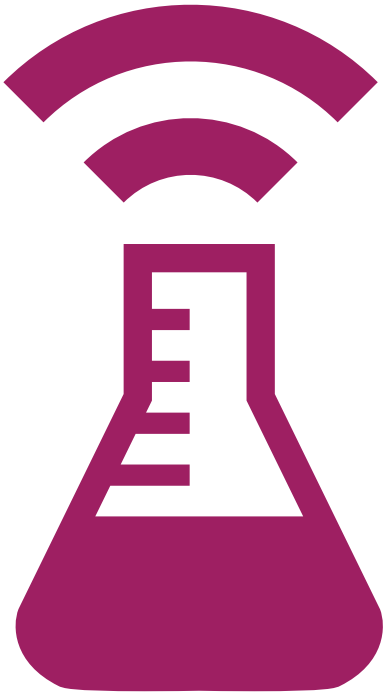


CONNECT ALL SCIENTIFIC AND RESEARCH CENTRES WITH ICTs

Target 3: Connect all scientific and research centres with ICTs[1]

Executive summary

In today's information society, the ways in which knowledge is created, processed, diffused and applied have been revolutionized – in part through rapid developments in ICTs (UNESCO, 2013). While the ICT revolution has not occurred at a uniform pace in all regions, to a large extent it has led to the creation of dynamic networks, cross-border collaborative processes, and internationalization of research and higher education. In line with the goal of making the benefits of ICTs available for all, Target 3 aims to connect all scientific and research centres with ICTs. The ICTs defined by the Target 3 indicators include broadband Internet[2] and connections to national research and education networks (NRENs). Data from multiple sources indicate that the target of "all" scientific and research centres has not been achieved, although significant progress has been made according to the three indicators for Target 3.

Indicator 3.1 focuses on connecting scientific and research centres with broadband Internet. Where data were available, connectivity was found to be high – typically 100 per cent – but there were a few countries that have yet to achieve this target. The conclusions that can be drawn from Indicator 3.1 were limited because of the low data availability and it is recommended that this indicator be removed. Indicator 3.2 measures whether a country has one or more NRENs and what their bandwidth is. Significant progress has been made in increasing the total number of NRENs, regional NRENs and countries with a NREN. Bandwidth has also increased considerably from megabit capacity to gigabit capacity. Progress was particularly noteworthy in Africa where the number of regional NRENs increased from none before 2006 to three by the end of 2013. Should there be tracking of Target 3 post-WSIS, it is recommended that monitoring of Indicator 3.2 be continued, with the possible addition of connectivity to NREN consortia, as regional NRENs will play a pivotal role in facilitating international research collaboration. Indicator 3.3 measures the proportion of public scientific and research centres that have direct or indirect broadband Internet access to a NREN, where at least one exists in the country. In most countries for which data are available, the majority of universities and research centres are connected to a NREN. On the other hand, very few government departments engaged in research and development (R&D) are connected to NRENs, suggesting that this is one area for greater collaboration between policy-makers, and scientific and research centres.

Target 3 indicators focus on infrastructure (connection to broadband Internet and NRENs) as a reflection of a country's ability to participate in international research. In the current review of the indicators, it is obvious that a focus on advanced infrastructure will not be sufficient post-2015, given the current and emerging needs of a dynamic research milieu. Should there be a post-WSIS target on technology and scientific research, it could consider the nature of information and knowledge that are shared, such as: different software models, innovative forms of networking, ways of adapting ICT infrastructure, software tools and applications, and international R&D efforts. An issue of interest would be open access to scientific publications and data. Open access is gaining traction with both

funding organizations and the scientific community. It was endorsed in 2013 as a principle for sharing research funded by the European Commission.[3] Open access to scientific publications and data would also address the current inequality in access to scientific information and knowledge in the world. Developing countries, particularly least developed countries (LDCs), continue to lag behind in access to scientific information and knowledge, as well as the benefits of science and technology. Easier access to knowledge and information should help to narrow the gap. As a way of moving forward, tracking the availability of open access scientific knowledge could be linked to WSIS Target 9 – Encourage the development of content.

Finally, the current review makes a strong recommendation for the intensification of global multistakeholder partnerships. The role of scientists and academics is essential in endeavours to share the benefits of technology and innovation; open access to data and knowledge is a key means for achieving this goal. To facilitate the achievement of a target on technology and scientific research, a conducive policy environment for sharing scientific knowledge will be fundamental in coming years.

Introduction

Historically, universities and other research centres have been at the forefront of scientific discovery. Many of the world's major technology companies began their life in universities and research institutions: Facebook was conceived at Harvard, Google at Stanford, Philips at the Eindhoven University of Technology, and Lenovo at the Chinese Academy of Sciences (Lambert, 2013). In each of these cases, a university or research centre played a pivotal role in incubating innovation.

International collaboration has brought together scientific groups that work on major challenges in areas such as health, climate change and renewable energy. In the area of technology, international research programmes are focusing on 3D imaging techniques, big data visualization, cybersecurity and mobile cloud computing, among others. The importance of science, technology and innovation, knowledge-sharing and capacity building for eradicating poverty and achieving sustainable development was confirmed at the Rio+20 Conference and the 2013 ECOSOC[4] Annual Ministerial Review (UNESCO, 2013). In order to make progress towards the Millennium Development Goals (MDGs) and other major global challenges, access to high-speed Internet is vitally important to enable researchers to connect with scientific communities around the world. When researchers can connect with their colleagues, they are better able to gain access to broader technical perspectives, pool their knowledge with others so as to advance their scientific disciplines, respond to changing patterns of scientific funding, and fulfil escalating demands for the rationalisation of scientific investment (Katz and Martin, 1997). In this sense, connectivity is an important prerequisite for the social and economic transformations that enable sustainable economic growth, human development and poverty eradication. Without connectivity, knowledge advancement and the impact of new discoveries could be limited.

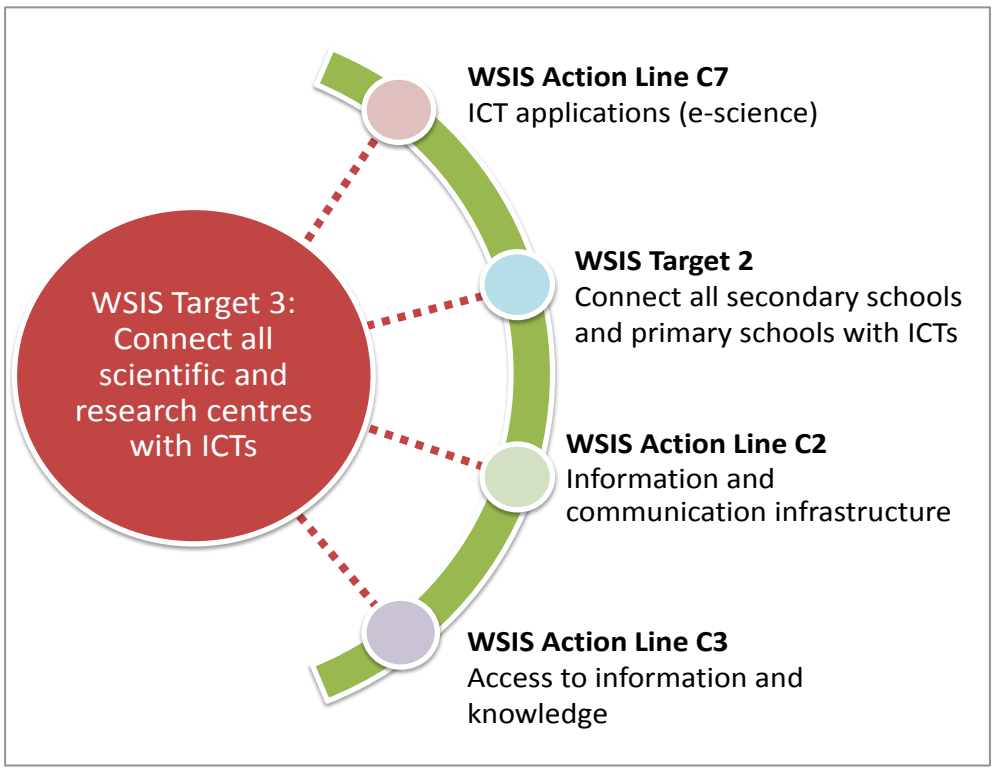
Target 3 is to "connect all scientific and research centres with ICTs." **Connectivity** has been interpreted as meaning high-speed Internet connection (ITU, 2010).This chapter focuses on public entities in the government and higher education sectors. Business enterprises and private non-profit sector entities are excluded for practical reasons (see *Partnership*, 2011). While the focus on public entities provides a feasible means for data collection, one limitation it poses is that private entities in the higher education sector are not covered by the target.

Other than WSIS Action Line C7 that defines its scope, Target 3 is also related to:

- WSIS Target 2: Connect all secondary schools and primary schools with ICTs (which originally included connecting universities)
- Action Line C2 (Information and communication infrastructure)
- Action Line C3 (Access to information and knowledge).

Figure 3.1 illustrates the relevance of Target 3 to other WSIS action lines and to Target 2.

Figure 3.1: Relevance of Target 3 to other WSIS action lines and targets



Action Line C7 focuses on ICT applications, including e-science. It states that stakeholders should "Promote affordable and reliable high-speed Internet connection for all universities and research institutions to support their critical role in information and knowledge production, education and training, and to support the establishment of partnerships, cooperation and networking between these institutions." (ITU, 2005) The focus on improving access to ICTs addresses an important challenge for researchers in developing countries who face high access costs for scientific journals and poor Internet connections.[5]

WSIS Target 2 originally included connecting universities and colleges with ICTs and was amended to track the availability of ICTs in primary and secondary schools only. Monitoring basic ICT infrastructure was deemed to be less relevant for higher-education institutions, since they are expected to have basic access to radios, televisions and computers (ITU, 2010). Post-WSIS, countries could consider examining targets 2 and 3 together in order to evaluate the overall status of ICT access in their educational institutions. Target 2 covers ISCED[6] levels 1 to 3, while Target 3 covers ISCED levels 5 and 6. Note that ISCED level 4, Post-secondary non-tertiary education, is not tracked in either Target 2 or 3 and the two targets focus on different types of ICT (Target 2 on basic ICT access and Target 3 on high-speed Internet connectivity).

Action Line C2 emphasizes the centrality of information and communication infrastructure in achieving the goal of digital inclusion (ITU, 2005). In relation to this, the achievement of Target 3 (as currently defined) implicitly involves the establishment of broadband network infrastructure in order to provide high-speed Internet connectivity to scientific and research centres. Action Line C2 also states the need to optimize connectivity between major information networks by:

- encouraging the creation and development of regional ICT backbones and Internet exchange points

- reducing interconnection costs
- broadening network access.

