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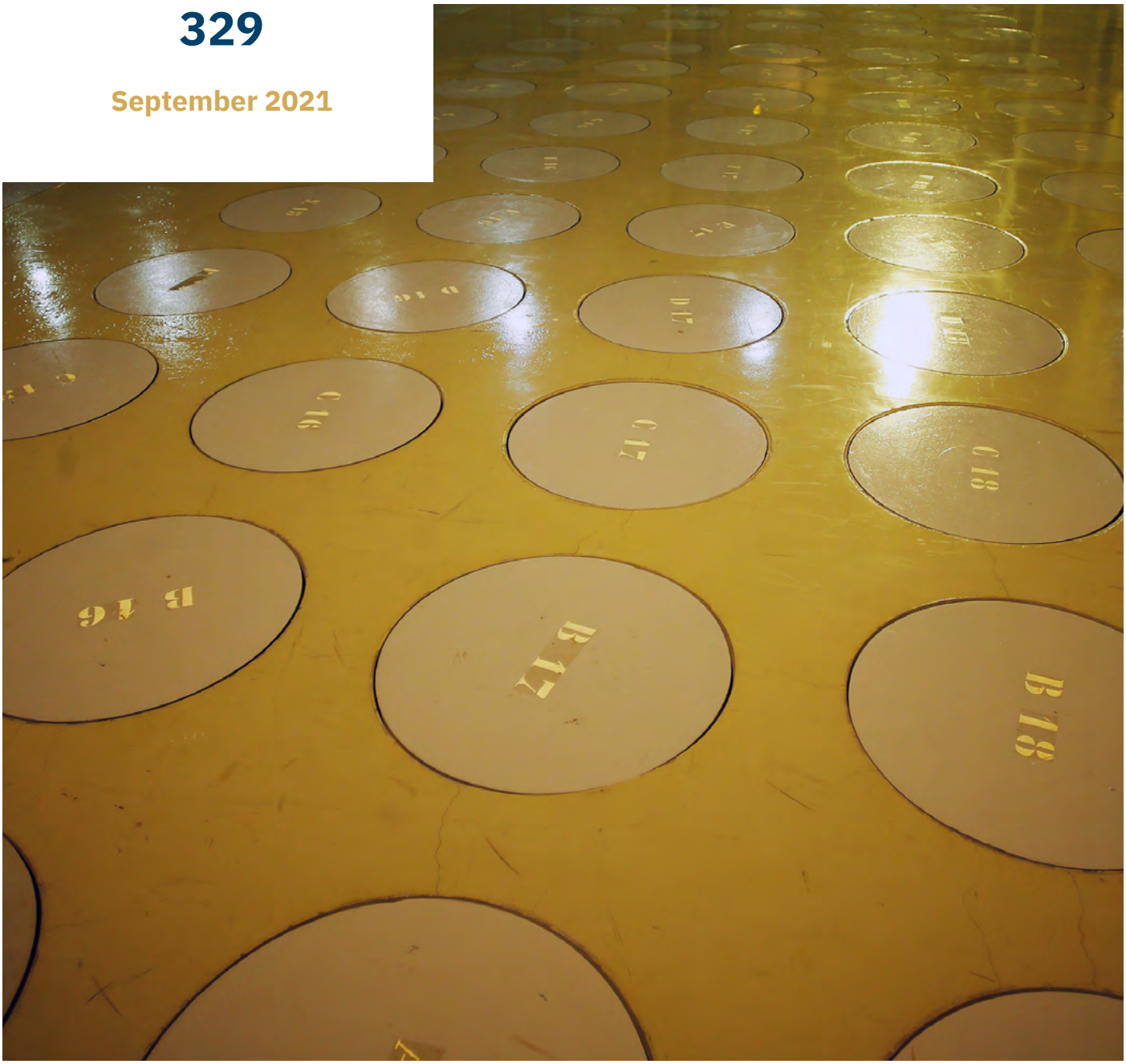

International Involvement in the African Nuclear Market

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African perspectives
Global insights

SAIIA
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Abstract

African countries want to become major competitors in the global economy. Socio-economic development inevitably leads to an increase in energy demand. Some African countries are considering nuclear power as an alternative, clean source of energy. Others already use nuclear technologies in medicine, industry and agriculture. Yet others are at various stages of embarking on establishing or expanding their nuclear programmes. With Africa supplying 14% of the world's uranium and with no foreseeable shortages, pursuing nuclear power is a viable option. International nuclear vendors and vendor countries will be involved in these nuclear programmes owing to a lack of local vendors in Africa. This paper considers the following vendor countries: Russia, the US, France, South Korea and China. Vendors and host countries will face typical challenges related to nuclear builds, such as the expense. However, in Africa these projects will also face unique challenges such as corruption and small electrical grids. In addition, vendors will be working in socio-economic and geopolitical circumstances that are complicated and uncertain.

Introduction

The AU's 55 member countries have embarked upon an ambitious 50-year plan, 'Agenda 2063: The Africa We Want', aimed at making Africa a major competitor in the global economy. As African economies develop, so too will their energy requirements. The development of a robust energy infrastructure is thus an essential part of this plan, which also aims to achieve development in a sustainable and inclusive manner.[1] Cleaner energy alternatives are needed to meet the growing global electricity demand while reducing the harmful environmental effects of fossil fuels.[2]

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Countries rely on different primary sources of energy to make them less vulnerable to political and economic uncertainties. Most of the global oil and gas reserves are in only a few countries. Political instability in these countries, and ones through which supply pipes run, could have a major impact on supply. Coal supply is less vulnerable since it comes from

1 Yarik Turianskyi and Jo-Ansie van Wyk, "'Atoms 4 Development' In Africa – Experts Weigh In", *AllAfrica*, December 11, 2020.
2 World Nuclear Association, "Nuclear Power in the World Today", June 2021.

a wider geographic variety of sources. Uranium supply is considered to have higher energy security than oil, gas and coal since it is sourced from an even wider variety of suppliers, both geographically and politically.[3] Table 1 presents the top five supplier countries of coal, oil, natural gas and uranium.

