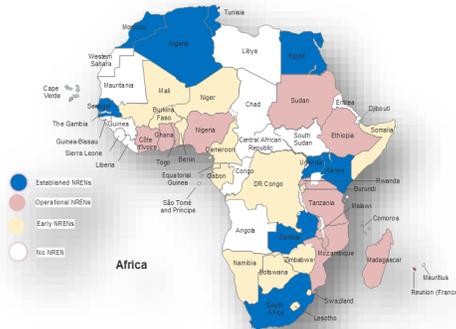




**ASSOCIATION OF AFRICAN UNIVERSITIES**  
**ASSOCIATION DES UNIVERSITÉS AFRICAINES**  
**اتحاد الجامعات الإفريقيه**

## Riding the National Research and Education Networking Train in Africa



## A Policy Brief for Stakeholders

## 1. Introduction

Information and Communication Technologies (ICTs) have become important tools for quality higher education and research. Countries and institutions recognize that academic and research networks are essential components of national infrastructures. In Latin America and Caribbean for example, cases were made for NRENs as “public goods”, because of their far-reaching implications on learning, teaching, research and many other scientific endeavours that have positive impact on economic growth and social development<sup>1</sup>. In this age of Massive Open Online Courses (MOOCs), most developed countries are investing heavily in the ICTs. They are focusing on technology-mediated learning approaches to match the changing learning styles among the youth.

There has also been a great deal of interest in establishing National Research and Education Networks (NRENs) for expanding access to information and communication technologies to the students, faculty and researchers. NRENs design, build or lease, operate and maintain physical telecommunication networks that interconnect the education and research community locally and internationally. They provide national-scale networks that link universities and research centres to each other separately from the Commercial Internet networks. NRENs provide un-congested, high-speed and advanced communications capabilities. Mature NRENs facilitate exchange of knowledge and collaboration, build technical capacities of their members and deliver other services like federated identity and roaming.

## 2. NREN as Physical Network and as “Organizations for Knowledge Networking”

National Research and Education Network (NREN) refers to:

- (i) a high performance physical network owned and operated by an education and research community that interconnects universities and research institutions to each other, and /or

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<sup>1</sup> See Red Clara White Book, Advanced Networks in Latin America: Infrastructures for Regional Development in Science Technology and Innovation, <http://www.redclara.net/index.php/en/noticias-y-eventos/publicaciones>

- (ii) an organization that designs, builds or leases, operates and maintains a physical network for the benefit of the education and research community.

NRENs were originally started as high performance communication links to interconnect universities and research institutions in order to facilitate sharing of information among them. The Algerian Research and Education Network (ARN), the Egyptian Universities Network (EUN) and the Tunisian National University Network (RNU) are some examples where NRENs began as university networks. The Tunisian National Academic Network, for example, was established in 1997 by the Tunisian Computing Center el Khawarizmi (CCK) to interconnect the campus networks of the various Tunisian universities, administrations, student's dorms, university restaurants, research centres and Technology Parks. CCK also manages a data centre and provides a set of Internet and applications and services, including email, Telnet, FTP, web hosting, e-learning, library services (BIRUNI), etc<sup>2</sup>.

The term NREN can also refer to the organization that is behind university networks. This could be constituted as a consortium of members, a dedicated agency, a company, an NGO, or other legal entity. There are a few exceptional cases, where National Research and Education Networks were established as organizations representing a network of academic institutions, without actually building a physical network. Examples include the Burundi National Research and Education Network (BERNet) in Burundi, the e@bale network that aims to interconnect universities in the Democratic Republic of Congo and Xnet that has been striving to link colleges, schools and universities in Namibia. These organizations have programmes for physical connection among universities in order to become relevant to the academic community.

Today, the term NREN represents the organizations that deliver affordable high-speed physical networks along with other services to universities and research institutions. Some of the key services include providing access to the Internet and educational resources like science gateways, labs and bulk data sets, facilitating collaboration through formation of research communities, technical capacity building and delivering other services like cloud hosting, federated identity and roaming<sup>3</sup>. The Kenya Education Network (KENET) is both the physical network and the organization delivering access to shared services like domain names, data center, cloud computing and science gateways. KENET also provides capacity building and network security services for its members.

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<sup>2</sup> <http://asrenorg.net/?q=content/tunisia-0>

<sup>3</sup> In some cases, the physical networks and the NREN organizations have different names; while in others, they are indistinguishable. In Canada, CANARIE represents the organization while CA\*Net stands for a physical network connecting Canadian Universities.

### **3. The Rationale for National Research and Education Networks**

National Research and Education Networks were originally driven by the need to provide cheap access to the Internet to a consortium of universities. Unlike commercial Internet providers that only deliver access to “commodity/commercial” Internet traffic, NRENs focus both on non-commercial Internet access and most importantly on the flow of research traffic. They operate the national backbone that connects campus networks to each other and to other NRENs globally, with its own routers, switches and servers. NRENs allow access to each other’s services, and route research and education traffic across each other’s network infrastructures—i.e., via the Global networks like GEANT, Red Clara or TIEN. They run their own Network Operations Centre (NOC) to monitor the network and manage all traffic on it.

In recent years, there has been a gradual shift towards combining the provision of high speed connectivity with the advanced value added services that contribute to improved teaching, research, administration and learning. In networks like Internet2 in the USA and many NRENs in Europe the focus is only connectivity to other NRENs and carrying educational and research traffic. In Africa, however, the attention has been in getting physical connection to the Internet in the first place, because of the vital importance of international bandwidth for access to the vast bulk of Internet sites and content.

African research and education networks also need to promote access to research and education traffic. The academic and research traffic allows universities access to scientific applications and data in the area of Engineering, Information Technology, Economics, Physics, Biological and Environmental studies. By providing access to educational resources, complex data sets and computing facilities (i.e. supercomputers and scientific instruments like optical and radio telescopes), NRENs create the platform for resolving economic and social challenges facing the continent. In agriculture, for example the advanced networks can create the platforms for research on biotechnology and genomics that will contribute to food security.

Research and education networks can also stimulate regional scientific collaboration. In recent years there has been a reduction of the network latency due direct interconnections between countries. Historically, all intra-regional traffic had to travel via routers in London and Amsterdam - incurring delays and additional costs. As a result of the UbuntuNet Alliance regional network, the network latency between Kenya and South Africa has been cut six fold from 360 milli seconds in 2011 to 60 milli seconds in 2015. This allowed for improved collaboration between researchers in the two countries. Scientists, researchers and students in Africa can

now work effectively with each other, are able to share data quickly and collaborate more efficiently.

There has also been gradual transition from the provision of connectivity to rolling out services. Matured NRENs like KENET (Kenya), TENET (South Africa), RENU (Uganda) and ZAMREN (Zambia) have already launched services such as Eduroam, identity management, hosting of Google caches and mounting digital library services that will encourage the exchange of scientific knowledge and improve global research collaboration. In sum, the establishment of National Research and Education Networks will:

- Provide high-speed, high performance and low cost broadband network for research organizations to link up to each other and carry out collaborative research or applications,
- Promote regional and international academic and research collaboration,
- Create economies of scale for building and sharing high speed networks and access to expensive research equipment and laboratories,
- Enable customization of connectivity solutions for research teams collaborating globally,
- Promote distance learning and video conferencing and access to services such as Domain Name Services, network security, identity management, network operation, caching, web hosting, IP telephony, e-mail, Eduroam, etc. for the entire education and research community.
- Provide centralized training, capacity building and advisory services to their member institutions and others such as local secondary schools,
- Promote linkages between the academic and research community, industry, government and other international research and educational networks,
- Allow for the running of data-intensive applications (e.g. bio-modelling and computation) and sharing of high end computing assets thereby facilitating advanced research
- Provide the experimental platform for researchers to investigate, develop and test new network and Internet technologies and applications prior to deployment within the public sector or for commercial use.