As national, regional and international broadband network infrastructure strengthens, connectivity among scientific and research centres should also improve.

Action Line C3 focuses on the role of ICTs in allowing people around the world to access information and knowledge (ITU, 2005). In relation to Target 3, Action Line C3 specifically refers to facilitating access to journals and books, and archives of scientific information – to be achieved by connecting scientific and research centres with high-speed Internet. Action Line C3 also includes other objectives pertaining to scientific research, including:

- Encourage research and promote awareness of different software models.
- Encourage research on the information society, including on innovative forms of networking, adaptation of ICT infrastructure, tools and applications.
- Undertake international R&D efforts aimed at making available adequate and affordable ICT equipment for end users.

These objectives are currently not covered by Target 3 and could be the focus of possible future targets on scientific research.

Scientific and research centres

Target 3 focuses on connectivity between scientific and research centres, which can be seen as an indication of a country's capacity to participate in international research. Scientific and research centres play a critical role in coping with emerging challenges, such as sustainable development and rising demographic pressures. For individual countries, the vitality of scientific research centres can be tied to the sustainability and growth of their economies. For example, through their R&D efforts, scientific and research centres generate intellectual capital that can be used in business innovation. Intellectual capital generates a knowledge base that can be mobilised for coping with major challenges and stimulating private sector entrepreneurship. To deal with the complex problems in the world today, scientific and research centres increasingly need to connect with one another to share resources and leverage the domain knowledge of other experts. Where technology gaps are evident, efforts should be made to close the gap so that the outcomes of scientific research can benefit all, including the most vulnerable and marginalized.

For an accurate assessment of Target 3, it is first important to identify the scientific and research centres within a country. This report initially adopted the recommendation of the 2011 WSIS statistical framework (*Partnership*, 2011) to use definitions from the UIS and OECD manuals.[7] Based on the two manuals (OECD, 2002; UIS, 2010a), the scope of scientific and research centres is all R&D-performing higher education and government organizations, defined according to the UIS manual but excluding units covered by other sectors, as follows:

- The higher education sector is composed of all universities, colleges of technology and other institutions providing tertiary education at International Standard Classification of Education (ISCED[8]) levels 5 and 6, whatever their source of finance or legal status. It also includes all research units, experimental stations and clinics operating under the direct control of, or associated with, higher education institutions. The treatment of borderline cases is discussed in the *Frascati manual* (OECD, 2002).

- The government sector is composed of all departments, offices and other bodies that furnish, but do not normally sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and the economic and social policy of the community. (Public business enterprises mainly engaged in market production and sale of goods and services are included in the business enterprise sector.) Non-profit institutions controlled and mainly financed by government, but not administered by the higher education sector, are also included. Government organizations include all levels of administration, that is: central or federal, state or provincial, and local or municipal.

The 2011 WSIS statistical framework also made recommendations for allocating units to business sectors and maintaining homogeneity across countries. However, it acknowledged that the homogeneity of units is likely to be impossible to achieve in the government sector and difficult for the higher education sector. More detailed discussions follow in the assessment of the individual indicators.

National research and education networks (NRENs)

As research and scientific challenges become more complex, research institutes need to connect with one another to share resources and develop cohesive solutions. In this chapter, ICT connectivity within the research community is defined as the existence of a **national research and education network (NREN),**[9] and is tracked by indicators 3.2 and 3.3. According to the 2011 WSIS statistical framework (*Partnership*, 2011), a NREN is:

> "…a specialized Internet service provider dedicated to supporting the needs of the research and education communities within a country. It usually administers and supports a high-speed backbone network; often offering dedicated channels for individual research projects" (p.24).

NRENs provide connectivity and services to higher education establishments (typically universities) and research institutes, but can also support schools, further education colleges, libraries and other public institutes. In some cases, services may be provided to government and healthcare sectors as well. There is usually only one recognised NREN in each country, although some countries may have separate networking organisations for different research and educational sectors. Where there is more than one networking organisation though, it is usual for international connectivity to be arranged through one of these organisations, or alternatively an umbrella organisation, which then becomes the de-facto NREN. In larger countries, it is also common to have separate regional or metropolitan networks interconnected by the NREN.

When NRENs were first highlighted by the *World Telecommunication/ICT Development Report 2010: Monitoring the WSIS Targets, A mid-term review* (WTDR) (ITU, 2010), they were introduced as high-capacity networks with three common characteristics:

- They are Internet Service Providers that are closely identified with the respective networks.
- They are a mix of dedicated channels and public Internet access, often through a combination of dedicated backbones, leased lines or private sector operators.
- They connect a range of different institutions, often with different needs.

Similarly, Europe's Delivery of Advanced Network Technology to Europe (DANTE)[10] notes that NRENs act as high-capacity ICT infrastructures to support the work of researchers, promote collaboration,

transfer data and share information or confirm experiments. In addition, it notes that NRENs can facilitate new research in their own right, by providing platforms and experimental test-beds for testing new services and advanced networking technologies.

NREN version 2 (NREN v2)

As testimony to the global progress in NRENs, there is already international discussion for NREN version 2 (NREN v2), which is envisioned as more than just networks. Instead of being specialized regional ISPs, version 2 NRENs will be essential global platforms for research and education institutions. On NREN v2 platforms, research institutes will be able to develop new technologies, solve common challenges, and develop common solutions in a collaborative environment – all of which are goals that go beyond connectivity.

Other proposed changes to transform NREN to NREN v2 include: from knowledge carrier to knowledge multiplier, from neutral collaboration connection to collaboration enabler, and from disinterested community service to community developer. With NREN v2, research and education institutes would be able to work in distributed laboratory environments, gain remote access to rare scientific instruments, and conduct large-scale computation. Box 3.1 describes the launch of the world's first intercontinental 100 Gbit/s link, called the Advanced North Atlantic 100G (ANA-100G), which will enable these collaborative research efforts.

Box 3.1: World's first intercontinental 100 Gbit/s link for R&E demonstrated

TERENA is the Trans-European Research and Education Networking Association. During the TERENA Networking Conference held in the Netherlands in 2013, six of the world's leading research and education (R&E) networks[11] demonstrated the world's first transatlantic 100 gigabits per second (Gbit/s or one billion bits per second) transmission link for research and education between North America and Europe.

The intercontinental 100 Gbit/s link, called the Advanced North Atlantic 100G Pilot Project (ANA-100G), will be used for engineering and testing the new transmission link, applications, resources, monitoring techniques and advanced technologies such as software-defined networking. According to SURFnet (the NREN of The Netherlands), the 100 Gbit/s Transatlantic connection reflects two trends in scientific research: science is increasingly data driven with datasets from large-scale experiments at the tera-scale level, and these experiments are increasingly carried out by international collaborations in which researchers around the globe expect immediate access to the datasets. The operation of this ultra high-speed link across the Atlantic Ocean also illustrates how the close collaboration between research and education networks and the commercial sector continues to evolve, with the ongoing deployment of cutting-edge networking technologies that underpin groundbreaking, globally collaborative science and discovery.

Demonstrations of the intercontinental 100 Gbit/s link included large data transfers between Maastricht and Chicago that took a few minutes, compared with many hours over the public Internet. The Transatlantic link will also advance high-end projects such as the experiments at the Large Hadron Collider in Switzerland, the ITER fusion reactor in France and similar international programs.

Source: SURFnet (2013).

Even as network administrators explore modalities to transform NREN to NREN v2, the fundamental intent of Target 3 remains relevant and that is to track a country's ability to participate in international research. Given the complexity of today's scientific challenges, demands on computation power will only increase; therefore research centres will increasingly look to NRENs as dedicated platforms for scientific advancements. Connectivity to NRENs and the degree of connectivity could be indicative of an economy's stock of intellectual capital. In fact, more fine-

grained measurement of NRENs would be possible as the number of countries with a NREN increases and connectivity between NRENs improves.

The rest of this chapter reviews the indicators for Target 3, reports the strong progress made towards the achievement of this target, since the 2010 mid-term review (ITU, 2010), and highlights pathways to accelerate progress for countries that are unlikely to achieve the target. Limitations, recommendations and conclusions are provided at the end of the chapter.

Data availability and scope

The following three indicators were identified in the 2011 WSIS statistical framework to track WSIS Target 3:

> Indicator 3.1: Proportion of public scientific and research centres with broadband Internet access
>
> Indicator 3.2: Presence of a national research and education network (NREN), by bandwidth (Mbit/s)
>
> Indicator 3.3: Proportion of public scientific and research centres with Internet access to a NREN.

Indicator 3.1 measures the proportion of public scientific and research centres with broadband Internet access. The indicator is focused on connectivity and does not provide any information on what the access is used for. Although broadband is of interest here, the rate of data transfer and processing required for some scientific research may far exceed broadband speeds currently available to the average consumer.

Indicator 3.2 measures whether a country has one or more NRENs and what their bandwidth is. The presence of a NREN indicates a country's ability to participate in national and international research. Bandwidth refers to the total capacity of NRENs in mega bits per second (Mbit/s).[12] Bandwidth determines the speed at which data are delivered to, and sent from, Internet users. It is measured in the number of bits that can be transferred per second.

Indicator 3.3 measures the proportion of public scientific and research centres that have direct or indirect broadband Internet access to a NREN, where at least one exists in the country. Table 3.1 presents the data sources used for measuring Target 3.

Table 3.1: Data sources for indicators for measuring Target 3

	Indicator	Data source	Data availability
3.1	Proportion of public scientific and research centres with broadband Internet access	Partnership on Measuring ICT for Development 2013 WSIS targets questionnaire	Very low. Only 16 countries provided data through the 2013 WSIS targets questionnaire. In the 2009 questionnaire, 24 countries provided data.
3.2	Presence of a national research and education network (NREN) by bandwidth (Mbit/s).	*Partnership* 2013 WSIS targets questionnaire, TERENA, NREN websites	Very low for questionnaire. Only 12 countries provided data through the 2013 WSIS targets questionnaire. TERENA had 59 countries with data available by end 2013.
3.3	Proportion of public scientific and research centres with Internet access to a NREN	*Partnership* 2013 WSIS targets questionnaire, TERENA	Very low for questionnaire. Only 15 countries provided data through the 2013 WSIS targets questionnaire. TERENA had 55 countries with data available by end 2013.

Source: ITU.

Indicators 3.1 and 3.3 are not collected on a regular basis by countries. Data for indicators 3.1, 3.2 and 3.3 were collected by the *Partnership on Measuring ICT for Development WSIS Targets Questionnaire, 2013* (*Partnership*, 2013). Of the 55 countries that responded to the survey at the time of writing, 14 to 16 had data available for Target 3. For indicators 3.2 and 3.3, the annual survey of NRENs conducted by the Trans-European and Education Networking Association (TERENA, 2013) served as the primary source of information for European and other responding countries.

