net, http://www.runnet.ru
38	Serbia and Montenegro	**AMREJ**	http://www.rcub.bg.ac.yu
39	Slovakia	**SANET**	http://www.sanet.sk
40	Slovenia	**ARNES**	http://www.arnes.si
41	Spain	**RedIRIS**	http://www.rediris.es
42	Sweden	**SUNET**	http://basun.sunet.se
43	Switzerland	**SWITCH**	http://www.switch.ch
44	Syria	SHERN	http://www.shern.net
45	Turkey	**ULAKBIM**	http://www.ulakbim.gov.tr
46	Ukraine	URAN	http://www.uran.net.ua
47	United Kingdom	**UKERNA**	http://www.ukerna.ac.uk

Table 1.0.2 NRENs not included in the Compendium

	Country	NREN	URL
	Armenia	ARENA	http://www.arena.am/
	Lebanon	CNRS	http://www.cnrs.edu.lb
	Palestine	PADI2	http://www.padi2.ps/

Table 1.0.3 NRENs from other countries that submitted data for the Compendium

	Country	NREN	URL
	Canada	CANARIE	http://www.canarie.ca
	Chile	REUNA	http://www.reuna.cl
	Colombia	RENATA	http://www.renata.edu.co
	Ecuador	CEDIA	http://www.cedia.org.ec
	El Salvador	RAICES	http://www.raices.org.sv
	Guatemala	RAGIE	http://www.ragie.org.gt
	Kazakhstan	KazRENA	http://www.kazrena.kz
	Kyrgyzstan	KRENA-AKNET	http://aknet.kg
	Peru	RAAP	http://www.rap.org.pe
	Taiwan	NCHC	http://www.nchc.org.tw
	Uganda	RENU	http://www.renu.ac.ug
	Uruguay	RAU	http://www.rau.edu.uy
	U.S.A.	Internet2	http://www.internet2.edu
	Uzbekistan	UzSciNet	http://www.uzsci.net

1.1 Legal Form of NRENs

NRENs have many different legal forms. Names and their translations may be misleading: what is called a 'foundation' in one country may be something very different from a 'foundation' in another country. The same is true for many other designations. In this section, two parameters are distinguished that together help to characterise the legal form of NRENs.

Separate Legal Entity

Many NRENs operate as a separate legal entity; many others form part of a larger organisation (often a ministry, a university or a research institution). A few NRENs have a special status in the sense that they do not operate as a separate legal body but are not part of a larger organisation either, for example, because they operate on a project basis. Typically, the final institutional identity of these NRENs has not yet been decided.

Relationship with Government

Those NRENs that are a government agency or part of a government ministry are typically directly controlled by the government, even though in some cases (e.g., Turkey) such agencies can enjoy a reasonable degree of autonomy, comparable to that of some of the NRENs that are separate legal entities (marked 'direct' in table 1.1.1).

A number of NRENs that are separate legal entities have governing boards that are at least half government-appointed. Those NRENs are marked with 'appoints' in the table. Many NRENs have a mixed model, being governed both by government representatives and representatives from the research and education community.

In the table, 'indirect' means an indirect relationship. If at least half the members of the NREN's governing body are appointed by research and education institutions, then that in itself means that NRENs are (largely) government-funded.

The table shows the relationship between the two parameters.

As can be seen from table 1.1.1, the most common model in the EU and EFTA countries is an NREN which is a separate legal entity. This separate legal entity is controlled by the research and education community, which itself is (largely) government-funded. It must be noted, however, that several other models exist. In the other countries, there is a larger variety.

It seems clear that NREN development requires the commitment of all major stakeholders, such as funders and users. A governing model that allows the participation of these stakeholders would seem to be the most appropriate; such situation can be achieved in a number of different ways.

NRENs that can operate with a certain amount of independence from government may have advantages, such as easier decision-making procedures and the ability to offer staff attractive terms of employment. This may help to explain why this model is more common in countries where research networking has developed over many years and is now well-established.

Table 1.1.1 Relationship with Government

Country	NREN	Separate Legal entity?	Relationship with Government	Remarks/Parent Organisation
EU and EFTA Countries				
Austria	ACOnet	no	indirect	Vienna University Computer Centre
Belgium	BELNET	no	appoints	Ministry of Science Policy
Cyprus	CyNet	yes	other	
Czech Republic	CESNET	yes	indirect	
Denmark	UNI•C	no	appoints	For Forskningsnet: Danish ministry of Science,Technology and Innovation, For UNI•C: Danish Ministry of Education
Estonia	EENet	yes	appoints	EENet is a public institution operating under the administration of the Estonian Ministry of Education and Research
Finland	Funet	no	appoints	CSC - Scientific Computing Ltd., owned by the Ministry of Education
France	RENATER	yes	indirect	
Germany	DFN	yes	indirect	
Greece	GRNET	yes	other	
Hungary	NIIF/HUNGARNET	yes	other	
Iceland	RHnet	yes	indirect	
Ireland	HEAnet	yes	indirect	
Italy	GARR	yes	indirect	
Latvia	LATNET	no	indirect	The LATNET network is working as a financially independent subunit (department) of the Institute of Mathemtics and Computer Science that is an independent unit of Latvia University.
Lithuania	LITNET	no	indirect	Ministry of Science and Education of Lithuania
Luxembourg	RESTENA	yes	indirect	
Malta	CSC	no		University of Malta
Netherlands	SURFnet	yes	indirect	Stichting SURF (English: SURF Foundation)
Norway	UNINETT	yes	other	
Poland	PIONIER	yes	indirect	
Portugal	FCCN	yes	indirect	
Slovakia	SANET	yes	indirect	
Slovenia	ARNES	yes	appoints	
Spain	RedIRIS	no	appoints	
Sweden	SUNET	no	appoints	
Switzerland	SWITCH	yes	indirect	
United Kingdom	UKERNA	yes	indirect	

Country	NREN	Separate Legal entity?	Relationship with Government	Remarks/Parent Organization
Other Countries				
Albania	ANA	no	indirect	Ministry of Education and Science, Academy of Sciences of Albania
Algeria	CERIST	no	appoints	Ministry of higher education and scientific research
Azerbaijan	AzNET	no	indirect	United Nations Development Programme (UNDP) Country Office in Azerbaijan
Azerbaijan	AzRENA		indirect	
Belarus	BASNET	no	indirect	National Academy of Sciences of Belarus
Bulgaria	IST Foundation	yes	other	
Croatia	CARNet	yes	appoints	
Georgia	GRENA	yes	indirect	
Israel	IUCC	yes	indirect	
Macedonia	MARNet	no	indirect	University Ss. Cyril and Methodius University in Skopje
Moldova	RENAM	yes	indirect	
Morocco	MARWAN	no	appoints	National Scientific and Technical Research Centre (CNRST)
Romania	RoEduNet	yes	appoints	
Russian Federation	RBNet/RUNNet	yes	indirect	
Serbia/Montenegro	AMREJ	no	appoints	
Syria	SHERN	yes	appoints	Ministry of Higher Education
Turkey	ULAKBIM	no	other	The Scientific and Technological Research Council of Turkey (TUBITAK)
Ukraine	URAN	no	indirect	Centre for European Integration Ltd. (CEI)

1.2 Major Changes in NRENs

NRENs were requested to give a short description of major changes that occurred in the network during the past year or that are foreseen for the coming year. The following tables present the answers that were given by the NRENs, only slightly edited for readability. Note that the fact that some NRENs did not answer does not necessarily mean that there are no major changes in those NRENs.

Although the answers are by no means complete, the table clearly shows that many NRENs are upgrading to dark fibre infrastructures. The capacity of these infrastructures can be increased fairly easily according to need. Several NRENs are introducing, or have already, introduced a dual structure for their network: on the one hand, they are continuing to provide the 'traditional' connections, based on the Internet Protocol. On the other hand, they are also planning to provide dedicated light paths to high-end users, allowing them to use whatever protocols or methods they want to use for transmitting data.

Table 1.2.1 Major Changes in NRENs

Country	NREN	Changes
EU/EFTA Countries		
Austria	ACOnet	We are currently in the process of planning a major upgrade of our NREN backbone for 2007
Cyprus	CyNet	The beginning of 2005 saw three changes in the CyNet network. Firstly, the connection of the network to GEANT was upgraded from 34Mbps to 155Mbps. Secondly, a new link was created to the EUMEDCONNECT network at 45Mbps. The EUMEDCONNECT PoP that CyNet is connected to is actually hosted by CyNet at its premises. Lastly, IPv6 was offered as a production service. In 2006, CyNet expects the introduction of a new PoP to expand its national backbone and an upgrade of the backbone capacity. As part of the EUMEDGRID project, a Grid site will be put in production by the end of the year. Work is also underway for the introduction of a pilot PKI service.
Czech Republic	CESNET	During the past year the main changes were: 1. DWDM optical network core deployment based on ROADM technology (up to 32x 10Gb/s). 2. CLA PB01 optical amplifiers deployment in the production environment (CBF interconnection CESNET-SANET) with the capacity up to 4x 10Gb/s channels. 3. IP/MPLS network capacity upgrade to 10Gb/s.
France	RENATER	- Change in the network with RENATER 4 : http://www.renater.fr/article.php3?id_article=70 - Change in the management organisation : http://www.renater.fr/article.php3?id_article=406 (both articles in French)
Germany	DFN	DFN introduced a new generation of the network, the X-WiN.
Greece	GRNET	GRNET S.A. has already acquired 15-year IRUs for 3 Dark Fibre (DF) links. As of today GRNET owns 2950Km of dark fibre pairs (not put in production yet) and plans to extend this to at least 3500Km this year. 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. The legal status of NIIFI has changed in May 2006. Earlier it has been the National Information Infrastructure Development Office, now it is the National Information Infrastructure Development Institute. 2. NIIFI has been operating under the umbrella of the Ministry of Communication and Informatics for several years. From June 2006 the structure of the Hungarian Government will change. The organisational relationship of NIIFI to the new Government will be determined later. 3. The research network in Hungary has been continuously developed (backbone and access network extensions and upgrades). International connectivity has been upgraded to GEANT2. No considerable changes in technology and user base occurred/foreseen.
Iceland	RHnet	A fibre pair has just been leased to connect two universities outside the Reykjavik area (about 40 and 100 km away). One of those universities is currently connected by a 30Mb/s wireless link. They will both get gigabit connectivity to start with. Extra fibre has also been leased in the Akureyri area to facilitate the establishment of a fibre ring between the connection points there. It is estimated that both of these projects will be finished before the end of May 2006. (Information last update 26 April.)
Ireland	HEAnet	We are deploying a new layer 2 network around the country and in metro areas, and also providing resilient connections for clients. Largely composed of dark fibre, the new network will provide IP transit as well as point-to-point links for inter- and intra-institutional traffic. We are also in the process of connecting all first and second-level schools in Ireland (about 4,000 in total) to the network. This was started in 2005 and will finish in 2006.
Italy	GARR	During the last part of 2005 GARR started to operate an owned-fibre infrastructure in the Milano-Como region and the provision of 1Gb/s end-to-end lambdas on it. The core backbone link capacity increased to 10Gb/s and the first 10Gb/s end-to-end lightpath has been provided for the connection of the Italian Tier1 in Bologna (INFN-CNAF) to the Tier0 in CERN.

Country	NREN	Changes
Malta	CSC	Core network equipment upgraded and IPv6 connectivity serviced. Ongoing work includes coordination of national IPv6 test-bed and national Grids initiative. Upgrade of GÉANT2 connection is planned for 2006.
Netherlands	SURFnet	In January 2006 SURFnet launched a new network, SURFnet6. This network is hybrid in the sense that it combines IP technology with lightpaths. The migration of connected institutions is ongoing and will be completed by July 2006.
Poland	PIONIER	During the past year the major change was to add additional 10G lambda on some backbone links.
Portugal	FCCN	Our own fibre entered into operation, connecting major universities in the main Portuguese cities. All schools have migrated from ISDN to ADSL.
Slovakia	SANET	Upgrade of most external connections and parts of backbone to 10 Gigabit ethernet.
Spain	RedIRIS	In the next weeks, a tender for the provision of the NREN backbone will be launched, as the existing backbone contract will expire before the end of the year. RedIRIS is currently participating in the following EU-Funded Projects: GN2, ALICE, EUMEDCONNECT, EGEE-II, EELA, EUMEDCONNECT and MUPBED.
Sweden	SUNET	SUNET will undertake a major upgrade in 2006 and start the operation of a new production network (OptoSunet).
Switzerland	SWITCH	The SWITCHlan network infrastructure has to a great extent been migrated to dark fibre over the past years.
United Kingdom	UKERNA	http://www.ja.net/sj5/index.html.
Other European and Mediterranean Countries		
Albania	ANA	In 2006 new representatives were appointed for the managerial board, following the changes in government and university structures. Accordingly, the structure of the technical board was updated slightly.
Belarus	BASNET	This year the channel capacity will be 155Mb/s.
Bulgaria	IST Foundation	The external connection was upgraded to 155 Mbps; the national backbone capacity was upgraded. The schools were added to the network.
Croatia	CARNet	In 2005 CARNet, together with the Ministry of Science, Education and Sports, started implementation of a major project of providing connectivity to all primary and secondary schools in the Republic of Croatia.
Egypt	EUN	• The EUN backbone currently comprises 12 main nodes (connecting 12 universities) with links of various bandwidths; the network is based on IP. • At the first of July we will have the 15 main nodes linked with fibre optics network (connecting 15 universities). • Every university and research center will have a single fibre connection (12core) from its central network to the nearest Telecom Egypt Exchange (POP). • The bandwidth for each university will be E3 and has a future expandability to T3, STM1 and Gigabit. • Our international bandwidth has been upgraded, currently the global internet transit is provided by Raya, Link Dot Net and Egynet (local internet service provider), and with 56Mbps the use of three suppliers ensures a degree of resilience from suppliers' failures. • Now we are in the process of adding a STM1 link to our international bandwidth. • EUN is connected to Geant through a 34 Mbps link through the EUMEDCONNECT project. • EUN will be connected to Internet2 through 34 Mbps at Sep. 2006. • EUN now upgrading the LAN infrastructure by: - adding new hardware required for the new fibre network; - upgrading the EUN servers, security and management equipment; - adding storage and backup solutions.
Georgia	GRENA	Part of our international connectivity is switched to a fibre optic link via Turk Telecom. Upgrade of the fibre backbone in Tbilisi to GE is completed.

Table 1.2.1 - continued

Country	NREN	Changes
Israel	IUCC	We replaced all our routers and lines during the past 8 months. We replaced all campus routers with 7206VXR NPE-G1 routers, and we replaced our two core routers with Cisco 7613 routers. All national E3/T3 lines were replaced and we now have primarily Gigabit Ethernet links as the primary link to each campus, ranging in speed from 100-450Mb/sec. Backup links are primarily STM1 (155Mb/sec) links. Our connection to GN2 was upgraded from dual STM1 links to dual STM4 links. In addition, the GN2 POP was moved to the Med-1 colocation site where we have a Gigabit Ethernet cross-connect to GN2.
Macedonia	MARNet	MARNet has built its own 20km optical infrastructure in Skopje metropolitan area connecting 6 major campuses, as well as a wireless network. International connectivity is upgraded from 4 to 34 mpbs and from 1 Jan 2007, 68 mbps is expected. A significant role is given to MARNet in the national eMacdeonia strategy and strategy for the modernisation of the educational system adopted by the Parliament. Fibre optic connectivity is foreseen for connectivity to other two major university towns, Bitola and Tetovo.
Moldova	RENAM	In 2005 the Council of the RENAM Association nominated Prof. Andrei Andries as General Director of the Association. New universities were connected to the common NREN infrastructure: the State Pedagogical University ”Ion Creanga”, the State Agrarian University, the University of Medicine and Pharmaceutics ”N. Testemiteanu”, the Balti State Pedagogical University ”A.Russo”. Wireless links as back-up connections and access network connections were installed within the Chisinau MAN backbone. The connection to the communication node in Balti City was upgraded up to 8 Mbps and wireless technology backbone was implemented in Balti City.
Ukraine	URAN	URAN is passing to its own CEF 100M/1G infrastructure in cities (Kiev, Odessa, Dnipropetrovsk, Zaporizhia, Kharkiv, Donetsk, Lugansk, Poltava, Lviv, Sevastoplo, Simferopol) and upgrading leased intercity channels from 128/512k to 10M/100M.
Other Countries		
Canada	CANARIE	CANARIE is undertaking a major deployment of a ROADM network with 72 channels at 40GBps per channel. This is in addition to our existing 5 x 10 Gbps wavelength network. Our intention in the coming years is to directly serve high end departments and researchers who need dedicated lightpaths at universities bypassing campus and regional networks.
Chile	REUNA	Topology: Founding - 1998 Backbone of 2Mbps (bus), 3 Core Nodes, star connection of the Institution to the respective core node at Kbps bandwidth. 1998 - 2006 Backbone of 155Mbps (bus), 8 Core Nodes, star connection of the Institution to the respective core node at 155Mbps each one. 2006 - We are seeking to have a 1Gbps backbone network. Services: Founding to 1997 REUNA was the first ISP in Chile, giving Commodity Internet to Universities. 2001 REUNA stopped giving Commodity Internet service to Universities. 2000 REUNA connects to STAR-TAP having access from there to the NRENs global community. 2001 REUNA connects to Internet2 directly by Miami, Ampath project, having access from there to the NRENs global community. 2004 - REUNA connects to RedCLARA having access from there to the NRENs global community.
Colombia	RENATA	RENATA was connected to Red CLARA by march 2006. RENATA is organised by regional network members. We have 6 members (networks: RUMBA, RUP, RUAV, RUANA, UNIRED, RUMBO). Institutions are members of the regional networks so they have their own regional physical network. 50 institutions are direct members of these regional networks. We are in the process of defining and legalizing RENATA as a formal institution. We are in the process of establishing RENATA, making the technical definitions, agreements, etc.

Country	NREN	Changes
Ecuador	CEDIA	The Ecuadorian NREN is one year old. Its implementation is based on 3 phases: 1. A national network based on a provider's infrastructure, at 10 Mbps. 2. International connectivity to red CLARA, at 10 Mbps and 3. The implementation of the national academic backbone based on a national fibre optic infrastructure owned and assigned to CEDIA by the government, at 45 Mbps.
El Salvador	RAICES	We were connected to RedCLARA on December 14, 2005.
Guatemala	RAGIE	Up to April, 2006 our local loop structure consisted of a collapsed backbone with each participating institution connecting via fibre optics at between 2 and 4 Mbps. As of April, 2006 all member institutions are connected at 100 Mbps.
Kyrgyzstan	KRENA-AKNET	The number of clients has increased. This year we are planning to extend our regional network.
Peru	RAAP	RAAP, the Peruvian NREN, is a recently created network, currently engaged in incorporating new members and users and developing research projects. RAAP has been initially formed for the main universities and research institutions of the country.
Taiwan	NCHC	Since 2005, TWAREN has extended its international connectivity to the US inland. Dual trans-Pacific connections, at 2.5 Gbps each, land in Palo Alto and Pacific Wave-LA. From Palo Alto, the 2.5 Gbps link continues to our colocation sites in STARLight and MANLAN. The other route, from Pacific WAVE-LA is also 2.5 Gbps. There is ONS equipment installed in Palo Alto, Pacific WAVE-LA, STARLight and MANLAN. Lightpath provisioning thus extends all the way from Taiwan to New York. At the domestic end, TWAREN is undergoing a major change in architecture to better integrate network resources and also to serve an expanded user base.
United States	Internet2	Internet2 has embarked upon planning and implementation of a major new nationwide network infrastructure to be fully operational by summer 2007. This will replace the existing Abilene backbone network. The new network infrastructure will be based on a fibre pair dedicated to Internet2's use on a nationwide footprint. The optical gear lighting the fibre will be dedicated to Internet2's use and under Internet2's control. Level3 will provide both the fibre and optical gear (Infinera). At the start, 10x10Gbps wavelengths will be lit across the entire infrastructure. Connectors (typically state or multi-state facilities-based research and education networks) will connect at 2x10Gbps with 1x10Gbps for shared IP access and 1x10Gbps for point to points services of varying bandwidth sizes. Information on the plans for this new network infrastructure and its implementation progress are to be found at: http://networks.internet2.edu.
Uruguay	RAU	Optic fibre has been installed on 30% of the metropolitan links. Also, in June 2005 we have connected to RedClara. This year we plan to enlarge the optic fibre connections.

2 Users/Clients

This section starts with information about the connection policies of NRENs (i.e., who is allowed to connect, in section 2.2). Section 2.3 provides an indication of what proportion of the total access capacity that is available to an NREN is used by various user categories. The last sections look more closely at the bandwidth of universities and at the percentage of schools that are connected through NRENs. Note that the Compendium website contains additional information. More information about European educational systems in general can be found at http://www.eurydice.org.

The 2005 edition of the Compendium contained an overview of Acceptable Use Policies of NRENs. Because these policies do not change much over time, the information is not repeated this year. Information on NREN AUPs can be found on the Compendium website.

The overview section (2.1) gives aggregate data and tries to identify trends in all of these areas.

2.1 Overview

Connection Policies

Table 2.2 gives an overview of which types of institutions can be connected to the NREN (the Connection Policies).

As is clear from the table, all NRENs can connect universities, research institutes and, with three exceptions, institutes of higher education. For other institutions, there are great differences in policy between NRENs. Note that sometimes there are further restrictions, not included in the table. For example, some NRENs only connect government departments that have a relation to research and education, etc.

For more details on individual NRENs, please consult the country entries on the website or the NREN websites themselves.

Connection Methods

NRENs are quite diverse when it comes to methods of connecting institutions. Indeed, reference to previous Compendia show that this has changed very little in recent years.

Most NRENs provide for institutions to connect directly either to one of their Points of Presence (PoPs) or, in some cases, to a Metropolitan Area Network or regional network run by the NREN. There are some exceptions with separate Metropolitan Area Network/Access Network (MAN/AN) layers run by third parties. This is the case, for example, with UKERNA (UK), RENATER (France) and PIONIER (Poland).

The following table provides aggregated data on connection methods, where the aggregation has been done from the perspective of NRENs, not from that of the institutions. Thus, the figures show the connection method for the different types of institutions for the 'average' NREN. These are averages across NRENs, not weighted by their size or the number of institutions they connect.

Table 2.1.1 Connection Methods (aggregated by NREN)

Type of Institution	NREN PoP or MAN	3rd party MAN or Regional Network	Via Another Institution	Some Other Way
University	88%	11%	2%	0%
Institute of Higher Education	75%	16%	9%	0%
Research Institute	85%	7%	7%	0%
Secondary School	53%	25%	3%	7%
Primary School	53%	31%	7%	8%
Other	66%	17%	17%	0%

These figures are not significantly different from those provided last year.

For reasons of space, the full tables are not available in printed form but they can be consulted on the Web by NRENs who have participated in the survey; they are available for others upon request.

Bandwidth of Universities

As part of the survey, NRENs have given the percentage of connections for each type of institution (university, research institute, secondary school, etc.) to the network at each of a set of bandwidths/technologies. The latter were given as ranges, such as "greater than 100Mbps and less than 1000Mbps". We have examined the bandwidth of universities a bit more in-depth, for two reasons. First, an NREN generally connects (almost) all universities in its country; in most countries where the NRENs are well established, the numbers of connected universities is not going to vary much over time. Second, universities tend to be the leaders in new and faster connectivity to NRENs, and we are interested in the trend of such connections in recent years.

For each access range, we have identified an average or typical bandwidth. Thus, for the example given above (>100Mbps and <1000Mbps) we select 155Mbps (STM-1) as being indicative of the type of connection. For each NREN, we have summed the product of the percentage of universities connected in that access range by the typical bandwidth for that range. This gives us an indicative weighted mean of university access bandwidth for the NREN.[1]

It should be noted that increases are usually not gradual, but occur in steps, with the introduction of new technologies. We have looked at this from the point of view of universities (rather than of NRENs).

Table 2.1.2 Average Access Capacity for Universities and Average Increases[2]

	2003		2005			2006		
Group of NRENs	Number of Connected Universities	Average Bandwidth (Mb/s)	Number of Connected Universities	Average Bandwidth (Mb/s)	Mean Annual Increase in University Access Capacity, 2003 - 2005	Number of Connected Universities	Average Bandwidth (Mb/s)	Mean Annual Increase in University Access Capacity, 2003 - 2006
EU-15/EFTA	637	254	639	410	27%	600	507	49%
New Member States	394	214	391	546	62%	636	568	38%

Note that the figures in Table 2.1.3 and 2.1.4 do not take into account the data from France. RENATER has provided data about connections to individual university sites, including both campuses with larger access capacities and a large number of sites with relatively limited access capacities. This is partly due to capacity-based charging policies in RENATER. It could be that other NRENs have reported their connections the same way.

Calculating a mean for the other countries would not yield a meaningful figure because of the more extreme diversity and the uneven availability of data.

[1] The equation and range of bandwidth: # of connections $\sum_{i=1}^{8} b_i \left(\frac{\text{\% of connections}}{100}\right)$
$b_i = \{0.128, 2, 10, 45, 155, 1000, 2488, 10{,}000\}$

[2] See also the country-by-country data in section 2.4

A second way of looking at the trend in access speeds is to consider the change in Gigabit or higher links to universities over the period 2003 to 2006. This gives the following results:

Table 2.1.3 Aggregated Gb Connections to Universities[2]

Group of NRENs	Percentage of Connections to Universities at >= 1Gb/s[3]		
	In 2003	In 2005	In 2006
EU/EFTA	15%	24%	31%
Other Countries			13%

The SERENATE study[4] recommended the promotion of Gigabit networking services. Gigabit connections can be seen as a necessary, though not necessarily sufficient, condition for a university to engage in high-end research and learning programmes.

The Compendium data suggest that the SERENATE recommendations on Gigabit networking are being followed in many countries. It seems that fibre optic technology is allowing NRENs to leap-frog immediately to much higher capacities. Gigabit Ethernet is being introduced by many to less-developed NRENs (such as AMREJ, MARNET and RENAM) and thus seems to make it possible, for the first time, to quickly address an important aspect of what was termed the 'digital divide' in Europe in the SERENATE study.

Connections to Primary and Secondary Schools

There is clear evidence from many sources that the connection of secondary and primary schools to the Internet via NRENs and also the provision of support and application services to schools features highly on the agenda in many countries in very recent years. The commitment by EU heads of government in Lisbon in 2000 to making Europe "the most dynamic and competitive knowledge-based economy in the world" by 2010 is a common factor underlying this activity. Secure access by schools to the Internet is seen as key to the development of the Information Society.