#### **4. Structure of Research and Education Networks**

The main building blocks of research education networks are campus networks that connect the users to local and global networks. Universities then aggregate their campuses into a single institutional network with intention to connect to a National Research and Education Network. The national networks in turn link to each other through Regional Research and Education Network (RREN) backbones like that of the UbuntuNet Alliance backbone in eastern Africa and

other international networks like **GÉANT** in Europe or **Internet2** in the United States. Figure 1. Shows the building blocks of research and education networks.

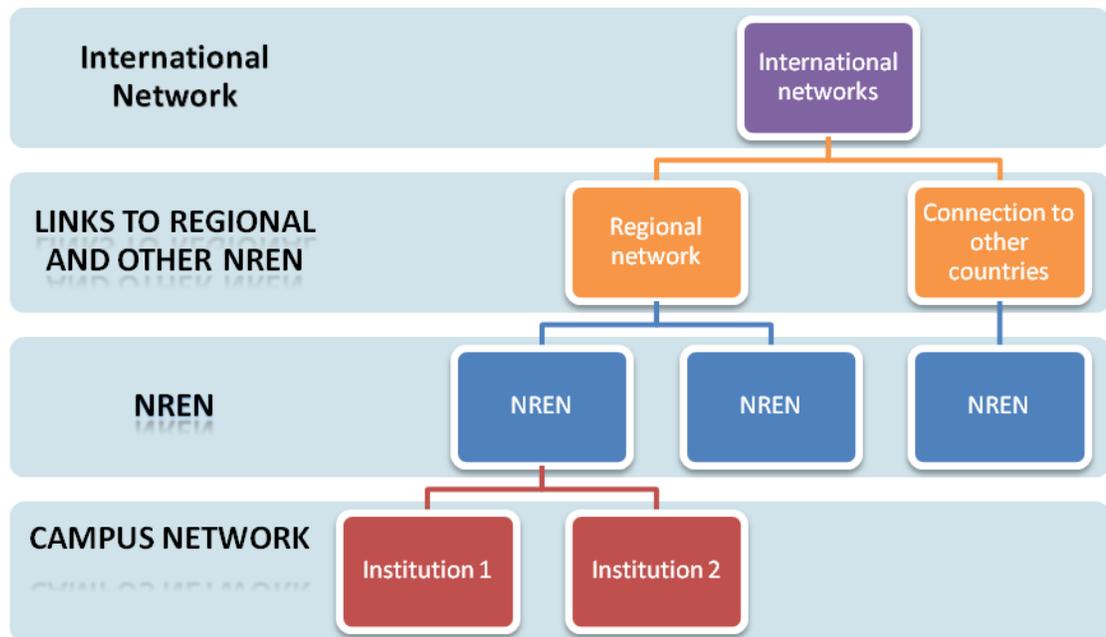


Figure 1. Building Blocks of Research and Education Connectivity

The international research and education network is an interconnection of regional networks in North America, South and Central America, Europe, Asia, Africa, the Caribbean and Australia. There are over 120 countries that have initiated NRENs. Australia, Europe, North America and Asia have successful NRENs with differing governance and funding models, organisational structures, types of members and the services that they provide to users.<sup>4</sup>

The GÉANT Association is the largest network that is owned by 36 European NRENs and NORDUnet, which participates on behalf of five Nordic countries. The GÉANT serves as an interconnection and support hub to the majority of the international networks. In Asia the Trans-Eurasia Network (TIEN) links research and education institutions in the Asia Pacific region including those in Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Japan, Korea, Laos, Malaysia, Nepal, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam to

<sup>4</sup> Dyer John (2009). The Case for National Research and Educational Networks (NRENs), [www.terena.org/publications/files/20090127-case-for-nrens.pdf](http://www.terena.org/publications/files/20090127-case-for-nrens.pdf)

the GEANT. Canarie in Canada, Internet 2 in the United States of America are other large networks that connect to Europe, Asia and South America. The Latin American Cooperation of Advanced Network (Red Clara) links universities from 17 South and Central American countries. The North African countries including Algeria, Egypt, Morocco and Tunisia are connected through EUMEDCONNECT network that link them to GEANT. They are members of the Arab States Research and Education Network (ASREN).

The last decade has seen a great deal of focus on research and education networking development in Africa, Eastern Europe, Central Asia and the Caribbean. The UbuntuNet Alliance for Research and Education Network<sup>5</sup> was formed in 2005 to interconnect universities in Eastern and Southern Africa. Through the AfricaConnect project that was financed by the European Commission the UbuntuNet Alliance was able to interconnect Universities within the region and to their international counterparts through the GÉANT. The West and Central African Research and Education Network (WACREN) was established in 2010 with the support of the Association of African Universities. WACREN has a family of nine formally established NRENs in Benin, Cote d'Ivoire, Gabon, Ghana, Mali, Niger, Nigeria, Senegal and Togo. However, these were not as active as NRENs in Eastern and Southern Africa.

Figure 2 shows the Global NRENs and Regional networks. It is evident that the emerging NRENs in West and Central Africa have not featured yet on the global map.



<sup>5</sup> <https://www.ubuntunet.net/>

## Figure 2. International and Regional Research and Education Networks

Source: GEANT Association

### 5. NREN Success Factors

Despite significant investments, the African continent still lags behind other regions in the development of research and education networks. For NRENs to be functional they need connectivity (routing traffic through the educational and research networks) and a management and governance framework. Other ingredients include promotion of the usage of advanced network resources, securing funding for start-up operations, building the technical capabilities of network engineers and launching essential services. The main success factors are:

- A dedicated physical network for interconnecting universities and research institutions,
- Coordination mechanisms for members' participation,
- Dedicated Staff, engineers to manage and maintain the networking infrastructure,
- Active support from the Government in terms of funding,
- Active support from the telecom regulators for funding and addressing regulatory and policy matters that affect them,
- Active support from the infrastructure providers, telecoms, electricity providers to leverage their right of way and infrastructure, where possible. This also includes good pricing terms for managed networks or securing Indefeasible Right for Use,
- Availability of financial resources for continued operation either from members, development partners or the government,
- Strong relationships with all potential member institutions facilitating reduction of fragmentation of the network resulting from independent connections,
- Cooperation with other NRENs and regional RENs like the UbuntuNet Alliance, WACREN or ASREN
- Training and skills development for technical staff of member institutions,
- Formal agreements and publication of Acceptable Usage Policy to be adhered to by members,
- Dedicated Autonomous System Number, and

- Dedicated IP space for NREN operation. NRENs could also become a Local Internet Registry (LIR) for the connected institutions and assist them in implementing the public IP address space.

