

3 Network

This section provides insights 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 and section 3.6 looks at the relatively new area of dark fibre.

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 3.2 provides information about the core usable backbone capacity of NRENs. By this, 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 that case, 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.

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, 5 out of 17 NRENs 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 2005, all 18 NRENs have a capacity of at least 1 Gb/s; the maximum is 10 Gb/s; 6 NRENs operate at this capacity.

In the new EU member states, in 2001, only 1 out of 8 NRENs already had a core capacity of 2.5 Gb/s (CESNET). Only two had a capacity of 155 Mb/s, all the others were operating at a lower capacity. In 2005, 5 of these NRENs had a capacity of at least 1 Gb/s; the lowest capacity was 45 Mb/s.

In the non-EU/EFTA GN2 partners, the situation is a bit less good, with only 2 out of 6 NRENs in this category operating at a capacity of at least 1 Gb/s.

We have data from 15 other NRENs. In 2005, 5 of these operated at 1 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 stages that the EU/EFTA NRENs went through.

The overall trend is that there is considerable growth year on year, with the new EU member states and the non-EU/EFTA countries to the fore in expansion¹.

¹See section 3.2.3 for country-by country data.

Network size

The same trend is also visible when looking at overall network size. By summing the product of bandwidth by distance for each link in a backbone network, we get a rough indicator of the size of a network, in terms both of geographic scale and transmission capacity. Of course it is a rough metric. Nonetheless, it can be useful in monitoring trends within NRENs and across many NRENs over time.

The 2005 survey shows some big changes in the Bandwidth x Distance metric for some countries, while others have remained the same, even since 2001. This may reflect the relatively long time-scale associated with backbone re-design. The average per annum per NREN growth is 136%, and this figure covers a range from 0%/year (no change in network scale) to over 400%/year scale-up. Note that growth in this area is never linear, but is always step-wise.

Table 3.1.1 Bandwidth growth 2001 - 2005²

Group of NRENs	Annual growth of Bandwidth x Distance
EU-15/EFTA	77%
New EU member states	201%
EU/EFTA	119%
Other	166%
ALL	136%

²See See section 3.4 for country-by-country data

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. NRENs also often 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.

It is interesting to note that some NRENs (SURFnet, CESNET, SANET, SWITCH) have their own 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. 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.

<http://www.silkproject.org/>

Dark fibre

There are indications that more and more NRENs are switching over to dark fibre as the technology of the future, with the EU NRENs being in the lead. The table below shows the number of NRENs that currently has at least two-thirds of its backbone as dark fibre, as well as the prediction for early 2007.

Table 3.1.2 Dark fibre on NREN backbones³

Group of NRENs	Number of NRENs in the survey	Proportion with at least two-thirds dark-fibre backbone now	Proportion with at least two-thirds dark-fibre backbone, early 2007
EU-15/EFTA	17	24%	53%
New EU member states	9	44%	44%
Non-EU/EFTA GN2 partners	6	0%	33%

³See See section 3.6 for country-by-country data. Data from other countries ws not fully reliable and has therefore not been included

As well as providing NRENs with the ability to better control, manage and exploit their network infrastructures, dark fibre provides new opportunities to enable users to define their own dedicated end-to-end links across the network, and to do so within fixed NREN budgets. In this sense, the uptake of dark fibre where it is possible is to be commended. Indeed, the procurement of the new GÉANT2 network has endorsed this development and has provided a pan-European dark fibre footprint, already linking fifteen countries.

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.