Achievements against Target 3

Overall, significant progress has been made in terms of connecting scientific and research centres with ICTs. The target of "all" public scientific and research centres has not been achieved but there is evidence to suggest that steady progress has been made since 2003. Data availability has improved significantly in recent years as more NRENs are established and make their information publicly available (however, data availability remains a challenge for Indicator 3.1). One major sign of progress is that connection speeds have improved to the extent that data were reported in 2013 using giga bits per second (Gbit/s)[13] rather than mega bits per second (Mbit/s) as determined by the 2011 WSIS statistical framework.

Public scientific and research centres with broadband Internet access

Indicator 3.1 measures the proportion of public scientific and research centres with broadband Internet access. Table 3.2 shows the results from the 2013 WSIS targets questionnaire. Sixteen countries had data available and 13 reported that all public scientific and research centres had broadband Internet access. Uruguay reported 63 per cent, Republic of Congo 70 per cent and Dominican Republic 91 per cent. In the 2009 WSIS targets questionnaire, 15 out of 16 countries reported 100 per cent broadband Internet access for public scientific and research centres. With the exception of Bhutan, Bulgaria and Singapore (which reported 100 per cent in both surveys), countries that participated in the 2013 survey were different from those that participated in the 2009 survey.

Table 3.2: Proportion of public scientific and research centres with broadband Internet access

2013 WSIS targets questionnaire		2009 WSIS targets questionnaire	
Country	Proportion of public scientific and research centres with broadband Internet access	Country	Proportion of public scientific and research centres with broadband Internet access
	%		%
Azerbaijan	100	Albania	96
Bhutan	100	Andorra	100
Bulgaria	100	Bhutan	100
Congo	70	Bosnia & Herzegovina	100
Dominican Republic	91	Botswana	100
Estonia	100	Bulgaria	100
Finland	100	Croatia	100
Iran, Islamic Rep.	100	Denmark	100
Lithuania	100	Djibouti	100
Maldives	100	Egypt	100
Moldova	100	Hungary	100
Serbia	100	Korea, Rep.	100
Singapore	100	Latvia	100
United Arab Emirates	100	Morocco	100
Uruguay	63	Netherlands	100
Viet Nam	100	Singapore	100

Source: ITU and Partnership on Measuring ICT for Development (2009 and 2013 WSIS targets questionnaires).

Given the low data availability for Indicator 3.1, the disaggregations by type and size of organizations recommended by the 2011 WSIS statistical framework were not tenable. As with many other indicators in this report, data from least developed countries (LDCs) were not available. This poses a major challenge for assessing the technology gap between LDCs, developing and developed countries.

Where data are available, broadband Internet access was high but comparisons between countries and over time was not possible. Furthermore, this indicator is not tracked at the international level by any organization and this makes monitoring very challenging. Given these limitations, it is recommended that the indicator be dropped from any possible future monitoring post-WSIS.

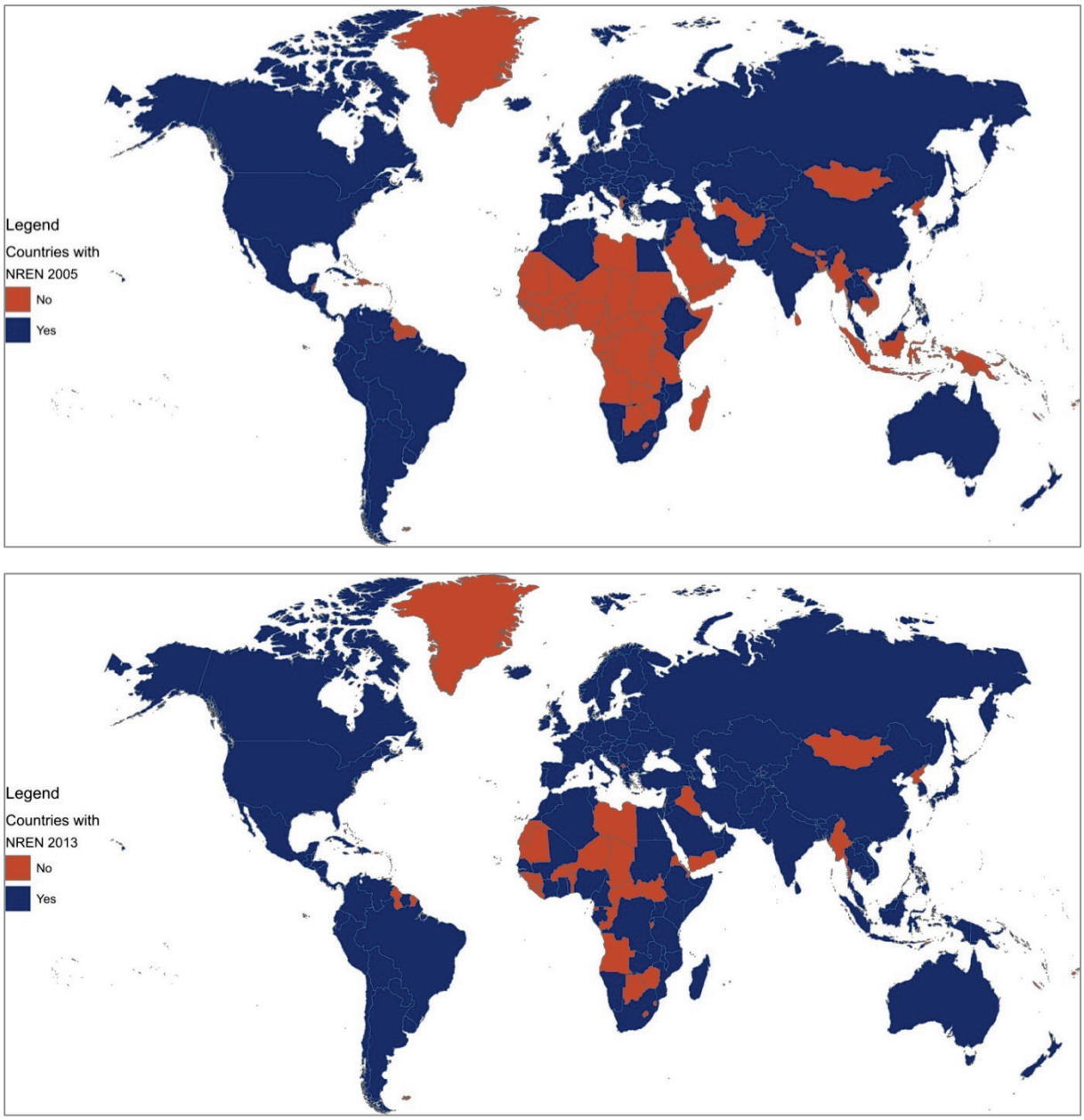
Countries with a national research and education network (NREN)

Indicator 3.2 measures whether a country has one or more NRENs and what their bandwidth is. The presence of a NREN indicates a country's ability to participate in national and international research.

In 2013, there were 170 known NRENs in 137 countries (out of a total of 206 countries tracked) (see Annex 3.1). Therefore, about two-thirds of countries tracked had at least one known NREN. By comparison, in 2009, 121 countries had at least one NREN and in 2005, an estimated 98 countries had at least one NREN (see Figure 3.2 for countries connected by at least one NREN in 2005 and 2013 respectively).

In terms of NRENs by region, in Europe, there were 39 countries with at least one known NREN in 2013, compared with 41 in Asia, 28 in the Americas, 26 in Africa and 3 in Oceania. In relative terms, 89 per cent of countries in Europe had at least one NREN, 80 per cent in Asia, 74 per cent in the Americas, 48 per cent in Africa and 16 per cent in Oceania (see Chart 3.1).

Figure 3.2: Countries with a national research and education network, 2005 and 2013



Source: ITU research based on TERENA Compendium and other publicly available information (see also Annex 3.1).

Substantial regional disparities still exist, with African and Oceanic countries lagging behind the rest of the world. Of the 19 countries in Oceania, only Australia, New Zealand and Papua New Guinea had a NREN in 2013; the other 16 countries had no known NREN. In Africa, 26 out of 54 countries had a NREN. Only 14 of the 34 LDCs in Africa had a NREN.

Data over time were not consistently available over the monitoring period. The most consistent data source was the Trans-European Research and Education Networking Association (TERENA). TERENA publishes the TERENA Compendium[14] that provides a reference source of research and education

networking in Europe (and beyond) since 2001. Of the 54 countries tracked by the *Compendium*, a record high of 59 NRENs responded to the 2013 TERENA questionnaire. This number has varied between 41 and 53 from 2003–2012.

At the time of writing, the concept of a NREN appears to be very well established and the identification of NRENs was fairly easy. Measurement of NREN bandwidth was less straightforward, as different data sources had slightly different interpretations of the term.

Bandwidth is defined in the 2011 WSIS statistical framework as the total capacity of NRENs in mega bits per second (Mbit/s). Bandwidth determines the speed at which data are delivered to, and sent from, Internet users. It is measured in the number of bits that can be transferred per second. TERENA adopts the concept of typical core usable backbone capacity on the network, meaning typical core capacity of the linked nodes in the core. The term "usable" is included because some NRENs have unused dark fibre with a very high theoretical capacity. For networks that do not have a core backbone (for example, because they have a star topology), TERENA asks for the maximum capacity into the central node of the network (TERENA, 2013). This definition is in line with the ITU definition of Internet bandwidth (ITU, 2011).

The TERENA Compendium also collects data on bandwidth of NRENs in its annual survey. Table 3.3 shows the bandwidth of the 65 NRENs that provided bandwidth information between 2012 and 2013. Fifty-nine NRENs provided data for the TERENA Compendium, six countries responded to the 2013 WSIS targets questionnaire and six countries responded to both questionnaires. Five NRENs reported core usable capacity below 1 giga bits per second (Gbit/s) – ASNET-AM (Armenia), GRENA (Georgia), KazRENA (Kazakhstan), SudREN (Sudan) and RAU2 (Uruguay). The highest core usable bandwidths of 100 Gbit/s were reported by DFN (Germany) and Internet2 (United States). Other NRENs that reported high bandwidths were mostly located in Europe; the highest of these was RENATAR (France) with 60 Gbit/s. CANARIE (Canada) had a bandwidth of 50 Gbit/s.

Only six NRENs based in African countries provided information about their bandwidth: CERIST (Algeria), Eeb@le (Democratic Republic of Congo), EUN (Egypt), MAREN (Malawi), MARWAN (Morocco) and SudREN (Sudan). All six had bandwidths less than or equal to 5 Gbit/s.