TABLE 1 TOP GLOBAL COAL, OIL, NATURAL GAS AND URANIUM RESERVES

Fuel	Country	Proven global reserve (%)
Coal[a]	US	21.9
	Russia	14.0
	Australia	12.9
	China	12.1
	India	8.9
Oil[b]	Venezuela	17.5
	Saudi Arabia	15.4
	Canada	9.6
	Iran	8.9
	Iraq	8.3
Natural gas[c]	Russia	23.7
	Iran	16.5
	Qatar	11.6
	US	6.4
	Turkmenistan	4.8
Uranium[d]	Australia	27.5
	Kazakhstan	14.7
	Canada	9.2
	Russia	7.9
	Namibia	7.3

a US Energy Information Administration, "International".

b EIA, "International".

c EIA, "International".

d WNA, "Supply of Uranium", December 2020.

Source: Compiled by author

Africa is an important player in the global supply of uranium. Uranium is used for, among others, power generation, production of medical isotopes, and marine propulsion, and is therefore becoming an increasingly sought-after commodity. The continent's first nuclear reactor was located in Kinshasa, Democratic Republic of Congo (DRC), which is also where

3 WNA, "Energy Security", April 2014.

the uranium was mined that was used to develop the atomic bomb that devastated Hiroshima.[4]

Uranium is a relatively common natural resource in Africa. There are three uranium mines on the continent producing 14% of the global uranium supply,[5] which is exported to nuclear facilities.[6] Other means by which uranium can be recovered are from the treatment of gold (as in South Africa) and other ores, as a by-product of copper recovery, and from phosphate deposits.[7] The World Nuclear Association (WNA) reports that there are over 8 million tonnes of recoverable uranium in the world, making it more abundant than gold and silver.[8] With further exploration and perhaps improved recovery techniques, this figure will only increase.[9] When considering the available uranium resources, it is clear there will be no shortages of uranium in Africa for years to come, allowing for the potential expansion of the nuclear industry.[10] Given economic considerations and ease of access, the uranium reserves in African countries make it a viable proposition to use nuclear technology.

Power in Africa is currently generated mostly from fossil fuels and hydro and geothermal sources. Concerns about these sources include limited financial and natural resources and volatile commodity prices. Some countries consider nuclear energy a clean, reliable and cost-effective alternative for power generation.[11]

An important application of nuclear technology in Africa is through research reactors that have medical, industrial and agricultural uses, and are potentially a starting point for nuclear power programmes

An important application of nuclear technology in Africa is through research reactors that have medical, industrial and agricultural uses, and are potentially a starting point for nuclear power programmes. They are also an extremely important resource for nuclear power reactors in training scientists and engineers. Their functions include experimental applications toward material damage, radiation shielding and waste containment. This can lead to improvements in safety, maintenance, operational efficiency, and safety and security culture.[12]

4 Neil Overy, "Part One: Nuclear Energy in Africa", *New Frame*, November 24, 2020.
5 Turianskyi and Van Wyk, "'Atoms 4 Development'".
6 Orano, "Orano Tricastin: 60 Years of Expertise in Uranium Chemistry and Enrichment"; Rössing Uranium, "Marketing Our Product".
7 WNA, "Uranium Mining Overview", December 2020.
8 WNA, "Supply of Uranium".
9 Turianskyi and Van Wyk, "'Atoms 4 Development'".
10 WNA, "Uranium Mining Overview".
11 Laura Gil, "Is Africa Ready for Nuclear Energy?", International Atomic Energy Agency, September 3, 2018.
12 IAEA, *Research Reactors in Africa: A Directory* (Vienna: IAEA, 2020).

Since Africa lacks local nuclear vendors, countries seeking to deploy nuclear programmes will have to cooperate with international vendors and vendor countries. The International Atomic Energy Agency (IAEA) defines vendors as organisations that supply designs, components, facilities or services to a client.[13] Nuclear programmes are faced with some common challenges, such as funding for these hugely expensive projects.[14] Other unique challenges that will be faced by vendors and African countries embarking on nuclear programmes are corruption[15] and small or unstable grids.[16]

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Vendors operating in Africa will have to compete in a complex and challenging arena. In general terms, when considering large-scale conventional Nuclear Power Plants (NPPs), there is little difference between vendors in terms of the technology on offer.[17] Other factors will thus come into play, including historical affiliations between vendor countries and their African counterparts, the ability to navigate a huge variation in domestic cultural and political conditions, and the economic and political influence vendor countries hold in African countries. One of the most crucial aspects will be the financing options vendors can offer. Although Russia has made early inroads into the African market,[18] China's economic might and willingness to invest heavily in large-scale projects will be a challenge for other nuclear vendors.[19]

Nuclear activities in Africa

Currently, South Africa has the only operational NPP on the continent. Egypt has embarked on a nuclear power programme to construct four nuclear power reactors, and has its sights set on becoming the continent's second country with nuclear power. Both South Africa and Egypt have committed to the peaceful use of nuclear technology as part of their strategy

13 IAEA, *IAEA Safety Glossary* (Vienna: IAEA, 2019).
14 Gil, "Is Africa Ready".
15 Transparency International, *Corruption Perceptions Index 2020* (Berlin: Transparency International, 2021).
16 Gil, "Is Africa Ready".
17 WNA, "Nuclear Power Reactors", July 2021.
18 Overy, "Part One: Nuclear Energy".
19 "China Is Africa's Top Creditor, but Will It Lead [to] Debt Relief?", *Aljazeera*, April 13, 2020.

to meet developmental goals on a national, continental (Agenda 2063) and global (UN Sustainable Development Goals) scale.[20]

South Africa is planning to expand its power supply by an additional 2 500 MW of nuclear power. The government has implemented plans to achieve this, and to steer South Africa to low carbon-emission energy sources. Department of Mineral Resources and Energy Minister Gwede Mantashe supports this initiative, which is backed by scientific evidence. As it is facing the end of its lifespan, it was decided to extend the operational life of the Koeberg NPP by 20 years, and the National Nuclear Regulator is expanding its regulatory framework to support the long-term operation of the plant.[21]

The production of radioisotopes for medical use relies on relatively few reactors worldwide. As an example, 88% of Molybdenum-99[22] is produced in four reactors located in the Netherlands, Belgium, Australia and South Africa.[23] The expansion of existing nuclear programmes, or the establishment of new ones, in Africa could provide an opportunity to enhance the medical isotope industry on the continent.