The following table summarises the policy position of NRENs with regard to the connection of schools, both primary and secondary.

Table 2.1.4 Connection Policies: Secondary and Primary schools

Group of NRENs	Allowed to Serve Secondary Schools?		Allowed to Serve Primary Schools?	
	Yes	No	Yes	No
EU/EFTA	23	5	21	7
Other	14	5	11	7

For EU/EFTA countries, there are only two NRENs which distinguish between primary and secondary schools when it comes to permission to connect

On the level of connection policies, not much has changed since 2003. However, the total number of connections did increase significantly.

No conclusions can be drawn about the situation in countries not included in the tables:

- The NREN may connect the relevant institutions, but may not have been able to answer these questions in the survey (see also the information in table 2.1);
- The Institutions may be connected through a different organisation. For example, secondary schools in many countries are connected to the Internet through separate organisations and many of them collaborate through the European Schoolnet;
- Institutions may be connected through commercial ISPs;
- Institutions may not be connected to the Internet at all.

[3] Taken as percentage of all university connections
[4] SERENATE summary report, p.5

A similar analysis has not been carried out for other categories of connected institutions (research institutes, institutions of higher/further education, other bodies). We have decided to focus on universities because all NRENs provide connections to them and because, by their nature, universities contain good samples of users from all disciplines. Looking at universities can thus indicate overall trends as well as important advances in networking technologies and applications. Secondary and primary schools are an emerging and potentially important new area for NRENs and therefore it seemed appropriate to feature them in this edition of the Compendium.

2.2 Connection Policies

Legend

	100% connected
	≥ 75% connected
	≥ 50%, < 75% connected
	≥ 25%, < 50% connected
	> 0, < 25% connected
yes	Percentage not reported

Note that the percentages here show the percentage of all institutions that is connected to the NREN. Institutions connected by other service providers are not taken into account.

Table 2.2.1 Connection Policies – categories of institutions for which connection to the NREN is allowed

Country	NREN	Universities	Institutes of Higher/Further Education	Research Institutes	Secondary Schools	Primary Schools	Libraries, Museums, National Archives	Hospitals (Other than University Hospitals)	Government Departments (National, Regional, Local)	Others
EU and EFTA Countries										
Austria	ACOnet				yes	yes				no
Belgium	BELNET	yes								yes
Cyprus	CyNet				no	no	no	no	no	yes
Czech Republic	CESNET									yes
Denmark	UNI•C				no	no			no	yes
Estonia	EENet							yes		no
Finland	Funet		no		no	no		no		yes
France	RENATER					no				no
Germany	DFN				yes	yes	yes	yes	yes	no
Greece	GRNET						yes	no	yes	no
Hungary	NIIF/HUNGARNET							no		yes
Iceland	Rhnet				yes	no		no	no	no
Ireland	HEAnet							no		yes
Italy	GARR									yes
Latvia	LATNET									yes
Lithuania	LITNET									yes
Luxembourg	RESTENA									no
Malta	CSC			yes	yes	yes	yes			yes
Netherlands	SURFNet								no	yes

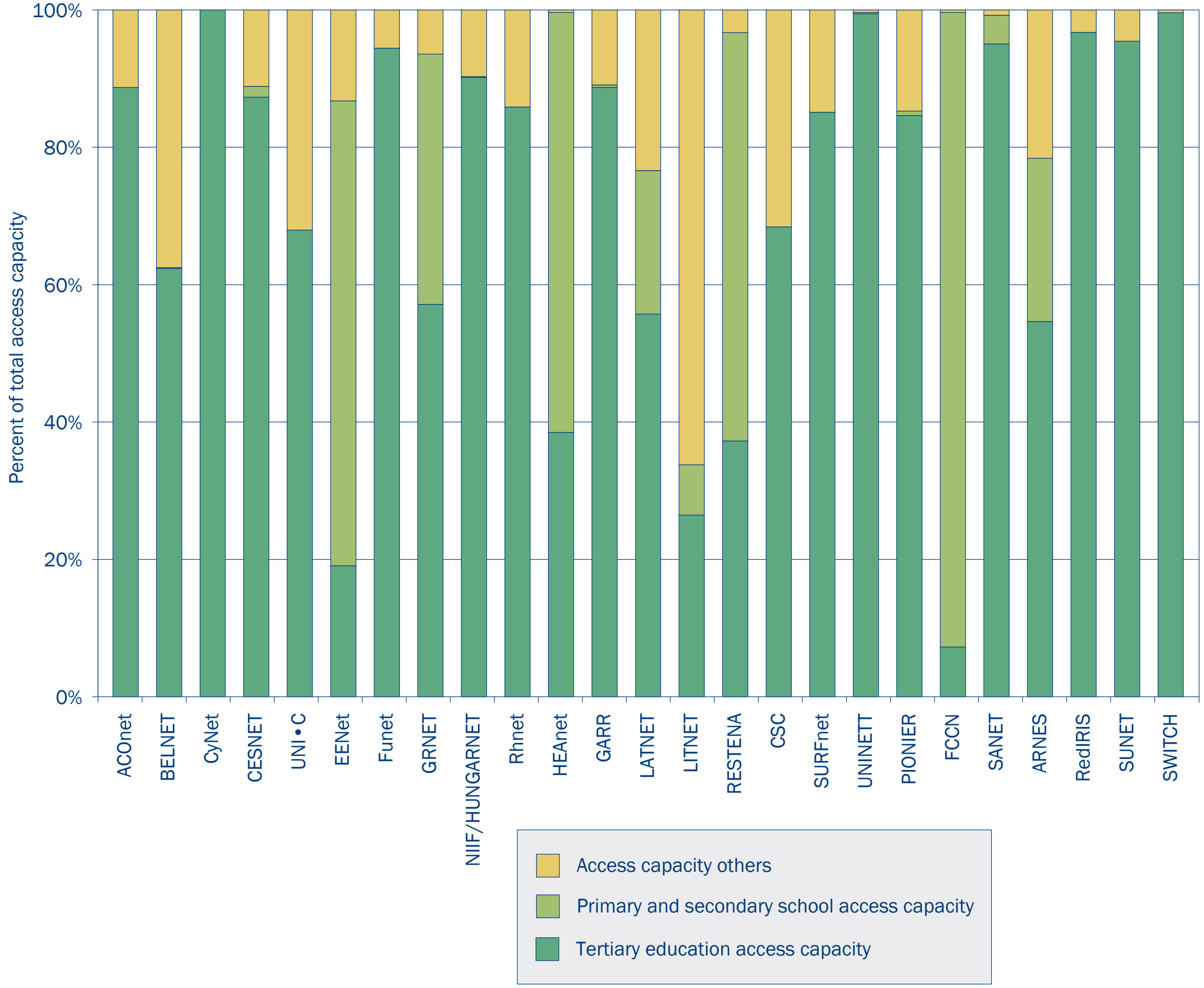
Table 2.2 Connection Policies – continued

Norway	UNINETT							no	no	yes
Poland	PIONIER		yes		yes	yes	yes	yes	yes	yes
Portugal	FCCN						no	no		no
Slovakia	SANET							no		no
Slovenia	ARNES							no		yes
Spain	RedIRIS		no		no	no				yes
Sweden	SUNET		yes		no	no		no		yes
Switzerland	SWITCH				yes	yes		yes		no
United Kingdom	UKERNA						yes	no	yes	yes
Other Countries										
Albania	ANA				yes		yes			
Algeria	CERIST					yes				no
Azerbaijan	AzNET					yes		yes	yes	yes
Azerbaijan	AzRENA		no		no	no		no		yes
Belarus	BASNET		yes			yes				no
Bulgaria	IST Foundation							no	no	no
Croatia	CARNet									yes
Egypt	EUN		yes	yes	yes	yes	yes	yes	yes	yes
Georgia	GRENA					no				no
Israel	IUCC				no	no	yes	yes	no	yes
Jordan	JUNet		yes	yes	no	no	yes	no	yes	no
Macedonia	MARNet		yes		yes	yes		yes		yes
Moldova	RENAM				yes	yes				yes
Morocco	MARWAN				yes	yes		yes		no
Romania	RoEduNet							no		no
Russian Federation	RBNet/RUNNet		yes			no		no		no
Serbia/Montenegro	AMREJ					yes				
Syria	SHERN				no	no	no	no	no	no
Turkey	ULAKBIM				no	no		no		no
Ukraine	URAN				yes	no	no	no		no

2.3 Access Capacity for Different Categories of Users

Graph 2.3.1 gives the percentage of the total access capacity as reported for institutions connected to the NREN for each category of institution. The graph shows three categories: tertiary education and research, primary and secondary schools, and all others. It seems logical that NRENs that connect a large proportion or all of the secondary and primary schools in their countries (e.g., GRNET of Greece and FCCN of Portugal) also devote a large part of the access capacity to schools. However, this is not always the case, because it is influenced, on the one hand, by the differences in access capacity between the different categories of institutions and, on the other hand, by the nature of access technology, which varies within and between these categories. Very often, schools are connected, nominally at 2Mbps, but in such a way that hundreds of them might share a connection of 45 Mbps in total. As a result, it is not surprising that the graph shows a wide diversity between the different NRENs.

Graph 2.3.1 Access Capacity by User Category



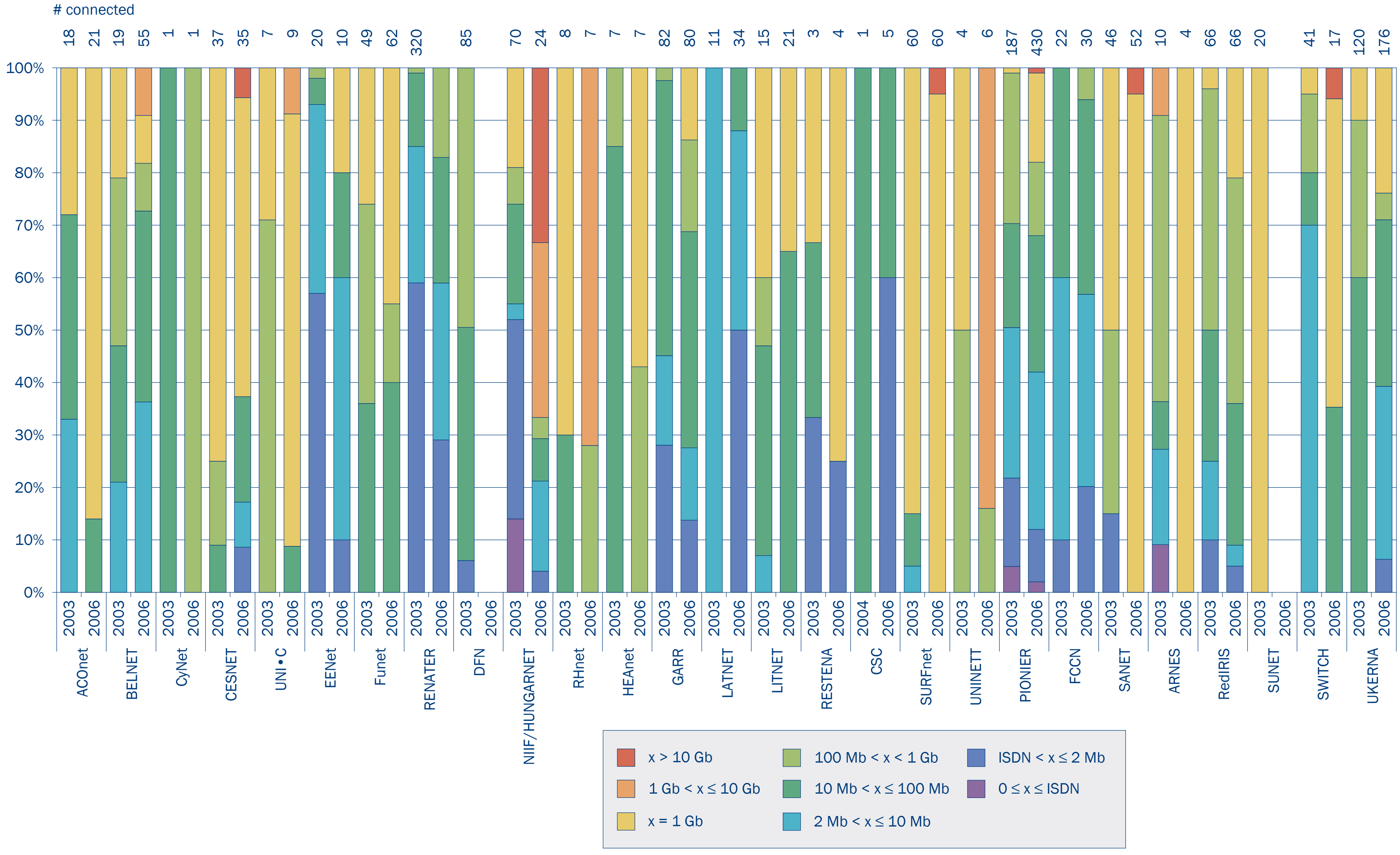
2.4 Number of Connections to Universities and Bandwidth

The organisational set-up of universities and other institutes can be very different from country to country. For example, in some countries research institutes are part of universities; in other countries, they are not. Some countries have relatively few but large universities; others have many, but smaller ones. Also, some universities have a single link to the NREN; in other cases, separate faculties or schools that form part of a university, but are geographically at different locations, have their own connections. Note that some NRENs have provided the data for entire universities for 2003 but for separate connections in 2006; in other cases, it has been the reverse.

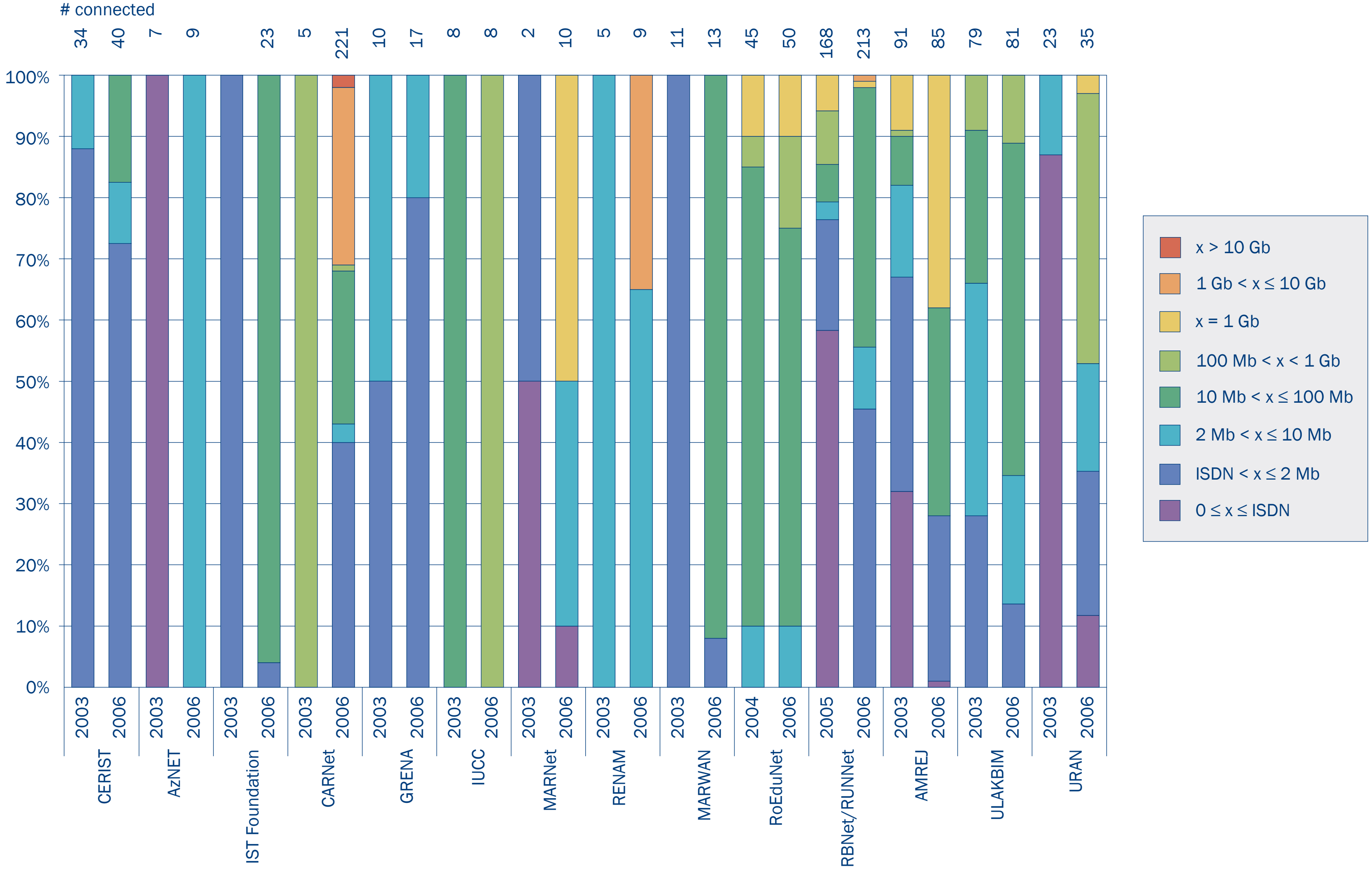
In this section, information is provided for 2003 and 2006, showing the evolution over the past years. The 2006 information is also published in table format on the Compendium website.

Note that the Polish information from 2006 was extrapolated from data gathered from fifteen out of the twenty-one MANs that form the PIONIER network.

Graph 2.4.1 University Bandwidth, EU/EFTA Countries



Graph 2.4.2 University Bandwidth, Other Countries



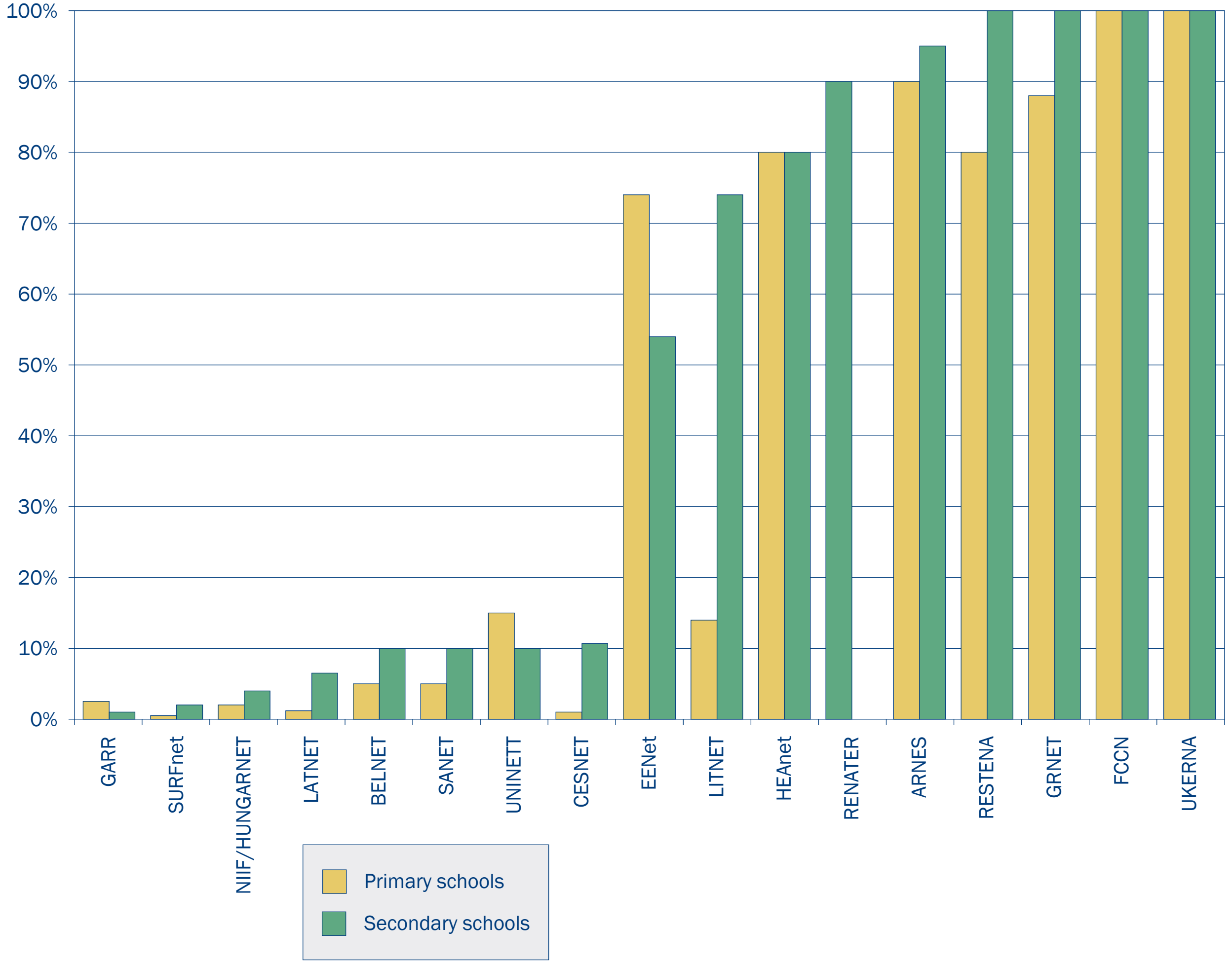
2.5 Percentage of Schools Connected Through the NREN

The following graphs provide information about the percentage of all secondary and primary schools that are connected through the NREN, according to estimates supplied by the NRENs.

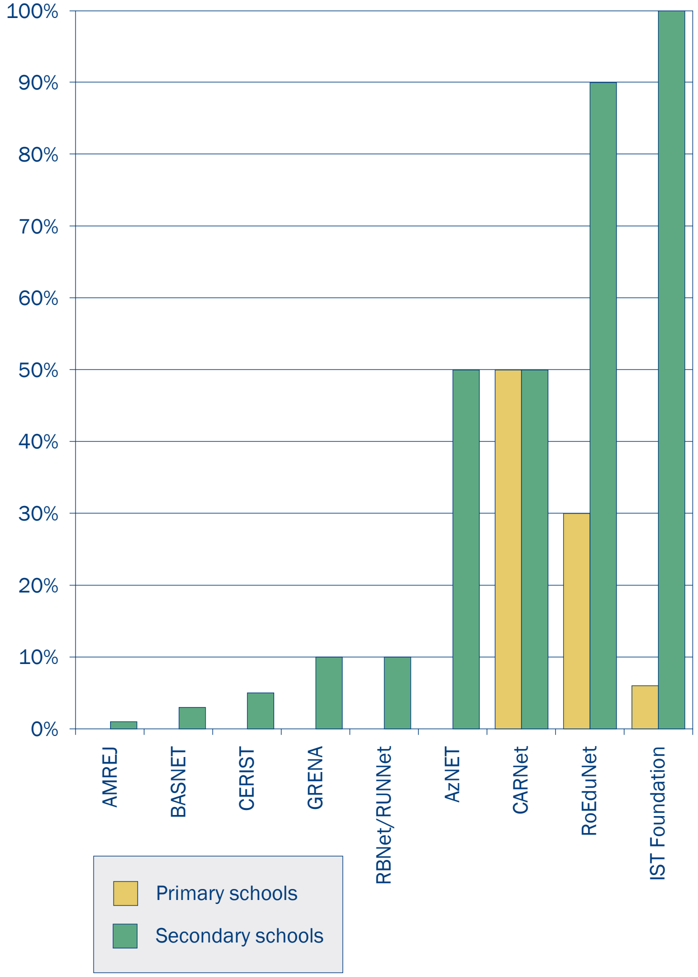
Note that aside from the connection itself, also the connection method and the type of services offered are important. Thus, in the UK, schools are not connected directly to the NREN but via the regional broadband consortia or local authorities who use the NREN as their backbone. Schools receive a reduced set of services. In other countries, schools may be connected directly to the NREN backbone and may receive an extended set of services, tailored to the needs of schools.

The graphs show that in a number of countries, the coverage is either 100% or close to it. In many countries, connections to schools are funded centrally through Ministries of Education. The percentage of connections is expected to rise sharply in some countries (e.g., Italy) because implementation of schemes to connect most or all schools has just started. Note also that in some countries, such as Denmark, connecting primary and/or secondary schools is not done by the NREN itself but by another organisation; sometimes, as in Denmark, these two organisations are closely related.

Graph 2.5.1 Percentage of Schools Connected Through the NREN, EU/EFTA Countries



Graph 2.5.2 Percentage of Schools Connected Through the NREN, Other Countries



3 Network

This section provides an insight into a number of important network characteristics. Section 3.2 starts with the core capacity on the networks; section 3.3 looks at the expected changes in this capacity over the next two years. Section 3.4 provides information about core network size. Section 3.5 is about external links that NRENs have. Section 3.6 looks at the relatively new area of dark fibre and section 3.7 gives information about cross-border dark fibre links. Section 3.8 provides information about the routers and switches used on the network. Section 3.9 looks at PoPs and Managed Links on the network.

The overview section, 3.1, provides information about different groups of NRENs and tries to identify key trends in the areas of core capacity, network size, external links and dark fibre.

3.1 Overview

Core Capacity

Table 3.3 provides information about the change in core usable backbone capacity of NRENs. By this, we mean the typical core capacity of the linked nodes in the core.

Many NRENs employ a range of capacities on their backbone. For more information about individual NRENs, please refer to the topology maps that many of them provide on their websites.

In 2001, five out of seventeen NRENs in the EU-15/EFTA countries already had a core capacity of 2.5 Gb/s – this was also the maximum capacity at that time. All the others, except RESTENA of Luxembourg, had a capacity of at least 155 Mb/s. In 2006, all but three of the EU/EFTA NRENs have a capacity of at least 1 Gb/s; the most common capacity 10 Gb/s or a multiple of this; eleven NRENs operate at this capacity.

From the data from the nineteen other NRENs, in 2006, seven of these operated at 1 Gb/s and one had a capacity of 2.5 Gb/s. What is interesting to note here is that these NRENs have typically made a larger jump than the EU/EFTA NRENs, thus skipping one or more of the network development stages that the EU/EFTA NRENs went through.