For the purpose of assessment, these success factors can be grouped into seven dimensions as shown in table 1. An NREN self-assessment matrix that builds on these success factors is provided in Annex I.

**Table 1. NREN Readiness Assessment Dimensions**

<b>Dimensions</b>	<b>National Factors</b>	<b>Regional Factors</b>
<b>Commitment</b>	Government awareness and understanding of benefits of NREN  Policy and regulatory endorsement	Awareness and commitment by regional and international institutions to host and support regional networks like WACREN, ASREN, UbuntuNet Alliance  Financial and regulatory support for a regional network
<b>Coordination</b>	Collaborative initiatives among tertiary education institutions to interconnect and share resources  Lean and efficient management framework for NREN comprising a management board and functioning secretariat	Support to institutional and governance frameworks for regional networks including operational management and staffing
<b>Connectivity</b>	Broadband availability  Affordable commercial conditions, e.g. IRU, regulatory endorsement  Uninterrupted equipment supply and warehousing	Regional backbone availability and commercial conditions such as Indefeasible Right of Use (IRU) for access to backbone network

		Supply of equipment for the regional network
<b>Capability</b>	Human resources and internet-working skills at university and national levels  Training opportunities for staff of member universities	Human resource development initiatives for NRENs  Technical skills for managing a regional REN
<b>Content and services</b>	Sharable content and resources, potential for strong research communities that leverage e-infrastructures  Services that respond to societal needs  Research communities  Advanced services such as science gateways, Euroam, identity management	Applications and services that can be shared at regional universities and institutions  Advanced services at regional levels that respond to regional cooperation and development goals  Cross-border research communities
<b>Cash (financial resources)</b>	Public funds, donor financing, universal access funds for NREN development  Continuous stream of membership fees	Financial and non-financial resources for the operation of a regional network  Continuous stream of membership fees

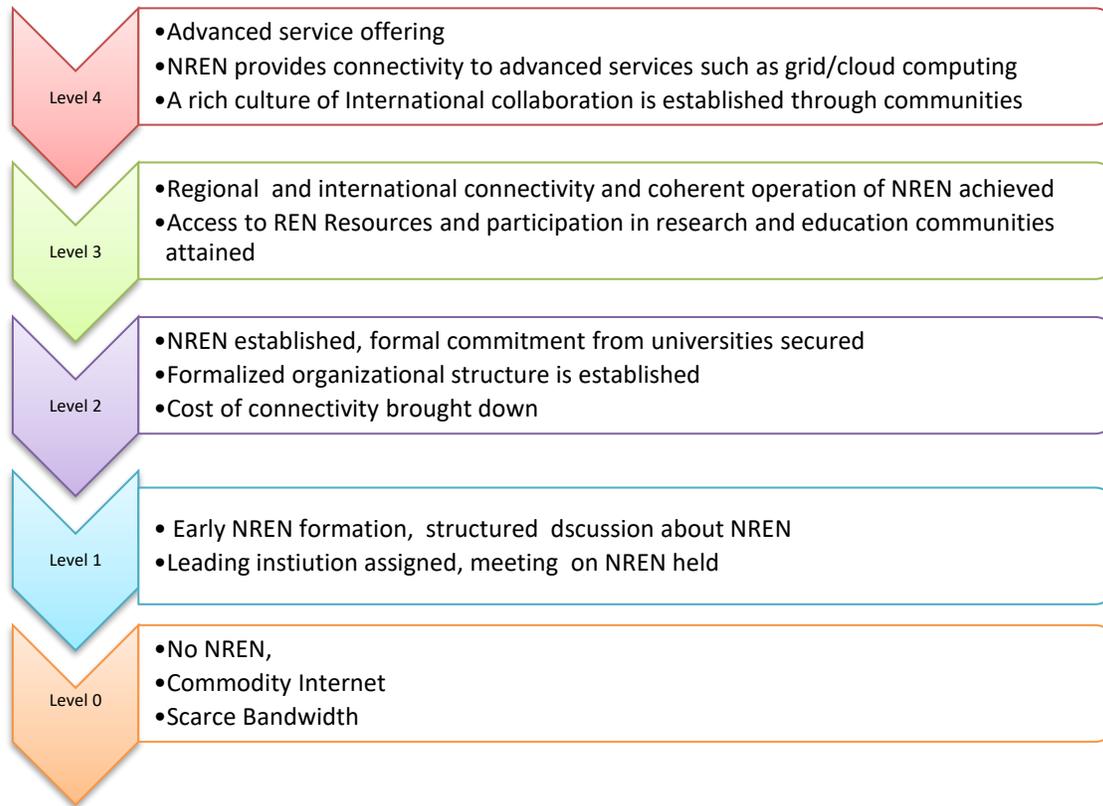
Drawing on the success factors dimensions and an NREN Maturity Model developed by Duncan Greeves<sup>6</sup> shown in Figure 3, it is possible to categorise African countries into four NREN development stages:

- One in six African countries have achieved a significant progress in terms of interconnecting universities and research institutions in 2016. The countries in these categories are Algeria, Egypt, Kenya, Morocco, Senegal, Tunisia, South Africa, Uganda and Zambia. Uganda and Zambia have seen progress over the last two years due to investment by local champions and favourable regulatory environments in these countries. The Tertiary

<sup>6</sup> Greeves, Duncan, NREN Capability Maturity Model, [http://www.ubuntunet.net/sites/ubuntunet.net/files/NREN\\_Capability\\_Maturity.pdf](http://www.ubuntunet.net/sites/ubuntunet.net/files/NREN_Capability_Maturity.pdf)

Education and Research Network (TENET) of South Africa is the most advanced NREN in the region. It has been providing technical and managerial support to other NRENs in the eastern and southern Africa regions. Similarly, the presence of a strong research and education network in Kenya is inspiring the eastern African countries especially Rwanda and Tanzania. The Senegalese research and education network (SnRER) is not only running the Network Operation Center (NOC) for the WACREN region but also serving as a capacity building platform for the rest of the French Speaking countries.

- The second category represents countries that have begun building physical networks for research and education institutions. These include Cote d'Ivoire, Ethiopia, Ghana, Madagascar, Mozambique, Nigeria, Rwanda, Sudan, Tanzania and Togo. These countries have already established physical networks among their universities and research institutions and have made links to international networks a priority.
- The third group of countries represents those, which initiated NREN activities, but have not yet built robust physical networks between academic institutions. Benin, Botswana, Burkina Faso, Burundi, Cameroon, Democratic Republic of Congo, Gabon, Lesotho, Malawi, Mali, Mauritius, Namibia, Niger, Swaziland, Somalia and Zimbabwe have activities on the ground that will lead to NREN formation, but these lag far behind in terms of establishing viable networks among their tertiary level institutions.
- The fourth category comprises countries that do not have NREN activities on the ground. They are: Angola, Cape Verde, Central African Republic, Chad, Comoros, Republic of Congo, Djibouti, Equatorial Guinea, Eritrea, Gambia, Guinea, Guinea-Bissau, Liberia, Libya, Mauritania, Sierra Leone, Sao Tome and Principe, Seychelles, and South Sudan.