While nuclear power is not yet widespread in Africa, many countries are already involved in other nuclear programmes. Table 2 shows nuclear facilities and activities in African countries, with 11 research reactors on the continent, one operational nuclear power plant in South Africa, and the one nuclear power plant that is expected to start construction soon in Egypt. Mining and remediation activities have been taking place in countries like Niger and Gabon. The DRC and Ethiopia, among others listed in Table 2, have signed cooperative agreements with ROSATOM, the Russian state-owned nuclear corporation, to train and educate the nuclear workforce. African countries have also entered into multiple other international agreements in preparation for nuclear power and research programmes.

TABLE 2 TOP GLOBAL COAL, OIL, NATURAL GAS AND URANIUM RESERVES

Country	Research reactor facilities	Type of reactor	Activities
Algeria	NUR Es-Salam	Pool Heavy water	Multiple vendor collaborations
Burundi			Approached ROSATOM in 2021 to help develop a nuclear plant
DRC	TRICO II	TRIGA mark II	2020: signed Memoranda of Understanding (MoUs) with ROSATOM on training and education of nuclear personnel of DRC

20 Turianskyi and Van Wyk, "'Atoms 4 Development'".

21 "New Rules: To Keep Koeberg Going, Eskom Must Convince Regulators It Has Enough Money", *Business Insider South Africa*, March 26, 2021.

22 NTP Radioisotopes SOC Ltd, "Fission Molybdenum-99".

23 Organisation for Economic Co-operation and Development and Nuclear Energy Agency, *The Supply of Medical Isotopes: An Economic Diagnosis and Possible Solutions* (Paris: OECD, 2019).

Country	Research reactor facilities	Type of reactor	Activities
Egypt	ETRR-1 ETRR-2	Tank WWR Pool	El-Dabaa ROSATOM NPP will start construction soon, as site preparations have been slowed by the COVID-19 pandemic 2017: signed contract with Russia for treatment of spent nuclear fuel
Ethiopia	–	–	2021: signed MoU with ROSATOM on training and skills development in nuclear energy
Gabon	–	–	1960–1999: Orano exploited uranium deposits 1999–present: remediation of mining site and continuing maintenance and environmental monitoring
Ghana	GHARR-1	MNSR	Plans to expand and refurbish a radioactive waste storage facility US assisting Ghana to develop a nuclear/radiological emergency response programme
Kenya	–	–	2015: signed MoU with China to help educate Kenyan nuclear experts prepare for future projects 2016: signed MoU with Kepco to develop nuclear energy in Kenya
Libya	IRT-1 TNRC	Pool, IRT Critical assembly	–
Morocco	MA-R1	TRIGA mark II	–
Namibia	–	–	Orano owns the Trekkopje uranium deposit in Swakopmund region, as well as a water desalination plant
Niger	–	–	Orano previously mined at three locations, one uranium mine currently still in operation, with plans for further mining Remediation and environmental monitoring of closed mines to continue for another 20 years
Nigeria	NIRR-1 (converted to low enriched uranium fuel in 2017)	MNSR	2017: signed agreement with ROSATOM for construction and operation of NPP Potential site selection for an NPP is underway
Rwanda	–	–	2020: approval for ROSATOM to build a nuclear research centre and reactor planned for completion by 2024
Senegal	–	–	2018: signed cooperative agreement with France to establish a centre of excellence in nuclear science and technology
South Africa	SAFARI-1	Tank-in-pool	Only operational NPP in Africa, requiring urgent investment to secure the extension of lifespan

Country	Research reactor facilities	Type of reactor	Activities
Sudan	–	–	2016: signed contract with China to build NPP
Tunisia	–	–	Investigating possibility of using NuScale SMR for desalination projects
Uganda	–	–	2017: signed MoU with ROSATOM on development of nuclear power infrastructure 2018: signed MoU with CNNC to cooperate on nuclear power Potential site selection for nuclear plants is ongoing
Zambia	–	–	2018: signed contract with ROSATOM for construction of a Centre for Nuclear Science and Technology
Zimbabwe	–	–	2021: signed MoU with ROSATOM to explore nuclear power and the feasibility of constructing a nuclear science and technology centre