The overall trend is that there is considerable growth inspite of the fact that on average, NREN budgets have remained almost static over time.[1]

External links

The graphs in section 3.5 clearly show that for most NRENs that are part of the GN2 project, the link to GÉANT is by far the most important in terms of capacity. Often NRENs also have peering arrangements at neutral Internet exchanges and many also have connections to commercial ISPs, but these generally do not have the same capacity as those to GÉANT.

It is interesting to note that some NRENs (SURFnet, CESNET, SANET and SWITCH) have their own links to other research bodies. Typically, these are dark fibre links. Some of these links are part of the emerging Global Lambda Integrated Facility, a world-scale lambda-based laboratory for application and middleware development on emerging LambdaGrids (see www.glif.is for more information).

The situation is different in the countries that are not part of GN2 project. For those countries, relatively low-bandwidth connections to commercial ISPs are the most important (see also section 4, for related information on traffic load). A number of NRENs that are part of the Silk Highway project can make use of the satellite-based connectivity that is provided through that project (see http://www.silkproject.org/ for more information).

[1] See section 3.2.3 for country-by-country data.

Dark Fibre

The table below shows a steady increase in the number of NRENs that currently have at least two-thirds of their backbone as dark fibre. This seems to be the technology of choice for NRENs that are planning to upgrade their networks now or in the near future. Note that in addition, UKERNA is changing to dark fibre and plans to have 60% of its backbone as dark fibre by 2008.

Table 3.1.2 Aggregated Dark Fibre on NREN Backbones[2]

Group of NRENs	Number of NRENs in the Survey (2006)	Proportion with at Least Two-thirds Dark Fibre Backbone		
		2005	2006	2008 (expected)
EU-25/EFTA	28	24%	36%	44%
Other Countries	18		6%	18%

As well as providing NRENs with the ability to better control, manage and exploit their network infrastructures, dark fibre provides opportunities that enable users to define their own dedicated end-to-end links across the network, and to do so within fixed NREN budgets. It also provides a number of NRENs in countries that were thus far less-privileged to take important steps towards bridging the 'digital divide'. Therefore, the uptake of dark fibre, where it is possible, is to be encouraged. The procurement of the new GÉANT2 network has endorsed this development and has provided a pan-European dark fibre footprint.

A new development is the implementation of cross-border dark fibre links between NRENs. Such links may serve to connect NRENs to GÉANT that previously did not have such a connection, or they may be there specifically to serve the needs of certain projects. They can also be general-purpose connections between neighbouring NRENs. Section 3.7 presents current and planned links of this type in a table.

[2] See section 3.6 for country-by-country data. 2005 data for other countries were not fully reliable and have therefore not been included.

3.2 Core Capacity on the Network

By 'core usable backbone capacity' we mean the typical core capacity of the linked nodes in the core. Some networks do not have a core backbone, for example, because they have a star topology. In those cases, we have asked for the maximum capacity into the central node of the network.

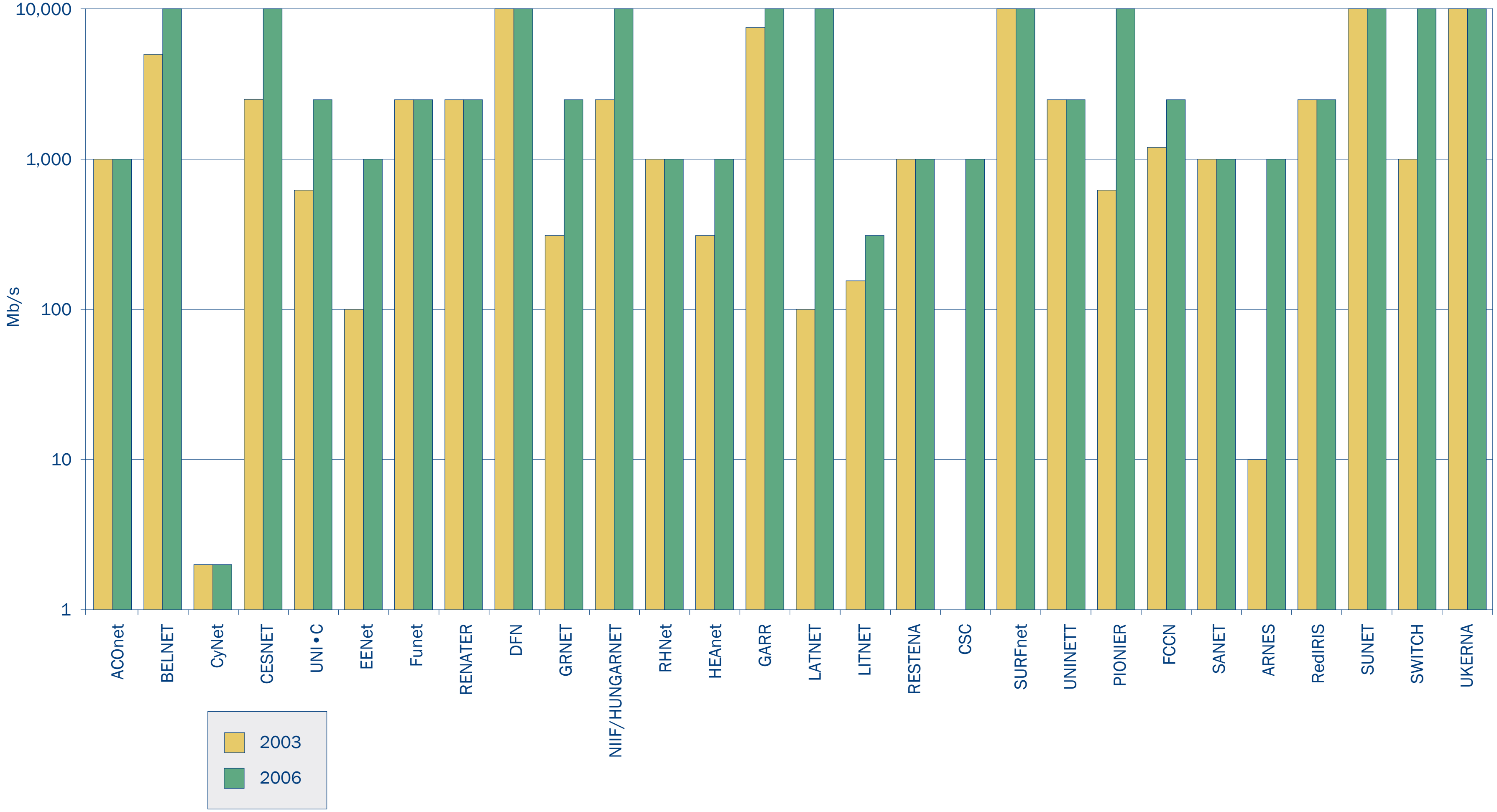
Some NRENs have dark fibre with a very high theoretical capacity. In those cases, we have asked for the usable IP capacity.

Graphs 3.2.1 and 3.2.2 give an idea of the evolution of network capacity from 2003 to 2006. For presentational purposes, the information is given in two graphs: 3.2.1 for the EU/EFTA and graph 3.2.2 for the other countries. Note that the scales are logarithmic and not the same for the two graphs.

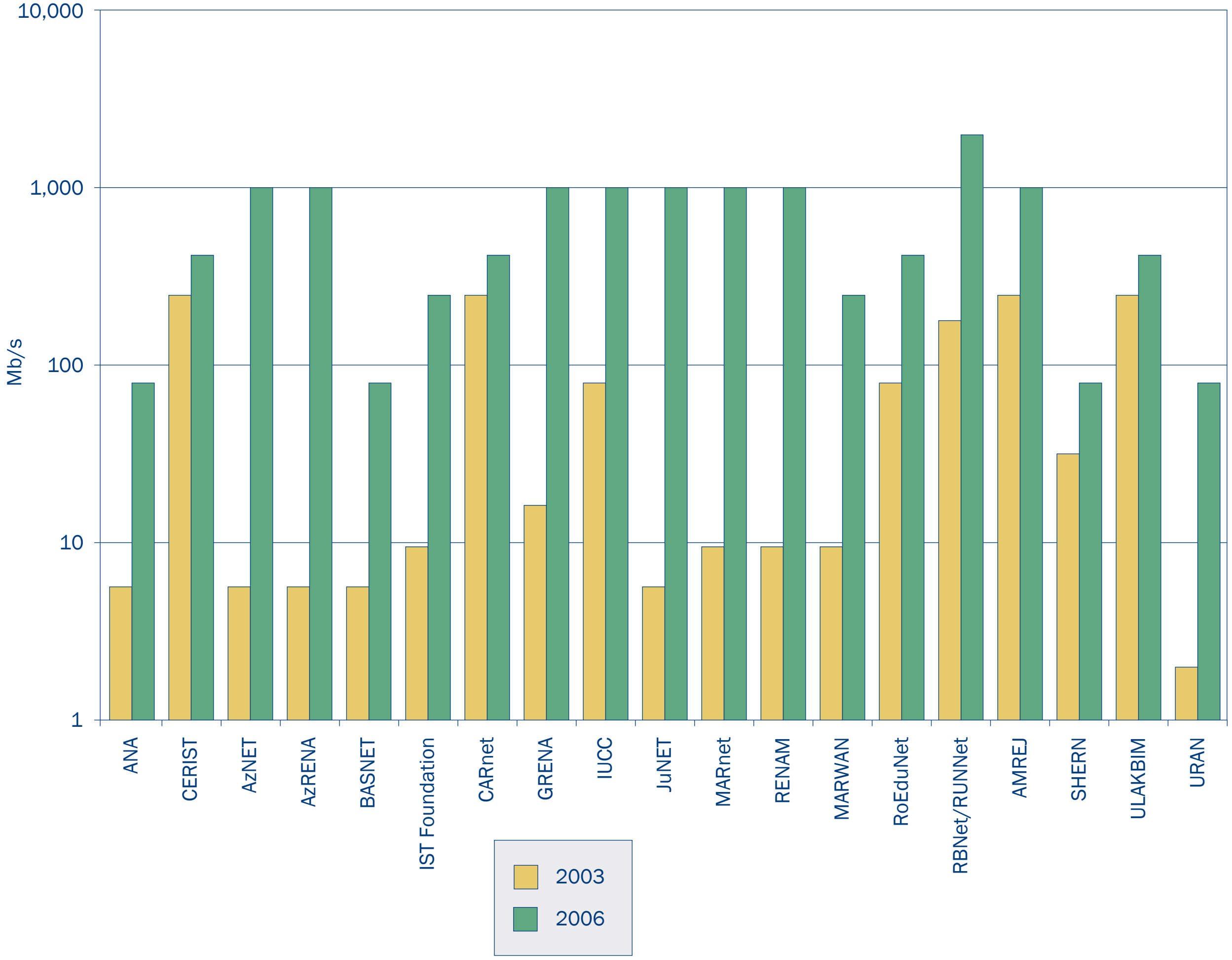
For the EU/EFTA countries, the average core capacity increased tenfold. However, for some NRENs, the capacity stayed the same, whereas for others (ARNES and LATNET) it increased a hundred-fold. For the 'Other' countries, the average core capacity increased more than 170 times, but this statistic is less meaningful because of the significant differences between the NRENs. However, it is interesting to note that in this group, no NREN stayed at the same level and one jumped in capacity from 1 Mb/s to 1 Gb/s.

For a number of NRENs, we have data going back to 2001. Table 3.2.3 gives the increase in core capacity on the networks between 2001 and 2005 for those countries.

Graph 3.2.1 Core Capacity on the Networks, 2003 – 2006, EU and EFTA Countries



Graph 3.2.2 Core Capacity on the Networks, 2003 – 2006, Other Countries



In table 3.2.3, capacities of 1 Gb/s and above have been colour-coded for increased readability.

Table 3.2.3 Core Capacity on the Network, 2001 – 2006

Country	NREN	2001	2002	2003	2004	2005	2006
EU/EFTA Countries							
Austria	ACOnet	155	1000	1000	1000	1000	1000
Belgium	BELNET	622	1000	4976	4976	4976	10000
Cyprus	CyNet			34	34		2
Czech Republic	CESNET	2488	2488	2500	2488	2488	10000
Denmark	UNI•C	622	622	622	1000	2488	2488
Estonia	EENet	24	60	100	100	1000	1000
Finland	Funet	2488	2488	2488	2488	2488	2488
France	RENATER	2488		2488	2488	2488	2488
Germany	DFN	622	2488	10000	10000	10000	10000
Greece	GRNET		310	310	2488	2488	2488
Hungary	NIIF/HUNGARNET	155	2488	2488	2488	10000	10000
Iceland	RHnet		1000	1000	1000	1000	1000
Ireland	HEAnet	155	310	310	1000	1000	1000
Italy	GARR		2488		2488	2488	10000
Latvia	LATNET	100	100	100	100	2488	10000
Lithuania	LITNET	4	155	155	155	310	310
Luxembourg	RESTENA	10	1000	1000	1000	1000	1000
Malta	CSC			0	100	100	100
Netherlands	SURFnet	2488	10000	10000	10000	10000	10000
Norway	UNINETT	2488	2488	2488	2488	2488	2488
Poland	PIONIER	155	155	622	10000	10000	10000
Portugal	FCCN	180	180	1200	1200	2488	2488
Slovenia	ARNES	100	100		310	1000	1000
Slovenia	SANET	4	1000	1000	1000	1000	1000
Spain	RedIRIS	155	155	2488	2488	2488	2488
Sweden	SUNET	622	10000	10000	10000	10000	10000
Switzerland	SWITCH	310		1000	1000	10000	10000
United Kingdom	UKERNA	2488	2488	10000	10000	10000	10000
Other Countries							
Albania	ANA			0			34
Algeria	CERIST			155	155	310	310
Azerbaijan	ARENA			0			
Azerbaijan	AzNET				1000	1000	1000
Belarus	BASNET			0		24	24
Bulgaria	IST Foundation		2	100		155	
Croatia	CARnet	155	155		155	310	310
Georgia	GRENA	0.896	2.048	4.1	4	1000	1000
Israel	IUCC			34	45	1000	1000
Kazakhstan	AzRENA			1	5	1000	1000
Macedonia, FYRo	MARnet	0.5	2	2		10	1000
Moldova	RENAM			2			1000
Morocco	MARWAN			2	34	45	155
Romania	RoEduNet			34	155	310	310
Russian Federation	RBNet/RUNNet			100		2488	2488
Serbia/Montenegro	AMREJ		2	155	500	100	1000
Syria	SHERN			10		10	34
Turkey	ULAKBIM	34	34	155	155	45	310
Ukraine	URAN		0.128	0.25	0.128	2	34

3.3 Expected Change in the Core Capacity in Two Years' Time

The following table gives the current core capacity (in Mb/s), the expected increase in two years' time and the expected (computed) core capacities for early 2008.

Note that, typically, the core capacity goes up in leaps, involving the change of one type of technology to another. Note also that it is not always easy to predict the evolution in core capacity. This is because this evolution depends on many factors, such as developments in technology, pricing and the availability of sufficient funds for investment.

> The trend is clearly that in the more advanced countries, the core capacity will evolve to 10 Gb/s or multiples of that.

In table 3.3, capacities of 1 Gb/s and above have been colour-coded for increased readability.

Table 3.3 Expected Change in the Core Capacity in Two Years' Time

Country	NREN	2006	2008
EU/EFTA Countries			
Austria	ACOnet	> 622 Mb/s ≤ 1.2 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Belgium	BELNET	> 5 Gb/s ≤ 10 Gb/s	> 10 Gb/s
Cyprus	CyNet	2 Mbit/s or below	> 34 Mb/s ≤ 155 Mb/s
Czech Republic	CESNET	> 5 Gb/s ≤ 10 Gb/s	> 10 Gb/s
Denmark	UNI•C	> 1.2 Gb/s ≤ 5 Gb/s	> 1.2 Gb/s ≤ 5 Gb/s
Estonia	EENet	> 622 Mb/s ≤ 1.2 Gb/s	> 1.2 Gb/s ≤ 5 Gb/s
Finland	Funet	> 1.2 Gb/s ≤ 5 Gb/s	> 5 Gb/s ≤ 10 Gb/s
France	RENATER	> 1.2 Gb/s ≤ 5 Gb/s	> 10 Gb/s
Germany	DFN	> 5 Gb/s ≤ 10 Gb/s	> 10 Gb/s
Greece	GRNET	> 1.2 Gb/s ≤ 5 Gb/s	> 10 Gb/s
Hungary	NIIF/HUNGARNET	> 5 Gb/s ≤ 10 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Iceland	RHNet	> 622 Mb/s ≤ 1.2 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Ireland	HEAnet	> 622 Mb/s ≤ 1.2 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Italy	GARR	> 10 Gb/s	> 10 Gb/s
Latvia	LATNET	> 5 Gb/s ≤ 10 Gb/s	> 10 Gb/s
Lithuania	LITNET	> 155 Mb/s ≤ 622 Mb/s	> 622 Mb/s ≤ 1.2 Gb/s
Luxembourg	RESTENA	> 622 Mb/s ≤ 1.2 Gb/s	> 622 Mb/s ≤ 1.2 Gb/s
Malta	CSC	> 622 Mb/s ≤ 1.2 Gb/s	> 622 Mb/s ≤ 1.2 Gb/s
Netherlands	SURFnet	> 10 Gb/s	> 10 Gb/s
Norway	UNINETT	> 1.2 Gb/s ≤ 5 Gb/s	> 1.2 Gb/s ≤ 5 Gb/s
Poland	PIONIER	> 5 Gb/s ≤ 10 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Portugal	FCCN	> 1.2 Gb/s ≤ 5 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Slovakia	SANET	> 622 Mb/s ≤ 1.2 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Slovenia	ARNES	> 622 Mb/s ≤ 1.2 Gb/s	> 10 Gb/s
Spain	RedIRIS	> 1.2 Gb/s ≤ 5 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Sweden	SUNET	> 5 Gb/s ≤ 10 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Switzerland	SWITCH	> 5 Gb/s ≤ 10 Gb/s	> 5 Gb/s ≤ 10 Gb/s
United Kingdom	UKERNA	> 10 Gb/s	> 10 Gb/s

Country	NREN	2006	2008
Other European and Mediterranean Countries			
Albania	ANA	> 2 Mb/s ≤ 34 Mb/s	
Algeria	CERIST	> 155 Mb/s ≤ 622 Mb/s	
Azerbaijan	AzNET	> 622 Mb/s ≤ 1.2 Gb/s	> 1.2 Gb/s ≤ 5 Gb/s
Azerbaijan	AzRENA	> 622 Mb/s ≤ 1.2 Gb/s	> 1.2 Gb/s ≤ 5 Gb/s
Belarus	BASNET	> 2 Mb/s ≤ 34 Mb/s	> 2 Mb/s ≤ 34 Mb/s
Bulgaria	IST Foundation	> 34 Mb/s ≤ 155 Mb/s	> 622 Mb/s ≤ 1.2 Gb/s
Croatia	CARnet	> 155 Mb/s ≤ 622 Mb/s	> 155 Mb/s ≤ 622 Mb/s
Georgia	GRENA	> 622 Mb/s ≤ 1.2 Gb/s	> 622 Mb/s ≤ 1.2 Gb/s
Israel	IUCC	> 622 Mb/s ≤ 1.2 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Jordan	JuNET	> 622 Mb/s ≤ 1.2 Gb/s	
Macedonia	MARnet	> 622 Mb/s ≤ 1.2 Gb/s	> 622 Mb/s ≤ 1.2 Gb/s
Moldova	RENAM	> 622 Mb/s ≤ 1.2 Gb/s	> 1.2 Gb/s ≤ 5 Gb/s
Morocco	MARWAN	> 34 Mb/s ≤ 155 Mb/s	> 155 Mb/s ≤ 622 Mb/s
Romania	RoEduNet	> 155 Mb/s ≤ 622 Mb/s	> 5 Gb/s ≤ 10 Gb/s
Russian Federation	RBNet/RUNNet	> 1.2 Gb/s ≤ 5 Gb/s	> 5 Gb/s ≤ 10 Gb/s
Serbia/Montenegro	AMREJ	> 622 Mb/s ≤ 1.2 Gb/s	> 622 Mb/s ≤ 1.2 Gb/s
Syria	SHERN	> 2 Mb/s ≤ 34 Mb/s	> 34 Mb/s ≤ 155 Mb/s
Turkey	ULAKBIM	> 155 Mb/s ≤ 622 Mb/s	> 5 Gb/s ≤ 10 Gb/s
Ukraine	URAN	> 2 Mb/s ≤ 34 Mb/s	> 622 Mb/s ≤ 1.2 Gb/s
Some non-European Countries			
Canada	CANARIE	> 10 Gb/s	
Chile	REUNA	> 34 Mb/s ≤ 155 Mb/s	
Colombia	RENATA	> 2 Mb/s ≤ 34 Mb/s	
Ecuador	CEDIA	> 2 Mb/s ≤ 34 Mb/s	
El Salvador	RAICES	2 Mbit/s or below	
Guatemala	RAGIE	> 34 Mb/s ≤ 155 Mb/s	
Kazakhstan	KazRENA	> 2 Mb/s ≤ 34 Mb/s	> 34 Mb/s ≤ 155 Mb/s
Kyrgyzstan	KRENA-AKNET	> 2 Mb/s ≤ 34 Mb/s	

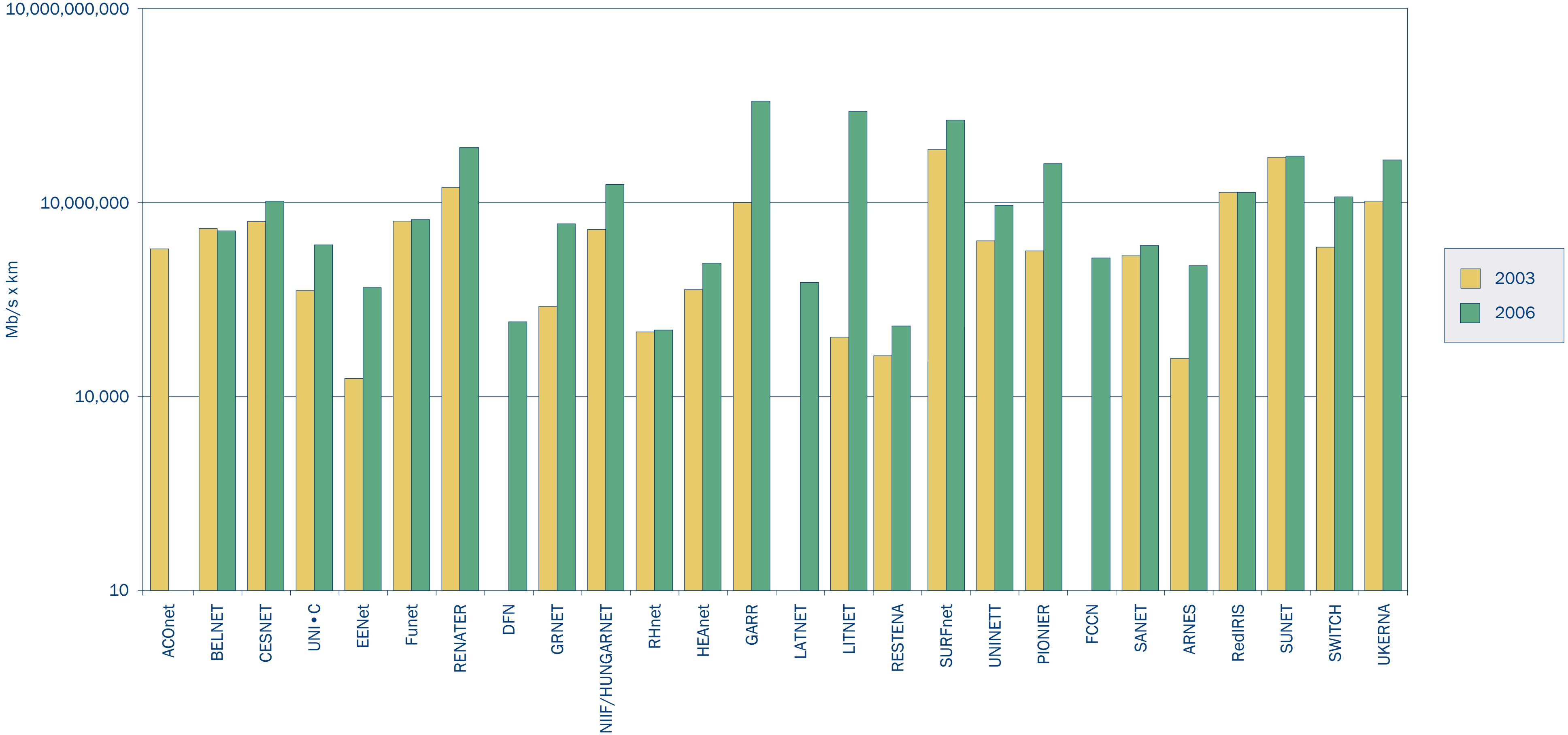
Country	NREN	2006	2008
Peru	RAAP	> 2 Mb/s ≤ 34 Mb/s	
Taiwan	NCHC	> 10 Gb/s	
Uruguay	RAU	> 2 Mb/s ≤ 34 Mb/s	
USA	Internet2	> 5 Gb/s ≤ 10 Gb/s	
Uzbekistan	UziSciNet	> 2 Mb/s ≤ 34 Mb/s	> 2 Mb/s ≤ 34 Mb/s

3.4 Core Network Size

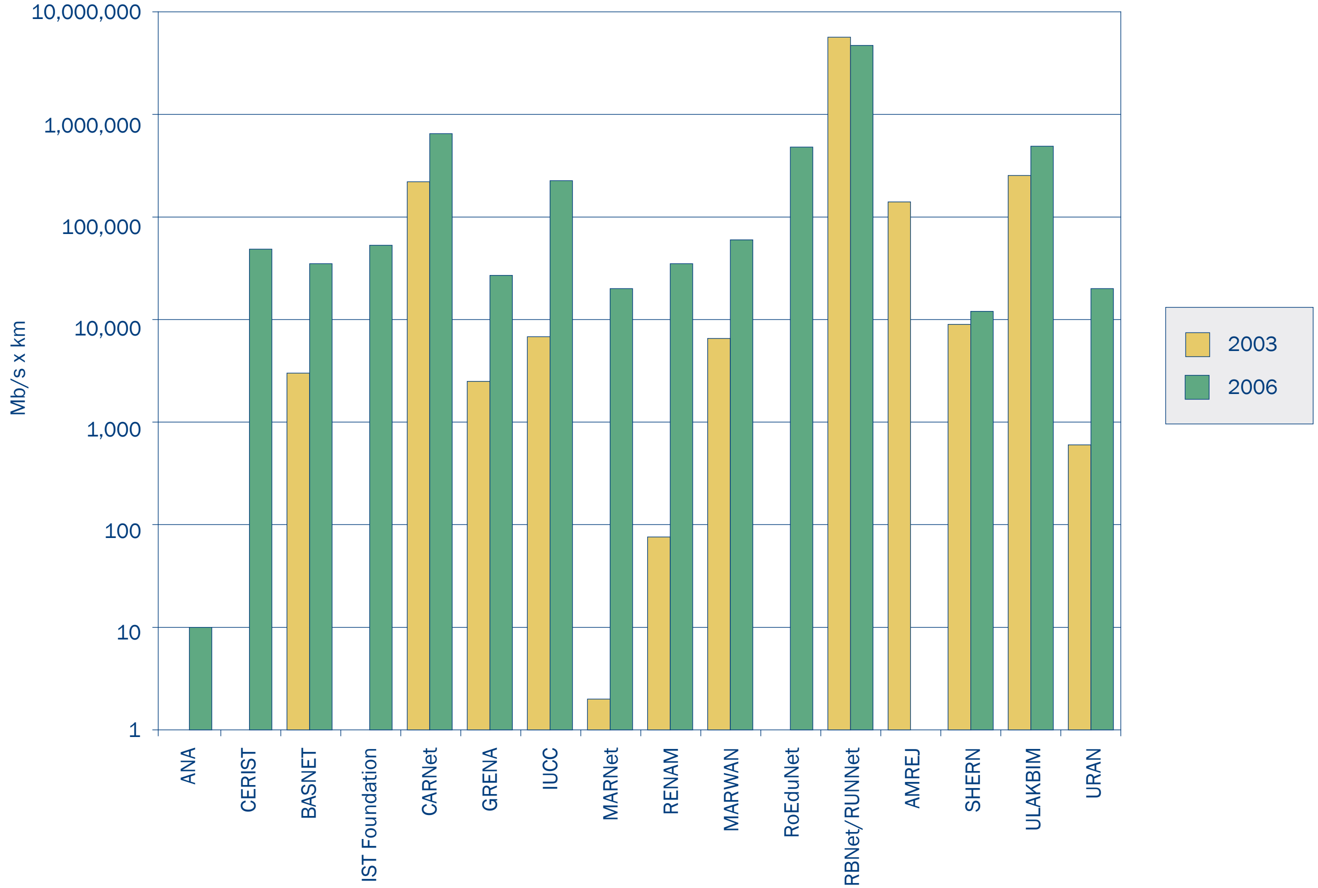
Similar to previous years, NRENs were asked to estimate the total size of their networks by multiplying the length of the various links in the backbone with the capacity of those links in Mb/s. The resulting unit is network size in Mb/s x km. This question is difficult to answer for some NRENs, but because it has been asked for a number of years, the answers have improved. It is interesting to note that GARR (Italy) has now overtaken SURFnet (Netherlands) as the NREN with the largest sized core network.