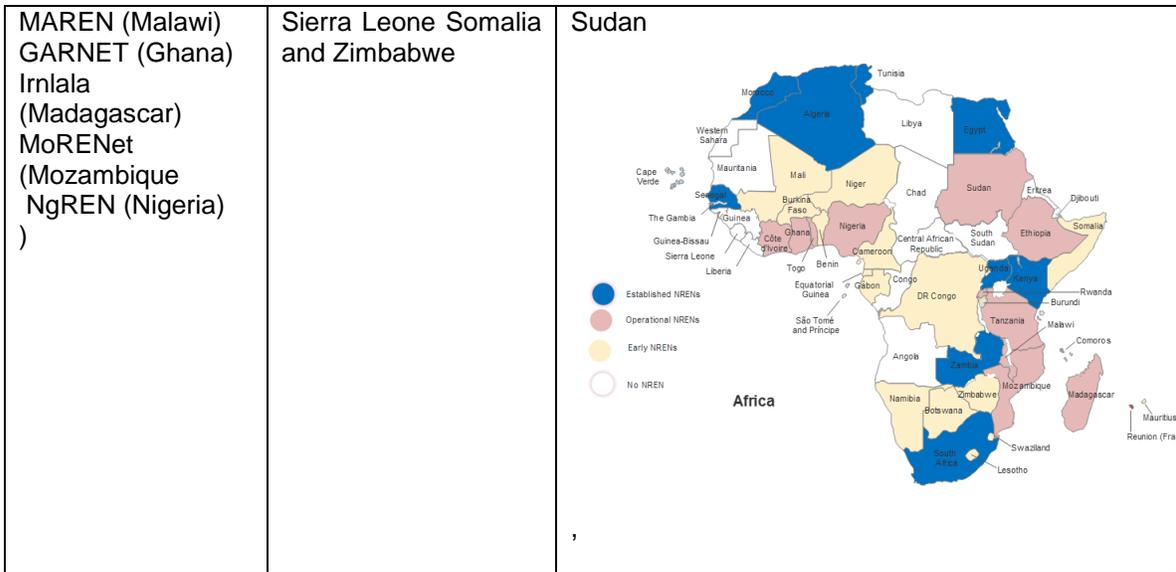
**Figure 3. NREN Maturity Model**

Source: Duncan Greaves,

[https://www.ubuntunet.net/sites/default/files/NREN\\_Capability\\_Maturity.pdf](https://www.ubuntunet.net/sites/default/files/NREN_Capability_Maturity.pdf)

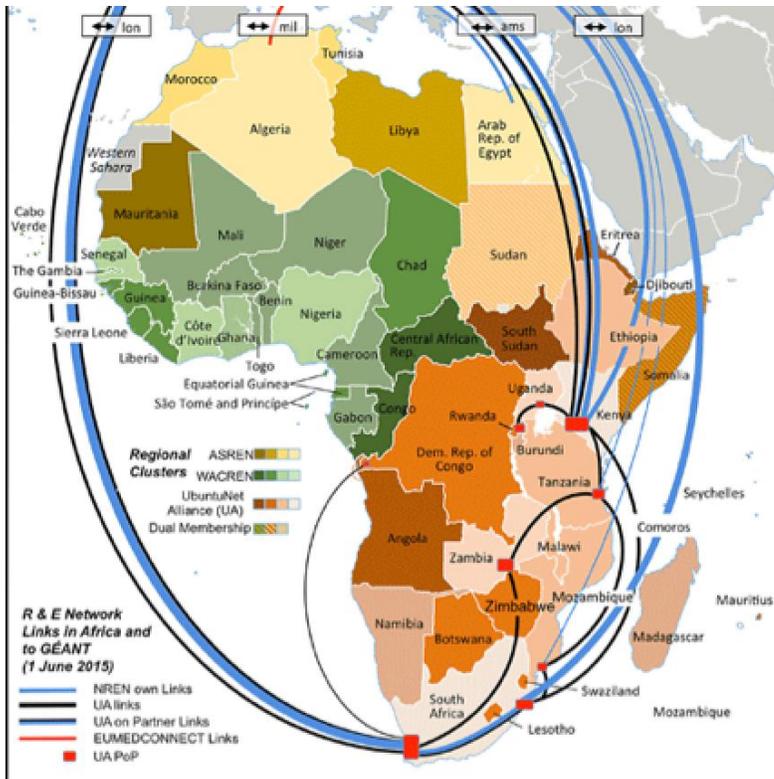
The full distribution of NREN in Africa is provided in Figure 4.

NREN	Initiatives	Figure 3. NREN Distribution in Africa
<b>Established NRENS</b> ARN (Algeria) EUN (Egypt) KENET (Kenya) MARWAN (Morocco) RENU (Uganda) RNU (Tunisia) SnRER (Senegal) TENET (South Africa) ZAMREN (Zambia)	RITER (Cote d'Ivoire) RWEdNeT (Rwanda) SUIN (Sudan) TERNET (Tanzania) ToGoREN (Togo)	No NREN - Angola, Cape Verde, Central African Republic, Chad, Comoros, Republic of Congo, Djibouti, Equatorial Guinea, Eritrea, Gambia, Guinea, Guinea-Bissau, Liberia, Libya, Mauritania, , Sao Tome and Principe, Seychelles and South
<b>Operational NRENS</b> EtherNet (Ethiopia)	<b>New NRENS</b> Benin, Botswana, Burkina Faso, Burundi, Cameroon, Democratic Republic of Congo, Gabon, Lesotho, Malawi, Mali, Mauritius, Namibia, Niger, Swaziland,	



**Figure 4. NREN Development in Africa**

It is evident from Figure 4 that the readiness of NREN varies considerably across Africa largely due to disparity in the commitment of government and university leaders. The Development of Research and Education Networks also vary considerably across regions. Southern and Eastern African countries that belong to the UbuntuNet Alliance backbone network and Northern African countries that belong to the ASREN network have the most advanced NRENs, while central north and western Africa has still not deployed a robust regional and international backbone. The Regional Research and Education Networks and their backbone are presented as shown in Figure 5.



**Figure 5. Regional Research and Education Networking in Africa**

Sources: World Bank, 2015

True NREN readiness can only be achieved when sufficient government commitment is secured and an organization that is recognized and supported by the public and private higher education institutions is created. The organisation needs to be properly staffed to handle both administrative and technical matters and to have the capacity to negotiate connectivity deals on behalf of their members.

The initial capital cost for building the research and education backbone is very high. The availability of resources from government and donor agencies is thus critical at the early stages of NREN formation. The most successful NRENS in Algeria, Egypt, Kenya, Morocco, South Africa, Uganda and Zambia have benefited greatly from government direct funding and from financial support provided by regulators from their Universal Access Funds. Kenya, South Africa and Zambia have also benefitted from donor funding at the start of their National Research and Education Networks. Significant funding has also been available from the European Commission to develop regional networks and interconnect NRENS to each other and to European Research Network GÉANT through the AfricaConnect and EUMEDCONNECT projects.

**The AfricaConnect Project**

The AfricaConnect project is a collaborative partnership project between Africa (represented by the UbuntuNet Alliance, the West and Central African Research and Education Network (WACREN) and the Arab States Research and Education Network (ASREN) and Europe through the GEANT Association). The first phase of the AfricaConnect project that ran between 2011-2015 focused on building regional research and education networks in Eastern and Southern Africa with a total budget of €14.75m for a period of four years, with 80% of the funding provided by the European Development Fund (EDF). Funding was shared 80:20, with 20% of the amount covered by the National Research and Education Network organisations within Eastern and Southern Africa. The project contributed to the development of the UbuntuNet Alliance regional and international backbone and to building the capacities of WACREN.