Sources: International Atomic Energy Agency, *Research Reactors in Africa: A Directory* (Vienna: IAEA, 2020); Arnaud Lefevre, "The Nuclear Power in Algeria", *NBN*, February 6, 2019; Ray Ndlovu, "Zimbabwe Signs Pact with Russia's Rosatom to Tap Nuclear Energy", *Bloomberg*, April 14, 2021; ROSATOM, "ROSATOM and the Democratic Republic of the Congo Will Develop Workforce Capacity and Make Efforts to Create a Positive Public Opinion on Nuclear Energy", November 20, 2020; WNA, "Nuclear Power in Egypt", May 2021; Nuclear Power Plants Authority, "How Will You Handle Nuclear Wastes in Egypt?"; ROSATOM, "ROSATOM and Ethiopia Will Develop Human Resources and Shape Positive Public Opinion on Nuclear Energy", April 15, 2021; Orano, interviewed by Lezani van der Merwe, May 2021; Mohammed Bashir Abubakar, *Radioactive Waste Management: Nigeria's Perspective* (Abuja: Nigeria Atomic Energy Commission); "South Korea, Kenya to Cooperate on Nuclear Energy", *Reuters*, September 2, 2016; "Nigeria Signs Rosatom Deals to Build Nuclear Power Plant", Reuters, October 30, 2017; Kate Hairsine, "Russia's Nuclear Play for Power in Africa", *DW*, June 30, 2020; Hubert Foy, "Senegal and France Ink Nuclear Framework Partnership Agreement", African Centre for Science and International Security, September 26, 2018; Yarik Turianskyi et al., *Nuclear Power & Governance Frameworks: Egypt, Ghana and South Africa*, Report (Johannesburg: South African Institute of International Affairs, 2021; Africa Nuclear Business Platform, "The Chinese Nuclear Industry Participation in the Emerging Market", July 4, 2016; Amal Elgahwaji and Sana Edoukali, "Introducing Nuclear Technology for Cogenerating in Libya" (Presentation, Workshop on Small Modular Reactor Safety and Licensing, Hammamat, December 12–15, 2017); Jilani Saadouni, "Desalination Option in the Tunisia Nuclear Power Project" (Presentation, 16th INPRO Dialogue Forum on Opportunities and Issues in Non-electric Applications of Nuclear Energy, December 12–14, 2018); "Uganda: Nuclear Agreement with Rosatom", *African Energy Newsletter* 349, June 30,2017; Yasuo Takeuchi and Tallulah Lutkin, "China's Nuclear Industry Shows Potential to Overpower Rivals", *NikkeiAsia*, July 3, 2018; ROSATOM, "Rosatom and the Republic of Zambia Signed a General Contract for the Construction of a Centre for Nuclear Science and Technology", May 15, 2018

Some of the countries listed in Table 2 already operate research reactors. These research reactors may be key to a future nuclear power programme, as it would be possible to take advantage of existing systems and Africa's vast uranium resources. Such projects could thus serve as a steppingstone towards commercial nuclear power. Some countries, such as Rwanda, are planning their first reactor projects, while countries like Nigeria are planning to add to their existing nuclear industry.[24]

The IAEA also has the Internet Reactor Laboratory (IRL) project for nuclear education and training, of which some African countries are already taking advantage. Morocco replaced France as the host of IRL transmissions for Africa in 2018.[25]

24 IAEA, *Research Reactors in Africa*.

25 IAEA, *Research Reactors in Africa*.

Nuclear development in Africa

When pursuing nuclear power expansion programmes, many factors come into play. For Africa to deploy nuclear technology, it is necessary to promote a strong safety culture, which should be fostered in national regulatory authorities and general populations. It is essential that every aspect of nuclear technology be used safely and securely.[26]

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It is also important to keep in mind that nuclear is not the only potential solution to the growing energy needs of the continent, especially because it is such an expensive option. It is important to ensure competitive interest rates to make nuclear projects economically viable, since it can take 20 to 25 years to pay for nuclear builds. However, the 50- to 60-year plant life makes these projects feasible.[27]

To ensure the credibility and effectiveness of these regulatory frameworks, collaboration between African countries, and with organisations such as the IAEA and AFCONE, is essential

Some African countries, including Ghana, Kenya and Nigeria, are preparing for nuclear power expansion by implementing the necessary legal and regulatory frameworks, establishing a regulator, and training personnel.[28] The importance of sharing information, particularly best practices and lessons learned, is acknowledged by many African leaders. To ensure the credibility and effectiveness of these regulatory frameworks, collaboration between African countries, and with organisations such as the IAEA and the African Commission on Nuclear Energy (AFCONE), is essential.[29]

26 Turianskyi and Van Wyk, "Atoms 4 Development".
27 Turianskyi and Van Wyk, "Atoms 4 Development".
28 Turianskyi and Van Wyk, "Atoms 4 Development".
29 Turianskyi and Van Wyk, "Atoms 4 Development".

The IAEA is an international organisation that provides support for, and information about, the safe and secure use of nuclear technologies. It aims to share technical expertise with member states. To help countries assess their readiness for nuclear technology, the IAEA suggests a milestone approach, which is a phased method that considers the legal framework, nuclear safety and security, radiation protection, environmental protection, and radioactive waste management.[30]

The IAEA supports its member states in the development of legal frameworks for the safe, secure and peaceful application of nuclear technology and ensures they understand the importance of abiding by international legal instruments. Member states are also assisted in fulfilling their international obligations.[31]

AFCONE's mandate is the fulfilment of the provisions of the African Nuclear Weapon-Free-Zone Treaty (Pelindaba Treaty). It liaises with the UN and the IAEA, as well as the IAEA's African initiatives such as the African Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology (AFRA) and the Forum of Nuclear Regulatory Bodies in Africa (FNRBA).[32]

While AFCONE has extensive roles and functions, its executive secretary, Messaoud Baaliouamer, has identified its main priorities. These are nuclear applications in human health; radioactive waste management; nuclear safety and material accounting and control; verification, information processing and monitoring technologies; aid in setting up legal and institutional frameworks for nuclear safety and security; and contributions to global non-proliferation and disarmament programmes.[33]

Established in 2009, the FNRBA currently incorporates regulatory bodies from 33 African countries. In 2020 it was restructured and now consists of six new thematic work groups that cover legislative and regulatory infrastructure, radiation and waste safety, nuclear safety and security, emergency preparedness and response, and transport.[34]

The FNRBA assists African countries in observing industry standards and best practices, and focuses on capacity building. It also supports knowledge sharing between relevant competent authorities, for instance AFRA and AFCONE.[35]

The IAEA and Morocco's National Centre for Energy and Nuclear Science and Technology (CNESTEN), for example, have recently expanded their collaboration to a wider range of nuclear-related technologies, including environmental protection and industrial applications. This makes CNESTEN the first nuclear institution in Africa to collaborate with the IAEA in more than one field of nuclear application. The collaboration focuses on