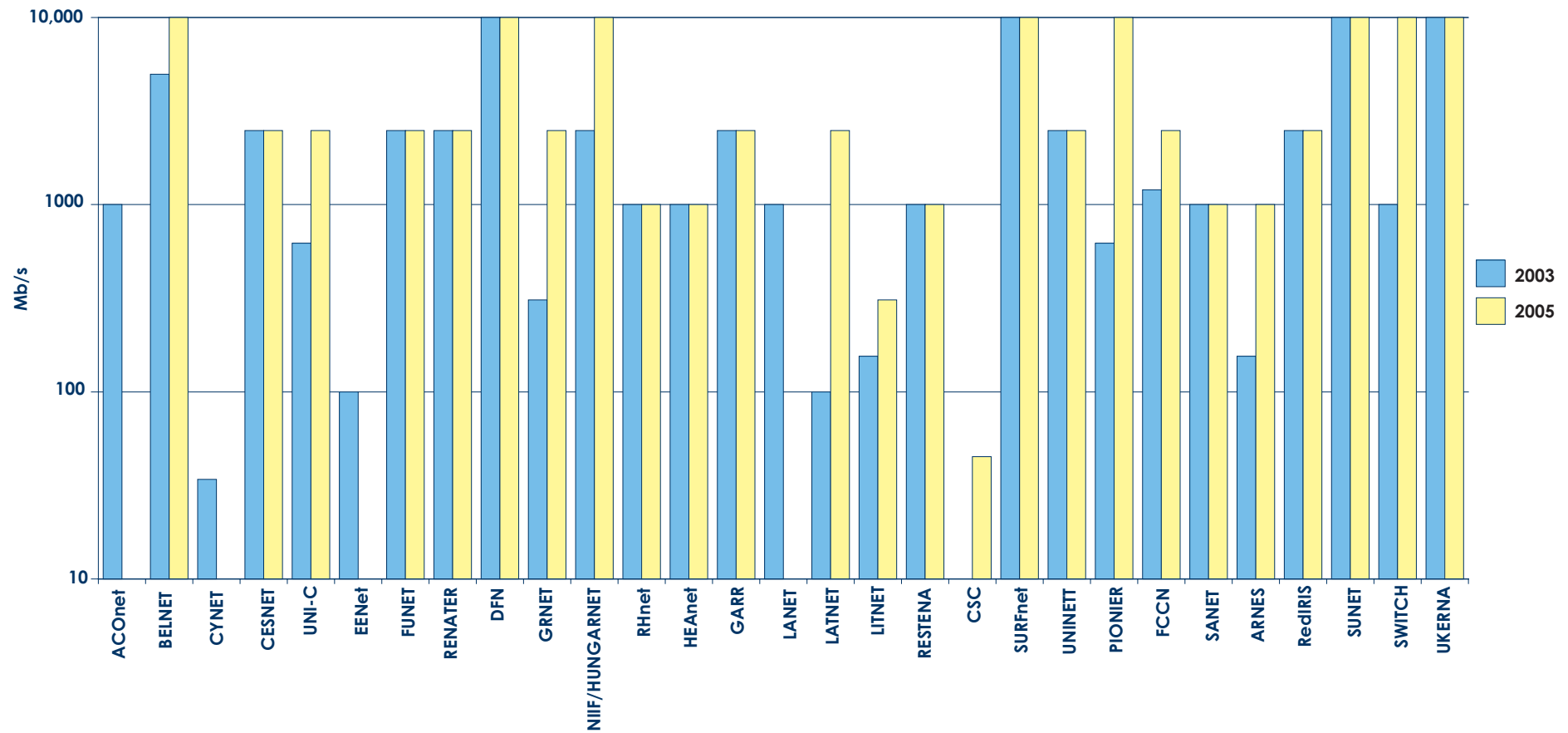
Some NRENs have dark fibre with a very high theoretical capacity. In those cases, we have asked for the usable IP capacity.

Graphs 3.2.1 and 3.2.2 give an idea of the evolution of network capacity from 2003 to 2005. For presentational purposes, the information is given in two graphs: 3.2.1 for the EU and EFTA countries, graph 3.1.2 for the other countries.

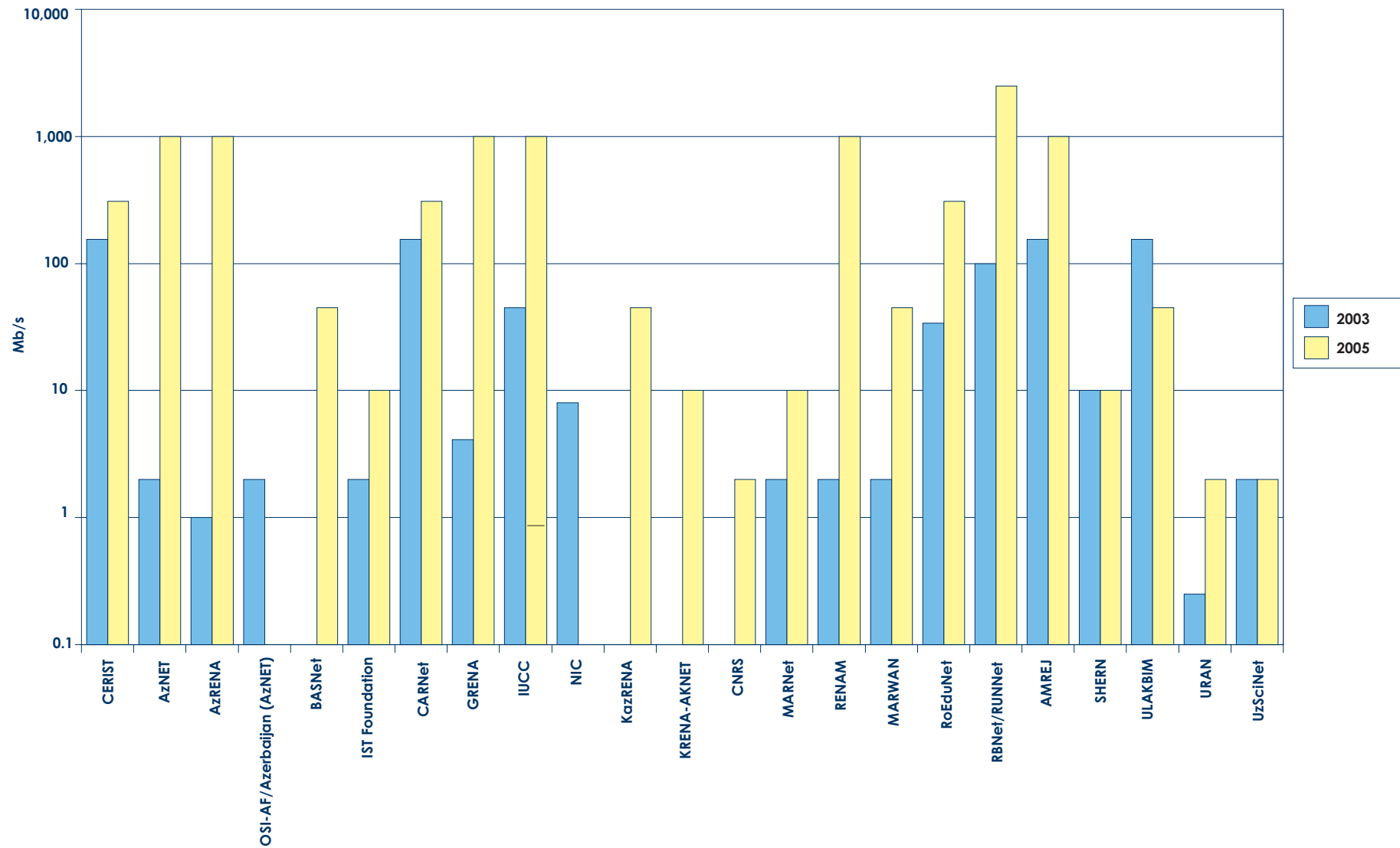
Note that the scales are logarithmic and not the same for the two graphs !