Note that the scales of the graphs are logarithmic and not the same for the two graphs.

Graph 3.4.1 Core Network Size 2003 – 2006: EU and EFTA Countries



Graph 3.4.2: Core Network Size 2003 – 2006: Other Ccountries



3.5 External Connectivity: Total External Links

NRENs were asked to list all of their external connections in January 2006.

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. What is listed in the graphs is the connection of the individual NRENs to NORDUnet. In addition, their other connections (peerings, connections to the commercial Internet) have been listed. For more information about the external connections of NORDUnet, see http://www.nordu.net/maps/map_nordunet.png.

In the graph, GÉANT/NORDUnet also contains the connections to GÉANT via the SEEREN and EUMEDCONNECT projects as well as connections to GÉANT based on bilateral agreements (BASNET, RENAM). Note that some NRENs connect to the wider Internet through the DANTE World Service, which makes use of the GÉANT network.

'Other Research' includes links to other NRENs, the links of several Central Asian NRENs to DFN via the Silk Highway project and connections to CERN, Starlight and similar.

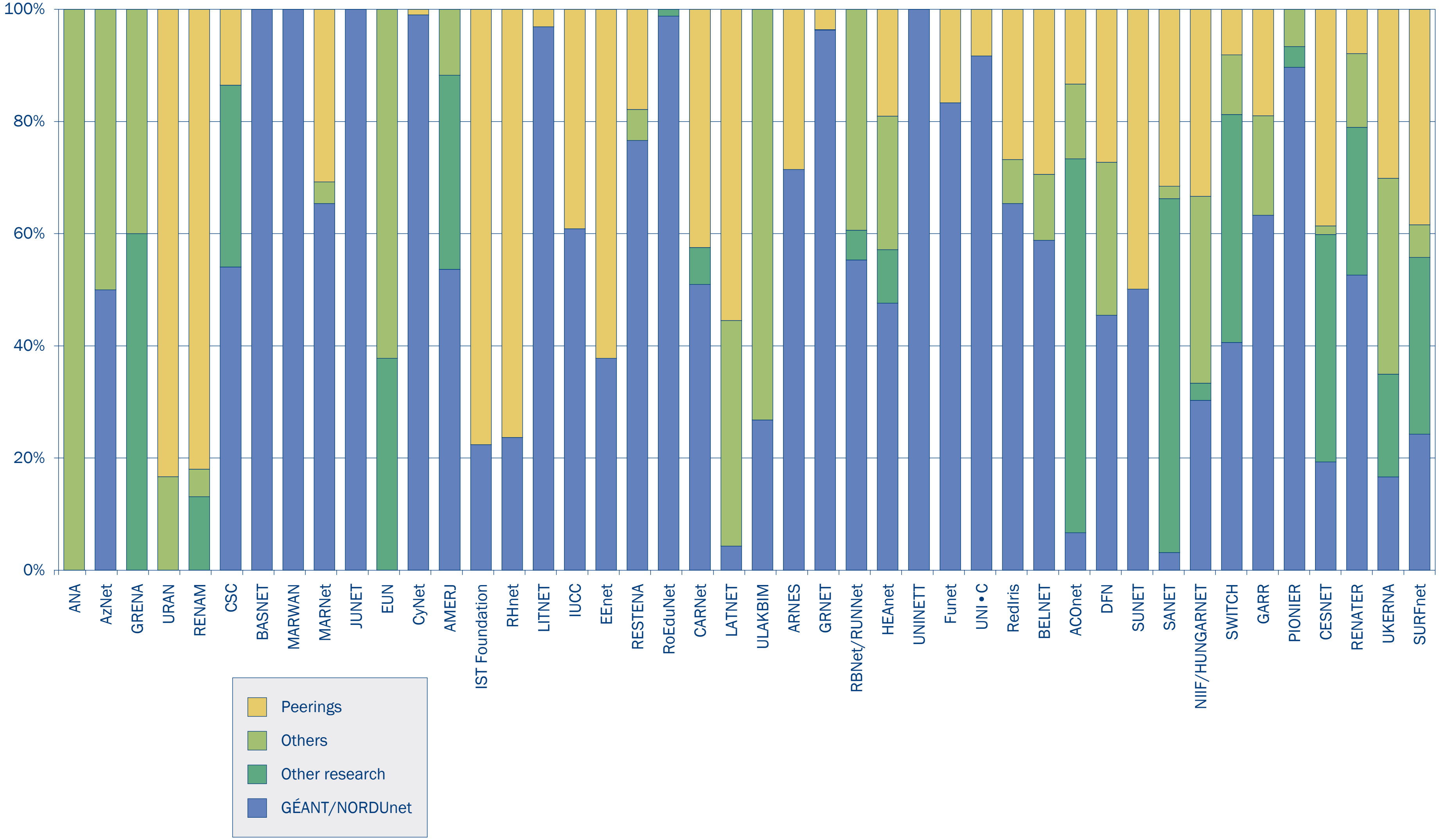
A peering is an exchange of IP routes in order to optimise traffic[3]. Often, traffic is exchanged, although no money changes hands. In some cases, restrictions may apply to such traffic.

The 'Others' category is used for connections with commercial ISPs.

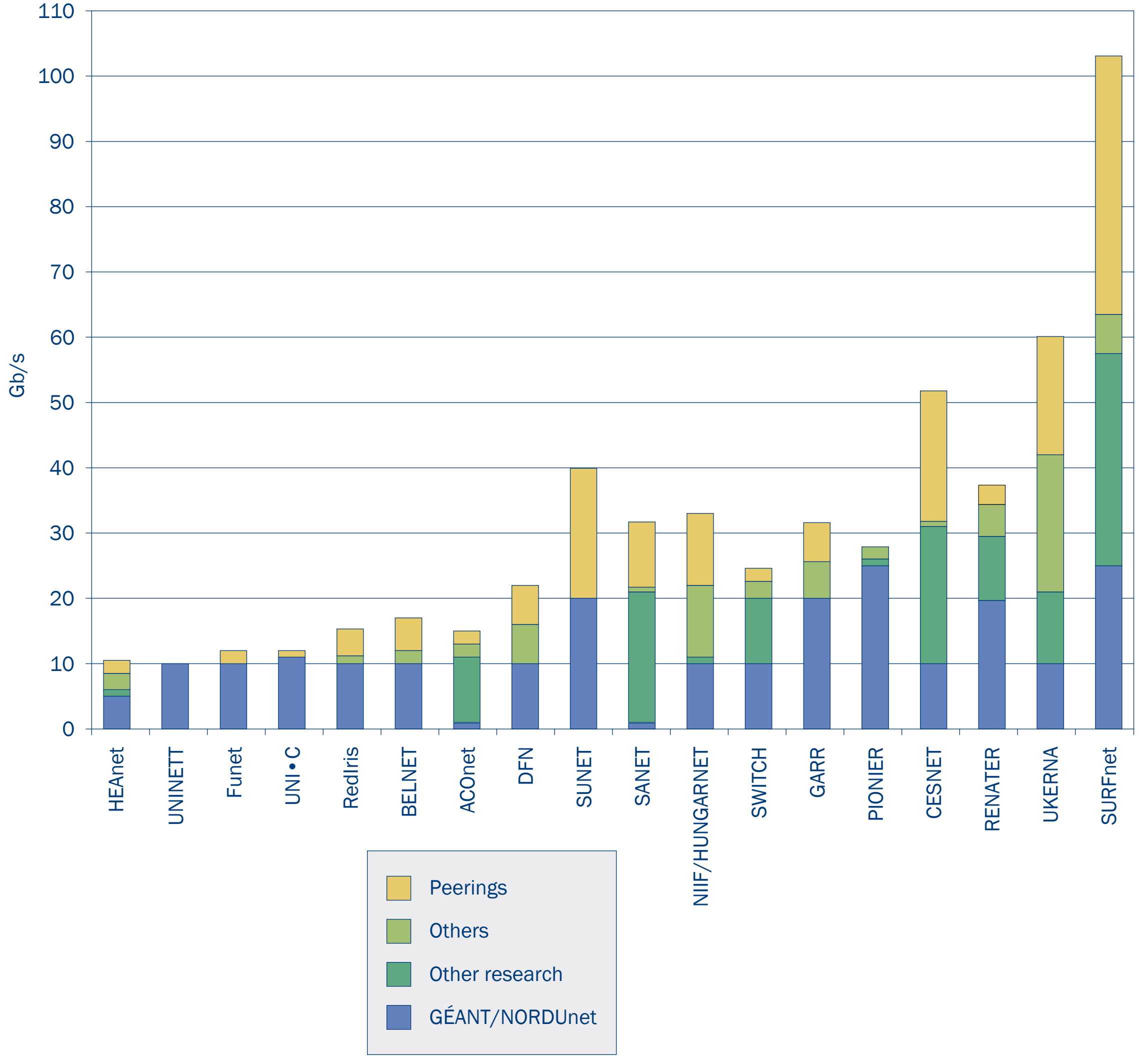
For presentational purposes, four graphs are presented.

[3] See for example http://whatis.techtarget.com

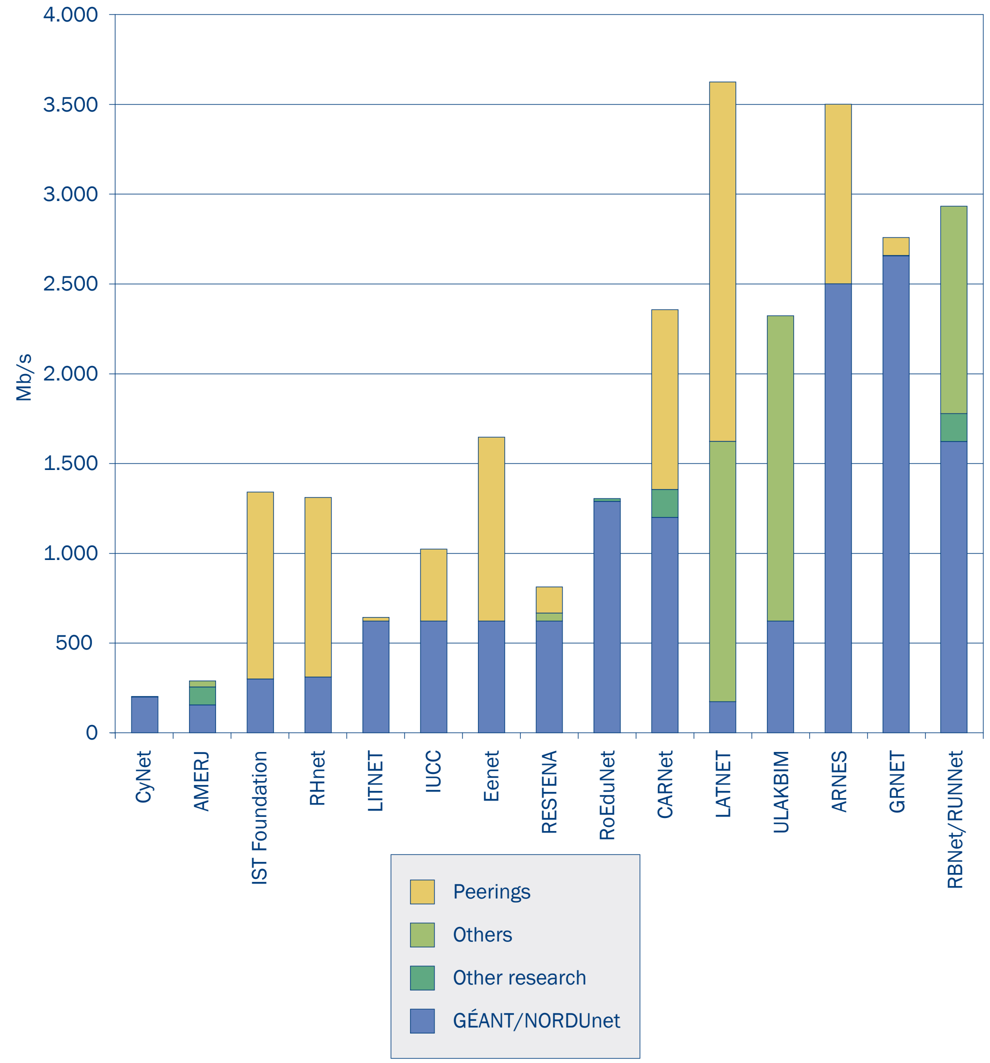
Graph 3.5.1 Division of External Connectivity over the Categories, January 2006



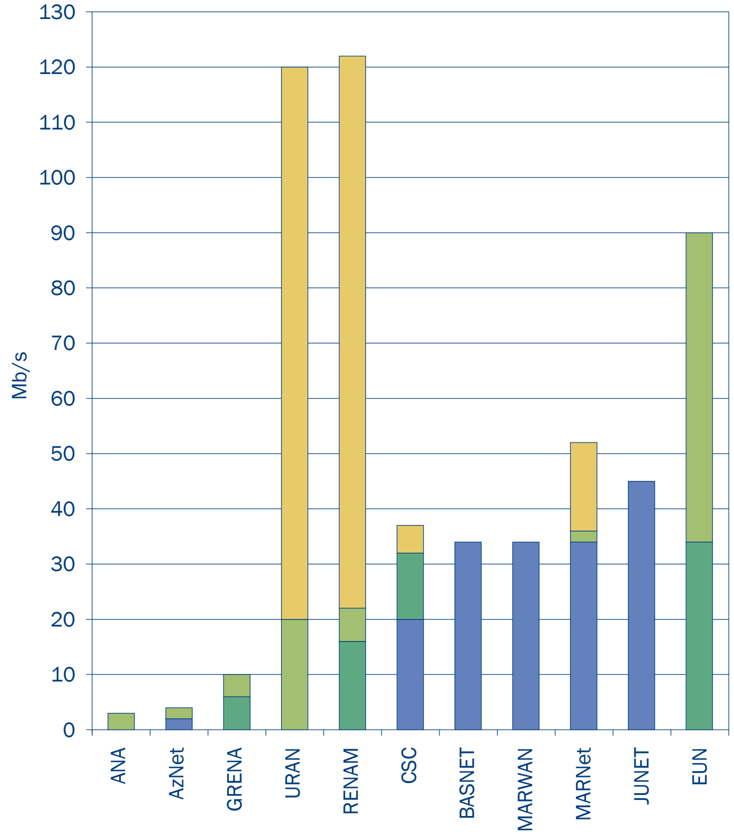
Graph 3.5.2 External Connectivity > 10 Gb, January 2006



Graph 3.5.3 External Connectivity > 200 Mb, < 10 Gb, January 2006



Graph 3.5.4 External Connectivity < 200 Mb, January 2006



3.6 Dark Fibre

Some NRENs own dark fibre or have IRUs[4] or lease dark fibre and can decide themselves what technology and what speeds to use on their fibre. NRENs were asked if they currently have IRUs or own dark fibre, or if they plan to get it during the coming two years. NRENs were also asked approximately what percentage of their backbone is dark fibre, in km, in point-to-point distances.

The coloured squares indicate where an NREN has a significant percentage of dark fibre and draws attention to significant changes that are expected over the next two years.

Table 3.6.1 Dark Fibre, 2005 to 2008 (darker colour highlights a significant change)

		2005		2006		2008	
		% of entire backbone that is dark fibre:					
Country	NREN	% own	% leased or IRUs	% own	% leased or IRUs	% own	% leased or IRUs
EU 25/EFTA countries							
Austria	ACOnet				1	0	90
Belgium	BELNET	0	0	0	3	0	90
Czech Republic	CESNET	0	0	0	100	0	100
Denmark	UNI•C	0	25	1	10	1	80
Estonia	EEnet			0	20	0	40
Finland	Funet	0	5		8		25
France	RENATER	0	5		25		
Germany	DFN	0	0		90		
Greece	GRNET	0	0		100		100
Hungary	NIIF/HUNGARNET	0	1	1	10	1	50
Iceland	RHnet	0	0		15		30
Ireland	HEAnet	0	10		18		58
Italy	GARR	0	3	1	2	2	10
Lithuania	LITNET	0	0	14	0	30	10
Luxembourg	RESTENA	4	47	5	50	10	60
Netherlands	SURFnet	0	100		100		100
Norway	UNINETT	2	95	50	50	50	50
Poland	PIONIER	73	0	77	11	100	
Portugal	FCCN	30	70	25	1	50	10
Slovakia	SANET	3	97	3	97	3	97
Slovenia	ARNES	0	80	0	68	0	90
Spain	RedIRIS	0	0	0	0	0	5
Sweden	SUNET	0	5		100		100
Switzerland	SWITCH	2	85	5	95	5	95
United Kingdom	UKERNA	0	2		50		60
Other countries							
Azerbaijan	AzNET	30	70		80		80
Belarus	BASNET			10	90		
Croatia	CARNet	0	5	5			
Georgia	GRENA			7	0	15	20
Israel	IUCC	0	2		2		2
Macedonia, FYRo	MARnet			10		10	60
Moldova	RENAM			5	2	30	20
Romania	RoEduNet	0	0	1	0	5	60
Russian Federation	RBNet/RUNNet	10	0				
Serbia/Montenegro	AMREJ			1	99	1	99
Ukraine	URAN	12	0	2		10	5

[4] IRU stands for 'Indefeasible Right of Use'. This is the effective long-term lease (temporary ownership) of a portion of the capacity of a cable. See, for example, http://whatis.techtarget.com for more information. The distinction between IRUs and lease is becoming less clear; therefore, these two categories have been combined.

3.7 Cross-border Dark Fibre

A number of countries have or are planning to install cross-border dark fibre links from one neighbouring NREN to the other. A relatively recent development, 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" ('Networks for Knowledge and Innovation,' SERENATE Summary Report, pg. 34-5). Table 3.7.1 provides an overview of current and planned cross-border dark fibre links.

As the table suggests, there are more planned links than current links and the majority of the cross-border links are concentrated in Central Europe. Being a recent development, any additional conclusions about the development of cross-border dark fibre are misplaced.

Table 3.7.1 Cross-border Dark Fibre

	Location
NREN to NREN	**Current**
ACONET-SANET	Vienna, Austria – Bratislava, Slovakia
AMREJ-NIF/HUNGARNET	Subotica, Serbia/Montenegro – Szeged, Hungary
CESNET-PIONIER	Ostrava, Cezch Republic – Cieszyn, Poland
CESNET-SANET	Brno, Czech Republic – Bratislava, Slovakia
DFN-SURFnet	Muenster, Germany – Enschede, Netherlands
DFN-SWITCH	Lörrach, Germany (BelWü) – Basel, Switzerland
PIONIER-DFN	Gubin, Poland – Guben, Germany
	Planned for 2006 and After
BASNET-PIONIER	Grodno, Belarus – Kuznica, Poland
CESNET-ACOnet	Brno, Czech Republic – Vienna, Austria
DFN-PIONIER	Pomellen, Germany – Kolbaskowo, Poland
DFN-RENATER	Kiel, Germany – Strasbourg, France
DFN-SWITCH	Karlsruhe, Germany – Basel, Switzerland
GARR-SWITCH	Milano, Italy – Manno, Switzerland
LITNET-PIONIER	Kaunas, Lithuania – Ogrodniki, Poland
PIONIER-UARNET	Hrebenne, Poland – Rawa Ruska, Ukraine
PIONIER-DFN	Slubice, Poland – Frankfurt(Oder), Germany
RBNet/RUNNet-PIONIER	Mamonovo, Russia – Granowo, Poland
SANET-PIONIER	Skaliste, Slovakia – Zwardon, Poland
SURFnet-DFN	Maastricht, Netherlands – Aachen, Germany

3.8 Routers and Switches

A router is a device or, in some cases, software in a computer, that determines the next network point to which a packet should be forwarded toward its destination.[5] Routers are thus important pieces of equipment for any NREN. Table 3.8 provides an overview of routers and switches currently used by NRENs. Note that several NRENs use routers and switches from more than one manufacturer. Information for each NREN is available from the Compendium website.

Table 3.8 Routers and Switches

EU/EFTA countries (27 NRENs in the survey)												
Vendor	**Cisco**	**Juniper**	**HP**	**Avici**	**Nortel**	**Extreme**	**Foundry**	**Enterasys**	**MikroTik**	**Tellabs**	**3Com**	**Planet**
Number of NRENs	24	9	2	1	1	1	1					
Other countries (18 NRENs in the survey)												
Number of NRENs	18		2					1	1	1	1	1

[5] Source: whatis.techtarget.com

3.9 Numbers of PoPs and Managed Links on the Network

The number of Points of Presence (PoPs) on the network and the number of managed links are both indicators of the amount of resources needed for the NREN to maintain the network. In this version, a PoP was defined more clearly than in 2005 as a point on the NREN backbone which can connect client networks or aggregations of client networks such as MANs or external networks. As can be seen from the table below, NRENs vary considerably in this respect. Thus, ARNES of Slovenia manages the equipment at many secondary and primary schools and thus has 983 managed links. In many other countries, the links from a PoP on the backbone or from a MAN to the end user are managed by other bodies.

Table 3.9 Number of PoPs and Number of Managed Links on the Network

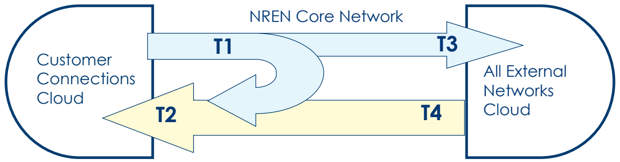
Country	NREN	# of POPs	# of Managed Links
EU and EFTA Countries			
Austria	ACOnet	15	22
Belgium	BELNET	16	29
Cyprus	CyNet	2	1
Czech Republic	CESNET	34	44
Denmark	UNI•C	6	0
Estonia	EENet	16	20
Finland	Funet	16	23
France	RENATER	40	80
Germany	DFN	43	102
Greece	GRNET	12	14
Hungary	NIIF/HUNGARNET	35	38
Iceland	RHnet	9	11
Ireland	HEAnet	8	26
Italy	GARR	38	60
Latvia	LATNET	48	60
Lithuania	LITNET	27	200
Luxembourg	RESTENA	12	59
Malta	CSC	1	0
Netherlands	SURFnet	232	306
Norway	UNINETT	40	240
Poland	PIONIER	25	29
Portugal	FCCN	15	16
Slovakia	SANET	22	26
Slovenia	ARNES	38	983
Spain	RedIRIS	20	34
Sweden	SUNET	22	60
Switzerland	SWITCH	24	46
United Kingdom	UKERNA	150	1,500
Other Countries			
Albania	ANA	2	1
Algeria	CERIST	4	3
Azerbaijan	AzNET	13	13
Azerbaijan	AzRENA	3	10
Belarus	BASNET	21	20
Bulgaria	IST Foundation	10	30
Croatia	CARNet	320	350
Georgia	GRENA	19	17
Israel	IUCC	2	16
Macedonia, FYRo	MARNet	1	0
Moldova	RENAM	18	31
Romania	RoEduNet	41	53
Russian Federation	RBNet/RUNNet	12	15
Serbia and Montenegro	AMREJ	50	60
Turkey	ULAKBIM	3	3
Ukraine	URAN	18	31

4 Traffic

In this section, a distinction is made between different types of traffic by source or destination. Figure 4.0.1 illustrates how the terms are used for the purposes of the Compendium.

External traffic is all traffic to GÉANT, the commercial Internet, Internet exchanges, etc. (made up of T3 and T4 in Figure 4.0.1).