Table 3.3: Bandwidth of selected NRENs, 2013/2012

Country	NREN	TERENA/Partnership* bandwidth	Country	NREN	TERENA/Partnership* bandwidth
Albania	ANA	10 Gbit/s	**Korea, Rep.**	KREONET	10 Gbit/s
Algeria	CERIST	1.2 Gbit/s	**Latvia**	SigmaNet	1 Gbit/s
Armenia	ASNET-AM	0.2 Gbit/s	**Lithuania**	LITNET	10 Gbit/s (10 Gbit/s*)
Australia	AARNet	20 Gbit/s	**Luxembourg**	RESTENA	1 Gbit/s
Austria	ACOnet	10 Gbit/s	**Malawi**	MAREN	1 Gbit/s
Azerbaijan	AzScienceNet	1 Gbit/s	**Malta**	UoM/RicerkaNet	10 Gbit/s
Belarus	BASNET	10 Gbit/s	**Moldova**	RENAM	1 Gbit/s (10 Gbit/s*)
Belgium	BELNET	20 Gbit/s	**Montenegro**	MREN	1 Gbit/s
Bosnia & Herzegovina	SARNET	1 Gbit/s	**Morocco**	MARWAN	1 Gbit/s
Brazil	RNP	10 Gbit/s	**Netherlands**	SURFnet	20 Gbit/s
Bulgaria	BREN	2 Gbit/s (1 Gbit/s*)	**New Zealand**	REANNZ	10 Gbit/s
Canada	CANARIE	50 Gbit/s	**Norway**	UNINETT	10 Gbit/s
Chile	REUNA	2.5 Gbit/s*	**Poland**	PIONIER	40 Gbit/s
Congo (Dem. Rep.)	Eeb@le	100 Mbit/s*	**Portugal**	FCCN	20 Gbit/s
Croatia	CARNet	10 Gbit/s	**Romania**	RoEduNet	10 Gbit/s
Cyprus	CyNET	1 Gbit/s	**Russia**	e-ARENA	20 Gbit/s
Czech Republic	CESNET	10 Gbit/s	**Serbia**	AMRES	1 Gbit/s (1
Denmark	DeIC; UNI-C	10 Gbit/s	**Singapore**	SingAREN	15 Gbit/s
Egypt	EUN	5 Gbit/s	**Slovak Republic**	SANET	10 Gbit/s
Estonia	EENet	10 Gbit/s (12 Gbit/s*)	**Slovenia**	ARNES	10 Gbit/s
Finland	Funet	10 Gbit/s	**Spain**	RedIRIS	40 Gbit/s
France	RENATAR	60 Gbit/s	**Sudan**	SudREN	0.3 Gbit/s
Georgia	GRENA	0.5 Gbit/s	**Switzerland**	SWITCH	10 Gbit/s
Germany	DFN	100 Gbit/s	**T.F.Y.R. Macedonia**	MARnet	1 Gbit/s
Greece	GRNET S.A.	1.5 Gbit/s	**Thailand**	ThaiREN; Uninet	51 Gbit/s*
Hungary	NIIF/HUNGARNET	20 Gbit/s	**Turkey**	ULAKBIM	10 Gbit/s
Iceland	RHNet	10 Gbit/s	**Ukraine**	URAN	10 Gbit/s
Iran, Islamic Rep.	IRANET/IPM	1 Gbit/s*	**UAE**	ANKABUT	10 Gbit/s*
Ireland	HEAnet	30 Gbit/s	**UK**	Janet	40 Gbit/s
Israel	IUCC	10 Gbit/s	**United States**	Internet2	100 Gbit/s
Italy	GARR	10 Gbit/s	**Uruguay**	RAU2	155 Mbit/s*
Japan	NII	20 Gbit/s (82 Gbit/s*)			
Kazakhstan	KazRENA	165 Mbit/s			

Source: TERENA Compendium 2013 and 2012; Partnership on Measuring ICT for Development WSIS Targets Questionnaire, 2013 (*Partnership* data are indicated by *).

TERENA (2008) noted that NREN bandwidth increased from megabit capacity in 2003 to gigabit capacity in 2008. This trend has continued and the number of countries with capacity of 10 Gbit/s or above has grown from 14 in 2008 to 40 in 2013.

Regional or NREN consortia[15]

Although Indicator 3.2 did not specify the monitoring of regional NRENs or NREN consortia, scientific networking has been developing in this direction in recent years. This section uses available data to describe regional or NREN consortia. Table 3.4 lists regional or NREN consortia and regions served, while Figure 3.3 shows a timeline of the starting year of operations. Figure 3.4 from GÉANT shows the geographic coverage of the regional or NREN consortia. Before 2003, there were seven regional NRENs, and by 2010, there were 12. RedCLARA covered Latin America, GÉANT covered Europe, EUMEDCONNECT the Mediterranean, CAREN Central Asia, and TEIN and APAN the Asia-Pacific. CANARIE covered Canada and Internet2 the United States. Both CANARIE and Internet2 are NRENs but have wide geographical reach and provide pan-network connectivity to the other regional NRENs.

Table 3.4: Regional or NREN consortia and regions served

Regional or NREN consortia	Region
AfricaConnect	Sub-Saharan Africa
Asia-Pacific Advanced Network (APAN)	Asia-Pacific
Arab States Research and Education Network	Arab States
Central Asian Research and Education Network	Central Asia
Canada's Advanced Research and Innovation Network	North America
Caribbean Knowledge and Learning Network	Caribbean
EUMEDCONNECT3	Southern and eastern Mediterranean
GÉANT network	Europe
Internet2	North America
Nordic Infrastructure for Research & Education	Nordic countries
Cooperación Latino Americana de Redes Avanzadas	Latin America
Trans-Eurasia Information Network (TEIN)	Asia-Pacific
UbuntuNetAlliance	Eastern and Southern Africa
West and Central African Research and Education Network	Western and Central Africa

Source: ITU Research.

Note: See Annex 3.2 for a list of regional or NREN consortia and their members.

Box 3.2 discusses the networks, TEIN and CAREN, in the Asia-Pacific region.

Box 3.2: Research and education networks in Asia and the Pacific

In the Asia-Pacific region, several policy initiatives are contributing to Target 3 – connect all scientific and research centre with ICTs. The Trans-Eurasia Information Network (TEIN), and the Central Asian Research and Education Network (CAREN) provide good illustrations of the efforts of the region to connect its education and research networks.

The Trans-Eurasia Information Network Initiative (TEIN)

Endorsed by the ASEM-3 Summit (October 2000, Seoul), the Trans-Eurasia Information Network (TEIN) Initiative seeks to connect research networks in Asia and Europe in order to promote information exchanges in research and education. The ASEM leaders emphasized the need to establish information and research networks between the two regions and among ASEM partners in order to facilitate the flow of knowledge and information. The TEIN network allows for high speed and high volume exchange of data and information between research and education centres. It facilitates a wide range of applications to enhance research and education, including e-learning, videoconferences and online research collaboration. TEIN supports collaboration across disciplines including medicine, climate and environmental monitoring, high energy physics and agriculture. In 2012, the Medical Tele Collaboration project was implemented with ten TEIN partners to perform live surgeries.

The TEIN initiative was unveiled in several stages. The first stage created a Paris-Seoul connection on December 2001. The second phase of the Trans-Eurasia Information Network programme (TEIN2) was launched in May 2004 and raised the initiative's ambition and coverage with the involvement nine Asian partners, of which six were significant beneficiaries of European Commission financing (China, Indonesia, Malaysia, Philippines, Thailand and Viet Nam) with three Asian partners participating at their own cost (Japan, Singapore and the Republic of Korea), and in some cases making in-kind or financial contributions to the TEIN2 programme. Australia was also connected to the TEIN2 network at its own cost. The TEIN2 programme was managed by DANTE (Delivery of Advanced Network Technology to Europe), in cooperation with Asian partners.

The third phase of the Trans-Eurasia Information Network programme (TEIN3) further developed the electronic network infrastructure for Asian research and education by reaching South Asia and included Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka, Cambodia and Laos. The management responsibility of the network was transferred from DANTE to Asia. The fourth phase of the Trans-Eurasia Information Network programme (TEIN4) and the establishment of TEIN*CC (Trans-Eurasia Information Network-star Cooperation Center) in the Republic of Korea was endorsed at the 8th ASEM in Brussels on October 2010.

The Central Asian Research and Education Network and cooperation with TEIN

The Central Asian Research and Education Network (CAREN) provides over 500 universities and research centres across Central Asia with high speed broadband Internet connection. In January 2009, the CAREN regional network was launched to connect the academic communities of Central Asia to GÉANT (the research and education networking project serving Europe) through fibre optic connections. CAREN replaced the previous Virtual Silk Highway project.

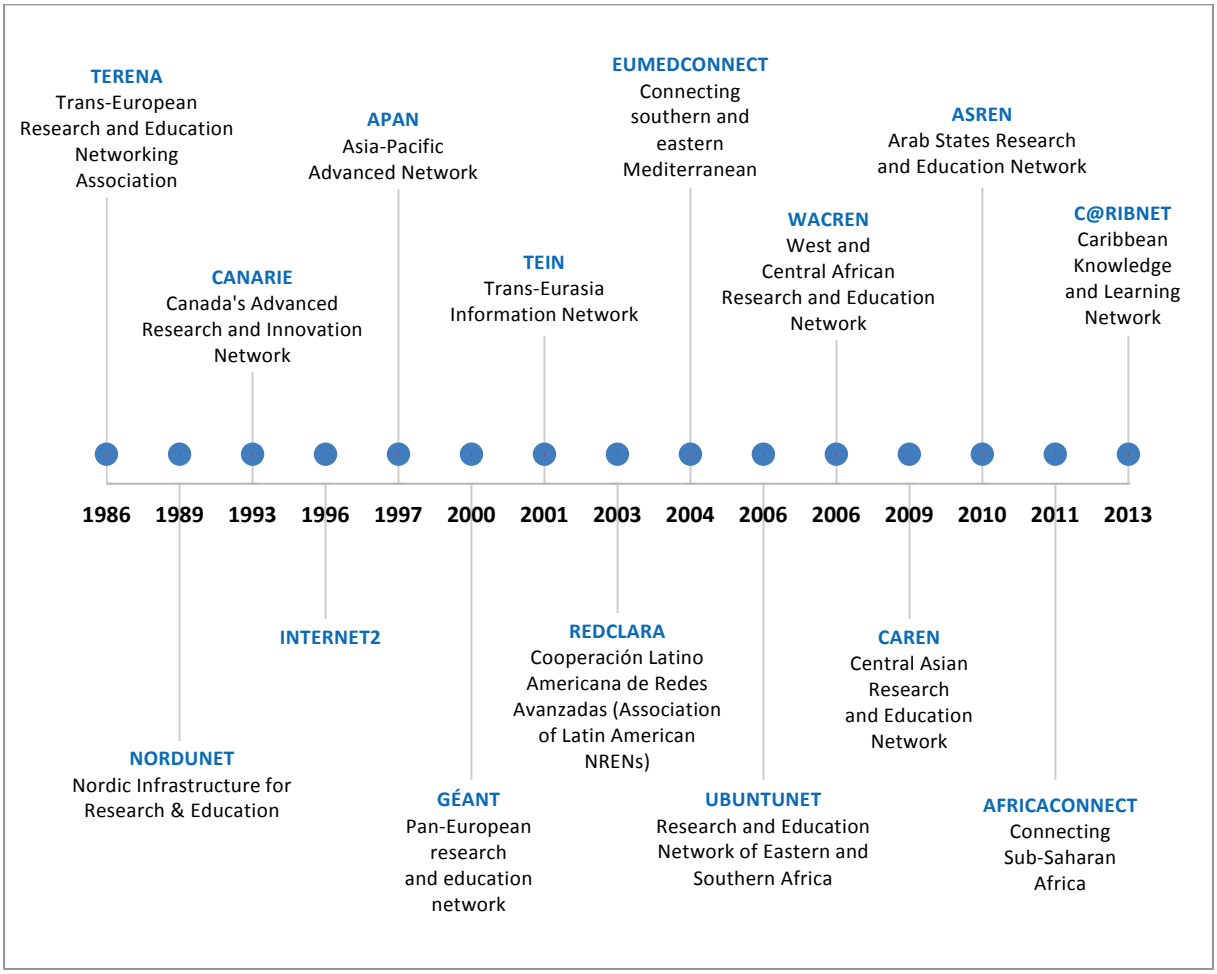
The CAREN project is coordinated by DANTE and currently involves the national research and education networks (NRENs) in Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan. Uzbekistan is expected to join the project in due course.