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.

Graph 3.2.1 Core capacity on the networks, 2003 - 2005, EU and EFTA countries



Graph 3.2.2 Core capacity on the networks, 2003 – 2005, other countries



In the table below, capacities of over 1 Gb/s have been colour-coded for increased readability.

Table 3.2.3 Core capacity on the network, 2001 – 2005

	NREN	2001	2002	2003	2004	2005
EU-15/EFTA countries						
Austria	ACOnet	155	1000	1000	1000	
Belgium	BELNET	622	1000	4976	4976	10000
Germany	DFN	622	2488	10000	10000	10000
Portugal	FCCN	180	180	1200	1200	2488
Finland	FUNET	2488	2488	2488	2488	2488
Italy	GARR		2488	2488	2488	2488
Greece	GRNET		310	310	2488	2488
Ireland	HEAnet	155	310	1000	1000	1000
Spain	RedIRIS	155	155	2488	2488	2488
France	RENATER	2488		2488	2488	2488
Luxembourg	RESTENA	10	1000	1000	1000	1000
Iceland	RHnet		1000	1000	1000	1000
Sweden	SUNET	622	10000	10000	10000	10000
Netherlands	SURFnet	2488	10000	10000	10000	10000
Switzerland	SWITCH	310		1000	1000	10000
United Kingdom	UKERNA	2488	2488	10000	10000	10000
Denmark	UNI•C	622	622	622	1000	2488
Norway	UNINETT	2488	2488	2488	2488	2488
New EU member states						
Slovenia	ARNES	100	100	155	310	1000
Czech Republic	CESNET	2488	2488	2488	2488	2488
Malta	CSC				100	45
Cyprus	CYNET			34	34	
Estonia	EENet	24	60	100	100	1000
Latvia	LANET			1000	1000	
Latvia	LATNET	100	100	100	100	2488
Lithuania	LITNET	4	155	155	155	310

	NREN	2001	2002	2003	2004	2005
Hungary	NIIF/HUNGARNET	155	2488	2488	2488	10000
Poland	PIONIER	155	155	622	10000	10000
Slovakia	SANET	4	1000	1000	1000	1000
Non-EU/EFTA GN2 partners						
Croatia	CARNet	155	155	155	155	310
Bulgaria	IST Foundation			2	100	10
Israel	IUCC			45	45	1000
Russian Federation	RBNet/RUNNet			100		2488
Romania	RoEduNet			34	155	310
Turkey	ULAKBIM	34	34	155	155	45
Other countries						
Azerbaijan	AzNET			2	1000	1000
Azerbaijan	AzRENA			1	5	1000
Belarus	BASNet					45
Algeria	CERIST			155	155	310
Lebanon	CNRS				0.448	2
Georgia	GRENA	0.896	2.048	4.1	4	1000
Iran	IRANET				56	
Kazakhstan	KazRENA					45
Kyrgyzstan	KRENA-AKNET				4	10
Macedonia, FYRo	MARNet	0.5	2	2		10
Morocco	MARWAN			2	34	45
Jordan	NIC		18	8	8	
Moldova	RENAM			2	4	1000
Serbia/Montenegro	AMREJ		2	155	500	1000
Syria	SHERN			10		10
Ukraine	URAN		0.128	0.25	0.128	2
Uzbekistan	UzSciNet		2	2	2	2

3.3 Expected change in the core capacity in two years' time

The following table gives the current core capacity, the expected increase in two years' time and the expected (computed) core capacities for early 2007. 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 and pricing and the availability of sufficient funds for investment.

have been colour-coded.