30 IAEA, "Milestones Approach".
31 WNA, "Emerging Nuclear Energy Countries", March 2021.
32 Jo-Ansie van Wyk and Yarik Turianskyi, "Peaceful Use of Nuclear Energy in Africa", SAIIA, August 18, 2020.
33 African Commission on Nuclear Energy, "Roles & Functions".
34 Omar Sabry, "FNRBA Aims to Further Strengthen Nuclear Safety and Security Infrastructure in Africa", IAEA, February 26, 2020.
35 Sabry, "FNRBA Aims to Further".

non-destructive nuclear testing, promotion of isotope hydrology in Africa and the Middle East, environmental protection, and training.[36] Khalid El Mediouri, director general of CNESTEN, has pointed out how the use of nuclear technology in Africa has been improved by the collaboration between the IAEA and CNESTEN.[37]

In a recent presentation to AFCONE, David Nicholls, the chairperson of the South African Nuclear Energy Corporation, discussed the idea of creating a Pan African Virtual Nuclear University.[38] This would initially create programmes related to training in nuclear technologies using existing resources in South Africa and Egypt. Once established, this virtual university could be expanded to other African countries, perhaps under the umbrella of the Pan African University (PAU). Launched in 2011, the PAU currently comprises four institutes in Algeria, Nigeria, Kenya and Cameroon, with a fifth planned for South Africa. These institutes already cover a range of disciplines identified by the AU Commission as crucial to further development in Africa.[39]

Nuclear technology available to Africa

There are two main conventional reactor types. The most common is the Pressurised Water Reactor (PWR), with about 300 in operation across the globe.[40] It is reasonable to assume that the PWR will be the most commonly proposed reactor type in any nuclear market, including in Africa. The second is the Boiling Water Reactor (BWR), whose design differs from that of the PWR only in that the water circulating through the core is at a lower pressure, causing the water to boil in the core.[41] The PWR and BWR designs offered by vendors are all similar in principle, and the construction and operating history of a reactor model will likely be more important in considerations. The biggest nuclear energy-producing country in the world is the US, with an installed capacity of 98.2 GW. Next in line is France with 63.1 GW and China with 47.5 GW.[42] This level of industry and operating experience will likely play a role in the decisions of host countries as to which vendor to cooperate with.

An important nuclear technology under consideration by developing countries, like those in Africa, is Small Modular Reactors (SMRs). These reactors typically generate up to 300 MW per unit. What makes SMR technology so attractive is that the major components are manufactured in a factory setting and then transported to the site where they are assembled. For the same power installed, more units can be built, fostering industrial learning and a reduction in the upfront investment per unit. This latter aspect makes SMR

36 Aleksandra Peeva, "Moroccan Nuclear Institute, IAEA Extend Partnership to Help the Spread of Nuclear Techniques in Africa", IAEA, January 28, 2021.
37 Peeva, "Moroccan Nuclear Institute".
38 David Nicholls, "Pan African Response to the Continental Consideration for Nuclear Power" (Presentation, Capacity Building in Nuclear Science and Technology in Africa, March 31, 2021).
39 Pan African University, "Pan African University".
40 WNA, "Nuclear Power Reactors".
41 WNA, "Nuclear Power Reactors".
42 "Top Ten Nuclear Energy-Producing Countries", *Power Technology*, February 12, 2021.

investment particularly attractive, considering the multi-billions upfront investment needed with conventional large-scale reactors.[43]

SMR technology presents certain advantages to developing countries. The simplified design has obviated the need for many safety systems and components found in larger-scale commercial reactors. As such, the financial burden and production costs of SMR technology are expected to be lower eventually than that for large-scale power reactors.[44]

Furthermore, interest in SMRs is growing because of the different applications the technology can be used for, such as electricity, heating, hydrogen production and seawater desalination.[45] African countries are generally looking to install known and trusted nuclear technologies and are therefore waiting for SMR technology to be tested in practice in other countries.[46] South Africa, however, has accepted that SMR technology is a potential option, stating that the nation's nuclear power programme 'must be implemented at an affordable pace and modular scale'.[47]

There are more than 70 SMR designs under development or construction in 18 countries for different applications.[48] In Russia the first SMR began commercial power operation in May 2020. This is the Akademik Lomonosov floating power unit with two-module KLT40S reactors.[49] Two industrial demonstration SMRs, CAREM in Argentina and HTR-PM in China, are at advanced stages of construction and scheduled to begin operation between 2021 and 2023.[50]

Estimating the financial implications of an SMR construction is complicated and there are many uncertainties. The Australian Nuclear Science and Technology Organisation (ANSTO) reports that the cost of building an SMR has been estimated at $1 billion, compared to $6 billion for a large 1 000 MW reactor. 'What is clear is that the economies of scale it offers are bringing down the price per kilowatt-hour of capacity significantly,' said Dr Mark Ho, an expert on nuclear reactors in ANSTO's Nuclear Analysis Section.[51]

Challenges for African nuclear programmes

African states face numerous challenges, such as insufficient infrastructure and lack of human resources, in their attempts to prepare for a nuclear industry.[52] NPP projects require

43 B Mignacca and G Locatelli, "Economics and Finance of Small Modular Reactors: A Systematic Review and Research Agenda", *Renewable and Sustainable Energy Reviews* 118 (February 2020).
44 NuScale Power.
45 Mignacca and Locatelli, "Economics and Finance".
46 Gil, "Is Africa Ready".
47 Government of South Africa, Department of Mineral Resources and Energy, "Integrated Resource Plan" (Government Notice, South African Government, Pretoria, 2019).
48 Matt Fisher, "Nuclear Power for the Future: New IAEA Publication Highlights Status of SMR Development", IAEA, October 30, 2020.
49 IAEA, "Nuclear Power for the Future".
50 IAEA, "Nuclear Power for the Future".
51 Australian Nuclear Science and Technology Organisation, "What Are Small Modular Reactors and What Makes Them Different?".
52 Jo-Ansie van Wyk and Yarik Turianskyi, "Peaceful Use of Nuclear Energy in Africa", SAIIA, August 18, 2020.