A memorandum of Understanding between the Trans-Eurasia Information Network (TEIN4) and the NRENs of Kazakhstan Kyrgyzstan, Tajikistan and Turkmenistan was signed in April 2013 in Ashgabat (Turkmenistan). It is expected to stimulate the development of joint applications and to foster the exchange of know-how and resources to promote cooperation between the scientific and educational communities of the two networks.

This agreement will allow universities, research institutes, medical centres and libraries of Central Asian countries to work more closely with its partners in the rest of Asia as well as in Europe. Through the TEIN-CAREN network, research and education network users will be able to access digital libraries, utilize a variety of online databases, and quickly and securely exchange large amounts of data around the world.

Source: UNESCAP, TEIN.

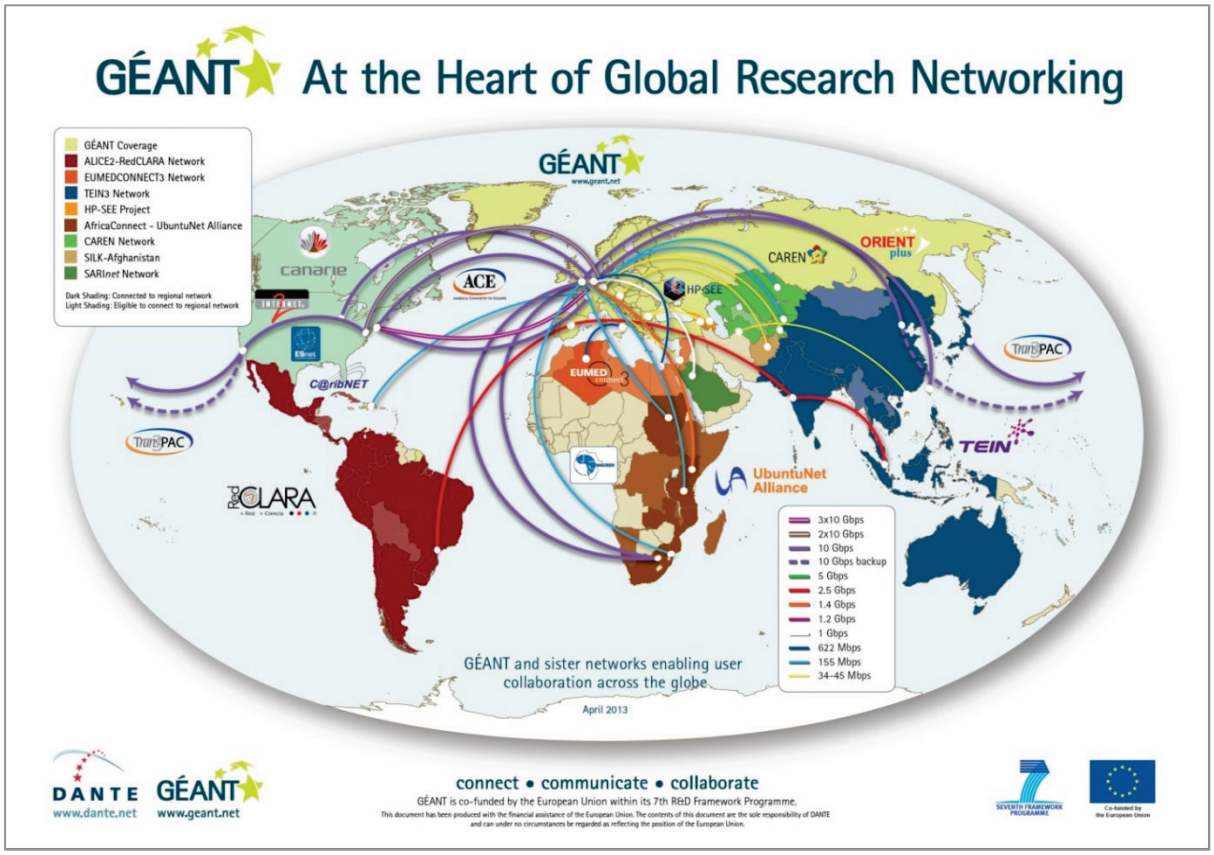
Figure 3.3: Timeline of starting year for regional NRENs and NREN consortia



Source: ITU Research.

Note: Starting year indicates publicly available official launch dates. However, regional NRENs typically take years to plan, test and implement so the definition of "starting year" varies from network to network. Networks may also have been implemented in phases. For instance, EUMEDCONNECT3 began as EUMEDCONNECT in 2001.

Figure 3.4: Coverage of regional or NREN consortia, 2013



Source: GÉANT (2013).

Since the WTDR 2010, three more regional NRENs have started operations: ASREN now serves the Arab states, AfricaConnect serves sub-Saharan Africa and C@ribNET serves the Caribbean countries.

In Africa, network administrators now have access to not just one but several regional NRENs, namely AfricaConnect, UbuntuNet and WACREN (see Box 3.3). AfricaConnect serves sub-Saharan African countries; UbuntuNet serves Eastern and Southern African countries; and WACREN serves Western and Central African countries. In the Americas, network administrators from the Caribbean countries are organizing themselves to form the Caribbean Knowledge and Learning Network, C@ribNET. Thus, all five world regions (Africa, Americas, Asia, Europe and Oceania) are now covered by at least one regional NREN.

Box 3.3: AfricaConnect – a regional Internet network for research and education in Africa

The AfricaConnect project is an initiative between the African Caribbean Pacific Islands (ACP) Secretariat and the European Commission (DEVCO). Its aim is to establish a high-capacity Internet network for research and education in Southern and Eastern Africa, thus providing the region with a gateway to global research collaboration (AfricaConnect, 2013). The project will support the data communications needs of the research and education community in the region by providing dedicated high speed data communications infrastructure that will connect African NRENs – both to each other and to other regional research and education networks worldwide. The project is expected to last four years and began in May 2011. It project comprises 20 project partners, including 15 African NRENS, 5 European NRENS and the UbuntuNet Alliance.

The objectives of AfricaConnect include:

- Foster the development of cooperative research programmes between European and the African research and education communities.
- Provide infrastructure that supports the development and deployment of the applications exploiting work done in Europe regarding the information society.
- Support the fulfilment of the region's Millennium Development Goals.
- Develop staff capacity at all levels in the existing African NRENs, taking into account their immediate needs. Due to low Internet penetration in the region, there is a lack of skilled technical, operational and managerial staff.
- Open up the research activities in the region and build cooperation with researchers in the rest of the world. Specific research application areas cover the fields of: health, climate, agriculture, education and environment.

Source: www.AfricaConnect.eu.

Work is currently in progress to develop connections between and among the regional NRENs. For instance, the ORIENTplus project connects the research and education communities of Europe and China. It links the Chinese NRENs, CERNET (China Education and Research Network) and CSTNET (China Science and Technology Network), with the 50 million users of the pan European GÉANT network via super-fast connectivity between Beijing and London (DANTE, 2013).

Impact of connectivity on increasing capacity for scientific research

In order to address challenges such as climate change, sustainable development, conflicts, human rights, rising inequality and demographic pressures, scientists and researchers increasingly have to work with colleagues in the rest of the world to develop integrated solutions. Regional NRENs and NREN consortia facilitate intra-region collaboration as well as connections to other regional NRENs. Connectivity to more advanced NREN consortia offers positive spillovers in technical expertise and experience. Very often, the availability of a regional NREN prompts countries that do not have NRENs to establish their own in order to join more advanced networks. Box 3.4 describes how 35 000 Cambodian researchers were connected with the rest of the world through the Trans-Eurasia Information Network (TEIN3). The connection to the high capacity regional network not only improved access to locally-relevant computing applications; it is also prompting universities and research centres to improve their infrastructure so that they can connect to the network and to other universities.

Box 3.4: CamREN – Connecting Cambodian researchers to the rest of the world

In April 2012, Cambodia became the most recent country to connect to the Trans-Eurasia Information Network (TEIN3). The new link initially connects to the Institute of Technology of Cambodia (ITC) in Phnom Penh and aims to connect Cambodia's 35 000 researchers with scientists around the world. The anticipated outcomes of this connection include improving the quality and quantity of research conducted in Cambodia's higher education institutes and research centres. Applications using the network include climate research and meteorology, food security and health programmes.

Initially, researchers connected to CamREN were invited to ITC as a pilot experience to get international data and documents. CamREN is the NREN of Cambodia and is a network of five leading universities in Cambodia: Institute of Technology of Cambodia (ITC), Royal University of Phnom Penh (RUPP), Royal University of Law and Economy (RULE), University of Health Science (UHS) and National Institute of Education (NIE). CamREN's mission is to facilitate the connection of all the other universities and research centres. In a second step, all universities will provide the same services in their own libraries. In the final step, other universities (public and private) in Cambodia will be invited to join the network according to their interest and development of their research activities.

The development of CamREN will be boosted by its link to TEIN3, as it works to strengthen national and international research collaboration. To achieve the physical connection, CamREN worked closely with VinaREN, the NREN of neighbouring Viet Nam. VinaREN arranged a dedicated link from its network in Hanoi to ITC and provided access to its existing TEIN3 connection. The TEIN3 network extends to the South Asian sub-continent, serving over 45 million users in more than 8 000 academic institutions and research centres across Asia. Starting with a single circuit between France and the Republic of Korea in 2001, TEIN3, the third generation of the project, now links 17 countries in the region to each other and to the global research community.