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

Table 3.3.1 Expected change in the core capacity in two years' time

For improved readability, capacities of over 1 Gb/s

	NREN	2005	Increase or comment	2007
EU-15/EFTA Countries				
Belgium	BELNET	> 5 Gb/s ≤ 10 Gb/s	20 Gb/s	20000
Denmark	UNI•C	> 1.2 Gb/s ≤ 5 Gb/s	10Gb/s	10000
Finland	FUNET	> 1.2 Gb/s ≤ 5 Gb/s	network will be upgraded if (and where) needed to the next step	
France	RENATER	> 1.2 Gb/s ≤ 5 Gb/s		
Germany	DFN	> 5 Gb/s ≤ 10 Gb/s	more than 10 Gb/s	20000
Greece	GRNET	> 1.2 Gb/s ≤ 5 Gb/s	Dark fiber will be leased for serving the GRNET backbone. The PoP connections will be served via multimedia (C/DWDM) connections. The total capacity for each backbone link is expected to be nX10Gbps	10000
Iceland	RHnet	> 622 Mb/s ≤ 1.2 Gb/s	≤ 10Gb	10000
Ireland	HEAnet	> 622 Mb/s ≤ 1.2 Gb/s	10 Gb/s	10000
Italy	GARR	> 1.2 Gb/s ≤ 5 Gb/s		
Luxembourg	RESTENA	> 622 Mb/s ≤ 1.2 Gb/s	same	1000
Netherlands	SURFnet	> 5 Gb/s ≤ 10 Gb/s	Multiples of 10 Gbit/s per link	20000
Norway	UNINETT	> 1.2 Gb/s ≤ 5 Gb/s	One 10 Gbit/s, parallel, 2,5 Gbit/s, Gigabit Ethernet	10000
Portugal	FCCN	> 1.2 Gb/s ≤ 5 Gb/s	> 10 Gbps	20000
Spain	RedIRIS	> 1.2 Gb/s ≤ 5 Gb/s	n * 10 Gbps	20000
Sweden	SUNET	> 5 Gb/s ≤ 10 Gb/s	4 x 10 Gbit/s	40000
Switzerland	SWITCH	> 5 Gb/s ≤ 10 Gb/s	still 10 Gb/s on the backbone links, may be backbone links, may be multiple parallel 10 Gb/s links	10000
United Kingdom	UKERNA	> 5 Gb/s ≤ 10 Gb/s	10 - 40Gb/s	20000
New EU member states				
Cyprus	CYNET	2 Mbit/s or below	Increase by a factor of 3	6
Czech Republic	CESNET	> 1.2 Gb/s ≤ 5 Gb/s	10	10000
Hungary	NIIF/HUNGARNET	> 5 Gb/s ≤ 10 Gb/s	No drastical change	

	NREN	2005	Increase or comment	2007
Latvia	LATNET	> 1.2 Gb/s =< 5 Gb/s		
Lithuania	LITNET	> 155 Mb/s =< 622 Mb/s	622 Mb/s-1.2 Gb/s	1000
Malta	CSC	> 34 Mb/s ≤ 155 Mb/s		
Poland	PIONIER	> 5 Gb/s ≤ 10 Gb/s		
Slovakia	SANET	> 622 Mb/s ≤ 1.2 Gb/s	10 Gbps	10000
Slovenia	ARNES	> 622 Mb/s ≤ 1.2 Gb/s	10 Gbit/s	10000
Non-EU/EFTA GN2 partners				
Bulgaria	IST Foundation	> 2 Mb/s ≤ 34 Mb/s	> 155 Mb/s ≤ 622 Mb/s	310
Croatia	CARNet	> 155 Mb/s ≤ 622 Mb/s	1 Gb/s	1000
Israel	IUCC	> 622 Mb/s ≤ 1.2 Gb/s	1Gb/sec	1000
Romania	RoEduNet	> 155 Mb/s ≤ 622 Mb/s	> 5 Gb/s ≤ 10 Gb/s	10000
Russian Federation	RBNet/RUNNet	> 1.2 Gb/s ≤ 5 Gb/s	5Gb/s	
Turkey	ULAKBIM	> 34 Mb/s ≤ 155 Mb/s	>622 Mb/s ≤ 1.2 Gb/s	1000
Other Countries				
Algeria	CERIST	> 155 Mb/s ≤ 622 Mb/s	between 622 Mb/s and 1.2 Gb/s	1000
Azerbaijan	AzNET	> 622 Mb/s ≤ 1.2 Gb/s		
Azerbaijan	AzRENA	> 622 Mb/s ≤ 1.2 Gb/s		
Belarus	BASNet	> 34 Mb/s ≤ 155 Mb/s	Will be a growth by a factor of five	
Georgia	GRENA	> 622 Mb/s ≤ 1.2 Gb/s		
Kazakhstan	KazRENA	> 34 Mb/s ≤ 155 Mb/s		
Kyrgyzstan	KRENA-AKNET	> 2 Mb/s ≤ 34 Mb/s	30% Increase	34
Lebanon	CNRS	2 Mbit/s or below	3 Mbit/s	3
Macedonia, FYRo	MARNet	> 2 Mb/s ≤ 34 Mb/s	We will have gigabit MAN in Skopje University	
Moldova	RENAM	> 622 Mb/s ≤ 1.2 Gb/s	factor 1,5	1244
Morocco	MARWAN	> 34 Mb/s ≤155 Mb/s	155 Mb/s ≤ 622 Mb/s	310
Serbia/ Montenegro	AMREJ	> 622 Mb/s ≤ 1.2 Gb/s		
Syria	SHERN	> 2 Mb/s ≤ 34 Mb/s	the same	10
Ukraine	URAN	2 Mbit/s or below	34...155 Mbit/s	45
Uzbekistan	UzSciNet	2 Mbit/s or below	2	2