extremely long-term national commitments, up to 100 years, as they must follow the entire lifecycle of the power plant, from construction through to decommissioning.[53]

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In addition, if a country is to embark on a nuclear programme it needs the commitment of its government, as well as public buy-in, to ensure that nuclear programmes are not top-down in nature. The best way to convince the public of the benefits of such programmes is through education on the peaceful applications of nuclear technology.[54]

Furthermore, there is the issue of licensing nuclear designs and operation, something in which African countries, in general, lack the necessary expertise and knowledge. To work around this problem many developing countries have relied on the support of vendor countries, including the UK, US, France, Russia and China. This would likely be the route that most African countries would follow, at least while they focus on capacity building.[55]

The decommissioning of an NPP is a long-term project that lasts 20 to 40 years. When an NPP is decommissioned, many highly radioactive components need to be disassembled and stored alongside high-level waste. This waste remains radioactive for thousands of years. As such, storage of high-level waste requires unique solutions that are highly specialised and extremely long term, thus resulting in enormous costs.[56]

The IAEA promotes two important aspects of radioactive waste management: a universally applicable safety regime through the development of safety standards and the application of safe and proven technologies in radioactive waste management.[57] There are, however, some serious concerns regarding nuclear programmes in African countries, mainly in terms of inadequate applicable waste administration and a shortage of capable staff.[58]

Another important question is whether African nations can safely operate and maintain nuclear facilities and material. Safety concerns have led to nuclear programmes being phased out in European countries such as Germany, Spain and Switzerland. In African

53 Gil, "Is Africa Ready".
54 Van Wyk and Turianskyi, "Peaceful Use of Nuclear".
55 WNA, "Emerging Nuclear Energy Countries".
56 Neil Overy, "Part Three: Nuclear Energy in Africa", *New Frame*, December 8, 2020.
57 IAEA, "Improving Radioactive Waste Management in Africa", July 9, 2015.
58 IAEA, "Radioactive Waste Management Infrastructure" (Presentation, IAEA, Vienna).

countries these safety concerns are intensified by political instability[59] combined with the emerging global insecurity regarding potential misuse of radioactive material by terrorists and criminal groups.[60]

The 2020 Nuclear Threat Initiative (NTI) uses publicly available information along with advice from nuclear experts to assess the nuclear security of countries. The report ranks countries based on their ability to maintain the security of weaponisable nuclear materials (if they have them), to support global nuclear security efforts, and to protect existing nuclear facilities against sabotage. With a few exceptions such as Nigeria, Morocco, Ghana and Namibia, African countries generally scored poorly (Table 3).[61]

TABLE 3 NUCLEAR THREAT INDEX FOR AFRICAN COUNTRIES

Country	Theft: Support global efforts (ranked out of 153 countries + Taiwan)	Sabotage: Protect facilities (ranked out of 46 countries)
Nigeria	26	–
Morocco	29	34
South Africa*	–	35
Ghana	41	–
Algeria	50	44
Namibia	56	–
Botswana	59	–
Burkina Faso	71	–
Mali	71	–
Niger	71	–
Gabon	75	–
Côte d'Ivoire	75	–
Kenya	75	–
Tunisia	79	–
Tanzania	83	–
DRC	85	–
Uganda	85	–
Cameroon	87	–
Rwanda	87	–
Madagascar	92	–
Mozambique	92	–
Malawi	97	–
Eswatini	99	–

59 Kate Hairsine, "Russia's Nuclear Play for Power in Africa", *DW*, June 30, 2020.
60 Resource Centre Network Ghana, "Ghana Inaugurates Radioactive Waste Storage Facility".
61 Nuclear Threat Initiative, *Nuclear Security Index 2020* (Washington DC: NTI, July 2020).

Country	Theft: Support global efforts (ranked out of 154 countries)	Sabotage: Protect facilities (ranked out of 47 countries)
Lesotho	101	–
Djibouti	106	–
Libya	110	–
Egypt	116	45
Ethiopia	116	–
Sierra Leone	120	–
Central African Republic	123	–
Sudan	127	–
Burundi	134	–
Guinea-Bissau	134	–
The Gambia	137	–
Liberia	137	–
Guinea	140	–
São Tomé and Príncipe	140	–
Chad	145	–
Zimbabwe	145	–
Angola	150	–
Eritrea	153	–
Somalia	154	–

* South Africa does not appear on the "Theft: Support Global Efforts" index

Source: Nuclear Threat Initiative, Nuclear Security Index 2020 (Washington DC: NTI, July 2020)

NPP projects are expensive and African countries will require funding support for these. Costs also include waste management and decommissioning.[62] A possible solution to the cost issue could be financing mechanisms presented by vendors.[63]

NPPs have often been provided on a turnkey basis (the provision of a complete product or service that is ready for immediate use).[64] For developing countries, this could be a good option as the technical and commercial risks involved in delivering a functioning plant on schedule and in budget fall on the vendor. However, owing to a lack of human resources and expertise, African countries might need additional support for which this model might not be ideal. Another option is the Build-Own-Operate (BOO) model, where the vendor builds and operates the plant and then sells the generated electricity back to the host country.[65] This model also has challenges. One such challenge arises from vendors' chasing financial goals, leading to their cutting corners and so compromising safety and security.