Source: TEIN3 (2013).

While Indicator 3.2 shows that Target 3 has not been achieved, significant progress has been made in increasing the total number of NRENs, regional NRENs and countries with a NREN. Bandwidth has also increased considerably from megabit capacity to gigabit capacity. Looking forward, the demand for information-sharing and digitally-driven data collection will only intensify. NRENs and regional NRENs help to meet these demands by improving access to, and use of, information and knowledge that will facilitate the achievement of the MDGs. To maintain the current momentum in the progress made according to Indicator 3.2, stakeholders can look into improving the policy environment, redesigning infrastructure investment and investing in higher education so that the full potential of NRENs can be realized.

Should there be a post-WSIS target related to scientific research, tracking should include connectivity to NREN consortia because regional NRENS will undoubtedly play a central role in enabling interconnectivity and collaboration with other regional NRENs. Given that Target 3 measures the capacity of a country to participate in international research, connectivity to a regional NREN would add another dimension to the measurement of that capacity.

Public scientific and research centres with Internet access to a NREN

Indicator 3.3 measures the proportion of public scientific and research centres that have direct or indirect Internet access to a NREN, where at least one exists in the country. This indicator monitors the extent of connectedness of public scientific and research centres to NREN(s) and, like indicators 3.1 and 3.2, focuses on infrastructure. Indicator 3.3 can also serve as a proxy indicator for the collective research capacity of public scientific and research centres in a country. However, the indicator does not monitor the quantity or quality of scientific research that results from the connectivity.

Data for indicator 3.3 were collected by the 2013 WSIS targets questionnaire, in a survey conducted by the *Partnership* in 2013. Data connectivity and bandwidth are also collected by TERENA for European Union countries (and other countries that respond to their annual survey). Table 3.5 shows information collected by the WSIS targets questionnaire on the proportion of public scientific and research centres with Internet access to NRENs. Data availability was low, with only 15 countries providing data for this indicator. The values of Indicator 3.3 varied greatly between countries, ranging from zero in Bhutan (which is planning to implement its NREN – DrukREN) to 100 per cent in Bulgaria, Estonia, Japan, Lithuania and Singapore.

Table 3.5: Public scientific and research centres with Internet access to a NREN

Country	Percentage	Country	Percentage
Bhutan	0	**Moldova**	89
Bulgaria	100	**Serbia**	59
Chile	27	**Singapore**	100
Congo	90	**Thailand**	90
Estonia	100	**United Arab Emirates**	19
Iran, Islamic Rep.	4	**Uruguay**	63
Japan	100	**Venezuela**	32
Lithuania	100		

Source: Partnership on Measuring ICT for Development WSIS Targets Questionnaire, 2013.

TERENA also collects data on connectivity and bandwidth, by types of institutions for European Union countries and some other countries that respond to their annual survey. The TERENA data deviate from the guidelines in the 2011 WSIS statistical framework in two ways. First, Indicator 3.3 (and 3.1) refer to 'proportions of entities with ICT' and recommended the following disaggregations:

- type of organization (higher education and government)
- size of organization in ranges of persons employed: 1-9, 10-49, 50-249 and 250 or more
- type of government organizations (if possible).

The suggested size classifications were not used by TERENA. Also, TERENA collects data disaggregated by types of institutions and the extent of coverage in ranges (greater than 80 per cent being most extensive and less than 20 per cent being least extensive). Table 3.6 shows NRENs and connectivity to institutes based on data from the TERENA Compendium 2012.[16]

Table 3.6: NRENs and connectivity to institutions

Country	NREN	Universities	Research Institutes	Institutes of further education	Government departments[17]
Algeria	ARN; CERIST; CNTI	57 (over 80%)	25 (over 80%)	34 (over 80%)	4 (20%–40%)
Armenia	ASNET-AM	2 (20%–40%)	35 (over 80%)	..	.. (60%–80%)
Australia	AARNet	41 (over 80%)	24 (40%–60%)	13 (20%–40%)	1 ..
Austria	ACOnet	36 (over 80%)	29 (20%–40%)	1 (over 80%)	35 (20%–40%)
Azerbaijan	AzRENA; AzScienceNet	..	30 (over 80%)	..	..
Belarus	BASNET	10 (20%–40%)	57 (20%–40%)	..	8 (under 20%)
Belgium	BELNET	65 (over 80%)	37 (over 80%)	6 (under 20%)	50 (20%–40%)
Bosnia & Herzegovina	SARNET	25 (60%–80%)	1 (20%–40%)	1 (20%–40%)	..
Bulgaria	BREN	22 ..	50 ..	2 ..	..
Canada	CANARIE	89 ..	70 ..	184 ..	50 ..
Croatia	CARNet	141 (over 80%)	36 (over 80%)	46 (over 80%)	9 (under 20%)
Cyprus	CyNET	6 (over 80%)	2 (under 20%)	3 (20%–40%)	..
Czech Republic	CESNET	26 (over 80%)	25 (40–60%)	10 (20%–40%)	39 (20%–40%)
Denmark	DeIC; UNI-C	8 (over 80%)	12 (20%–40%)	7 (20%–40%)	4 (under 20%)
Estonia	EENet	21 (over 80%)	21 (over 80%)	16 (20%–40%)	3 (20%–40%)
Finland	Funet	51 (over 80%)	12 (40%–60%)	..	8 (under 20%)
France	RENATAR	445 (over 80%)	368 (over 80%)	335 (60%–80%)	20 (under 20%)
Georgia	GRENA	10 (20%–40%)	5 (20%–40%)	18 (20%–40%)	2 (under 20%)
Germany	DFN	.. (over 80%)	.. (60%–80%)	.. (over 80%)	.. (under 20%)
Greece	GRNET S.A.; Ariadnet	43 (over 80%)	28 (over 80%)	146 (60%–80%)	727 (20%–40%)
Hungary	NIIF/HUNGARNET	25 (over 80%)	73 (over 80%)	28 (over 80%)	4 (20%–40%)
Iceland	RHNet	9 (over 80%)	11 (60%–80%)	2 (under 20%)	..
Ireland	HEAnet	25 (over 80%)	10 (60%–80%)	10 (over 80%)	8 (under 20%)
Israel	IUCC	12 ..	5 ..	..	..
Italy	GARR; INFN	139 (over 80%)	203 (over 80%)	0 (under 20%)	5 (under 20%)
Kazakhstan	KazRENA	51 ..	7 ..	..	2 ..
Korea, Rep.	KOREN; KREONET	51 (20%–40%)	61 (60%–80%)	..	18 (20%–40%)
Kyrgyzstan	KRENA-AKNET	27 (40%–60%)	17 (20%–40%)	.. (20%–40%	1 (under 20%)
Latvia	SigmaNet	15 (40%–60%)	13 (20%–40%)	4 (under 20%)	0 (under 20%)
Lithuania	LITNET	42 (over 80%)	31 (over 80%)	55 (40%–60%)	35 (under 20%)
Luxembourg	RESTENA	6 (over 80%)	22 (over 80%)	1 (over 80%)	14 (under 20%)
Malta	UoM/RicerkaNet	1 (over 80%)	3 (40%–60%)	2 (40%–60%)	.. (under 20%)
Moldova	RENAM	5 (over 80%)	36 (60%–80%)	1 (under 20%)	1 (under 20%)
Montenegro	MREN	19 (over 80%)	2 (60%–80%)	1 (over 80%)	1 (20%–40%)
Morocco	MARWAN	15 (over 80%)	8 (40%–60%)	80 (over 80%)	2 (under 20%)
Netherlands	SURFnet	14 (over 80%)	32 (over 80%)	64 (over 80%)	..
New Zealand	KAREN; REANNZ	8 (over 80%)	13 (over 80%)	13 (60%–80%)	2 (under 20%)
Norway	UNINETT	8 (over 80%)	81 (40%–60%)	56 (over 80%)	..
Poland	PSNC; PIONIER	180 (over 80%)	194 (over 80%)	.. (under 20%)	.. (under 20%)
Portugal	FCCN	42 (over 80%)	12 (over 80%)	..	13 (20%–40%)
Romania	RoEduNet	50 (over 80%)	55 (over 80%)	10 (60%–80%)	30 (under 20%)
Russia	e-ARENA; RUNNet/ RBNet; FREEnet	250 (60%–80%)	240 (40%–60%)	.. (20%–40%)	.. (under 20%)

Country	NREN	Universities	Research Institutes	Institutes of further education	Government departments[17]
Serbia	AMRES	87 (40%–60%)	41 (20%–40%)	9 (under 20%)	2 (under 20%)
Singapore	SingAREN	4 (20%–40%)	2 (20%–40%)	.. (under 20%)	1 (under 20%)
Slovak Republic	SANET	38 (over 80%)	20 (40%–60%)	7 (20%–40%)	.. (under 20%)
Slovenia	ARNES	4 (over 80%)	54 (over 80%)	20 (over 80%)	18 (under 20%)
Spain	RedIRIS	90 (over 80%)	170 (over 80%)	0 (under 20%)	75 (under 20%)
Sweden	SUNET	30 (over 80%)	4 (60%–80%)	9 (60%–80%)	20 (under 20%)
Switzerland	SWITCH	43 (over 80%)	10 (20%–40%)	3 (under 20%)	6 (under 20%)
T.F.Y.R. Macedonia	MARnet	19 (20%–40%)	5 (40%–60%)	..	1 (under 20%)
Tanzania	TERNET	4 (under 20%)	1 (under 20%)	4 (under 20%)	..
Turkey	ULAKBIM	89 (over 80%)	18 (20%–40%)	.. (over 80%)	6 (under 20%)
Ukraine	URAN; UNREN; UARNet	64 (over 80%)	16 ..	..	1 (under 20%)
United Kingdom	Janet	200 (over 80%)	35 (over 80%)	550 (over 80%)	6 (20%–40%)

Source: TERENA Compendium 2012, Table 2.2.1.

Note: .. not available.

Table 3.6 shows that in most countries, the majority of universities and research centres are connected to a NREN. Three in four countries (37 out of 50) had more than 80 per cent of universities connected by the NREN(s). Russia, and Bosnia and Herzegovina had between 60 to 80 per cent of universities connected by NREN(s) and remaining countries had a lower level of connection or had data missing. The data are consistent with the overall results from Table 3.5 above that suggest that universities and research centres are connected to a large extent.