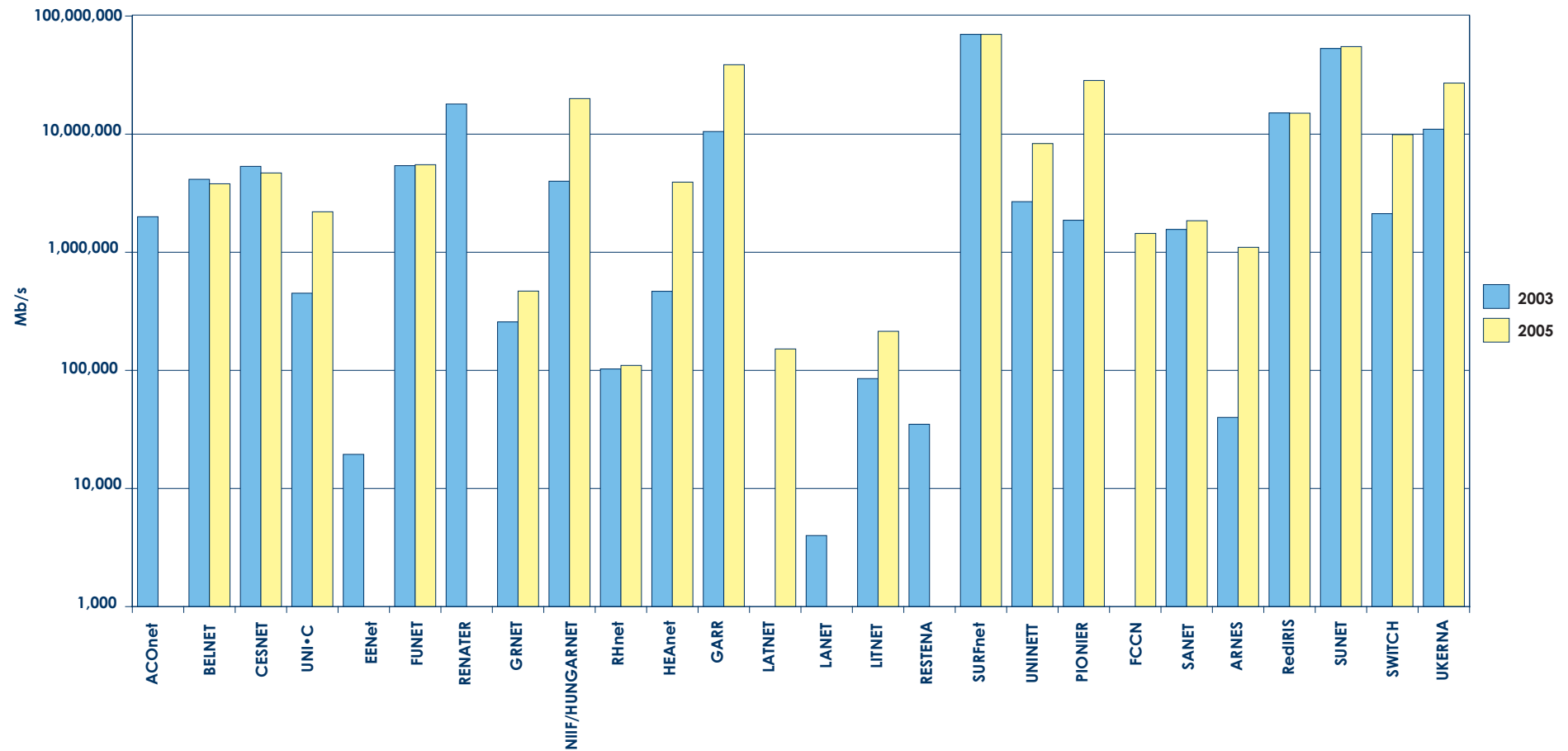
3.4 Core network size

Like earlier years, we have asked NRENs 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.