Figure 4.0.1 Elements of Traffic Flow on NREN Network



T1 - all traffic from customer sites
T2 - all traffic to customer sites
T3 - all traffic to external networks
T4 - all traffic to the NREN backbone

Section 4.2 provides information about the traffic volume in 2005. Section 4.3 looks at traffic load and provides data from January 2003 through to January 2006. Section 4.4 provides information about IPv6. The overview section, 4.1, looks at all these and a few other aspects, provides information about NRENs from different groups of countries and tries to identify key trends.

4.1 Overview

Traffic Trends

From the data presented in section 4.2, it is possible to quantify trends in traffic for the various NRENs. Grouping NRENs, we get the following summary of mean growth per annum, calculated using figures for 2003, 2004 and 2005. In each group of NRENs, traffic is aggregated, so that the resulting growth figures are weighted.

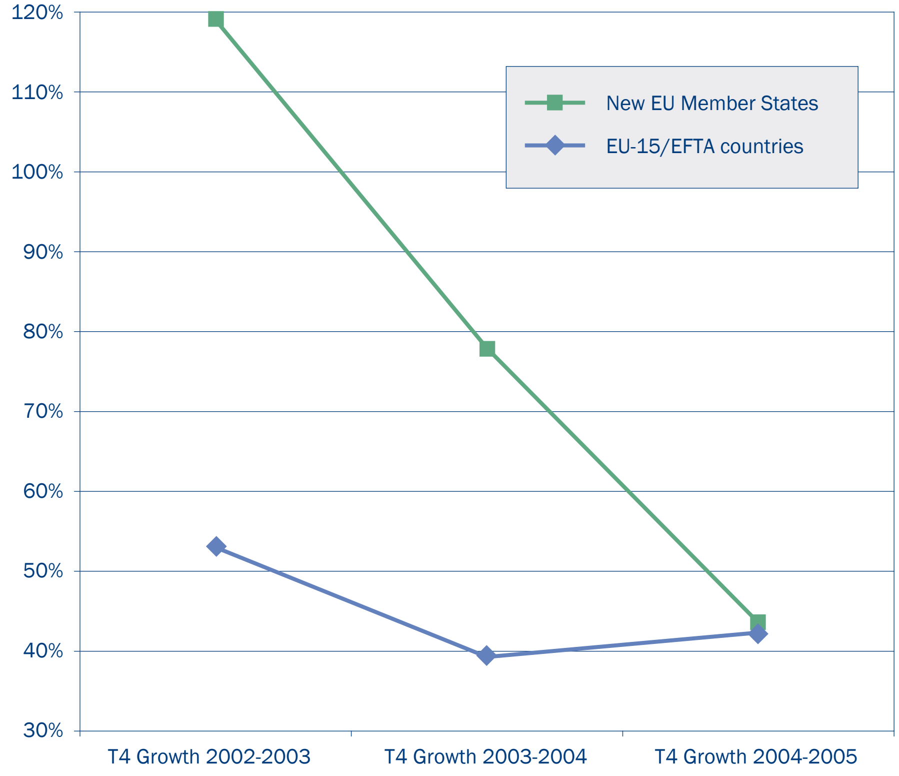
Table 4.1.1 Aggregated Traffic Growth, 2003 - 2005

	'T3' growth a year		'T4' growth a year		'T3' growth a year	'T4' growth a year
Group of NRENs	2003-2004	2004-2005	2003-2004	2004-2005	2003-2005	2003-2005
EU-15/EFTA[1]	30%	25%	39%	42%	28%	41%
New EU member states[2]	85%	36%	78%	44%	59%	60%
EU/EFTA[3]	42%	28%	48%	43%	35%	45%
Other[4]	28%	41%	45%	35%	34%	40%

The 2005 edition of the Compendium showed a significant distinction between the growth rates in the new EU member states and in non-EU/EFTA countries. The growth rates in the 'new' member states were clearly higher than those in the 'old' EU member states. As is clear from the new data, the growth rates have now converged.

[1] Based on data from thirteen out of eighteen NRENs
[2] Based on data from eight out of ten NRENs
[3] Based on data from twenty-one out of twenty-eight NRENs
[4] Based on data from eleven NRENs (AMREJ, AzNET, CARNet, CERIST, GRENA, MARWAN, RENAM, RoEduNet, RBNet/RUNNet, ULAKBIM and URAN)

Graph 4.1.2 Traffic Growth in the 'Old' and 'New' EU Member States, 2002 – 2005



As stated last year, it seems that in the EU, traffic is now determined more by (changes in) user demand, rather than by limitations in network capacity. In the 'Other' group of countries, this is probably not yet the case.

The lower growth rate for the EU/EFTA countries that was evident when comparing 2002/2003 to 2004/2005 now seems to have stabilised. It is difficult, if not impossible, to predict what the future will bring – new applications relative to Grids, for example, may change the picture.

However, in that case, growth will be driven by demand, rather than by changes in network capacities. In addition, changes in technology (such as the introduction of lightpaths for certain categories of users) may change the picture.

It is important to note that traffic growth is not a natural phenomenon, but can be and is being influenced by the policies both of NRENs and of their users. One noteworthy example in this context is that of Funet (Finland), where traffic decreased more than 10% between 2003 and 2004 and a further 9% between 2004 and 2005. Funet staff offered the following explanation for this: "The reason is that some universities started to filter traffic that they suspect to include illegal copyrighted material. Another motivation was our charging policy, which punishes heavy-users." There may be other factors at work here as well, such as the adoption of anti-spam measures.

Note that at least fifteen NRENs from the EU/EFTA region have traffic monitoring tools on their website (a few more have password-protected pages or pages for customers only); sixteen publish traffic statistics on their website. Many NRENs from other countries do this as well. A list of all urls is available from the Compendium website.

Traffic with the General Internet

The level of **NREN traffic with the general Internet**, as distinct from inter-NREN traffic, is quite uniformly high. The overall average proportion across all NRENs in the survey is approximately 75%. However, the spread between NRENs is considerable, ranging from just under 30% for RHnet (Iceland) to more than 90%, for example, for ULAKBIM (Turkey).

Congestion

NRENs were asked to give a rough estimate of the percentage of institutions connected to their network that experience none or little, some or moderate, or serious congestion at the different network levels.

A single metric was derived for the level of congestion in each network element from the subjective levels reported by NRENs, using the following formula[5]:

Congestion Index = 0.05*little + 0.2*some + 0.5*serious

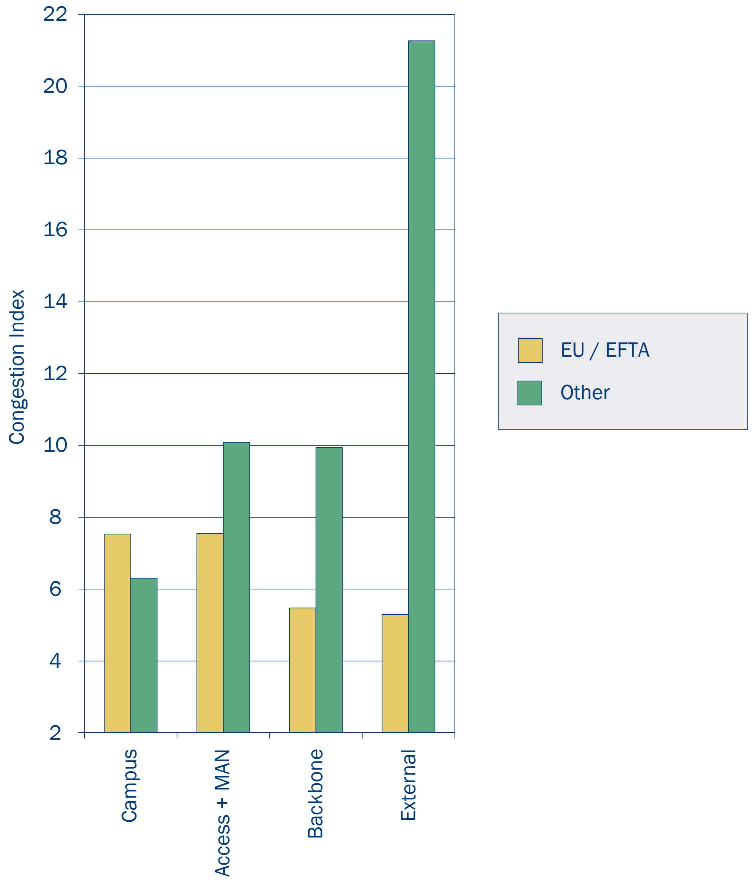
The minimum value of congestion on the network, based on the Congestion Index is 5.

The data for MANs and for access networks were combined. Applied to all the reported values, this formula provides a single uniform metric.

The overall picture is the same as in 2005: in EU/EFTA countries, NRENs report relatively little congestion in those parts of the network within their domain of responsibility. Uniformly, they see no serious congestion on external circuits, virtually none in their core networks, and little in the MAN or regional network. Any serious congestion, they report, is largely confined to access networks or, to the campus LANs of connected institutions.

The 'Other' NRENs reported that the most congestion is found on the external connections. In those countries, the restrictions imposed by low-capacity external connections mean that constraints at the campus and other levels are less apparent. It is to be expected that these constraints will show up as soon as the problems at other levels have been solved.

Graph 4.1.3 Congestion Index

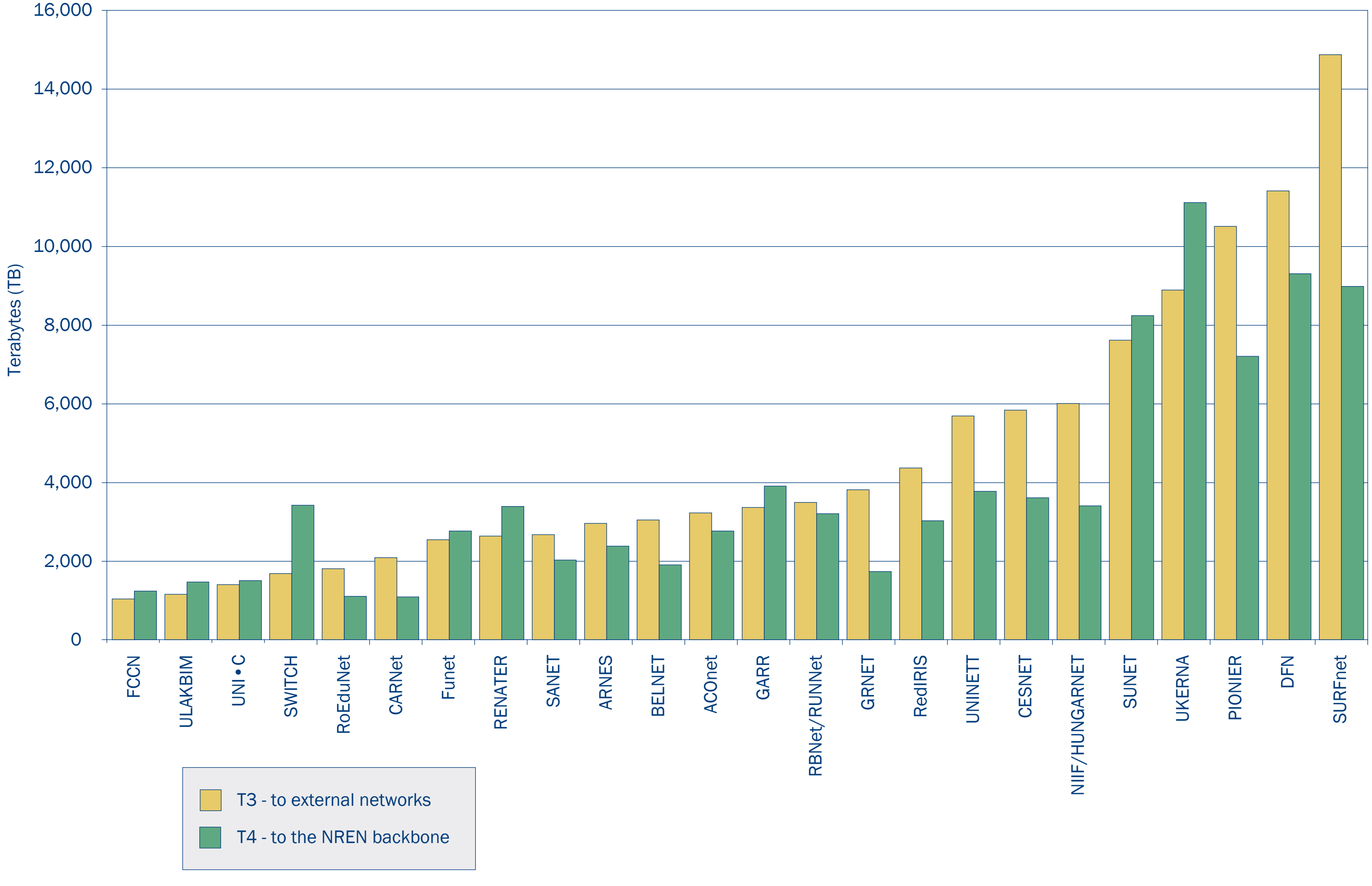


[5] This index has been developed for the Compendium by Mike Norris, HEAnet.

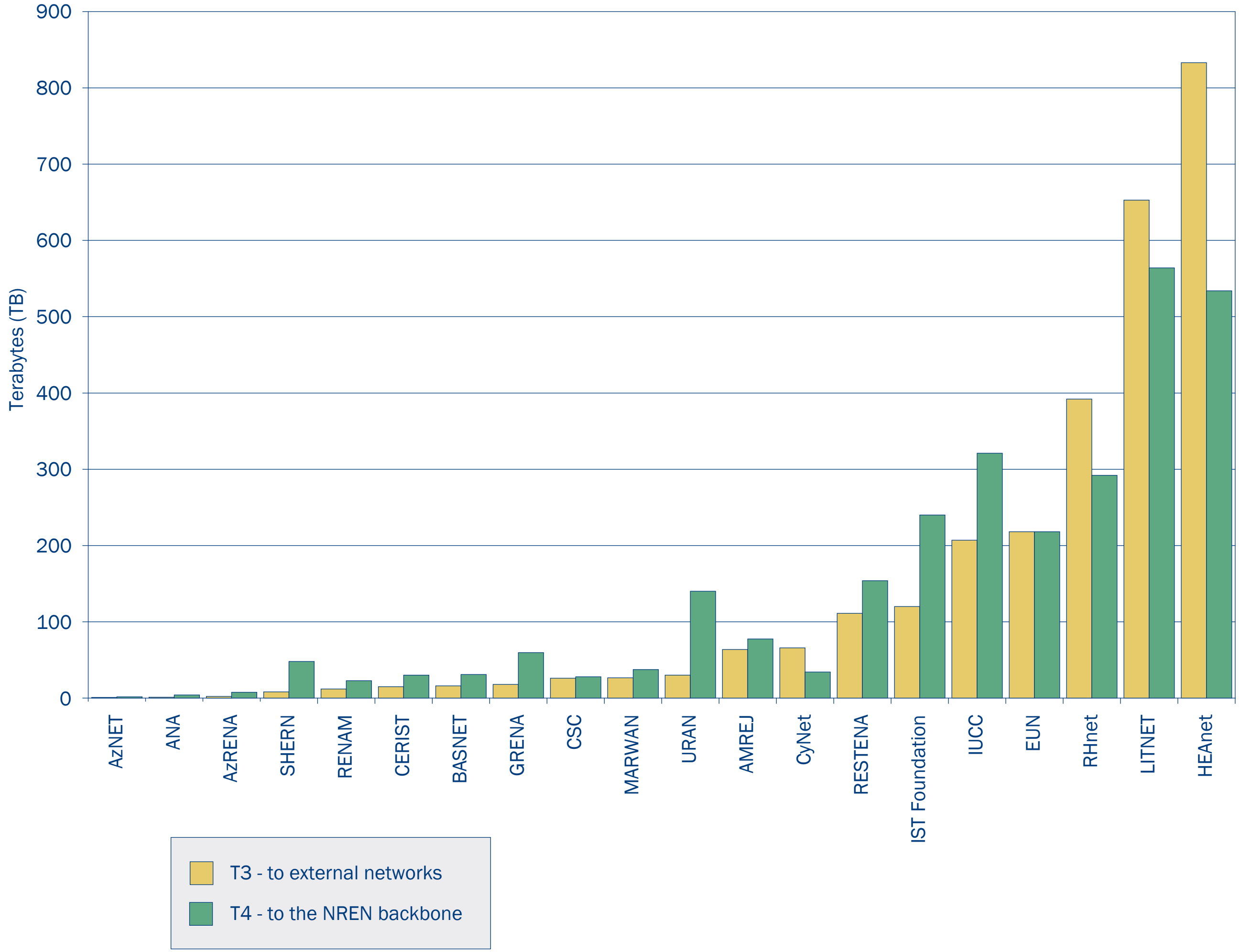
4.2 Traffic in 2005

Two graphs are presented: graph 4.2.1 shows the information for those NRENs with external traffic above 1000 Terabytes; graph 4.2.2 gives the same information for NRENs with external traffic below 1000 Terabytes.

Graph 4.2.1 Incoming and Outgoing External Traffic 2005, > 1000 Terabytes (TB)



Graph 4.2.2 Incoming and Outgoing External Traffic 2005, < 1000 Terabytes (TB)



4.3 Traffic Load

Measuring the traffic load on the network is one potential way of measuring congestion and thus is also an indicator of the extent to which customer demand for bandwidth is being satisfied. For the following graphs, the traffic load has been calculated by dividing the actual traffic in January of each year by the theoretical maximum capacity of all external links of an NREN in that month. The theoretical maximum capacity is calculated by multiplying the total capacity of the external links in Mb/s by the number of seconds in January.

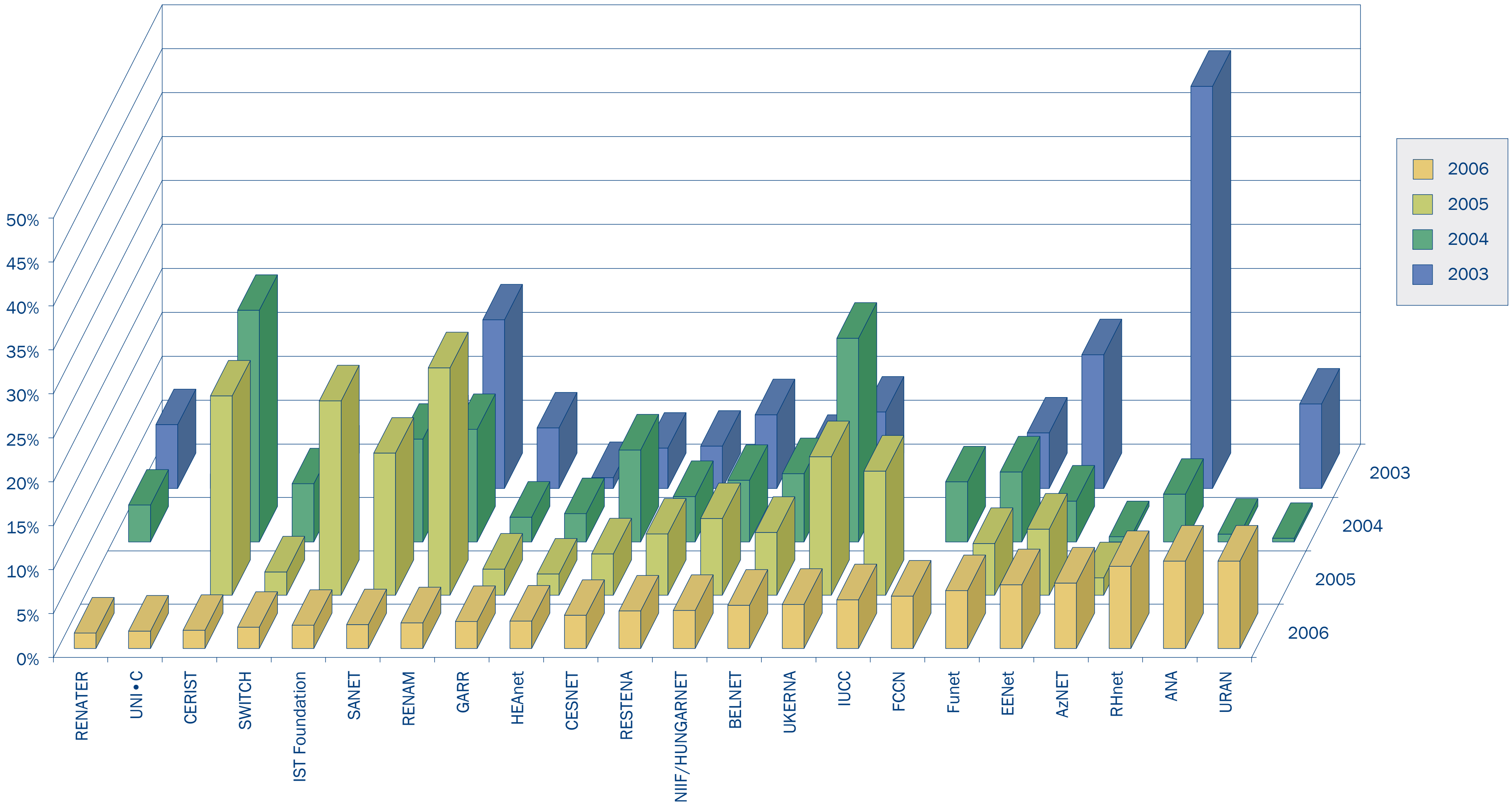
In practice, it is impossible to reach the theoretical maximum capacity and therefore it is impossible to reach a 100% traffic load. This is because traffic is typically not evenly distributed over the hours in a day and over the days of a week.

For an indication of sustained peak usage, the load figures in the table should typically be multiplied by three. In other words, users will certainly experience serious congestion if the traffic load is above 33%; even at lower loads, users may sometimes experience congestion in network performance.

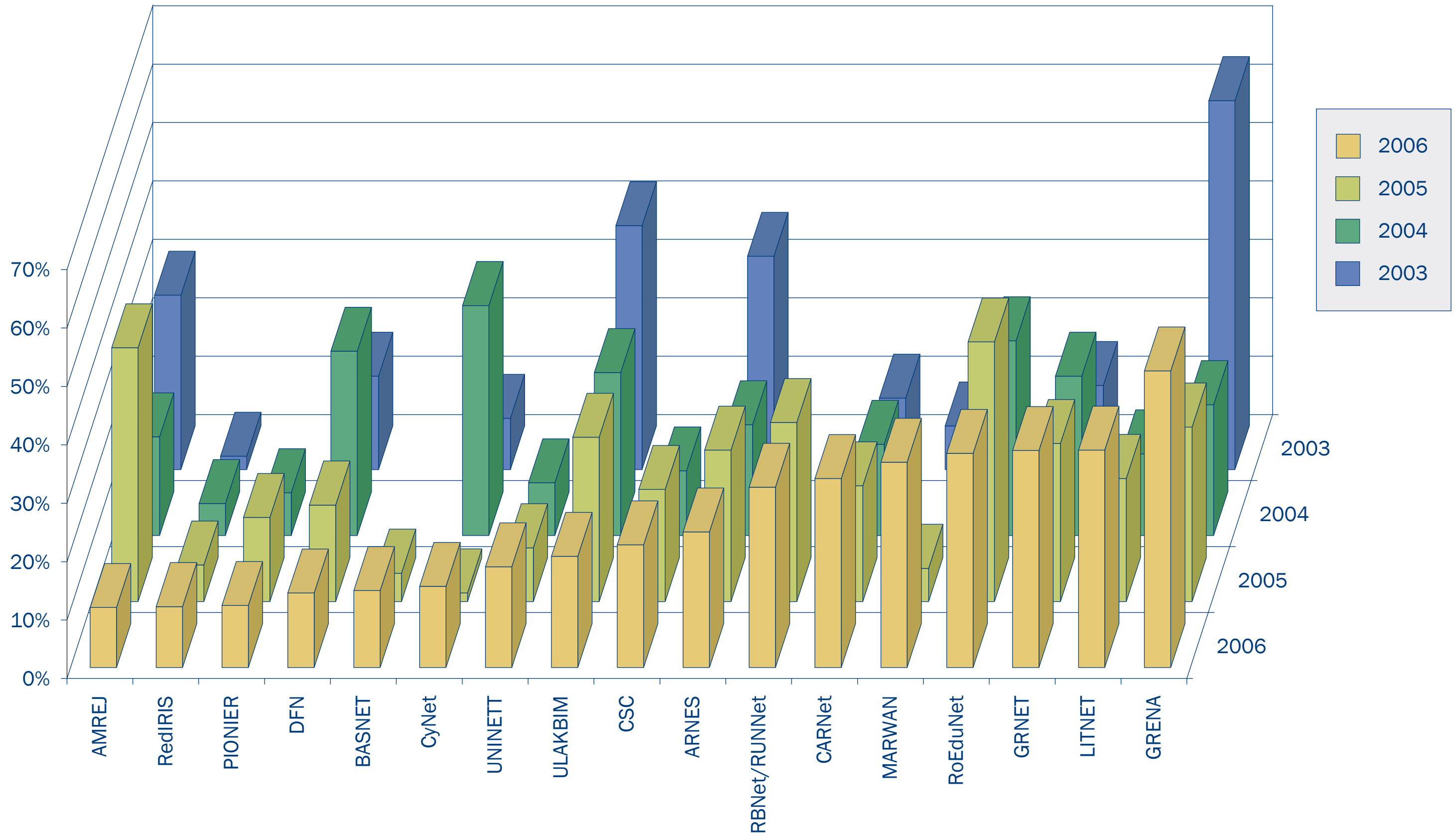
In addition, traffic is not distributed evenly over all the external links of an NREN, because not all links offer the same possibilities. Thus, it could be that the overall traffic load, as computed here, is low but that certain links are still overloaded.

The graphs illustrate in a very general way that NRENs need to upgrade their external links from time to time in order to keep up with increasing demand.

Graph 4.3.1 Average Outgoing Traffic Load January 2003 - 2006, NRENs with < 10% Traffic Load (as percentage of the theoretical maximum capacity) in January, 2006.



Graph 4.3.2 Average Outgoing Traffic Load January 2003 – January 2006, NRENs with >10% Traffic Load (as percentage of the theoretical maximum capacity) in January 2006.



4.4 IPv6

The 2005 edition of the Compendium showed that universities were taking the lead in IPv6. It was suggested that it would not be unusual for at least some departments in a university to have a professional interest in a new Internet Protocol.

As can be seen from table 4.1.1, the number of universities that have some form of IPv6 connectivity has increased in the past year, both in absolute numbers and proportionately.