However, Table 3.6 also shows that very few government departments engaged in R&D are connected to NRENs. Two in three countries (31 out of 43) had fewer than 20 per cent of their government departments engaged in R&D connected to NRENs. This suggests missed opportunities as government departments implement far-reaching policies that can advance progress made towards the MDGs; such efforts are likely to be strengthened by stronger connections to scientific research through NRENs. Government departments also determine the extent of resources that can be mobilized for the development of NRENs; NREN administrators could therefore do more to reach out to government departments engaged in R&D. For NRENs to be sustainable, the commitment of all major stakeholders is required. For research centres and universities, having direct access to government departments means potentially gaining access to large data sets that can enrich their research. Without strong links to government departments, NRENs may not be fully realizing their potential for enabling policy-relevant research and innovation. Even as Table 3.6 shows good connectivity between NRENs and universities and research centres, it also suggests that there is room for greater collaboration between policy-makers, and scientists and academics.

On the other hand, TERENA (2013) noted that NRENs may be advantaged if they can operate independently of government, with advantages including easier decision-making processes and the ability to recruit and retain suitably-qualified staff. There is of course no 'one-size-fits-all' model for the establishment and development of NRENs, and their future development at country level depends on factors such as the priority given to R&D.

Besides facilitating innovation and collaboration, NRENs also serve the important function of making the delivery of tertiary education viable for developing countries. Box 3.5 describes the challenges that Caribbean tertiary institutions face and the role that NRENs play in meeting those challenges. This case study also illustrates why the consideration of local context is important in implementing NREN development plans.

Box 3.5: Caribbean NRENs and tertiary education

Tertiary institutions in the Caribbean face a number of challenges with regard to the quality of education they can offer.[18] Apart from the University of the West Indies, which had a student population of 48 000 in 2012, most colleges and universities are relatively small and offer a narrow range of programmes. Because of their size, institutions do not have the critical mass required to offer all the programmes needed to satisfy the demand for skilled professionals in the Caribbean. These smaller universities and colleges are also unable to individually afford the cost of infrastructure and resources required to adequately deliver courses to students. There are only a few institutions offering programmes in the areas of critical need such as science and technology; this situation is exacerbated by a lack of qualified lecturers in mathematics and science subjects.

Without the prospect of quality education, young and talented Caribbean citizens are leaving their home countries in order to complete their education. In Jamaica, roughly 80 per cent of the potential number of tertiary graduates has left the country. The resulting 'brain drain' is likely to hold back the development of Caribbean countries.

One way that Caribbean universities can improve their capacity to deliver higher quality education is to work in networks. By establishing a NREN and connecting it to the regional NREN (C@ribNET), universities can improve the viability of their education and research efforts. In November 2013, UWI conducted its first telemedicine transmission from its campus in Jamaica to medical students and staff in Trinidad and Tobago, and Barbados, using C@ribNET. This was a demonstration of how a regional NREN can “enable much greater teaching and learning possibilities and reach the thousands of students that matriculate annually but are not afforded tertiary education due to lack of space” said Mr Ken Sylvester, CEO of the Caribbean Knowledge and Learning Network, CKLN.

About C@ribNET

The aim of C@ribNET is to bridge the digital divide in the region and achieve social cohesion of Caribbean people through digital inclusion. The Caribbean was, until recently, one of the few regions of the world without a regional research and education network. Through C@ribNET, communities of interest are now being organised to implement priority applications such as a digital library, a shared student information system for tertiary institutions, and applications supporting issues such as climate change, disaster management, crime and security, telehealth and culture.

Source: www.ckln.org.

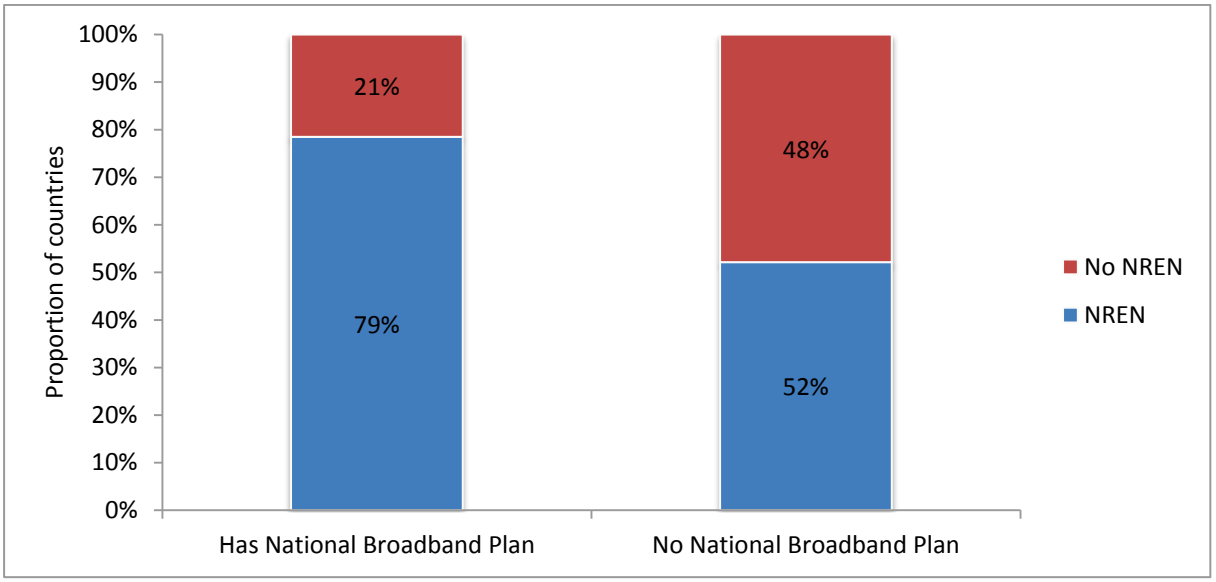
NRENs and national broadband plans

Ideally, the development of national broadband plans would bring together policy-makers and NREN administrators. Research conducted by the Broadband Commission for Digital Development (Broadband Commission for Digital Development, 2013) suggests that the introduction or adoption of a national broadband plan is associated with, on average, 2.5 per cent higher fixed broadband penetration and 7.4 per cent higher mobile-broadband penetration. This improvement is a logical consequence of the focusing of policies and efforts that is associated with development of a national broadband plan.

This section examines the relationship between the presence of a national broadband plan and a NREN. Chart 3.1 illustrates the status of national broadband plans and NRENs in the 193 countries that provided information to the Broadband Commission for Digital Development (2013).[19] The chart

shows that countries that had a national broadband plan in 2013 were much more likely to also have a NREN. Of the 193 countries for which data are available, 135 had broadband plans and 79 per cent of these countries had at least one NREN. Of the 46 countries with no national broadband plan, slightly over half had at least one NREN. Of the 12 countries reporting that they were in the planning phase of a national broadband plan, five had a NREN and seven did not.

Chart 3.1: Status of national broadband plans and NRENs, 2013



Source: ITU research.

National agencies that implement a national broadband plan and NREN in tandem could benefit from synergies between the two sets of activities, in the form of streamlined processes and resulting cost savings. Formulating national broadband plans that encompass the implementation of NRENs would allow countries to incorporate the infrastructure needs of scientific and research institutes.

Conclusions and recommendations

In the information society, the ways in which knowledge is created, processed, diffused and applied have been revolutionized – in part through rapid developments in ICT (UNESCO, 2013). Sophisticated ICTs can facilitate the creation of dynamic networks, cross-border collaborative processes and internationalization of research and higher education. In line with the goal of making the benefits of ICT available for all, the aim of Target 3 is to connect all scientific and research centres with ICTs. The indicators defined by Target 3 include broadband Internet and connections to NRENs. Data from the three indicators for Target 3 indicate that the target of "all" scientific and research centres has not been achieved, but that significant progress has been made.

Indicator 3.1 focuses on connecting scientific and research centres with broadband Internet. Where data were available, connectivity was high – typically 100 per cent – but there were a few countries that had yet to achieve this target. Unfortunately, the conclusions that can be drawn from Indicator 3.1 are limited because of very low data availability. Should there be tracking post-WSIS, it is recommended that Indicator 3.1 be dropped because lack of data results in a limited and unrepresentative picture of the connection of scientific and research centres with broadband Internet. In addition, there is no international organization collecting data for Indicator 3.1, therefore making it difficult to update.

Indicator 3.2 measures whether a country has one or more NRENs and what their bandwidth is. For this report, Indicator 3.2 was extended to include monitoring of regional NRENs and NREN consortia. Significant progress has been made in increasing the total number of NRENs, regional NRENs and countries with a NREN. Bandwidth has also increased considerably from megabit capacity to gigabit capacity. Progress was particularly noteworthy in Africa, where the number of regional NRENs increased from none in 2010 to three by the end of 2012. Looking forward, it is recommended that monitoring of this indicator be continued, with the addition of monitoring of regional NRENs and NREN consortia.

Indicator 3.3 measures the proportion of public scientific and research centres that have direct or indirect broadband Internet access to a NREN, where at least one exists in the country. In most countries for which data are available, the majority of universities and research centres are connected to a NREN. On the other hand, very few government departments engaged in R&D are connected to a NREN, suggesting that this is an area requiring greater collaboration between policy-makers, and scientific and research centres.

As the requirements of research and education continue to evolve, any effort to track progress should keep pace with technological developments. The current indicators focus on infrastructure (connection to broadband Internet and NRENs) as a reflection of a country's ability to participate in international research. Indeed, the three action lines that inform Target 3 emphasize the role of ICTs in networking of research institutions and thereby supporting access to, and production of, information and knowledge. Should there be future monitoring of this area post-WSIS, a revised target could include the means of sharing information and knowledge, including different software models, innovative forms of networking, ways of adapting ICT infrastructure, and software tools and applications.

To mobilize resources required to continue the development of NRENs and regional NRENs, network administrators are increasingly engaging other stakeholders, such as government departments. NRENs may offer a variety of services and activities beyond infrastructural connectivity. As an example, a paper produced by NORDUnet on the role of NRENs in 2020 (NORDUnet, 2013) proposes that NRENs should adopt a user-centric approach that integrates the following concepts of NRENs:

1. as global network service providers
2. as community service providers
3. as e-science enablers
4. as e-education enablers
5. as innovative framework providers.

The preceding discussion suggests three possible areas related to science and research in the information society that could be tracked post-2015.

First, in order to ensure that developing countries that are just beginning to establish their NRENs are not left behind, it is important to monitor the presence of a NREN in the country.

Second, researchers will find that global partnerships and major research programs will offer resources and capabilities that are beyond those that can be mustered by a single country. Thus, the linkages between the national NREN to regional NRENs should also be tracked to reflect the trend in global collaborative research.