62 Gil, "Is Africa Ready".
63 Gil, "Is Africa Ready".
64 Oxford Languages Online, "Turnkey".
65 Gil, "Is Africa Ready".

This issue can be mitigated if the host country closely monitors construction and operation processes, with safety inspectorates receiving the necessary technical expertise and proper funding.[66]

Financing mechanisms are crucial, and support in this matter will be needed from the export agencies of vendor countries.[67] Some vendors have expressed an interest in the rising nuclear market in Africa and are coming to the table with funding proposals, which will make such projects more viable in developing countries.

The Nuclear Industry Association of South Africa has indicated that there are currently at least six prospective possibilities for financing a new NPP:[68]

- government funding of the entire project, or government-backed loan guarantees, supported by money from state-owned companies;
- an intergovernmental loan;
- corporate financing;
- financing by plant vendors;
- a special investment vehicle to finance the project; or
- a BOO structure.

A nuclear accident could damage the environment and harm people, as happened, for example, during the Fukushima Daiichi Nuclear Power Plant disaster in 2011. Tens of thousands of people had to be evacuated.[69] The costs of responding to, and dealing with the aftermath of, a nuclear accident can be phenomenal and no adequate financial insurance is available.[70]

Small and unstable electrical grids are a major challenge for African countries pursuing nuclear power.[71] NPP grids are often bigger than the fossil fuel plants they aim to replace.[72] The IAEA recommends that a country's power grid be 10 times the size of the planned nuclear installation.[73] This will allow the plant to be taken offline for refuelling, maintenance and any unexpected events.[74]

Increasing a country's grid size can be costly. For this reason, some African countries are also looking at sharing a common grid. Initiatives like the West African Power Pool aim to do

66 Overy, "Part Three: Nuclear Energy".
67 Gil, "Is Africa Ready".
68 Darrell Proctor, "Russia, China Drive Africa's Plan for Nuclear Expansion", *Powermag*, July 1, 2020.
69 Gil, "Is Africa Ready".
70 Overy, "Part Three: Nuclear Energy".
71 Gil, "Is Africa Ready".
72 WNA, "Emerging Nuclear Energy Countries".
73 Gil, "Is Africa Ready".
74 WNA, "Emerging Nuclear Energy Countries".

just that, in this case by integrating the national power systems in ECOWAS.[75] An attractive feature of SMR technology is that it does not require a major electrical grid and can be deployed in remote areas or where small grid size is a challenge.

In the 2020 Corruption Perceptions Index, published by Transparency International, sub-Saharan Africa is the lowest scoring region globally, with the highest perceived levels of corruption in the world.[76] Clearly, corruption is a problem that is likely to have ramifications for nuclear builds in many African countries. Nuclear projects are susceptible to corruption as they rely on hundreds of contractors and sub-contractors. Furthermore, the secrecy surrounding nuclear industries has led to perceptions that such a shielded environment, free from public scrutiny, could create further opportunities for corruption.[77]

Global nuclear vendors

A crucial step in establishing nuclear programmes in African countries is reaching cooperative agreements between vendors and host countries. With Africa's electricity shortages, international nuclear vendors are approaching countries with ambitious proposals.[78]

Any new NPP build is inherently complex and challenging. Embarking upon such large-scale projects in developing countries exacerbates many of these challenges.[79] Several of the vendors discussed here have prior experience working with developing countries, which may be beneficial for nuclear projects in Africa.

According to the WNA, about 50 countries globally have expressed an interest in pursuing nuclear power. While some have already begun constructing reactors, others are at various stages of planning and consideration.[80] While some of these countries have established economies, most are still developing. Increasing socio-economic development results in a higher demand for energy. Eventually, developing countries will have similar demands for energy as the Global North.[81]

Host governments, vendors and governments of vendor countries are closely involved in nuclear projects, from planning through to financing and operation. Inter-governmental agreements and cooperation allow developing countries to embark on these specialised and expensive projects. As the industry of the country matures, existing agreements can be updated or new agreements made, including public–private partnerships.[82]

75 Gil, "Is Africa Ready".
76 Transparency International, *Corruption Perceptions Index* 2020.
77 Neil Overy, "Part Two: Nuclear Energy in Africa", *New Frame*, December 1, 2020.
78 Overy, "Part One: Nuclear Energy".
79 US Department of Energy, Office of Nuclear Energy, "Advantages and Challenges of Nuclear Energy", March 29, 2021.
80 WNA, "Emerging Nuclear Energy Countries".
81 WNA, "Emerging Nuclear Energy Countries".
82 WNA, "Emerging Nuclear Energy Countries".

In developing nations, Russian and Chinese nuclear vendors are leading the charge in promoting their technologies, usually offering fuel, technical expertise and financing services along with the technology.[83] In Africa one also expects to see involvement from France and the US since they currently are, or have been, involved in nuclear programmes (as well as telecoms and other energy programmes) on the continent. South Korea has recently joined the group of international nuclear vendors after selling its advanced reactor technology to the United Arab Emirates (UAE).[84] South Korea's SMART Power Company could also join the race with its cutting-edge SMR technology.[85] Table 4 summarises the major global vendors that are likely to feature in the African nuclear market.

TABLE 4 MAJOR GLOBAL NUCLEAR VENDORS

Vendor	Country of origin	Ownership	Services	Commercial reactors	Presence in Africa
CGN	China	State-owned	• Design • Construction • Operation • Fuel cycle • Financing	16 (in China)	–
CNNC	China	State-owned	• Design • Construction • Operation • Fuel cycle • Financing	21	–
EDF	France	Private (83% owned by French government)	• Design • Construction • Operation • Fuel cycle	57	Senegal Egypt Côte d'Ivoire South Africa
Framatome	France	Private (majority owned by EDF)	• Design • Components • Fuel cycle	56	–
Orano	France	–	• Mining • Fuel cycle	n/a	Gabon Namibia Niger
ROSATOM	Russia	State-owned	• Design • Construction • Operation • Fuel cycle	38	South Africa