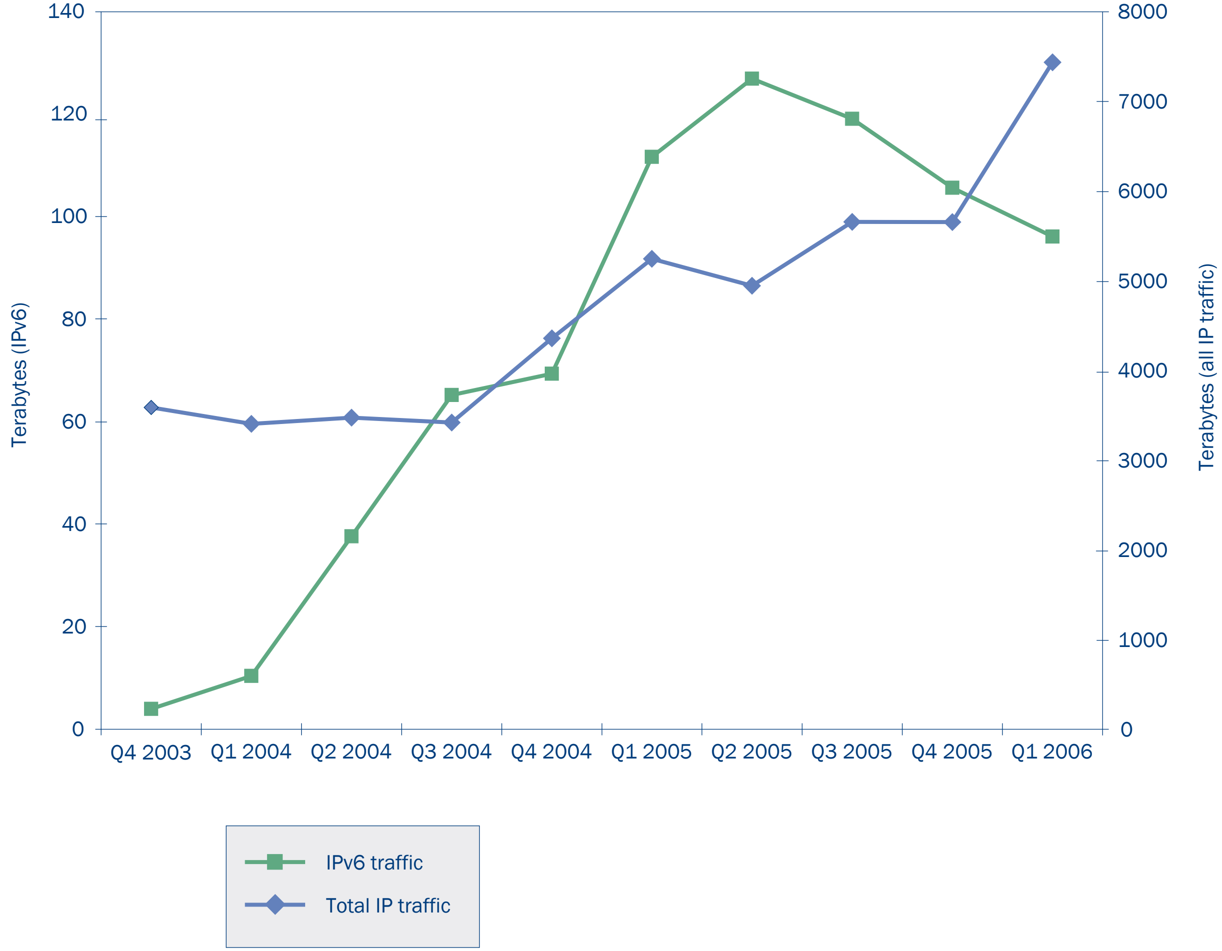
Table 4.1.1 Universities Connected via IPv6, EU/EFTA

	2005	2006
# of Universities with IPv6 connectivity	205	431
% of Universities with IPv6 connectivity	15.4%	34.8%

There are other indicators of the uptake of IPv6, particularly within the NREN community. The GÉANT monthly reports give the volume of IPv6 traffic for each NREN access (or group of NRENs, as in the case of NORDUnet).

From the data, it seems that the growth in IPv6 traffic on the GÉANT backbone has peaked, at least for the time being. It seems that institutions are adopting the connection, but are not using it.

Graph 4.4.2 IPv6 Traffic vs. Total IP Traffic



5 Services

Many NRENs are involved in providing a number of important services to their customers, in addition to providing connectivity. This section provides information about NREN work in eight service areas: Network Operations Centres (5.2), Performance Monitoring and Management (5.3), Authorisation and Authentication Infrastructure (5.4), Security Incident Response (5.5), Bandwidth on Demand (5.6), Grid Services (5.7), IP Telephony (5.8) and Videoconferencing (5.9). The Compendium website provides more detailed information in a number of cases and also provides information on user support, public relations and communications, NREN involvement in other Internet-related activities and NREN interests in research and development.

5.1 Overview

Services are receiving more and more attention from NRENs. There are a few trends that can be noted from the data:

- More users have come to expect reliable, high-capacity Internet connections. NRENs are doing more to provide such connections and to provide assistance in case of problems. One way of doing this is through the 'PERTs'. These now exist in roughly half of the NRENs. In cases where a PERT does not exist, an NREN is able to call upon the central GÉANT PERT;

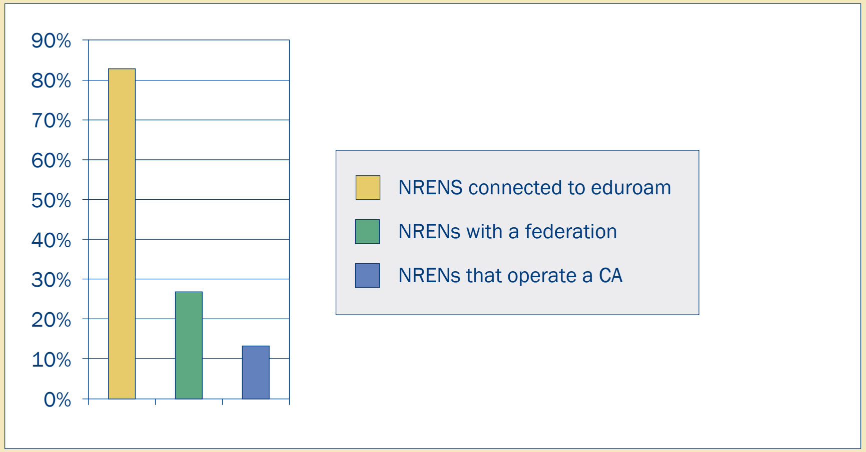
- There is an increased need for an authorisation and authentication infrastructure (AAI) in the NREN environment and many NRENs are taking steps to develop such an infrastructure. However, the work is by no means finished. Currently deployed AAI's have very different capabilities, ranging from simple username/password-based authentication systems to sophisticated middleware for granting or denying access to resources;

- There is renewed and increasing interest in the Public Key Infrastructure (PKI) area;

- Many NRENs are now introducing or have introduced eduroam, a facility that provides roaming access for users to wireless networks.

The current uptake of AAI in the EU/EFTA countries can be summarised as follows:

Graph 5.1.1 AAI in the EU/EFTA Countries



- A related area is that of security incident response. The figures indicate that in this area, there is still a large gap between the EU/EFTA countries and the other countries in the region;

- Approximately 25% of the NRENs are currently offering a Bandwidth on Demand service; approximately the same percentage is planning to introduce it in the next two years, with a significant percentage of NRENs still in doubt;

- Grid services are currently running at most NRENs – several others are planning to introduce such a service. There has been a clear increase over the past year. A striking element in the responses is that the take up of Grid technology has widened beyond the initial high-energy physics and biomedical communities. All disciplines seem to be well represented;

- Several NRENs have introduced IP Telephony services on their network; however, the scale and types of implementation vary widely, depending on different national situations;

- Videoconferencing is now part of the day-to-day collaboration activities in universities and research centres.

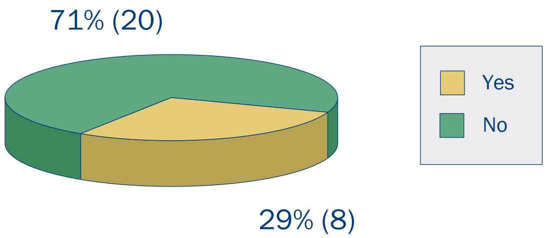
85% of the NRENs in the EU/EFTA countries currently offer such a service.

5.2 Network Operations Centres

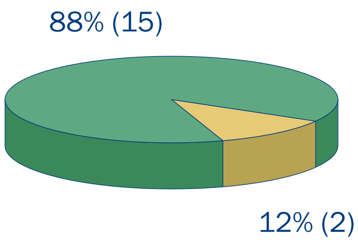
Some NRENs manage the physical centre of their network operations in-house; others have outsourced this, for example, to a supercomputing centre. Also, some NOCs serve all the customers of NRENs. In other NRENs, certain categories of customers (for example, secondary schools) receive those services from other organisations. The Compendium website provides country-by-country information (section 5.1). A series of pie charts summarises this information.

In the EU and EFTA countries, 71% of the NOCs are not outsourced; in the other countries, 88% of the NOCs are not outsourced. 85% of the NOCs in the EU and EFTA countries serve all of the NREN customers. In the other countries, this percentage is at 100% (pie chart not pictured).

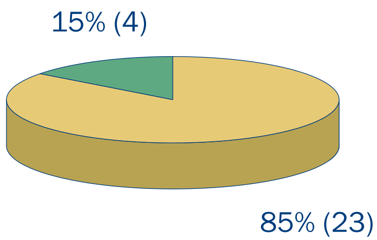
Graph 5.2.1 NOC Outsourced, EU/EFTA Countries



Graph 5.2.2 NOC Outsourced, Other Countries



Graph 5.2.3 NOC Serves All Customers, EU/EFTA Countries



5.3 Performance Monitoring and Management

A Performance Enhancement and Response Team (PERT) is a group of network engineering experts who assist end users who are experiencing network performance issues. Degraded network performance can be caused by any factor along the end-to-end network path (including the end systems themselves). Unlike network failures, it is often hard to diagnose which component is actually at fault and, as such, PERTs must often work together to locate the problem area. For education and research networks which do not have their own PERTs, the central GÉANT PERT is able to provide support on request; the PERT service also includes a knowledge base, using wiki technology.

The table below summarises the situation in Europe and the Mediterranean countries; again, the Compendium website provides more comprehensive information per country.

Table 5.3.1 PERTs

	PERT: Yes	PERT: No
EU/EFTA Countries	15	13
Other Countries	8	8

5.4 Authorisation and Authentication Infrastructure [1]

Authorisation and Authentication have always been important topics at the campus level, with an emphasis for the last few years on campus-wide identity management systems.

An **identity management system (IdM)** is a system that combines technologies and policies to allow institutions to store users' personal information and keep them up-to-date. An IdM is the first building block to provide and control users' access to critical on-line resources whilst at the same time to protect resources from unauthorised access.

When an identity management system is used by different administrative domains within the same campus, it also reduces the overhead of user management when users move from one place to another.

Users moving from one place to another make it necessary to share resources between different administrative domains. At the same time, there is a need to reduce user management overheads. This has led to the creation of **federations**.

Within federations, individual entities agree to allow access to each others' resources; they adopt compatible technologies enabling them to do so.
A federation makes it possible for end users to access information from another entity (which is also part of the federation) without the necessity of requesting new credentials from this entity. The benefit of this is a reduced number of credentials that users are requested to manage.

In addition, different federations can make agreements to share resources (known as **confederations**), but the workings of the requisite trust models and how to manage the increased complexity are still open question.

[1] Text contributed by Licia Florio, TERENA.

This leads to an important new role for NRENs: facilitating such federations through harmonisation, standardisation and implementation of the necessary trust fabric.

The increased need for an Authentication and Authorisation Infrastructure (AAI) in NREN environments reflects a number of tendencies:

- Users travel more and demand to have their familiar environment, services and privileges available whenever they move from one site to another;
- The network, although still improving, has reached a good level of stability, so that it is becoming easier to offer reliable services;
- Security has become more important due to the increasing number of resources accessible on-line and the increasing level of sophistication of hackers;
- Various NRENs have been developing AA tools over the past few years; these tools are now stable enough to look for inter-operability among the various pieces and to try to seek harmonisation;
- Grid applications are being used by more scientists and due to the nature of Grids (typically distributed computers and resources in different geographical locations) authentication and authorisation play a key role.

AAI solutions can deliver significant service improvements and cost reductions, in particular, as key enablers of important continent-wide initiatives like the Bologna Process.

It is important to note that the currently deployed AAI's have very different capabilities, ranging from simple username/password-based authentication systems to sophisticated middleware for granting or denying access to resources.

To address the need for an AA Infrastructure at European level, the GN2 project has set up a dedicated Joint Research Activity to focus on the creation of a European AAI infrastructure.

The following definitions have been developed in this Joint Research Activity:

- Authentication: The process of verifying the identity of an entity, either in person or electronically, where credentials are requested and checked to verify or disprove an entity's claimed identity;

- AAI: An infrastructure that supports Authentication and Authorisation Services. The minimum service components would be the management of identities and privileges specific to users or resources;

- Authorisation: The assignment of rights and capabilities granted to a specific principal (such as a person). Normally authorisation takes place when a user has been authenticated;

- Federated AAI: An AAI that supports multiple Identity and Privilege Providers, trusted by the members of the federation;

- eduroam [2] is the pan-European educational roaming infrastructure to provide wireless access to visited institutions. eduroam allows users visiting another institution connected to eduroam to log on to the WLAN using the same credentials the user would use if he were at his home institution.

NRENs have been asked questions about their current AAI situation: whether they run the infrastructure or outsource it; what kind of AAI they have, if they run a federation in the country and if so, whether it is

[2] eduroam is a registered trademark of TERENA. See also http://www.eduroam.org.

Shibboleth-based or not, if the NREN uses a schema and if so, what kind it is and if the NREN operates a Certification Authority (CA)?

Table 5.4.1 summarises the results that have been received. It also provides urls to more information on NREN websites.

One of the trends is renewed and increasing interest in the PKI (Public Key Infrastructure) area. This is due to several factors, some of which are listed:

- One of the factors is the requirement for trust relationships when building federations; PKI is a good candidate to provide a high level of security. The increasing popularity of AA Infrastructures and **eduroam** will most likely increase the demand for PKIs even more;

- The greater involvement of NRENs in Grid projects and the need to support Grid applications. The widest end-user PKI community is represented by Grid users, where the access to the Grid resources is granted to the users upon verification of their digital X.509 certificates. Many NRENs increased the operation of their sometimes dormant CAs or, in some cases, have established a CA to issue certificates to work with the Grid middleware;

- The demand for server certificates has increased over the last years, due to more demand for security triggered by awareness of possible security incidents when users access sensitive data on-line.

The other trend is a tendency to establish federations. Factors that drive this trend are listed above. Technology-wise, we see a convergence towards the same standards. This makes inter-operability among the various federations or parts of them much easier.

The following table shows another interesting and new result: many NRENs say that they are part of **eduroam** and that they see this as a federation in their country.

As the table shows, almost all the EU/EFTA countries are connected to eduroam.

It is important to point out that Web-enabled infrastructures (like Shibboleth) and eduroam are used for different purposes: the first provides federated access to applications, whereas eduroam provides access to a (wireless) network.

NRENs that employ Web-enabled infrastructures or similar (like Shibboleth) technologies also need to define a national schema. The following table shows this.

Note that for many NRENs, AAI is still a relatively new subject; therefore, not all NRENs have answered these questions.

Table 5.4.1 AAI overview

EU/EFTA Countries	NREN	AAI Managed by NREN or Outsourced?	AA Federation?	Schema Used / What Kind?	eduroam[3]	Do You Run a CA?
Austria	ACOnet	outsourced	no		yes	no
Belgium	BELNET	nren	no		yes	yes
Cyprus	CyNet		no		no	no
Czech Republic	CESNET	nren	no		yes	yes
Denmark	UNI•C	nren	no		yes	no
Estonia	EENet	nren	no		yes	yes
Finland	FUNET	nren	yes, Shibboleth-based HAKA (http://www.csc.fi/suomi/funet/middleware/english/index.phtml)	funet-edu-person	yes	no
France	RENATER	outsourced	no		yes	yes
Germany	DFN	nren	no		yes	yes
Greece	GRNET	nren	Yes, Shibboleth based		yes	yes
Hungary	NIIF/HUNGARNET	outsourced	no		yes	yes
Ireland	HEAnet	nren	no		yes	yes
Italy	GARR	outsourced	no		yes	yes
Latvia	LATNET	nren	no		yes connected via LANET	no
Lithuania	LITNET	nren	no		yes	yes
Luxembourg	RESTENA	-	no		yes	no
Malta	CSC	nren	no		yes	no
Netherlands	SURFnet	nren	yes, Shibboleth compatible A-Select (http://a-select.surfnet.nl)		yes	yes
Norway	UNINETT	nren	yes, Shibboleth-compliant FEIDE running a Moria-based federation (http://www.feide.no/index.en.html)	Nor-edu-person	yes	no
Poland	PIONIER	nren	no		yes	yes
Portugal	FCCN	nren	no		yes	
Slovenia	ARNES	nren	yes	siEduPerson	yes	no

[3] The column reports whether there is a national Top Level RADIUS Server in the country and whether it is connected to the European Top Level RADIUS Server operated on behalf of TERENA by SURFnet and UNI•C. All results in the table depict the situation as of March 2006.

EU/EFTA Countries	NREN	AAI Managed by NREN or Outsourced?	AA Federation?	Schema Used / What Kind?	eduroam[3]	Do You Run a CA?
Spain	RedIRIS	nren	yes, shibboleth compatible PAPI (http://papi.rediris.es/)	LDAP-based (see http://www.rediris.es/ldap/esquemas/index.en.html)	yes	yes
Sweden	SUNET	outsourced	no		no	yes
Switzerland	SWITCH	nren	yes, Shibboleth-based SWITCH-AAI (http://www.switch.ch/aai/)	swissEduPerson derived from eduPerson	yes	yes
UK	UKERNA		no		yes	no
Other countries						
Algeria	CERIST	nren	no		no	no
Azerbaijan	AzNET	nren	no		no	no
Azerbaijan	AzRENA	nren	no		no	no
Belarus	BASNET	nren	no		no	no
Bulgaria	IST Foundation	nren	no		yes	no
Croatia	CARNet	outsourced	yes AAI@EduHr http://www.aaiedu.hr/	yes, hrEduPerson i hrEduOrg.	yes	no
Georgia	GRENA	nren	no		no	no
Kazakhstan	KazRENA	nren	no		no	no
Kyrgyzstan	KRENA-AKNET	outsourced	no		no	no
Moldova	RENAM	nren	no		no	no
Morocco	MARWAN		no		no	no
Romania	RoEduNet	nren	no		yes	no
Slovakia	SANET		no		no	no
Turkey	ULAKBIM		no		no	yes
Ukraine	URAN	nren	no		no	yes

5.5 Security Incident Response

Security Incident Response is increasingly being considered as vital to the end users. They expect NRENs to provide such services or to make sure that somebody else provides them.

Table 5.5.1 summarises the information on whether security incident response is provided by the NREN itself, or if it has been outsourced. Often Computer Security Incident Response Teams (CSIRTs) are formed to ensure a timely response to (potential) security threats. International collaboration is of key importance to CSIRTs. A precondition for such collaboration is that CSIRTs have to be able to trust one another. In order to facilitate such trust relationships, TERENA has been instrumental in setting up the Trusted Introducer scheme (see www.trusted-introducer.nl for more information). The table shows which NRENs have CSIRTs that are either accredited with the scheme or candidates for accreditation (note that only the information that is at www.trusted-introducer.nl is fully up-to-date and authoritative).

The table clearly shows that there is still a large difference in this area between EU/EFTA NRENs and NRENs in other countries in the region. Now that many of these countries are getting better connections, we expect to see more Accredited CSIRTs in the future in these countries as well.

Table 5.5.1 Security Incident Response Teams

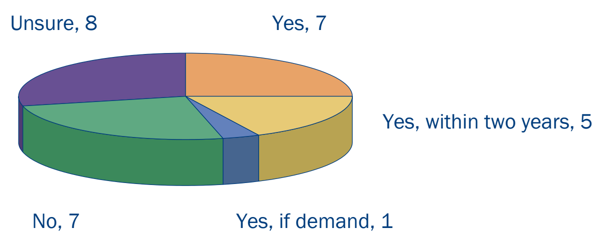
	Security Incident Response by NREN	Outsourced
EU/EFTA Countries	77%	23%
(n=27)	Accredited CSIRT: 58%	
Other Countries	94%	6%
(n=15)	Accredited CSIRT: 6%	

5.6 Bandwidth on Demand

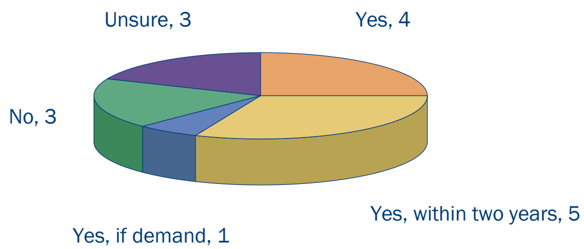
Bandwidth on demand (point-to-point dedicated bandwidth services at layer 2 or below) is being introduced as a new service as part of the GN2 project. The following table provides information on how many NRENs are planning to introduce such a service. Some NRENs have definite plans for this, others would like to find out first what the demand is for such services. Others are not planning to introduce such a service.

Approximately 25% of the NRENs currently offer such a service; approximately the same percentage is planning to introduce it in the next two years, with a significant percentage of NRENs still in doubt.

Graph 5.6.1 Bandwidth on Demand, EU/EFTA Countries



Graph 5.6.2 Bandwidth on Demand, Other Countries



5.7 Grid Services[4]

Grid services have recently become an important area for NRENs. Projects such as EGEE and DEISA aim to introduce a production Grid service for scientific research purposes, making use of distributed computing services. In many cases, the NRENs provide the networking infrastructure for such services.

Table 5.7.1 gives information on whether or not Grid services are currently running over the NREN's network and if such services are planned over the next year or two. The table also lists who provides the Grid service – either the NREN itself, the institutions concerned together with the NREN, the concerned institutions alone, discipline-based groups, virtual organisations or some other body. The geographical extent of the service is also listed.

The data show that Grid services are currently running in twenty (or 71%) of the EU/EFTA NRENs (last year, the figure was 56%); this will rise to nearly 100% over the next two years (with only Iceland and Slovakia not foreseeing Grids being developed in this time frame). Grid services are also running in nine of the seventeen NRENs from other countries in the survey. Six more NRENs from these countries foresee such services being developed in the next two years.

NREN support is involved in running the service in the great majority of cases. The geographical extent of the service is in almost all cases international.

Table 5.7.1 provides an overview of the disciplines that are running Grid-enabled applications. Note that many NRENs indicate that they are not aware of Grid services in certain disciplines. That does not necessarily mean they do not exist; therefore, it seems clear that the responses given do not present the full picture.

The most striking element in the responses is that the uptake of Grid technology has widened very much beyond the initial high energy physics and biomedical communities. All disciplines seem to be well represented.

The answers in the following table are 'now' (service is currently running), 'planned' or '-', the NREN is not currently aware of the situation in that discipline.

[4] Information for this section has been contributed by John Dyer, TERENA.

Table 5.7.1 Disciplines That Are Running Grid-enabled Applications

Country	NREN	High-energy Physics	Other Physics	Computational Chemistry	Other Chemistry	Biomedical	Astroscience	Earth Science	Climatology	Other Disciplines
EU/EFTA Countries										
Austria	ACOnet	now	planned	-	planned	now	planned	-	planned	Applied Numerical Simulation
Belgium	BELNET	now	now	now	-	now	-	-	-	
Cyprus	CyNet	-	planned	-	planned	planned	-	-	-	
Czech Republic	CESNET	now	now	now	now	planned	-	planned	-	
Estonia	EENet	now	now	now	now	planned	planned	-	-	Material Science - Now running
Finland	Funet	now	now	now	planned	planned	now	planned	planned	
France	RENATER									research on grids - supercomputing
Germany	DFN	now	-	-	-	-	-	-	-	
Greece	GRNET	now	-	now	-	now	now	now	now	Regional Catch All Virtual Organisation
Hungary	NIIF/HUNGARNET	now	now	now	now	now	now	now	planned	
Ireland	HEAnet	planned	now	now	now	now	now	now	now	
Italy	GARR	now	now	now	now	now	now	now	-	
Latvia	LATNET	-	now	-	planned	planned	planned	-	-	
Netherlands	SURFnet	planned	-	-	-	-	now	-	planned	
Norway	UNINETT	now	-	planned	-	planned	planned	-	-	
Poland	PIONIER			now						
Spain	RedIRIS	now	now	now	now	now	now	now	now	
Sweden	SUNET	now	now	now	-	now	now	now	-	
Switzerland	SWITCH	planned	-	-	-	planned	-	-	planned	
United Kingdom	UKERNA	now	now	now	now	now	now	now	now	

Country	NREN	High-energy Physics	Other Physics	Computational Chemistry	Other Chemistry	Biomedical	Astroscience	Earth Science	Climatology	Other Disciplines
Other Countries										
Albania	ANA		planned			planned		planned		
Algeria	CERIST	planned	planned	planned	planned	planned	-	planned	planned	
Azerbaijan	AzRENA	planned	planned	planned						
Bulgaria	IST Foundation	planned	planned	planned	-	planned	planned	planned	planned	
Georgia	GRENA	planned				planned	planned			
Israel	IUCC	now	-	-	-	planned	-	planned	-	
Macedonia, FYRo	MARNet					now				
Moldova	RENAM	planned	planned	-	-	planned	-	planned	-	Nanotechnology 3D Imaging
Morocco	MARWAN	planned	planned	planned	-	planned	planned	planned	-	
Romania	RoEduNet	planned	planned	planned	-	-	-	-	-	
Russian Federation	RBNet/RUNNet	now								
Serbia/Montenegro	AMREJ	planned	planned	-	-	-	-	-	-	
Turkey	ULAKBIM	planned	now	now	planned	-	-	planned	-	
Ukraine	URAN									

5.8 IP Telephony [5]

Now that IP telephony and its protocols are becoming more mature and products more manageable, NRENs are starting to deploy it. Table 5.8 summarises the answers that have been received. The last column provides urls to more information on NREN websites.