The second phase of the AfricaConnect project was launched at the end of 2015 with a budget of €26.6m to provide dedicated high-speed academic network all over Africa. The UbuntuNet Alliance, ASREN, WACREN and the GEANT Association are working towards developing high-capacity internet networks across the African continent and connect them to the European GÉANT network, to allow students, researchers and academics in Africa and beyond to collaborate. The connectivity boost is expected to advance research and education locally with opportunities like e-learning and cloud computing and also contribute to advanced research in climate change, biodiversity, food security, malaria and other infectious diseases.

Source:- <http://www.africaconnect.eu/Project/Pages/Home.aspx>

Leadership at regional and national level has also been a major catalyst of research and education networking in Africa. At the national level, the leadership was provided by NREN CEOs and other champions. The success of research and education networks in the countries like Kenya, Senegal, South Africa, Uganda and Zambia attribute their successes very much to the highly dedicated CEOs.

The Association of African Universities is a key leader in the development of Research and Education Networking at the continental level. The AAU did not only contribute to the actual development of the UbuntuNet Alliance and the West and Central African Research and Education Network (WACREN), but also played a major role in building their capacities.

#### **NREN Leadership Role of the Association of African Universities**

The AAU has played a considerable role in driving the development National Research and Education Networks in Africa. The AAU established a Research and Education Networking Unit (RENU) on the subject following the 11<sup>th</sup> Conference of Rectors, Vice Chancellors and

Presidents (COREVIP) in 2005 that gave the Secretariat a strong mandate to assume focal point role for ICT initiatives for African higher education institutions. Subsequently, the AAU paid a great deal of attention in promotion of NRENs and the creation of regional research education networks.

The AAU is one of the founders of the UbuntuNet Alliance and has been the founder and host of the WACREN since its establishment in 2010. The AAU mobilized resources and launched activities at national levels including NREN policy advocacy, organization of national workshops that led to the formation of all NRENs in west and central African countries.

The AAU has built strong strategic partnerships with donor agencies and regional institutions to mobilize technical and financial resources for facilitating NREN development. It has negotiated the allocation of Internet Protocol numbers to NRENs at a discount tariff with AfriNIC. The AAU has signed collaborative agreements with the Africa Network Operators Group (AfNOG) and the Network Start up Resource Centre (NSRC) at the University of Oregon to build the capacities of network engineers at universities at national levels.

The Secretariat has continued its multi-pronged effort to promote collective action, especially in relation to lobbying for affordable and open access to bandwidth and develop a “clearinghouse” of information on ICT and research and education networking initiatives, trends, opportunities, good practices, expertise and funding sources. AAU continues to play a further and critical role in fostering regional cooperation and providing the platform for resource mobilization, policy harmonization, and promoting effective integration of ICTs into the process of teaching/learning, research, information management and dissemination in higher education in Africa. The development of NREN policy briefs input to the policy advocacy effort of the Secretariat.

## 6. Strategies for Riding the NREN Train

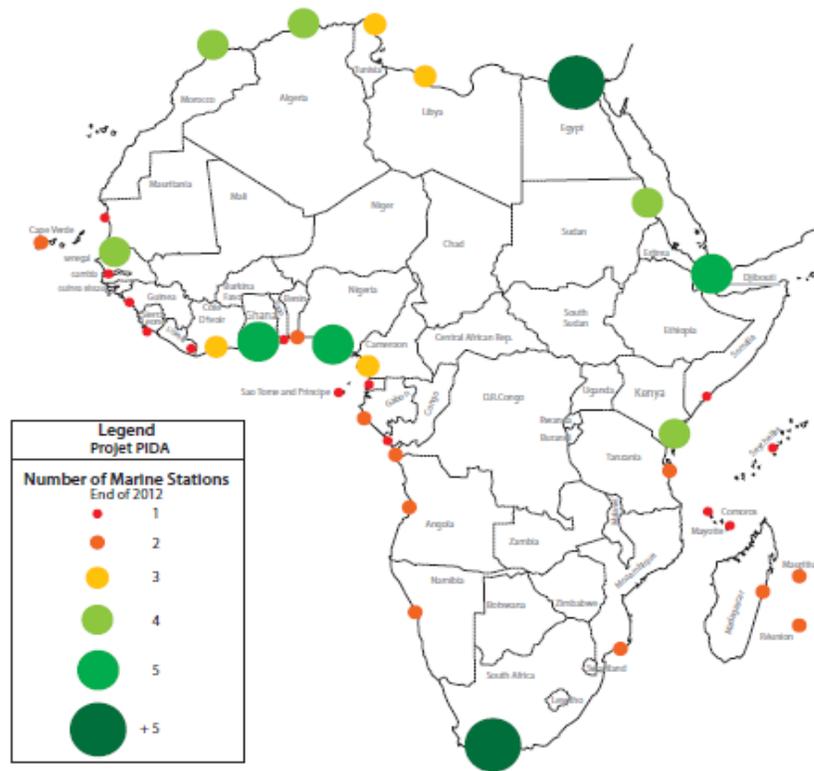
Notwithstanding the progress that was made over the last decade, many African countries have not been able to ride the research and education train. About 45 countries in Africa have yet to establish sustainable research and education networks that promote access to global educational resources and

facilitate interaction at national and regional levels. To be sustainable, NRENs need to have access to state of the art broadband networks at affordable prices, build resilient network at campus, institutional and national levels. They require access to state of the art capacity building in networking technologies tailored to their needs. NRENs need to be governed by flexible management and organizational frameworks that allow equitable opportunities for small colleges and larger national universities alike. The support from decision makers and regulators is important for their success especially for access to affordable bandwidth. Finally there is a need for NRENs to contribute to the societal mission of educating skilled human resource for the information economy.

#### **a. Bandwidth Availability**

The mission of most NRENs, and especially younger NRENs, is to provide Internet services over the fastest possible bandwidth for their user institutions. NRENs aggregate universities' demands for connectivity and so secure much greater bandwidth, through rentals or through the purchase of long-term Indefeasible Rights of Use (IRUs) to capacity on terrestrial and/or submarine circuits. The availability of such bandwidth is the corner stone for NREN's success.

The African communication infrastructure that serves the research and education networking community has been improving over the last decade. Almost all coastal countries except for Eritrea and Guinea Bissau have established their landing stations. Landlocked countries have at least one link to the undersea cable through neighbouring countries. Figure 6. Shows connections to submarine cables.



**Figure 6: Access to Undersea Cable**

Source: Programme for Infrastructure Development in Africa (2015)

Countries have also been investing in the development of their national backbones to create opportunities for connecting research and education institutions in their hinterlands. Angola, Botswana, Burundi, Ethiopia, Ghana, Kenya, Malawi, Madagascar, Rwanda, Tanzania, Sudan, South Africa and Uganda are among the countries. At the moment much of the fibre is concentrated in the Southern and Eastern parts of Africa and around Nigeria in the West. Fibre backbone networks are very sparse in central Africa. Connections between North Africa and the rest of the regions are very limited. A low density national fibre backbone network increases the costs of connectivity due to reliance on expensive cross-border routes and limits the quality of Internet access and services available to academic and research institutions.