Third, Target 3 should evolve from measuring infrastructure to measuring impacts and outputs of the infrastructure. As scientific and research centres around the world become increasingly inter-connected, attention should also turn to the impact of NRENs in terms of generating and sharing scientific knowledge. Developing countries, particularly LDCs, continue to lag behind in access to scientific information and knowledge and open access to research articles and data would help to narrow the gap. Open access has reached a 'tipping point' according to the European Commission (2013). Following recommendations arising from three studies, the European Commission has mandated open access for scientific publications that are produced with funding from *Horizon 2020*, the EU's Research and Innovation funding programme for 2014–2020.[20] The articles produced from Horizon 2020-funded research will either immediately be made accessible online by the publisher, or researchers will make their articles available through an open access repository no later than six months (12 months for articles in the fields of social sciences and humanities) after publication.

As a way of moving forward, tracking the availability of open access scientific knowledge could be linked to WSIS Target 9 (Encourage the development of content). Tracking of the other suggested indicators could be done in collaboration with TERENA and other regional NRENs, given their increasing reach. The key challenges here are the standardization of statistical units and harmonizing efforts so that data collected are compatible and collection efforts are not duplicated.

Finally, one recommendation made earlier was that global multistakeholder partnerships need to be intensified. The role of scientists and academics is essential in the endeavour to share the benefits of technology and innovation. Open access to data and knowledge is a key means of achieving this goal and a conducive policy environment for sharing scientific knowledge would be fundamental to the achievement of a target on technology and scientific research.

Annex 3.1: List of known NRENs by end 2013

Country	NREN	Country	NREN
Afghanistan	AFRENA	**Lithuania**	LITNET
Albania	ANA	**Luxembourg**	RESTENA
Algeria	ARN; CERIST; CNTI	**Madagascar**	iRENALA
Argentina	Innova-Red; RETINA	**Malawi**	MAREN
Armenia	ASNET-AM	**Malaysia**	MYREN
Australia	AARNet	**Mali**	MaliREN
Austria	ACOnet	**Malta**	UoM/RicerkaNet
Azerbaijan	AzRENA; AzScienceNet	**Mexico**	CUDI
Bahamas	BAHAREN	**Moldova**	RENAM
Bangladesh	BDREN	**Montenegro**	MREN
Barbados	BREN	**Morocco**	MARWAN
Belarus	BASNET	**Mozambique**	MoRENet
Belgium	BELNET	**Namibia**	X-net
Belize	BELREN	**Nepal**	NREN
Bhutan	DrukREN	**Netherlands**	SURFnet
Bolivia	BOLNET; ADSIB	**New Zealand**	KAREN; REANNZ
Bosnia and Herzegovina	SARNET	**Nicaragua**	RENIA
Brazil	RNP	**Nigeria**	ngREN
Brunei Darussalam	BRUNET	**Norway**	UNINETT
Bulgaria	BREN	**Oman**	OMREN
Cambodia	ITC	**Pakistan**	PERN
Cameroon	CameroonianNRET	**Palestinian Authority**	PALNREN; GCC; PAD12
Canada	CANARIE	**Panama**	RedCyT
Chile	REUNA	**Papua New Guinea**	PNGARNet
China	CERNET; CSTNET	**Paraguay**	ARANDU
China, Hong Kong	HARNET	**Tajikistan**	TARENA
Colombia	RENATA	**Peru**	RAP
Congo (Democratic Republic of the)	Eeb@le	**Philippines**	PREGINET; ASTI
Costa Rica	RedCONARE	**Poland**	PSNC; PIONIER
Cote d'Ivoire	RITER	**Portugal**	FCCN
Croatia	CARNet	**Qatar**	Qatar Foundation
Cuba	RedUniv	**Romania**	RoEduNet
Cyprus	CyNET	**Russia**	e-ARENA; RUNNet/RBNet; FREEnet
Czech Republic	CESNET	**Rwanda**	Rwednet
Denmark	DeIC; UNI-C	**Saudi Arabia**	Sarinet; ISU
Dominican Rep.	RADEI	**Senegal**	snRER
Ecuador	CEDIA	**Serbia**	AMRES
Egypt	EUN	**Singapore**	SingAREN

Country	NREN	Country	NREN
El Salvador	RAICES	**Slovak Republic**	SANET
Estonia	EENet	**Slovenia**	ARNES
Ethiopia	EthERNet	**Somalia**	SomaliREN
Finland	Funet	**South Africa**	TENET; SANReN
France	RENATAR	**Spain**	RedIRIS
Gabon	GabonREN	**Sri Lanka**	LEARN
Georgia	GRENA	**Sudan**	SudREN; SUIN
Germany	DFN	**Suriname**	SUREN
Ghana	GARNET	**Sweden**	SUNET
Greece	GRNET S.A.; Ariadnet	**Switzerland**	SWITCH
Guatemala	RAGIE	**Syria**	HIAST; SHERN
Haiti	CORPUHA	**T.F.Y.R. Macedonia**	MARnet
Honduras	UNITEC	**Tanzania**	TERNET
Hungary	NIIF/HUNGARNET	**Thailand**	ThaiREN; Uninet
Iceland	RHNet	**Togo**	TogoREN
India	ERNET; NKN	**Trinidad and Tobago**	TTRENT
Indonesia	INHERENT-DIKTI	**Tunisia**	CCK; RNRST
Iran, Islamic Rep.	IRANET/IPM	**Turkey**	ULAKBIM
Ireland	HEAnet	**Turkmenistan**	TuRENA
Israel	IUCC	**Uganda**	RENU
Italy	GARR; INFN	**Ukraine**	URAN; UNREN; UARNet
Jamaica	JREN	**United Arab Emirates**	ANKABUT
Japan	SINET; JGN2plus; MAFFIN, NII	**United Kingdom**	Janet
Jordan	JUNet/UniCo	**United States**	Internet2; NLR; CalREN
Kazakhstan	KazRENA	**Uruguay**	RAU2
Kenya	KENET	**Uzbekistan**	UzSciNet
Korea, Rep.	KOREN; KREONET	**Venezuela**	REACCIUN
Kyrgyzstan	KRENA-AKNET	**Viet Nam**	VinaREN; NACESTI
Lao P.D.R.	LERNET	**Zambia**	ZAMREN
Latvia	SigmaNet		
Lebanon	CNRS		

Source: ITU research based on TERENA Compendium and other publicly available information.

Annex 3.2: Regional or NREN consortia and their members by end 2013

Arab States Research and Education Network			
Algeria	Oman	Saudi Arabia	Tunisia
Egypt	Morocco	Somalia	United Arab Emirates
Jordan	Palestine	Sudan	
Lebanon	Qatar	Syria	
UbuntuNetAlliance – Eastern and Southern Africa			
Congo	Malawi	Somalia	Uganda
Ethiopia	Mozambique	South Africa	Zambia
Kenya	Namibia	Sudan	
Madagascar	Rwanda	Tanzania	
West and Central African Research and Education			
Cote d'Ivoire	Ghana	Niger	Senegal
Gabon	Mali	Nigeria	Togo
Asia-Pacific Advanced Network (APAN) – Asia/Pacific			
Australia	Japan	New Zealand	Sri Lanka
China	Korea, Rep.	Pakistan	Thailand
China, Hong Kong	Malaysia	Philippines	Viet Nam
India	Nepal	Singapore	
Central Asia Research and Education Network			
Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan
Cooperación Latino Americana de Redes Avanzadas			
Argentina	Costa Rica	Guatemala	Peru
Bolivia	Chile	Mexico	Uruguay
Brazil	Ecuador	Panama	Venezuela
Colombia	El Salvador	Paraguay	
Nordic Infrastructure for Research & Education			
Denmark	Iceland	Norway	Sweden
Finland			
Trans-European Research and Education Networking			
Albania	Estonia	Latvia	Romania
Armenia	Finland	Lithuania	Serbia
Austria	France	Luxembourg	Slovakia
Azerbaijan	Germany	Malta	Slovenia
Belarus	Greece	Moldova	Spain
Belgium	Hungary	Montenegro	Sweden
Bulgaria	Iceland	Netherlands	Switzerland
Croatia	Ireland	Norway	TFYR of Macedonia
Cyprus	Israel	Poland	Turkey
Czech Republic	Italy	Portugal	United Kingdom
Denmark			

Source: ITU research based on TERENA Compendium and other publicly available information.

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Endnotes

[1] The original WSIS indicator was worded slightly differently "Connect scientific and research centres with ICTs". Note that universities have been included in this target and removed from Target 2.

[2] Refers to high-speed access to the public Internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s (*Partnership*, 2011).

[3] Open Access policy for FP7 research has been endorsed since 2008, http://ec.europa.eu/research/science-society/index.cfm?fuseaction=public.topic&id=1300&lang=1.

[4] United Nations Economic and Social Council.

[5] See http://www.unesco.org/new/en/communication-and-information/flagship-project-activities/unesco-and-wsis/implementation-and-follow-up/unesco-and-wsis-action-lines/c7-e-science/.

[6] International Standard Classification of Education.

[7] WTDR 2010 used definitions from UNESCO's "Questionnaire on Statistics of Science and Technology" (UIS, 2010b). Scientific and technical research is defined as including "fundamental research, applied research (in such fields as agriculture, medicine, industrial chemistry etc.) and development work leading to new devices, products or processes". It includes research related to economics or sociology, but excludes routine testing, censuses and market studies.

[8] See the International Standard Classification of Education (UNESCO, 1997) at http://www.unesco.org/education/information/nfsunesco/doc/isced_1997.htm.

[9] The term "NREN" was originally a service mark of the U.S. government but the term is now applied to national research and education networks more widely.

[10] DANTE (Delivery of Advanced Network Technology to Europe) plans, builds and operates networks for research and education. It is owned by European NRENs and works in partnership with them and the European Commission.

[11] Internet2, NORDUnet, ESnet, SURFnet, CANARIE, and GÉANT.

[12] However, note that this report also uses the unit Gbit/s to describe this indicator.

[13] 1 Gbit/s = 1024 Mbit/s.

[14] See http://www.terena.org/activities/compendium/.

[15] At a regional level, NRENs join together to form regional research and education (R&E) networks, greatly enhancing the opportunities for working together on issues of concern to more than just one country. NREN consortia can comprise research institutes within a country, for example, Consortium GARR in Italy, or between countries, for example, the GÉANT consortium that comprises NRENs from over 65 countries, see http://www.dante.net/Research_Networking/Pages/Home.aspx.

[16] The 2013 TERENA Compendium has been made available after this chapter was completed (http://www.terena.org/activities/compendium/index.php?showyear=2013).

[17] Refers to government departments involved in research and development.

[18] See NRENs in the Caribbean at http://www.ckln.org/home/content/publications.

[19] Of those countries, 12 reported that they were in the planning phase of a national broadband plan. Those countries are excluded from Chart 3.1.

[20] See http://ec.europa.eu/research/science-society/index.cfm?fuseaction=public.topic&id=1294&lang=1.