50% of the NRENs in the EU/EFTA countries are running an IP telephony deployment, while about 30% of the NRENs in other countries are running one. This suggests that the use of IP telephony technology is currently more widespread in EU and EFTA countries.

Another interesting result is that only a few NRENs are exchanging IP telephony traffic with their operators; the reasons for not doing so could be manifold. A possible explanation could be that many IP telephony deployments are mainly experimental and not designed to exchange traffic with operators; another explanation could be that currently IP telephony peering architectures are being defined and operators are not yet ready to support it.

The answers collected point to areas where more work for the community could be done, namely: dissemination, supported by documents on best current practices [6], choosing standard protocols and conducting inter-operability testing, developing relationships with telecommunication operators in order to facilitate the adoption of peering agreements to promote data convergence and cost savings achievable through this kind of peering.

Table 5.8 IP Telephony

Country	NREN	Running IP Telephony?	Protocol Used	Traffic with Telco via IP?	URL to More Information
EU/EFTA Countries					
Austria	ACOnet	no			http://www.at43.at/
Belgium	BELNET	no		no	
Cyprus	CyNet	no		no	
Czech Republic	CESNET	yes	SIP and H.323	Via IP and via PSTN/ISDN	http://www.ces.net/project/05/
Denmark	UNI•C	no	SIP and H.323	no	
Estonia	EENet	no		no	
Finland	Funet	no		no	
France	RENATER	yes			
Germany	DFN	no			
Greece	GRNET	yes	H.323	no	http://www.grnet.gr/index.php?op=modload&modname=Sitemap&action=sitemapviewpage&pageid=198&language=en
Hungary	NIIF/HUNGARNET	yes	SIP, H.323, Skinny	Via IP and via PSTN/ISDN	http://www.voip.niif.hu/
Iceland	RHnet	no			
Ireland	HEAnet	no	H.323	no	
Italy	GARR	yes	H.323	no	
Latvia	LATNET	no			
Lithuania	LITNET	yes	H.323	yes	
Luxembourg	RESTENA	yes	SIP	no	
Malta	CSC	no			

[5] Text contributed by Saverio Niccolini, NEC Europe.
[6] See, for example, the 'IP Telephony Cookbook that was published by TERENA in 2004 and is available on the Web via http://www.terena.nl/activities/iptel/credits.html

Country	NREN	Running IP Telephony?	Protocol Used	Traffic with Telco via IP?	URL to More Information
Netherlands	SURFnet	no		no	
Norway	UNINETT	no			
Poland	PIONIER	yes	SIP	yes	
Portugal	FCCN	yes	SIP	no	
Slovakia	SANET	yes	SIP	no	
Slovenia	ARNES	yes	Cisco Skinny	no	
Spain	RedIRIS	no	other	no	
Sweden	SUNET	yes	SIP	yes	
Switzerland	SWITCH	yes	Cisco	no	
United Kingdom	UKERNA	yes	SIP	no	http://www.ja.net/development/voip/
Other Countries					
Algeria	CERIST	no			
Azerbaijan	AzNET	no		no	
Azerbaijan	AzRENA	yes	SIP	no	
Belarus	BASNET	no		no	
Bulgaria	IST Foundation	no			
Croatia	CARNet	yes	H.323	Via IP and via PSTN/ISDN	
Georgia	GRENA	no			
Israel	IUCC	no			
Macedonia	MARNet	no			
Moldova	RENAM	no		no	
Morocco	MARWAN	no			
Romania	RoEduNet	yes	SCCP	no	
Serbia/Montenegro	AMREJ	no			
Turkey	ULAKBIM	yes	H.323	no	
Ukraine	URAN	no		no	

5.9 Videoconferencing[7]

Videoconferencing is now part of the day-to-day collaboration activities in universities and research centres. Its wide acceptance is partly due to the ever-decreasing prices for high-quality equipment and more user-friendly software and interfaces.

Best practice documents, such as the ones produced under the auspices of TERENA's Task Force on Voice and Video Collaboration (TF-VVC), brought the details of organising such conferences closer to the common, non-expert user level. A videoconferencing system requires a connection to a Multipoint Control Unit (MCU) in order to be used by more than two participants. Software (both free and commercial) and hardware MCUs are available on the market. A numbering method, known as the Global Dialling Scheme, was developed by members of the research and education community to provide a solution that enables easy single and multi-point video and voice conferencing at an international scale. The NRENs were asked whether they make videoconferencing services available to the connected institutions, what types of services are offered and details about the support for GDS. Full information on this is available from the Compendium website.

Table 5.9 Videoconferencing

	NREN Offers Videoconferencing?	
	Yes	No
EU/EFTA Countries	85%	15%
Other Countries	46%	54%

[7] Text contributed by Cătălin Meiroşu, TERENA.

6 Tasks, Staffing and Funding

Note that some NRENs provide services only to the research or education communities in their country. Some provide additional services as well; for example, they administer the country-code top level domain or they connect companies or institutions that are clearly outside of the research or education communities. For the sake of comparability, we have asked NRENs to provide information only about the activities for the research or education communities. For short, we have called these 'NREN activities'.

Section 6.1 provides information about various aspects of NREN Staffing. Section 6.2 deals with NREN Budgets and 6.3 and 6.4 provide more information about Income Sources and Expenditure Categories, respectively.

6.1 Staffing

Since many NRENs contract out part of their work, staff size is not a reliable measure of the amount of person-power that is available to an NREN. This section gives an overview of the staff that is directly employed in NREN activities, plus subcontracted staff, in Full-Time Equivalents (FTE).

Graph 6.1.3 provides that information specifically for technical staff.

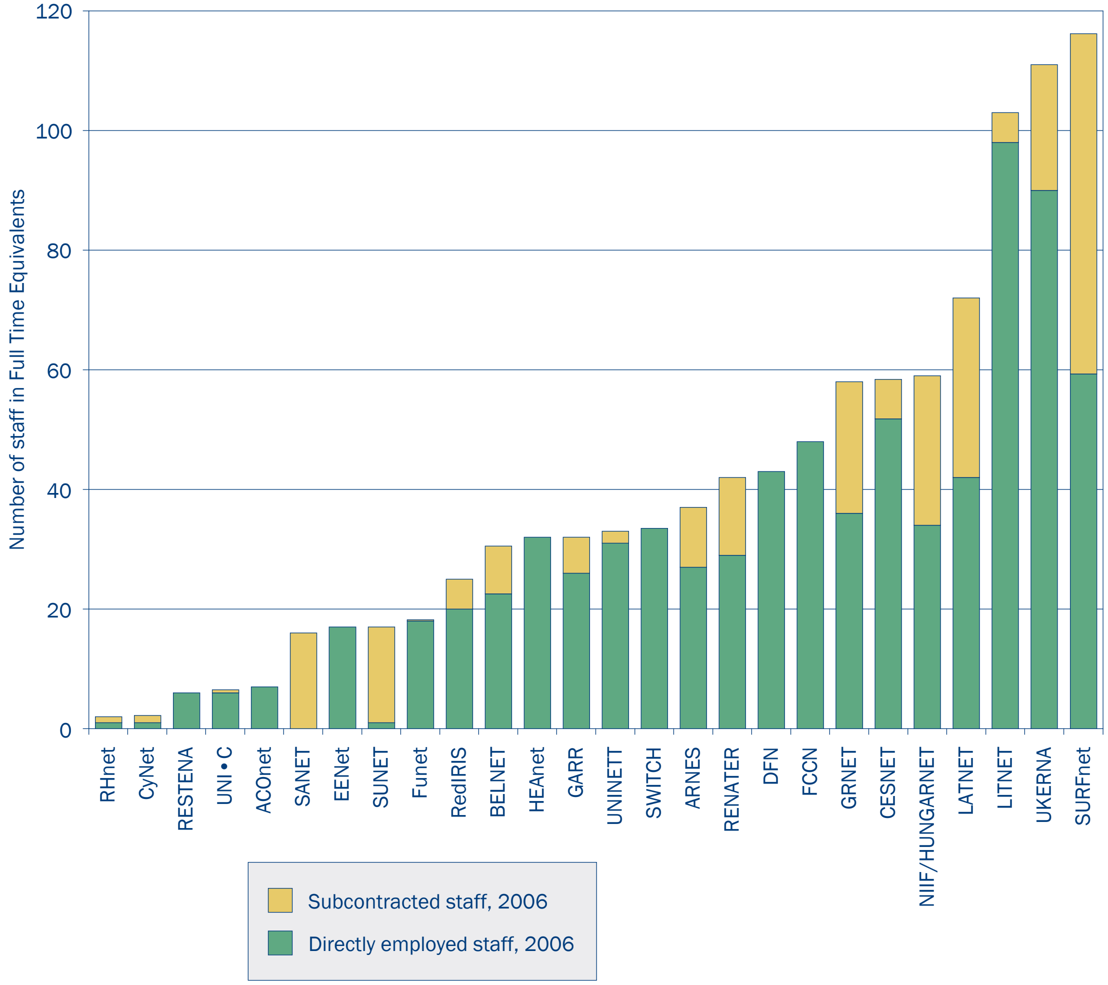
The graphs demonstrate considerable differences in the number of staff NRENs have and in the types of staff they employ.

One explanation is that in some NRENs, the research network is provided as a service by a parent organisation; it is not possible for all those NRENs to give a specific estimate of the non-technical staff time devoted to the NREN functions (e.g., accounting, personnel, etc.). This helps to explain why some NRENs have a high proportion of technical staff to total staff.

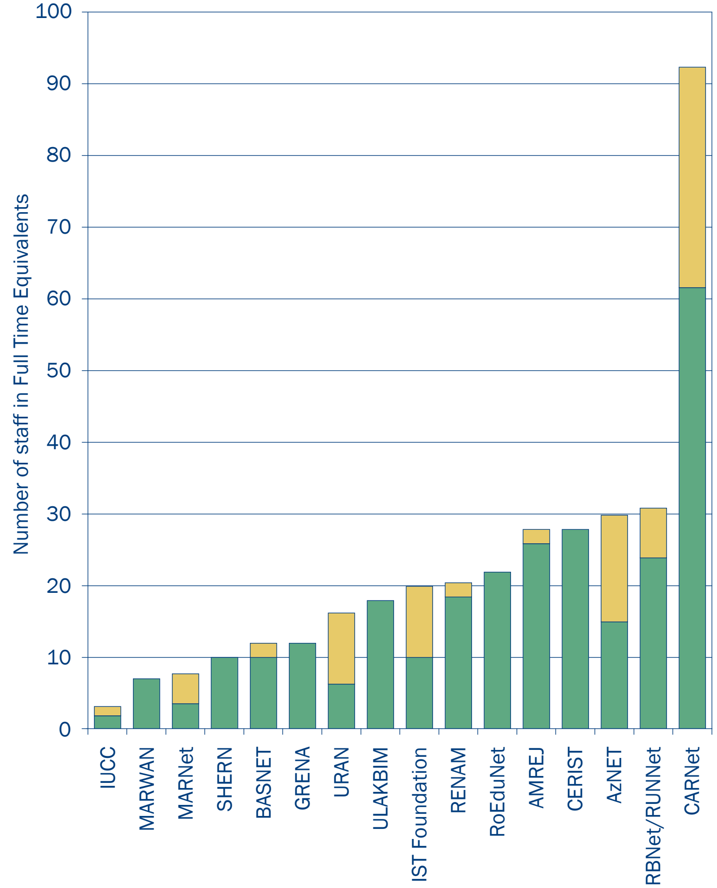
In addition, it should be noted that the tasks performed by individual NRENs are very different. Some NRENs, for example, provide connection to Metropolitan Area Networks or to Access Networks, who, in turn, connect the institutions. Other NRENs connect institutions directly and some also manage MANs themselves. Also, the connection policies of NRENs (see 2.2) are different, for example, with respect to secondary and primary schools. This also explains some of the differences seen in the graphs.

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. Of course, this can also have an important effect on necessary staff levels.

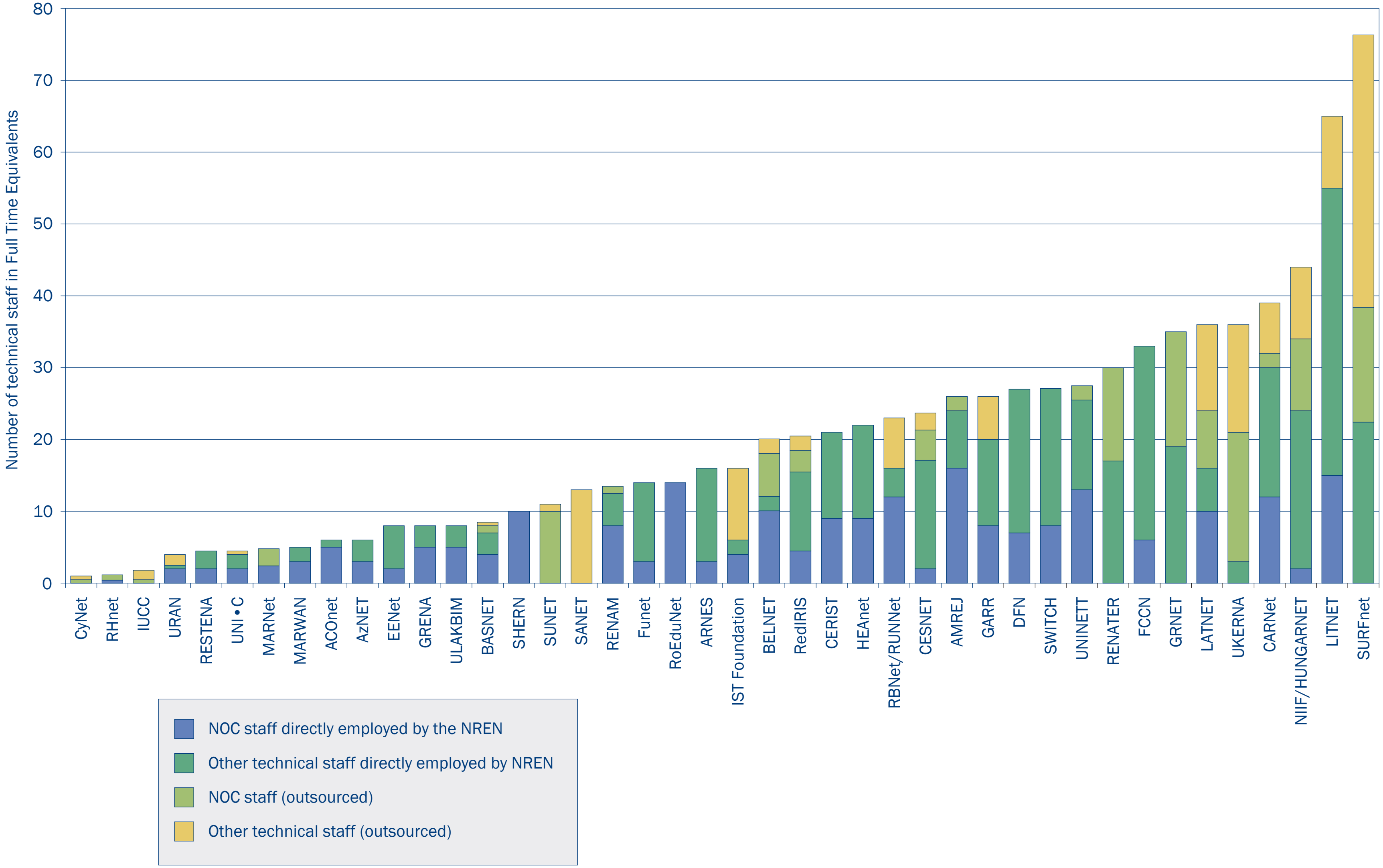
Graph 6.1.1 Total NREN Staff in FTE, EU/EFTA Countries



Graph 6.1.2 Total NREN Staff in FTE, Other Countries



Graph 6.1.3 NREN Technical Staff in FTE[1]



[1] For some NRENs, it may have been difficult to distinguish between the staff that performs Network Operations Centre (NOC) functions and other technical staff.

6.2 Total Budgets, 2005 and 2006

The following graphs give the total NREN budgets for 2005 and 2006.

NREN budgets may fluctuate from year to year, because investments can vary considerably. Note that the budget year of CERIST (Algeria) runs from March to February; while that of UKERNA (UK) runs from August to July. In those cases, the 2005 budget is really the 2005/2006 figure.

As explained in section 6.1, NRENs have many different tasks and are organised in different ways. Some NRENs provide services only to the research or education communities in their country. Others provide additional services as well; for example, they administer the country-code top-level domain or they connect others who are clearly outside of the research or education communities. For the sake of comparability, we have asked NRENs to provide information only about the budget for the activities for the research and education communities in their countries.

Even so, a comparison between the budgets of different NRENs is difficult. We have asked NRENs if the budget figure given includes the EU grant for the GÉANT activity - for some NRENs, this grant is shown in the budget, for others, it appears as a reduced cost and is not shown in the budget.

In graphs 6.2.3 and 6.2.4, the NRENs that include the GÉANT subsidy in their budget have been marked with an asterisk. As can be seen in section 6.3, the proportion of funds received from the EU (not always only for GÉANT) varies considerably between NRENs.

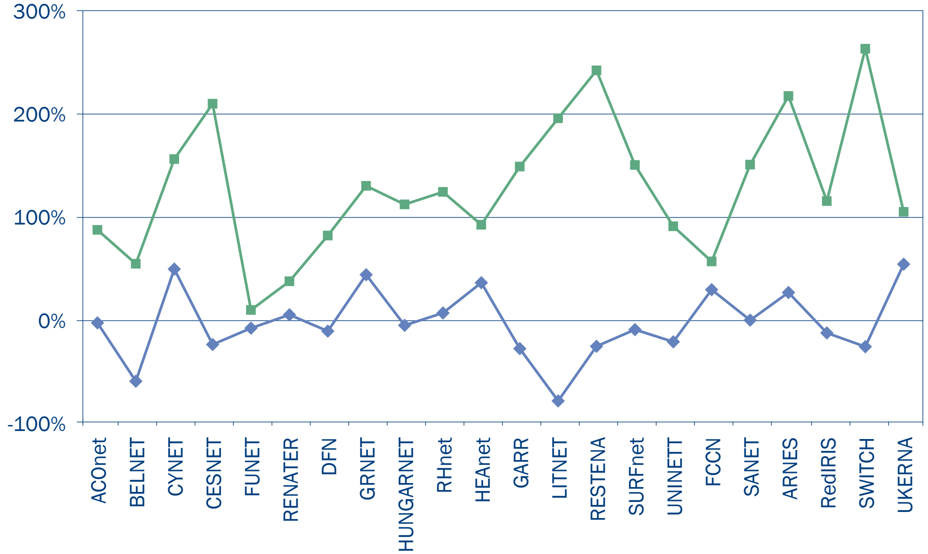
There are also other reasons why comparisons are difficult:

- Funding for regional and/or metropolitan area networks is handled differently in different countries;
- In some countries, clients pay for their line to the nearest NREN PoP; in others the NREN pays for this;
- Some spend a large part of their budget connecting primary and secondary schools; others do not, or may account separately for this;
- In section 6.4, it appears that some NRENs do not spend money on salaries. Yet, they do have staff, but the staff is not paid from the NREN budget. Similar situations may apply for other budget categories as well.

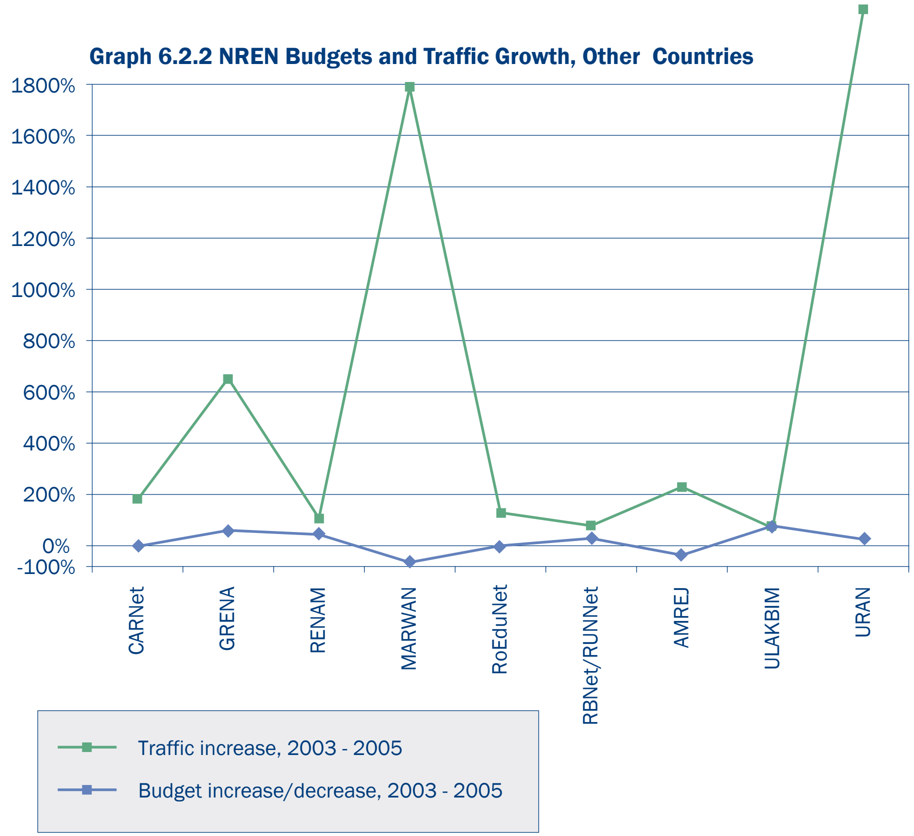
When comparing current budget data with data from past editions of the Compendium, it becomes clear that NREN budgets tend to be stable over time. There are fluctuations from year to year, depending on whether or not an important investment takes place during that year. But on the whole, the trend is that budgets stay relatively stable and that NRENs are able to deliver more bandwidth and more services for roughly the same amount of money.

This trend is illustrated by the following graph, which shows traffic increase vs. budget increase (or decrease). Note that this graph is meant to illustrate the general trend – because of the difficulties in comparing NREN budgets that have been explained, this graph is not suitable for making direct comparisons between NRENs.

Graph 6.2.1 NREN Budgets and Traffic Growth, EU/EFTA Countries



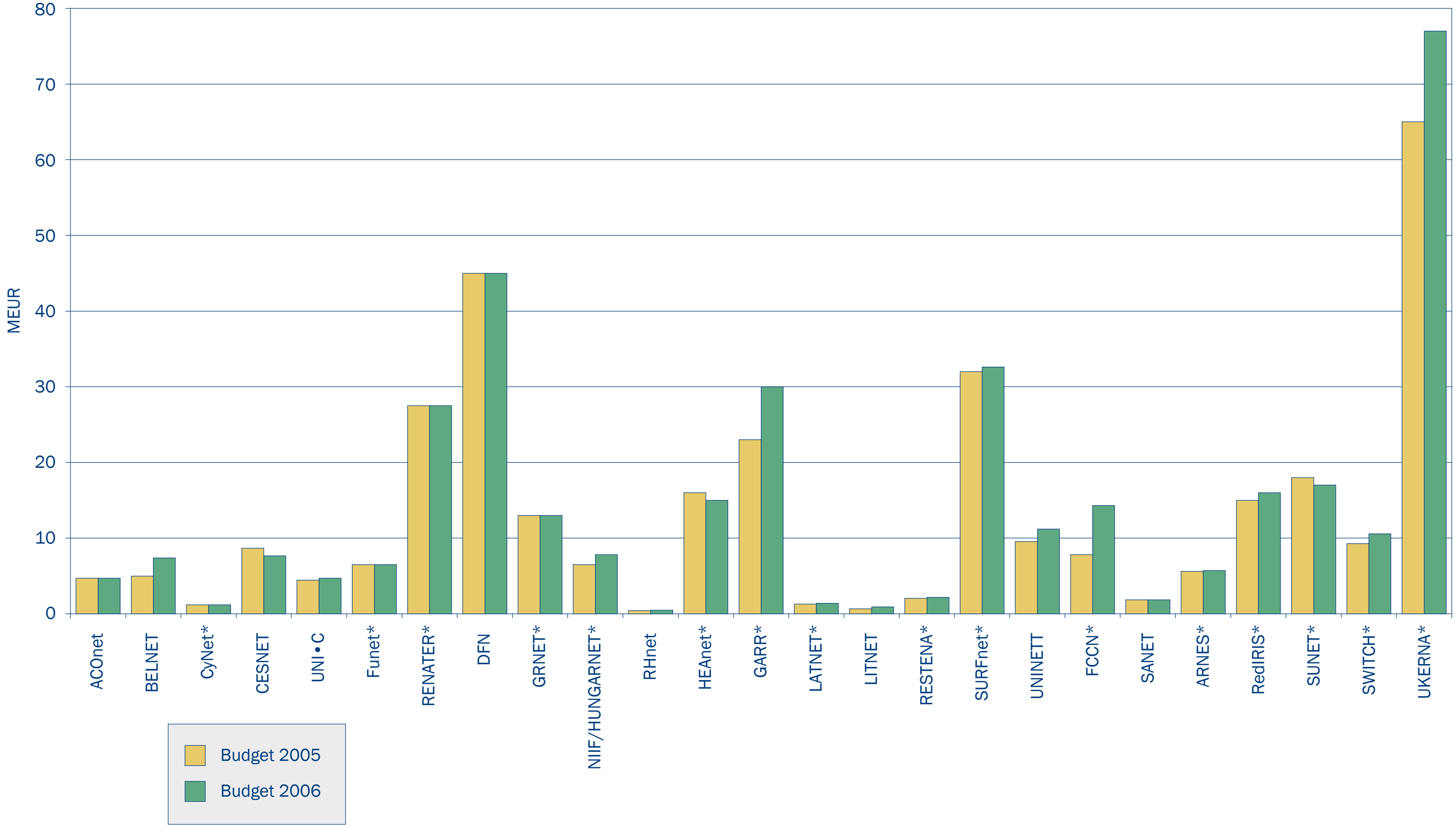
Graph 6.2.2 NREN Budgets and Traffic Growth, Other Countries



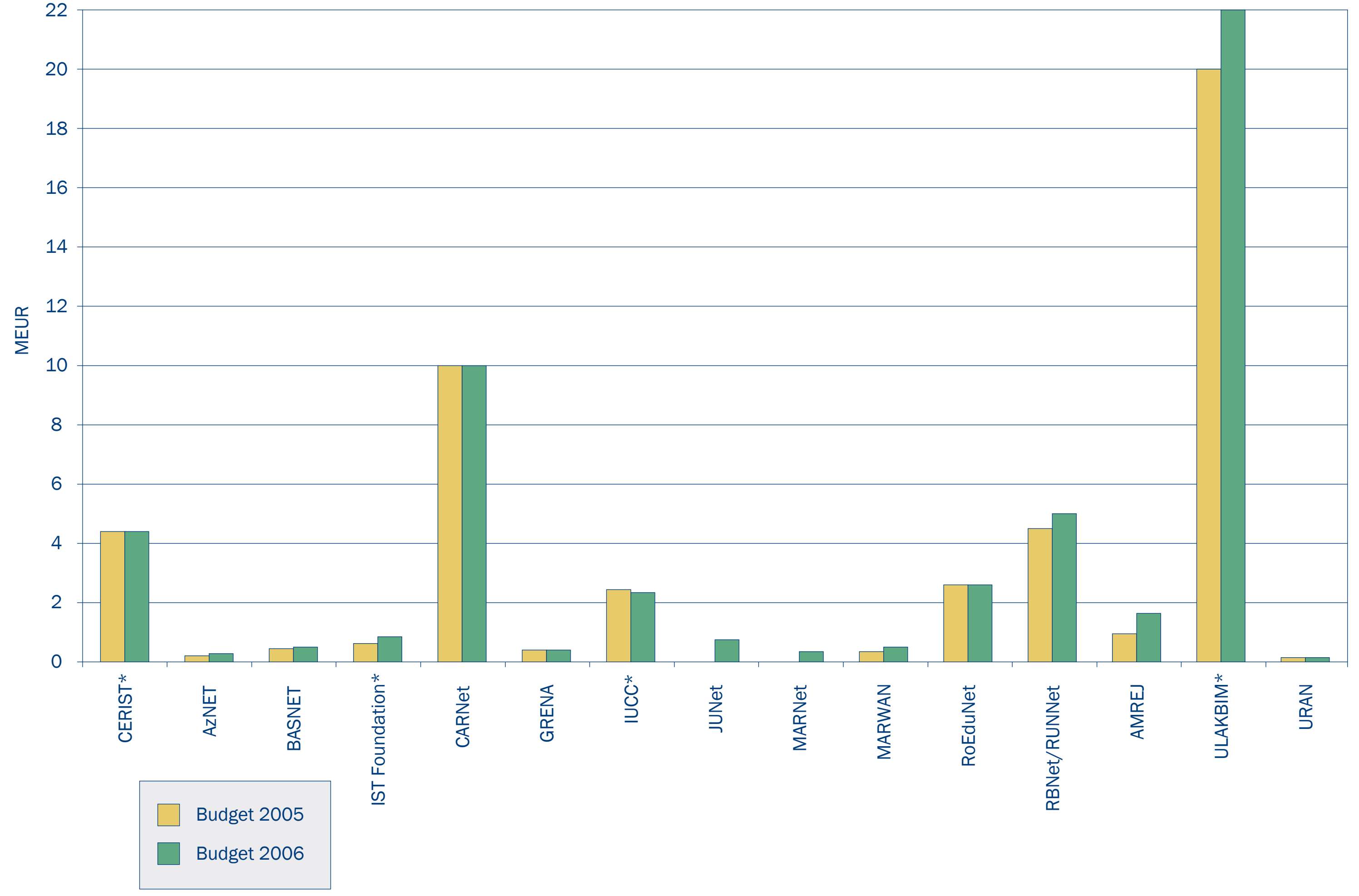
The situation is different in the less developed NRENs. There, new possibilities for significantly upgrading international bandwidth (for example, under the GN2, EUMEDCONNECT or SEEREN projects) seem to act as a catalyst for increased national NREN budgets. A case in point is CERIST of Algeria. In 2005, it received extra funding for a major upgrade of its backbone and of the access network. It could be that this increase has, in fact, been catalysed in part by the improved international connectivity that has become available to CERIST through the EUMEDCONNECT project.