Cross-country links present challenges in Africa due to different regulatory environments and the high cost of regional backhaul connections to submarine cables. The main infrastructure related challenges facing NRENs at early stages include:

- Limited access to last mile fibre networks,

- Lack of national backbones to interconnect universities and research institutions,
- Limited options for cross-border interconnection between universities and national research and education networks, and
- Tendency to assume a small amount of bandwidth (1 to 5 Mbps) as sufficient to carry out teaching, research and learning at university levels.

### **b. Reduction in Bandwidth Cost**

Broadband prices in Africa have come down recently but they are still high compared to those in Asia, and Latin America. Prices of bandwidth are very high especially in land locked countries, where the commercial condition do not allow for long term Indefeasible Right of Use of fibre networks. In West Africa, for example, the price of a 1 Mbps circuit has gone down from between US\$3000 and US\$9000 in 2008 to between US\$500 and US\$1800 in 2014. In 2015, the price has come down to between \$300 and \$1200 in 2015. This is an achievement when compared to satellite access prices that ranged from an average of \$5000 per Mbps/month 10 years ago. Again, these prices are generally high when compared to Asian prices that range between US\$32 to US\$70 per Mbps/month and the Latin American which range between US\$32 and US\$80 per Mbps/month<sup>7</sup>.

In Eastern and Southern Africa, the prices have been falling fast partly due to emergence of regional carrier of carriers like Liquid Telecom and the effort by champions in negotiation for long term Indefeasible Right of Use (IRUs) on fibre network. One of the key benefits of the AfricaConnect programme in Eastern and Southern Africa was its negotiation for reduction of international and regional circuit costs based on favourable Indefeasible Right of Use (IRU) prices. Negotiation of an IRU in Eastern and Southern Africa has brought the access costs down, making it cheaper for research and education institutions in the long term. On the average the cost of a 1 Mbps circuit has fallen between four to five folds from tariffs in 2011 to \$120, \$180 and \$300 in 2016 in Kenya, Uganda and Zambia respectively as shown in Table 3.

Country	Price of 1Mbps circuit /month - 2011	Price of 1Mbps circuit /month 2015	Prices in 2016
Kenya	\$600	\$160	\$120
Uganda	\$630	\$210	\$180

<sup>7</sup> <https://blog.cloudflare.com/the-relative-cost-of-bandwidth-around-the-world/>

Zambia	\$1200	\$380	\$300
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**Table 2. Broadband Price changes in selected countries**

Source: AfricaConnect Project

A bulk cross-country price negotiation based on the IRUs under the AfricaConnect 2 project is expected to bring the connection tariffs in West and Central Africa down and making them comparable to those in Eastern and Southern Africa.

### **c. Building Resilient Campus Networks**

The basic tasks of access to the Internet and content and user management functions like data protection, bandwidth reservation and management, helpdesk services, training, documentation, security and authentication take place at the campus levels. Sub optimal campus networks can limit the performance of an NREN.

The majority of campus networks in African universities are not designed such that they do not utilize high bandwidth connection. This is partly due to limited capacity to redesign campus network to benefit from NREN connectivity. Lack of investment is another challenge facing the campus networks that require continuous upgrade of:

- Network infrastructure with adequate bandwidth (preferably Gigabit Ethernet) and high quality of services. The networks should be secured and have support for mobility and roaming. This requires the integration of wireless networks into the campus networks.
- Servers with redundant storage capacities running different functions such as e-learning, mail and web access, streaming media, collaboration and support to numerous research and instructional applications,
- User services comprising technical support, training and help desk,
- Access to specialized computing resources such as labs, high graphics and simulation equipment, and
- Network monitoring and tuning tools.

The improvement of the campus networks for optimal bandwidth management requires considerable training and financial resources to acquire state of the art equipment. Universities need to consider the upgrade of their campus networks when they subscribe to join the NRENs.

### **d. Securing Political Will and Support**

As discussed above, securing support from policy makers is an important success factor for research and education networking. Government buy-in is especially critical at early stages where investment in NREN infrastructure and operation

demands public financing and support. Government will also help in securing donors' support to NRENs. There is a wide range of NREN stakeholders that influence the overall course of progress. These include:

- Ministries responsible for higher education (e.g. Ministry of Education, Ministry of Science and Technology),
- Ministries responsible for communication (e.g. Ministry of Transport and Communication, Ministry of Communication and Information Technology),
- Ministries responsible for finance and economy (e.g. Ministry of Finance),
- Leaders of tertiary education institutions (college deans, university presidents/vice chancellors,)
- Communications sector regulator,
- National university councils,
- Champions (usually a director of corporate IT services from the largest university in a country),
- Lead researchers or practitioners that are often regarded as national icons (e.g. lead surgeon, lead educator, etc.)

The interaction among these players and their overall commitment towards a common NREN goal is critical.

#### **e. Regulatory Support for the NREN Cause**

The high price of broadband network can partly be attributed to regulatory problems in the African countries. The licensing frameworks in most countries were developed in the early 1990s before the advent of NRENs, thus, they do not cater for closed user groups like NRENs. Some of the regulatory issues that affect NRENs include:

**Securing Licenses:** The conventional licensing frameworks in African countries forbid other entities, apart from telecom operators, from providing services to wider user communities. Occasionally there is a misunderstanding of the NREN' service model as a Closed User Group dedicated to an academic and research community. Operators often regard them as competitors. In some countries in Eastern and Southern Africa like Kenya and South Africa, NRENs have already been granted formal licenses to own and operate their own networks. However, most countries in Africa do not allow NRENs to deploy their self-owned networks. Instead NRENs are required to lease or rent capacity from the monopoly providers. This denies them the option of building cost effective networks for special research purposes. NRENs should be able to build and own physical networks. They should be allowed to access to the dark fibre that is available from the alternative service providers like the electricity companies. Furthermore, NRENs should be able to access international gateway without restrictions.

**Commercial Conditions for Network Access:** Broadband pricing and commercial conditions to access the network are other issues that need to be addressed by regulators. Monopoly telecom operators do not only over price bandwidth, but also prevent NRENs from accessing long term Indefeasible Right to Use (IRU) over their fibre networks. Regulatory interventions are important to promote favourable pricing and commercial conditions.

**Spectrum Licensing and Fees:** The increasing interest in roaming (e.g. Eduroam) and the demand for broadband wireless networks for interconnecting campuses has made access to spectrum very important for NRENs. Among the regulatory issues in this area are: unrestricted access to unlicensed spectrum and regulatory provision for access to desired spectrum by NRENs at a lower cost.

**Benefiting from Universal Access Funds:** Regulators across the continent have been developing universal service strategies and collecting funds to close the gap of access to communication services. Realizing that the voice gap has now been closed, some regulators are investing part of their universal access proceeds on the development of research and education networks. NRENs in Kenya, Rwanda and Uganda have already benefited from universal access funds for covering some of their operational costs.

Regulators can also play a key role in studying broadband demand in general and the requirements of NRENs in particular in order to develop long term plans that will stimulate further network rollout by operators and governments through public and private partnership models.