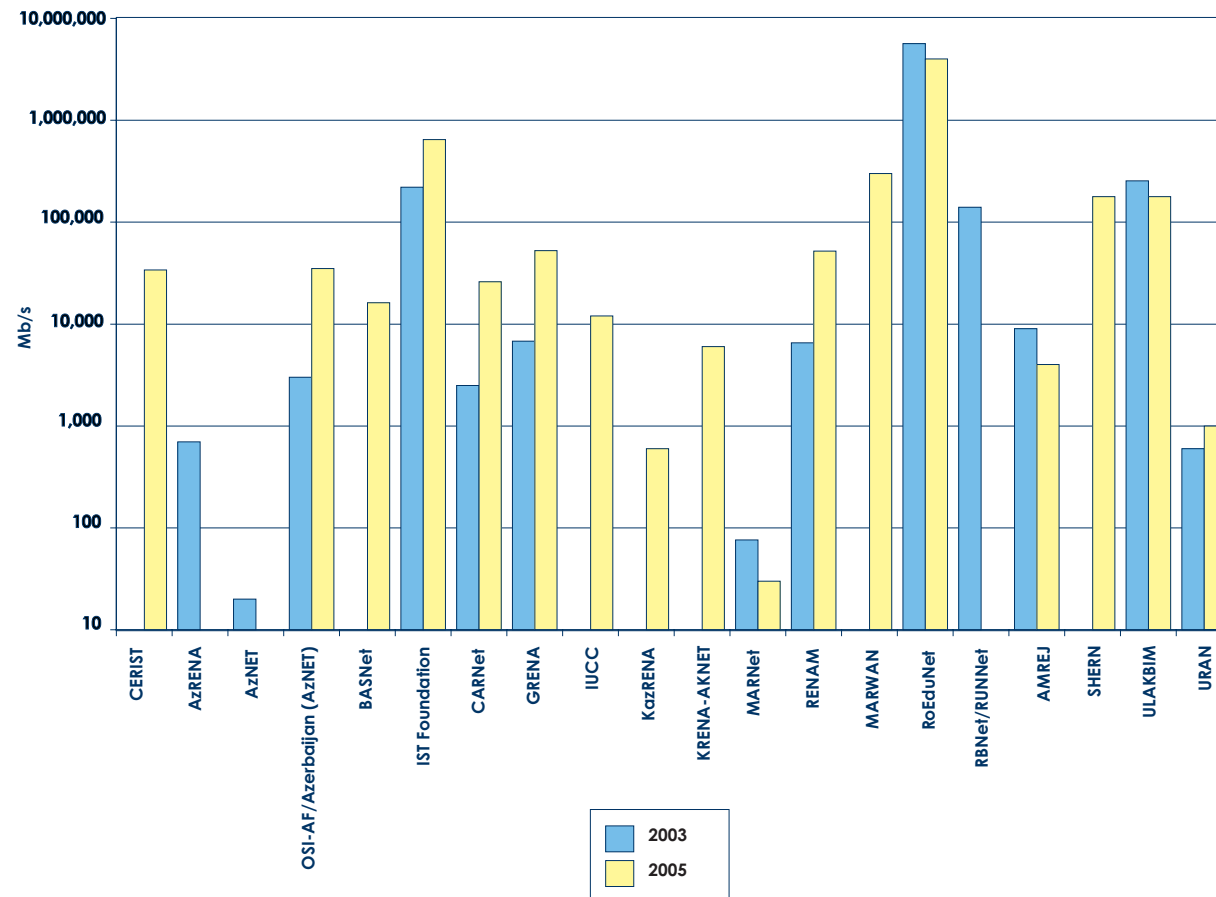
The resulting unit is network size in Mb/s x km. This question is difficult to answer for some NRENs, but because it has been asked for a number of years, the answers have improved..

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 - 2005: EU and EFTA countries



Graph 3.4.2 Core Network size 2003 - 2005: other countries



3.5 External connectivity: total external links

NRENs have been asked to list all of their external connections in January 2005.

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.

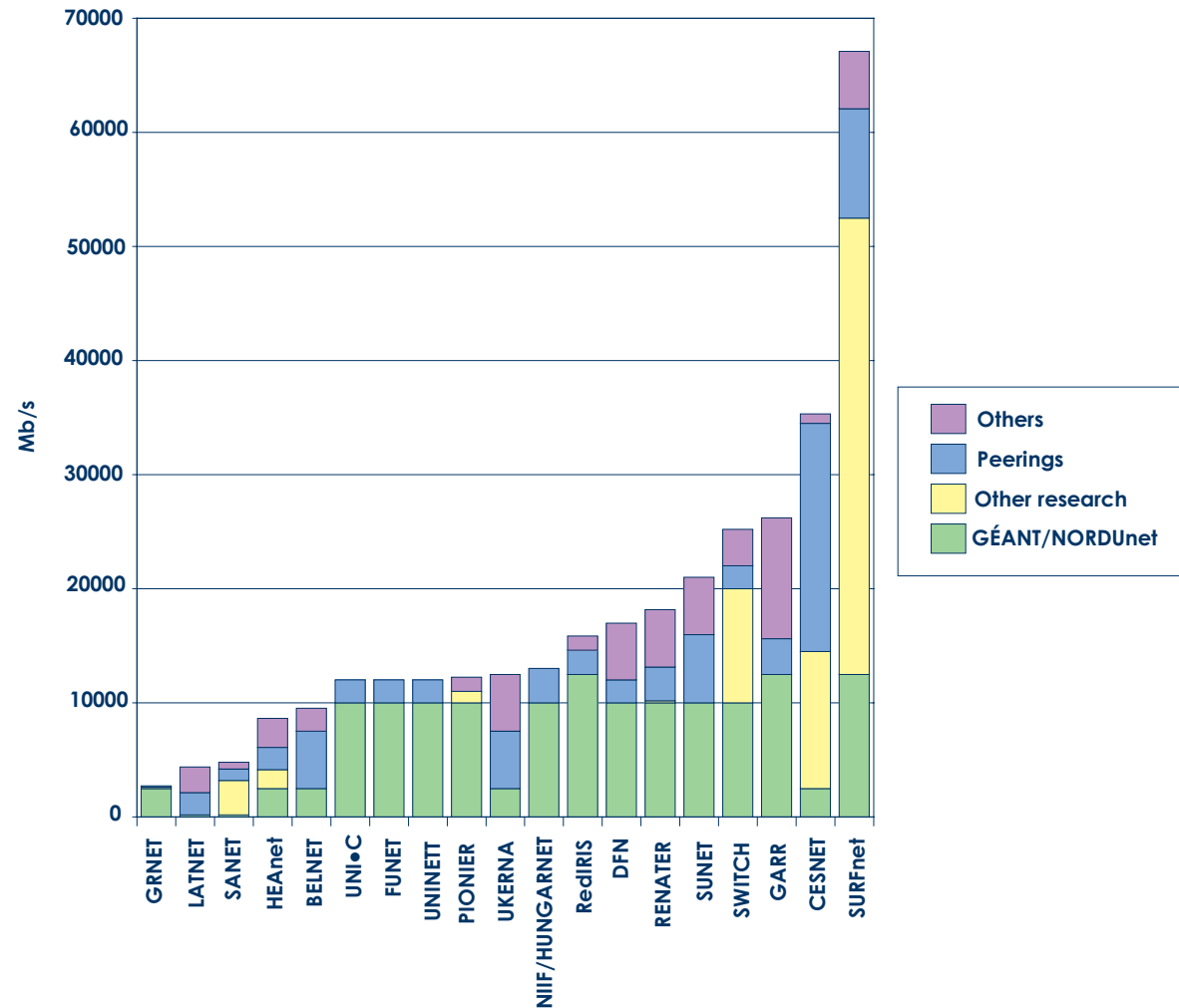
‘Other research’ includes links to other NRENs, the links of several Central Asian NRENs to DFN via the Silk Highway project and connections to CERN, Starlight and similar.