Graph 6.2.2 clearly shows, however, that in these countries a modest increase in budget leads, in many cases, to a great leap in traffic. As is clear from Chapter 5, however, there is often not yet a commensurate increase in services.

Graph 6.2.3 Total Budget 2005 and 2006, EU/EFTA Countries



Graph 6.2.4 Total Budget 2005 and 2006, Other Countries

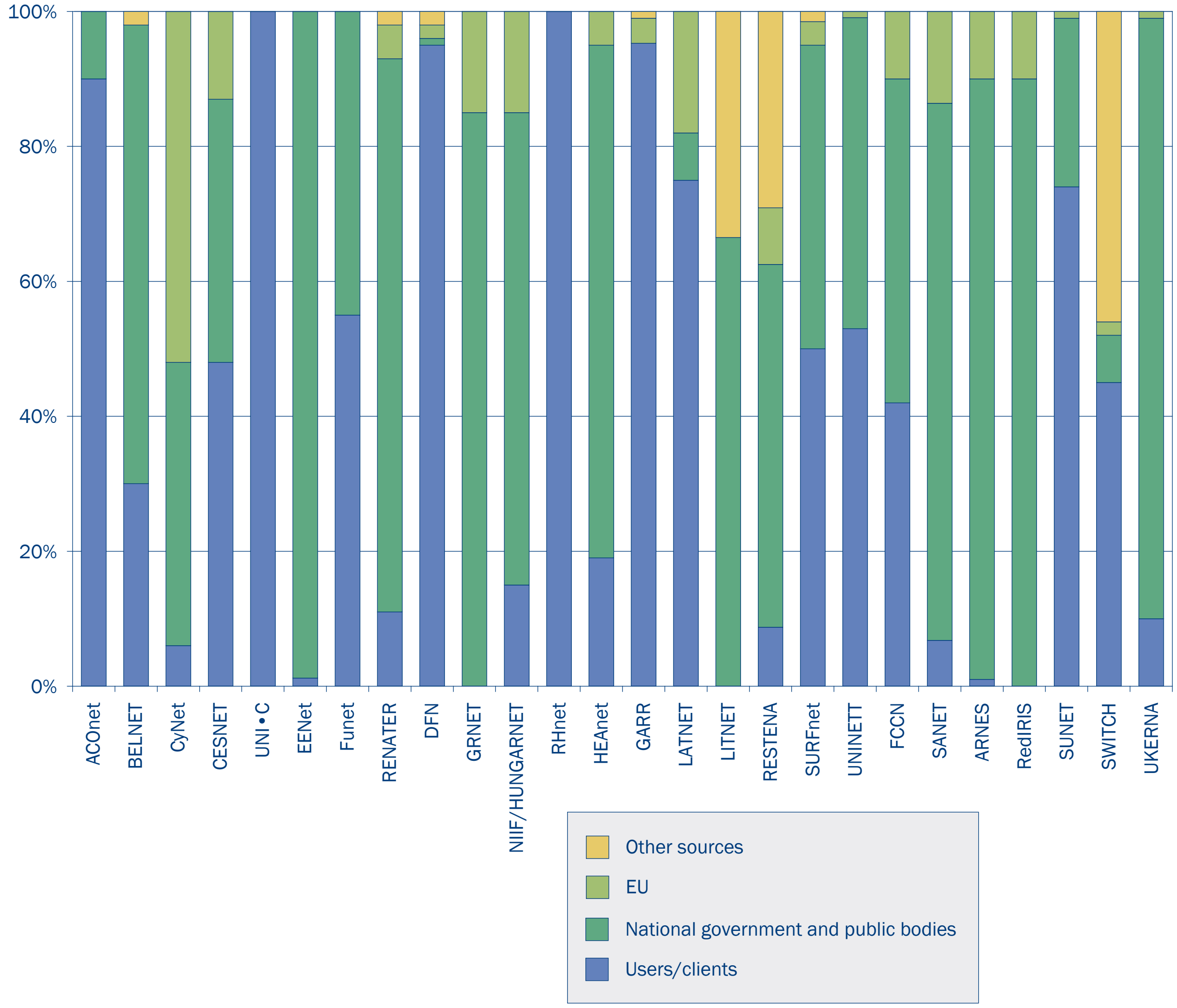


6.3 Income Sources

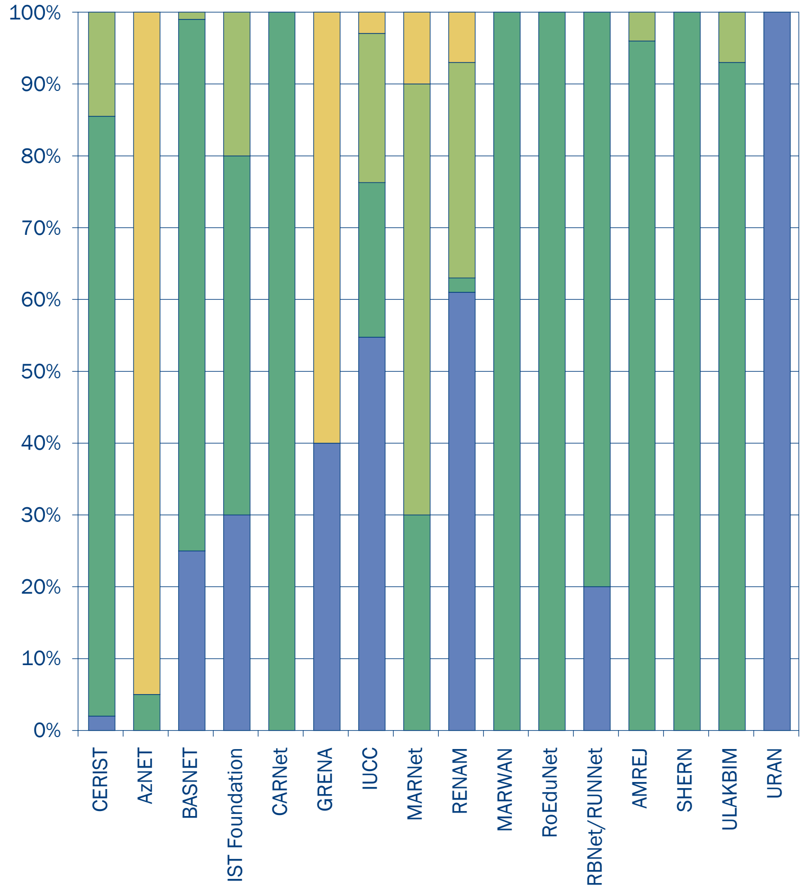
NRENs are funded in different ways: some receive all of their funding directly from the national government, while others are funded largely by their users (who may, in turn, be government-funded). Graphs 6.3.1 and 6.3.2 give information on what percentage of NREN funds come from which source and clearly show the differences. Note that in many cases (see also graph 6.2.3 and 6.2.4) the amount of funding received from the EU is not shown in this table.

> It is impossible to provide general recommendations for NREN funding mechanisms. However, it would seem that a model that involves the various stakeholders of NRENs in some way provides the best guarantees for an NREN's continued success. It should be noted that many NRENs are involved in innovation in their fields. Such innovations are often steered by separate funding mechanisms. It would seem important for NRENs to try to make use of such funds wherever they exist.

Graph 6.3.1 Income Sources, EU and EFTA Countries



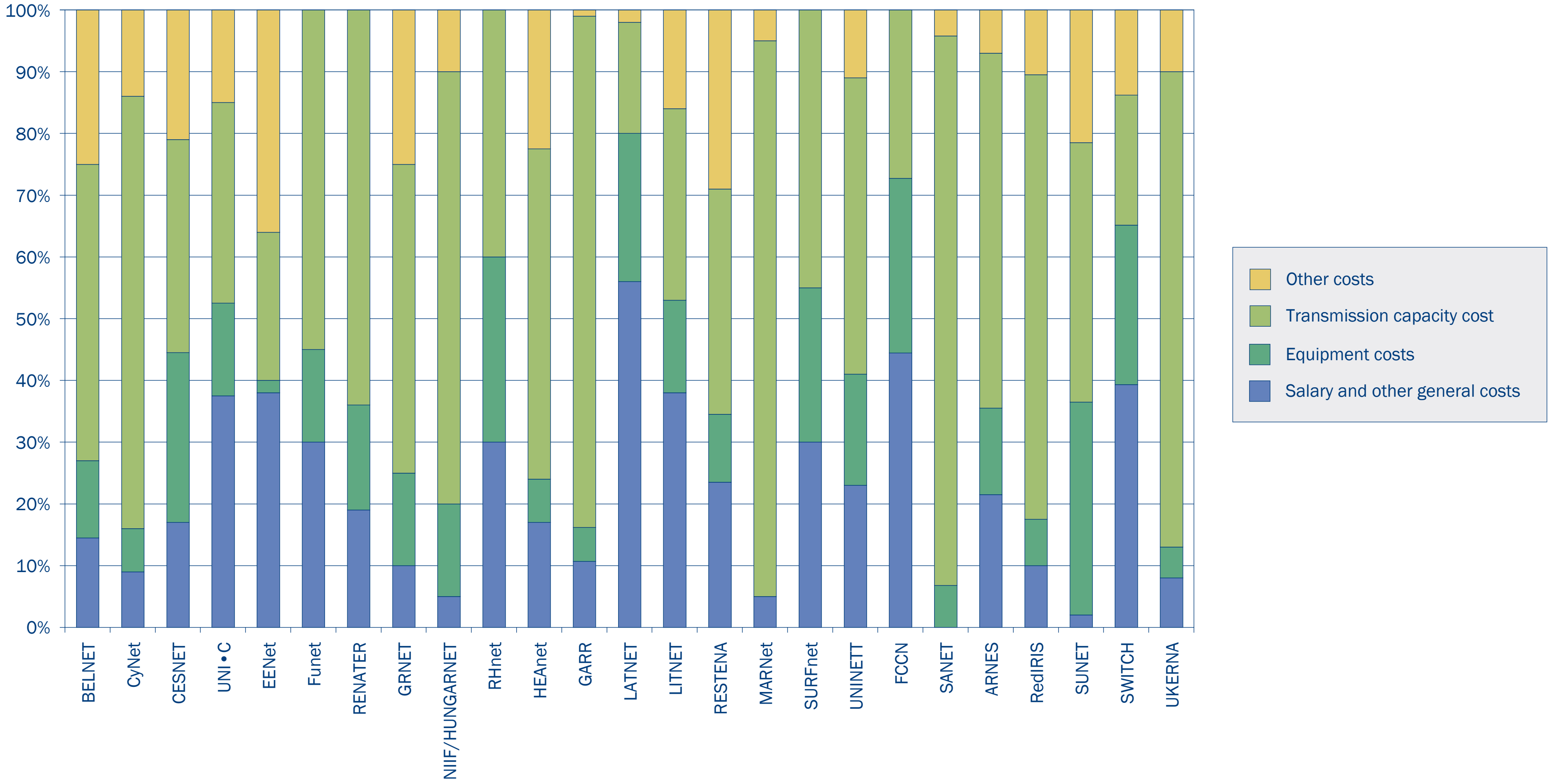
Graph 6.3.2 Income Sources, Other Countries



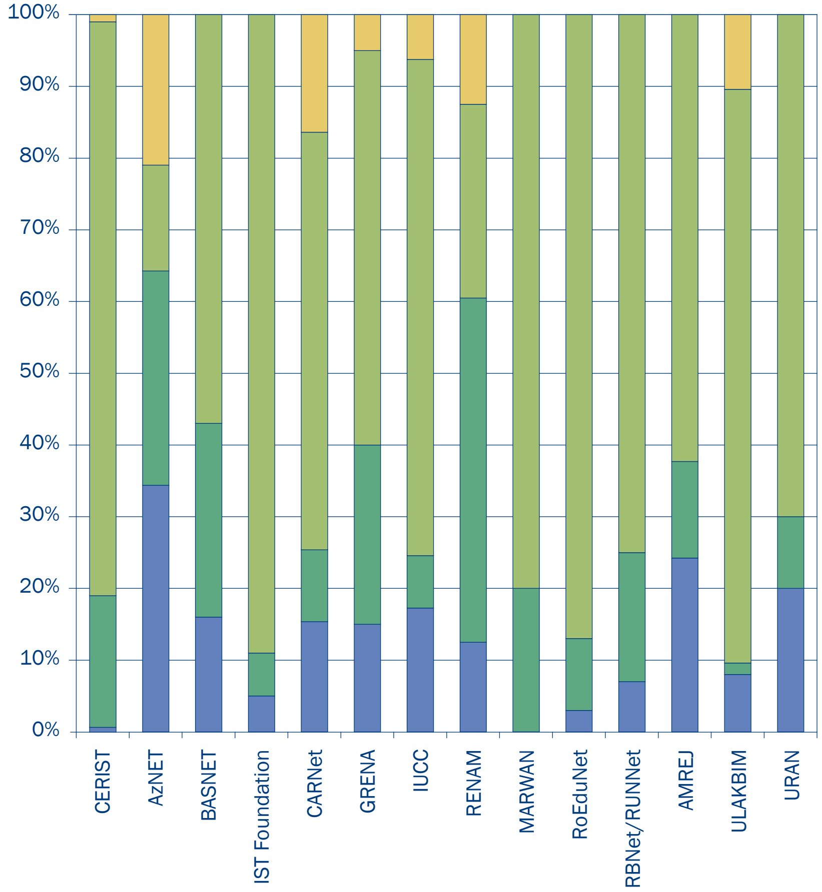
6.4 Expenditure by Category

Graphs 6.4.1 and 6.4.2 show which percentage of NREN income is spent on which categories of expenditure. Because of the influence of investments, these expenditures can fluctuate considerably from year to year. In order to partly compensate for that, the graphs give an average for the years 2005 and 2006. Note that not everything may be funded through the NREN budget in all countries. More information about this can also be found in the "Focus Study on Funding, Management and Operation of European Research Networks: analysed by network hierarchy" by John Martin and Baiba Kaškina, TERENA, May 2004.

Graph 6.4.1 Average Expenditure by Category, 2005/2006 Average, EU and EFTA Countries



Graph 6.4.2 Average Expenditure by Category, 2005/2006 Average, Other Countries



Appendices

1 Alphabetical List of NRENs

Note that the country entries at http://www.terena.nl/compendium contain additional information, including the full name of the NREN in English and in the national language(s). Table 1.1.2 provides the name of the parent organisation where relevant.

NREN Acronym	NREN Acronym in the National Language(s) if Different	European and Mediterranean Countries
ACOnet		Austria
AMREJ		Serbia/Montenegro
ANA		Albania
ARENA		Armenia
ARNES		Slovenia
AzNET		Azerbaijan
AzRENA		Azerbaijan
BASNET		Belarus
BELNET		Belgium
CARNet		Croatia
CERIST		Algeria (operates ARN, the Academic Research Network)
CESNET		Czech Republic
CNRS		Lebanon
CSC		Malta (Computing Services Centre of the University of Malta)
CyNet	KEAD	Cyprus
DFN		Germany
EENet		Estonia
EUN		Egypt
FCCN		Portugal
Funet		Finland (operated by CSC, the Centre for Scientific Computing)
GARR		Italy

NREN Acronym	NREN Acronym in the National Language(s) if Different	European and Mediterranean Countries
GRENA		Georgia
GRNET	EDET	Greece
HEAnet		Ireland
IRANET		Iran
IST Foundation	FTIO	Bulgaria
JANET		UK (in the UK, the network is called JANET; it is operated by UKERNA)
IUCC	MACHBA	Israel
JUNet		Jordan
LATNET		Latvia
LITNET		Lithuania
MARNet		Former Yugoslav Republic of Macedonia
MARWAN		Morocco (operated by the CNRST)
NIIF/HUNGARNET		Hungary
PADI2		Palestine
PIONIER		Poland (in Poland, the network is called PIONIER; it is operated by the Poznań Supercomputing and Networking Centre)
PSNC	PCSS	Operates PIONIER, the Polish network
RBNet/RUNNet		Russian Federation
RED.ES		Spain (in Spain, the network is called RedIRIS; it is operated by RED.ES)
RedIRIS		Spain, see above
RENAM		Moldova
RENATER		France
RESTENA		Luxembourg
RFR		Tunisia
RHnet		Iceland
RNC		Romania
RoEduNet		Romania
SANET		Slovakia

NREN Acronym	NREN Acronym in the National Language(s) if Different	European and Mediterranean Countries
SHERN		Syria
SUNET		Sweden
SURFnet		Netherlands
SWITCH		Switzerland
UARNet		Ukraine
UKERNA		UK – operates the JANET network
ULAKBIM		Turkey
UNI•C		Denmark; operates the Forskningsnettet
UNINETT		Norway
URAN		Ukraine

Appendices

2 Glossary of Terms

Terms not listed in this glossary are either explained in the text or are too specialised to be included here. A good on-line glossary can be found at http://whatis.techtarget.com. A basic introduction to the Internet in general is at http://gnrt.terena.nl/.

AAI	Authentication and Authorisation Infrastructure. An infrastructure typically makes use of a scheme (or 'schema') and transmits information about certain relevant attributes of a person to other institutions (such as in the 'eduPerson' scheme). When several providers of attributes decide to trust each other, they form a 'Federation'.
AUP	Acceptable Use Policy.
Bandwidth on Demand	Point-to-point dedicated bandwidth services.
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).
CA	Certification Authority.
CCIRN	Coordinating Committee for Intercontinental Research Networking.
CEENet	Central and Eastern European Networking Association.
CERN	l'Organisation Européenne pour la Recherche Nucléaire - European Organisation for Nuclear Research.
Confederation	When different Federations agree to share resources.
Congestion index	Is a measure of congestion at different levels of network access. It was developed by Mike Norris of HEAnet.
country name tld	Country-name top-level domain: designation of country names (or 'country domains') used in the Internet, such as .uk, .de or .fr.
CSIRT	Computer Security Incident Response Team.
CWDM	Coarse Wavelength-Division Multiplexing.
DANTE	The company, owned by European NRENs, that plans, builds and operates pan-European networks for research and education.
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 client institution.
DEISA	Distributed European Infrastructure for Supercomputing Applications.
DWDM	Dense-Wavelength Division Multiplexing.
eduroam	A pan-European educational roaming infrastructure that provides wireless access to visited institutions. eduroam allows 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.
EFTA	European Free Trade Association.
EGEE	Enabling Grids for E-sciencE project.
EU	European Union.
EUMEDCONNECT	A project to connect NRENs in the Mediterranean region to the GÉANT network.
European Schoolnet	A not-for-profit organisation that represents twenty-eight ministries of education in Europe that aims to promote the use of technology in the classroom.
Federation	A trust-based collection of AAI schemes.
FTE	Full-time Equivalent.
GBE	Gigabit Ethernet.
GÉANT	A project mainly to develop the GÉANT network, the multi-gigabit pan-European data communications network, reserved for research and education.
GÉANT2	The next generation of the GÉANT network.
GN2	The project to develop the GÉANT2 network and carry out a number of other, related tasks.
Grid computing	Applying the resources of many computers in a network to a single problem at the same time.
Hybrid networking	The seamless integration of two different networking technologies on a network.
Identity Management system	A system that combines technologies and policies to allow institutions to store users' personal information and keep them up-to-date. An IdM is the first building block to provide and control users' access to critical on-line resources and at the same time to protect resources from unauthorised access.
IP	Internet Protocol: the method by which data – in the form of data packets - is sent over the Internet. Currently, the dominant protocol is IPv4. The next generation, IPv6, is currently being implemented.

IPv6	The latest generation of the Internet Protocol. Institutions can have different types of IPv6 connections: • native: direct connection to the NREN via IPv6; • tunnelled, 6to4 and tunnel brokers: techniques for sending IPv6 data packets encapsulated in IPv4 packets.
IPv6 Multicasting	The ability to transmit data to and have a single data stream reach multiple destinations using the IPv6 protocol.
IRU	Indefeasible Right of Use.
ISP	Internet Service Provider.
LAN	Local Area Network.
MAN	Metropolitan Area Network.
MCU (Multipoint control Unit)	Device in videoconferencing that connects two or more audiovisual terminals together into one single videoconference call.
NOC	Network Operations Centre - a place from which a network is supervised, monitored and maintained.
NORDUnet	An international collaboration between the Nordic NRENs. It interconnects these networks and connects them to the greater research and education community and to the commercial Internet.
NREN	National Research and Education Network.
PERT	A Performance Enhancement and Response Team (PERT) is a group of network engineering experts who assist end-users who are experiencing network performance issues.
PKI	Public Key Infrastructure – enables the use of encryption and digital signature services across a wide variety of applications.
PoP	Point of Presence.
RedCLARA	A non-governmental association in Latin America that aims to improve the infrastructure for NRENs in the region and foster their development.
ROADM	Reconfigurable Optical Add/Drop Multiplexing – offers the ability to switch at the wavelength level with the use of remote software.
SDH	Synchronous Digital Hierarchy, an international standard for synchronous data transmission.
SEEREN	South-Eastern European Research & Education Networking project.
Shibboleth	An infrastructure for building Federations and for transferring authentication and authorisation information between sites.
Silk Highway Project	A NATO Scientific Committee sponsored project that provides a satellite-based network that will provide Internet access to scientists and researchers in countries of the Southern Caucasus and Central Asia.

UbuntuNet	A not-for-profit organisation of NRENs that aims to provide the tertiary research and education community is sub-Saharan Africa with increases in connectivity.
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.

What is TERENA?

TERENA is an acronym for the Trans-European Research and Education Networking Association. This is an association of National Research and Education Networks (NRENs) in and around Europe. These NRENs provide advanced, high-speed and high-performance Internet connectivity for universities, research institutions and schools in their countries.

TERENA is first and foremost a collaborative organisation. The development and advances in Internet infrastructures and technology have been led by the academic community since the very beginning of the Internet, some twenty-five years ago. In Europe, this leading role has been made possible by cooperation and collaboration between network engineers, managers and researchers in the academic community all over the region. TERENA and the founding organisations and initiatives that precede it contribute significantly to this leading role.

The core business of the association is to bring together managers, technical specialists and other people in the research networking community with their counterparts from other countries in Europe, mobilizing the expertise and experience of hundreds of professionals in the research and education networking area.

TERENA activities are highly dependent on the human and other resources that are contributed by the research networking community. The membership of TERENA encompasses not only national research and education networking organisations but also regional research networking organisations, research organisations that are large users of networking infrastructure and services, and equipment vendors and telecommunication operators.

Many of the people who participate in TERENA task forces, projects, conferences or workshops are not employees of TERENA member organisations but work the wider research networking community: universities, research institutes or in industry.