#### **f. Governance and Organization**

Governance and management is considered a strategic issue for the sustainable operation of an NREN because inclusiveness and participation of members is an essential ingredient for success. While it is possible to start an NREN as a project with a few people managing it, stable NRENs require a full governance framework composed of a members' assembly, a management board and technical working groups. An NREN should have engineers and administrative staff headed by a Chief Executive Officer (CEO).

Every NREN requires a dynamic CEO/leader and technical personnel who maintain the network, deliver applications and services and guide the evolution of the network and services to meet the changing needs of member institutions. NREN CEOs can make or break research and education networking; therefore efforts need to be put in place in appointing a steadfast and self-motivated manager.

#### **g. Access to Financial Resources**

NREN formation and its subsequent operations require seed funding and a continuous stream of resources from members. Initial seed funding from government is very important to establish the first few links between institutions in order to showcase NREN success. The long-term financial sustainability of NREN needs to be ensured through increased membership. A wider customer base will guarantee better income that will reduce the burden on the government financing. NREN managers also need to seek resources from donors, private sector and regulators in order to increase its annual budget and balance the dependency on government financing and membership fees.

#### **h. Training and Capacity Building**

The creation of NRENs needs to be accompanied by technical skill development right from the inception. This training should be carried out at the individual academic institution and at the NREN secretariat levels. A wide range of training opportunities exist including those available through the UbuntuNet Alliance, WACREN, ASREN in coordination with the NSRC and AFNOG. Holding a national workshop for member institutions and training of trainers has proved to be a good start for building capacities at the local levels. Peer-to-peer training programmes where staff from one college and research institution undertakes attachments to other campuses have also been successful. Universities can also forge alliances with communications service providers and IT companies to get on-the-job training in network deployment and management for their staff.

#### **i. Applications and Service for Users**

The higher goal of NRENs is providing content and applications for researchers, students, academic and administrative staff. Different NREN users require different connectivity, applications and content options, therefore NRENs should be ready to meet the services needed by different groups. The most desired applications of the user communities include:

- Internet Access,
- Access to digital library resources,
- Access to Open Educational Resources (OER) including local Learning Management Systems,
- Connections to high speed networks and computing power, grids, labs and scientific equipment,
- Video conferencing,
- Domain Name Services,
- Network operations and management, and

- Network security.

While the focus of NREN has generally been on providing access to the Internet, it is essential to optimize the network for high-end users that are often involved in cutting edge-research in medicine, engineering, sciences, economics relevant to social and economic development. NRENs should ultimately be relevant to the development mission of the society; therefore access to advanced applications and services such as science gateways, grid computing and large scale databases should be promoted.

Regionally, NRENs need to build on platforms and initiatives that promote sharing of educational resources and encourage collaboration. The Database of African Theses and Dissertation (DATAD)<sup>8</sup> that was established in 2002 by the Association of African Universities has been working towards building a regional database of theses and dissertations to improve the accessibility to the works of African scholars both within and outside the continent. The Natural Product Research Network for Eastern and Southern Africa (NAPRECA) is another regional programme running since 1984. NAPRECA aims to promote exchange of knowledge on natural products in the region. There are also other initiatives such as OER Africa that aim to increase access to open course materials that need to be tapped by the research and education networks. Promotion of access to these and other regional initiatives is critical to facilitate regional scientific collaboration.

In addition, there is a need to tap into international efforts like the European Commission sponsored projects like MAGIC and Sci-GaIA that aim to increase collaboration between scientists worldwide.

#### **EU Sponsored projects supporting scientific collaborations**

Middleware for collaborative Applications and Global virtual Communities (MAGIC),

MAGIC is a cooperation project that aims to significantly improve the ability of researchers and academics around the world to collaborate together. It builds on the achievements of the ELCIRA project that provided tools and services for collaborative research between Europe and Latin America, and is led by the Latin-American networking organization RedCLARA. With partners in West, Central, Eastern, Southern and North Africa, the Middle East, Central Asia and

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<sup>8</sup> <http://www.aau.org/?q=datad>

Asia-Pacific as well as Latin America and the Caribbean, MAGIC focuses on the following aspects:

- Expanding the global reach of eduroam and identity infrastructures for the academic world.
- Establishing middleware to enable national research and education networks (NRENs) around the world to share services and real-time applications for international and inter-continental research groups via a common marketplace.
- Supporting Global Science Communities.

### **Energising Scientific Endeavour through Science Gateways and e-Infrastructures in Africa (Sci-GaIA).**

Sci-GaIA proposes to produce clearly structured guides and educational documents that can be used to train and support representatives of NRENs, Communities of Practice (CoPs), and Universities to develop Science Gateways and e-infrastructures in Africa. This will give a sustainable foundation on which African e-infrastructures can be developed. Sci-GaIA will work with new and emerging Communities of Practice to develop these exciting technologies, strengthen e-Infrastructure service provision, especially in terms of open access linked data, and deliver training and dissemination workshops. The results of Sci-GaIA are expected to be usable by Communities of Practice in Europe and the rest of the world.

Source: <http://magic-project.eu/index.php/component/tags/tag/17-sci-gaia>

## **7. Role of Stakeholders**

The steps listed represent the main activities that different stakeholders need to undertake to enable African countries to join and ride the NREN train. NREN champions are at the forefront of these efforts and need to be supported by policy makers, regulators, operators, their university leaders and regional organizations.

### **a. Policy Makers**

Policy makers have a major role to play in the development of National Research and Education Networks. They hold the key to the development of NREN infrastructure and to the allocation of resources for their operation. Decision makers from the high level of the government including the Minister of Higher Education, Minister of Communications and the Minister of Finance need to support and champion the NREN agenda. The main roles include:

- Development of the underlying broadband infrastructure,

- Ensuring that the budget for National Research and Education Networks is allocated at central government level, and
- Supporting NREN champions in mobilization of resources from domestic sources such as the Universal Access Fund.

## b. Regulators

Regulators, in coordination with decision makers play a crucial role in creating the enabling environment that support NREN development. These include relaxing the licensing framework that ensure NRENs own and operate their network as a Closed User Group. Other key roles of regulators include:

- Ensure that NRENs get access to affordable commercial conditions for access to bandwidth,
- Provide preferential treatment for NREN access to radio frequency spectrum, and
- Make provisions for financing NRENs infrastructure and their operations through a universal service fund.

## c. University leaders

University leaders have the most important role of championing NRENs, by convincing decision makers and regulators of their importance. This begins with raising the awareness of the decision makers and regulators on their service models in order to secure favourable pricing on managed networks and attain full network ownership in the future. University leaders need to make serious and on-going investments in academic networking at campus and NREN levels. The main roles of Presidents and Vice Chancellors include:

- Advocating for NREN causes by building the awareness of decision makers on their benefits and lobbying for preferential fees for national research and education networks,
- Allocating resources for campus and national research and education networks,
- Allocating resources for technical and manager capacity building and building human resources capabilities at campus levels, and
- Working with their peers in building a collaborative national research and education network.

## d. Private Sector

The private sector will be the key beneficiary of a successful research and education network. NRENs are the largest customers of the private network providers. NRENs serve as a platform for future customers to the private sector, because the students of today that use advanced networks will demand for the same from their employers in their work life. The private sector should see NRENs not as competitors but rather as customers and collaborators. The role of the private sector include:

- Making access to broadband network at affordable pricing and favourable commercial terms,
- Stimulating the development of broadband network,
- Collaborating with NRENs in research related to advanced network services such as routing, security, roaming and identity management,. that will benefit the society, and
- Participating in capacity building and exchange of experiences.