A peering is an exchange of IP routes in order to optimise traffic⁴. Often, traffic is exchanged; no money changes hands. In some cases, restrictions may apply to such traffic.

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

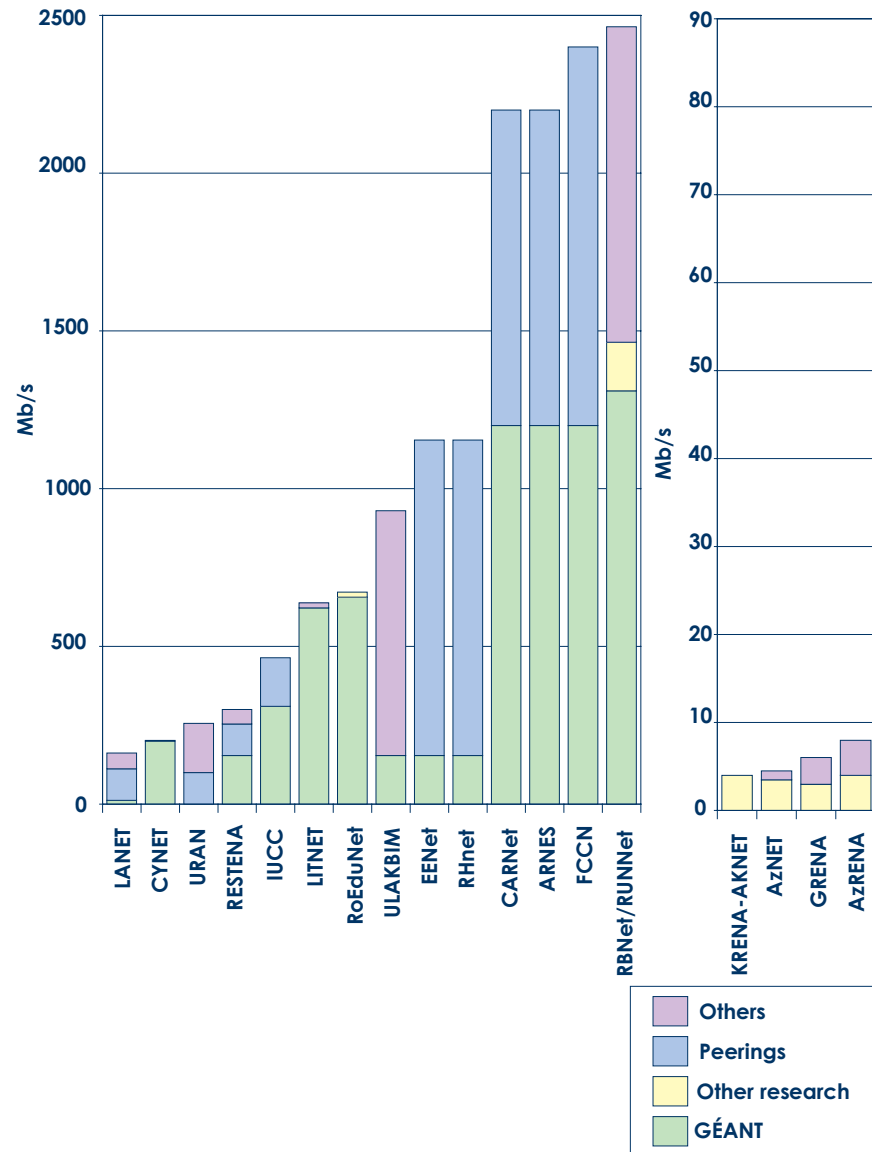
For presentational purposes, three graphs are presented.