#### e. Development Partners

The development partners like the European Union and the International Development Research Centre have been key catalysts for NREN development in Africa. A significant resource gap exists at national and regional levels in order to build the capacities of technical personnel at universities, equip campus networks, link universities to each other, developing cross-border networks and promoting research collaboration. Development partners have key roles in bridging the resources gaps. Their main roles include:

- Financing the development of research and education networks at regional and national levels including capacity building efforts and research collaborations,
- Promoting experience exchange between NRENs, and
- Analysing gaps in research and education networks and advocating for evidence-based policy, regulatory and programme support to NRENs.

#### f. Regional Bodies

The regional bodies like the Association of African Universities, the African Union Commission and Regional Economic Communities will need to continue the advocacy and resource mobilization roles and highlight the NREN development agenda at national and regional levels. The major roles will include:

- Advocating for NREN development at the highest government levels.
- Creating more awareness of the policy issues and sensitizing decision makers on NREN benefits, opportunities and challenges,

- Mobilizing resources for network development and capacity building programmes at national and regional levels,
- Mobilizing technical and financial resources for regional NREN activities like WACREN, ASREN and the UbuntuNet Alliance,
- Mobilizing resources for research communities that develop solutions for regional problems
- Monitoring and evaluating the progress on the development of research and education to provide cross country comparison and benchmarking, and
- Promoting regional policy and regulatory harmonization in order to support uniform network pricing and interconnection across countries.

## 8. Conclusion

Information and Communication Technologies, in particular high speed connectivity bring unprecedented opportunities for advancing education, collaboration, scientific research and innovation that will have impact to social and economic growth in Africa. Research and education networking has become the “oxygen” of academic activities without which modern education cannot be provided and knowledge cannot be transferred more efficiently and effectively. The one NREN per country model advanced in Europe is now well established and has become a key mechanism for achieving the desired research and educational connectivity.

African countries have made some effort in developing NRENs over the last decade due to efforts made by regional organizations like the Association of African Universities, donors like the European Commission and the International Development Research Center and local and regional champions.

Notwithstanding the progress that was made over the last decade, many African countries have not been able to ride the research and education train. Apart from the nine countries (i.e. Algeria, Egypt, Kenya, Morocco, Senegal, Tunisia, South Africa, Uganda and Zambia) that have well established networks, the remaining 45 countries in Africa are yet to establish sustainable National Research and Education Networks.

To be sustainable, NRENs need to have access to state of the art broadband networks at affordable prices and to a state of the art capacity building in networking technologies tailored to their needs. NRENs need to be governed by flexible management and organizational frameworks that allow equitable participation of small colleges and larger national universities.

The support from decision makers and regulators are important for their success especially for access to affordable bandwidth. Development partners need to continue their support for regional and national network rollout and capacity

building. The role of the regional organizations like the AAU and the AUC is also crucial in raising the awareness of decision makers and promoting harmonized regulatory and policy frameworks that underpin NREN networks development, pricing and resource allocation.

## Abbreviations

AAU	Association of African Universities
AFNOG	Africa Network Group
ARN	Algerian Research Network
ASREN	Arab Scientific, Research and Education Network
AUC	Africa Union Commission
CCK	Computing Center el Khawarizmi
CEO	Chief Executive Officer
COREVIP	Conference of Rectors, Vice Chancellors and Presidents
DATAD	Database of African Theses and Dissertation
CUG	Closed User Group
EDF	European Development Fund
EU	European Union
EUN	Egyptian Universities Network
IRU	Indefeasible Right of Use
KENET	Kenya Research and Education Network
MAGIC	Middleware for collaborative Applications and Global virtual Communities
APRRECA	Natural Product Research Network for Eastern and Southern Africa
NREN	National Research and Education Network
NOC	Network Operation Centre
NSRC	Network Start Up Resource Centre
OER	Open Educational Resources
RENU	Research and Education Network of Uganda
SCI-GAIA	Energising Scientific Endeavour through Science Gateways and e-Infrastructures in Africa
SenRER	Senegal Research and Education Network
TIEN	Trans-Eurasian Network
TENET	Tertiary Education Network
WACREN	West and Central Africa Research and Education Network
ZAMREN	Zambia Research and Education Network

**Annex: NREN Readiness self-Scoring Matrix**

<p><b>Commitment Levels (1 low, 5 high)</b></p> <ol style="list-style-type: none"> <li>1. ICT department heads of the universities meet and interact</li> <li>2. ICT champion has emerged and secured support</li> <li>3. University leaders are aware of NREN and committed resources</li> <li>4. Policy and regulatory endorsement from ministries and regulators secured</li> <li>5. High level government endorsement (prime ministerial and presidential commitment including sustainable financing of NREN) has been secured</li> </ol>	<p><b>Coordination Levels (1 low, 5 high)</b></p> <ol style="list-style-type: none"> <li>1. NREN discussion has emerged from idea to practice</li> <li>2. Formal membership – NREN has larger than three members that coordinate nationally</li> <li>3. NREN is formally registered,</li> <li>4. Sustainable NREN organization has been created- with office and staff (CEO, CTO, Admin and applications support,</li> <li>5. Formal process including assembly, board, working groups and sustainable secretariat has been attained</li> </ol>
<p><b>Connectivity Levels (1 low, 5 high)</b></p> <ol style="list-style-type: none"> <li>1. Basic Internet connection to institutions has been achieved</li> <li>2. Inter-connection between selected universities has been achieved, NREN has AUP, IP number and ASN</li> <li>3. National NREN backbone was developed and up and running,</li> <li>4. Affordable backbone (IRU and lambdas) secured</li> <li>5. Wider link to Tertiary Level Institutions has been established</li> </ol>	<p><b>Capacity/capability Levels (1 low, 5 high)</b></p> <ol style="list-style-type: none"> <li>1. NREN has Certified Engineers to carryout network setup and management</li> <li>2. Adequate capacity to manage and operate NRENs has been built</li> <li>3. Technical internetworking training opportunities at Masters levels and short term courses are available</li> <li>4. Critical mass of technical personnel are available to run networks and services for members,</li> <li>5. Advanced network research capacity built to investigate into network security, middleware, etc.</li> </ol>

<b>Content Levels (1 low, 5 high)</b>	<b>Cash (financing) Levels (1 low, 5 high)</b>
<ol style="list-style-type: none"> <li>1. Access to the Internet has been achieved</li> <li>2. Universities have e-resources that can be exchanged – (e.g. Moodle e-learning content and virtual libraries)</li> <li>3. Advanced federated services (i.e. identity management and Eudorom) have been implemented</li> <li>4. Advanced e-infrastructure (instrumentation, grid computing and labs) access is in place</li> <li>5. Robust REN communities that use e-infrastructures has been established</li> </ol>	<ol style="list-style-type: none"> <li>1. Seed funding to start the NREN development process has been secured</li> <li>2. Budget allocation from universities for NREN operation has been secured</li> <li>3. Membership fees were collected</li> <li>4. Central government sustainable funding has been secured</li> <li>5. Strong donor and industry funding has been secured</li> </ol>