Graph 3.5.1 External connectivity > 2.4 Gb, January 2005

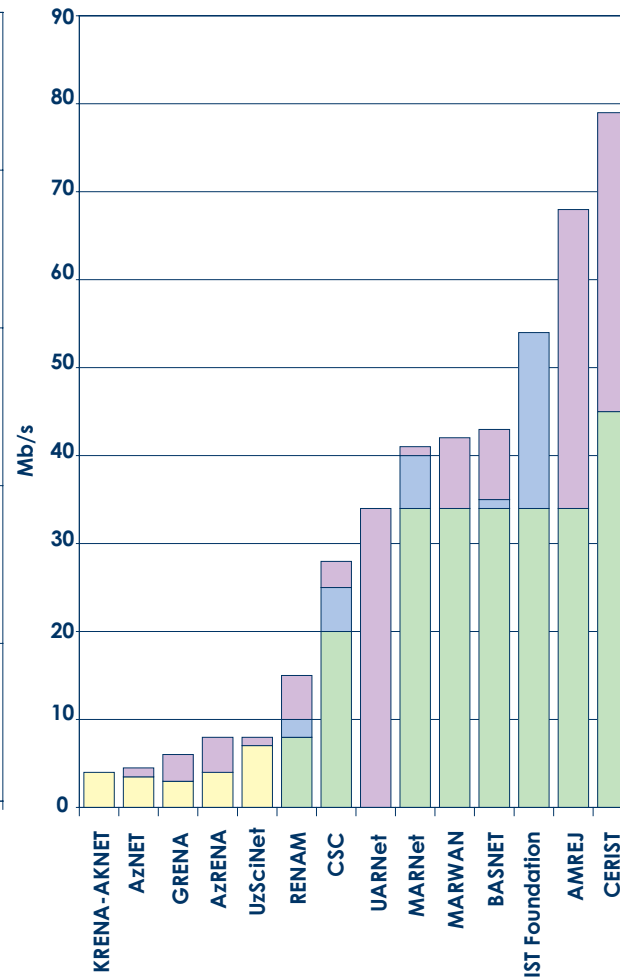


⁴ See <http://www.euro-ix.net> for information on nearly all European Internet exchanges

Graph3.5.2 External Connectivity > 100 Mb, < 2400 Mb, January 2005



Graph3.5.3 External Connectivity < 100 Mb, January 2005



3.6 Dark Fibre

Some NRENs own dark fibre or have IRUs⁵ or lease dark fibre and can decide themselves what technology and what speeds to use on their fibre. We have asked NRENs if they currently have IRUs or lease or own dark fibre, or if they plan to get it during the coming two years. We have 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 draw attention to significant changes that are expected over the next two years. UKERNA is currently in the process of procuring its next generation network and cannot yet predict how much of it will be dark fibre.

⁵ IRU stands for 'Indefeasible Right of Use'. This is the effective long-term lease (temporary ownership) of a portion of a cable. See, for example, <http://whatis.techtarget.com> for more information. The distinction between IRUs and lease is becoming less clear.

Table 3.6, Dark Fibre, 2005 and 2007 (darker colour highlights a significant change)

	NREN	2005			2007		
		% own	% IRUs	% leased	% own	% IRUs	% leased
EU-15/EFTA countries							
Belgium	BELNET	0	0	0	0	5	5
Denmark	UNI•C	0	25	0	0	90	0
Finland	FUNET	0	0	5	0	0	15
France	RENATER	0	0	5	0	0	33
Germany	DFN	0	0	0	0	0	95
Greece	GRNET	0	0	0	0	100	0
Iceland	RHnet	0	0	15	0	0	15
Ireland	HEAnet	0	10	0	0	80	10
Italy	GARR	0	3	0	0	15	10
Luxembourg	RESTENA	4	0	47	5	0	55
Netherlands	SURFnet	0	50	50	0	100	0
Norway	UNINETT	2	90	8	2	90	8
Portugal	FCCN	30	5	65	40	10	50
Spain	RedIRIS	0	0	0	0	0	10
Sweden	SUNET	0	0	5	0	0	100
Switzerland	SWITCH	2	20	65	2	20	78
United Kingdom	UKERNA	0	0	2	0	0	?
New EU member states							
Cyprus	CYNET	0	0	0	0	0	0

	NREN	2005			2007		
		% own	% IRUs	% leased	% own	% IRUs	% leased
Czech Republic	CESNET	0	0	100	0	0	100
Hungary	NIIF/HUNGARNET	0	1	10	0	2	50
Latvia	LATNET	0	0	0	0	0	0
Lithuania	LITNET	0	0	0	5	0	0
Malta	CSC	0	0	0	0	0	0
Poland	PIONIER	73	0	0	100	0	0
Slovakia	SANET	3	97	0	3	97	0
Slovenia	ARNES	0	0	80	0	0	80
Non EU/EFTA GN2 partners							
Bulgaria	IST Foundation	0	0	0	0	0	0
Croatia	CARNet	0	0	5	30	30	40
Israel	IUCC	0	2	6	0	2	6
Romania	RoEduNet	0	0	0	10	30	60
Russian Federation	RBNet/RUNet	10	0	0	10	0	0
Turkey	ULAKBIM	0	0	0	0	0	0



Highlights a significant percentage of dark fibre



Indicates anticipation of a significant change in the next two years