83 Overy, "Part One: Nuclear Energy".
84 WNA, "Emerging Nuclear Energy Countries".
85 SMART Power Company.

Vendor	Country of origin	Ownership	Services	Commercial reactors	Presence in Africa
KEPCO	South Korea	Private (majority owned by South Korean government)	• Design • Construction • Operation • Fuel cycle	25	South Africa
SMART Power Co.	South Korea	Private	• Design	0	–
NuScale	US	Private (majority owned by Fluor Corporation)	• Design	0	–
Westinghouse	US	Private	• Design • Construction • Operation • Fuel cycle	57 (in US) Westinghouse technology is incorporated in 430 reactors worldwide	South Africa

Source: Compiled by author

Russia

ROSATOM is operating in multiple industries, including power engineering, machine engineering and construction. It provides more than 20% of Russia's electricity, making it the largest electricity producer in the country, and has more than 250 000 employees globally. It is also involved in other areas such as research, manufacturing of medical isotopes and equipment, materials studies, and manufacturing of various nuclear and non-nuclear products. ROSATOM controls 17% of the global nuclear fuel market and has the only nuclear icebreaker fleet in the world.[86]

ROSATOM was contracted by the Egyptian government to construct the El Dabaa nuclear power station with 4 800 MW capacity in the north of Egypt. In August 2020 the Egyptian Nuclear Power Plants Authority said it expected a construction permit to be issued in the second half of 2021. However, in February 2021 representatives of the Russian and Egyptian governments reported that the COVID-19 pandemic had slowed preparations at the site.[87] The Egyptian government will fund 15% of the project while ROSATOM will fund the remainder over 35 years. Further agreements were reached with ROSATOM to provide plant maintenance and nuclear fuel for the operating life of the plant.[88]

86 ROSATOM.
87 WNA, "Nuclear Power in Egypt", May 2021.
88 Overy, "Part One: Nuclear Energy".

US

US private nuclear company Westinghouse built the first commercial PWR in the world at the Shippingport Atomic Power Station. There are now 430 nuclear reactors with Westinghouse technology operating globally. The Westinghouse nuclear technology ranges in type and size, from the AP1000 to the eVinci micro-reactor aimed at rural areas.[89]

Another private US company, NuScale Power, develops modular light water reactor technology. The NuScale SMR has 77 MW capacity units, which can be scaled up to 12 units (924 MW) per plant. This scalability means that the technology is suitable for a wide variety of platforms such as baseload electricity, load-following support for renewables, process heat or steam for district heating.[90]

France

Électricité de France (EDF), the French state-owned nuclear company, is constructing the Hinkley Point C NPP in the UK. This plant was not commissioned following the BOO model – instead, a 35-year electricity price based on inflation was negotiated.[91] It will become the most expensive object on earth,[92] and the electricity it generates is thus expected to be very expensive.[93]

Framatome came into existence when EDF, Japanese Mitsubishi Heavy Industries and Assystem bought New NP (a subsidiary of Areva NP).[94] It employs 14 000 people globally, and designs, services and installs components, fuel, and instrumentation and control systems for nuclear power plants.[95]

Orano (originally known as New Areva) comprises the remaining nuclear fuel cycle activities of Areva following the sale of New NP (now known as Framatome).[96] It is an international nuclear fuel cycle enterprise headquartered in France. The group covers the entire nuclear fuel cycle from mining and processing of raw materials to processing of waste, and employs 16 000 people worldwide.[97]

Orano Mining is involved in widespread uranium exploration and mining. The company's properties include high-grade mining operations in Canada, an in-situ recovery joint venture in Kazakhstan, and mines in the desert region of Niger. It also handles the

89 Westinghouse, "About Us".
90 NuScale Power.
91 Overy, "Part Two: Nuclear Energy".
92 Overy, "Part One: Nuclear Energy".
93 Overy, "Part Two: Nuclear Energy".
94 Nuclear Engineering International, "Areva NP Becomes Framatome and Atmea Is Reorganised", January 8, 2018.
95 Framatome, "Who We Are: Designer and Supplier of Nuclear Steam Supply System and Nuclear Equipment Services and Fuel for High Levels of Safety and Performance".
96 NEI, "Areva NP Becomes Framatome".
97 Orano, "Group".

remediation and environmental monitoring of mining sites, limiting the impact on the population and the environment.[98]

South Korea

The Korea Electric Power Company (KEPCO) is a South Korean state-owned corporation, established to meet South Korea's energy needs and contribute to the socio-economic development of the country through the development of innovative power solutions.[99]

KEPCO built the Barakah NPP in the UAE consisting of four APR1400 units, with one in commercial use and the others in the final stages of construction and testing. The APR1400 has advanced South Korean PWR technology with 1 400 MW capacity.

Another South Korean nuclear vendor is the SMART Power Company, established to develop a commercial SMR to be deployed internationally. Its services have been expanded to include dismantling, decommissioning and engineering.[100]

China

With 48 operational NPPs and several others under construction, China is the second largest country in terms of nuclear power capacity.[101] The China General Nuclear Power Group (CGN) was founded in 1994, and focuses on the development of clean energies such as nuclear power, nuclear fuel, wind power and solar power. It has a global workforce of about 39 000 people, and is the biggest nuclear power constructor in the world.[102] CGN has signed nuclear cooperation agreements with Kenya and Sudan.[103]

The China National Nuclear Corporation (CNNC), also state-owned, is mainly engaged in research and development, construction, production and operation in the fields of nuclear power, nuclear fuel cycle, nuclear applications, environmental protection and nuclear engineering, as well as international cooperation, imports and exports.[104]

Socio-economic and geopolitical influences

Large-scale construction projects, including NPP builds, come with inherent risks and challenges. The size and complexity of these projects expose them to problems arising

98 Orano, interviewed by Lezani van der Merwe, May 2021.
99 KEPCO, "About KEPCO: Overview".
100 SMART Power Company.
101 "Top Ten Biggest Nuclear Power Plants in China", *Power Technology*, September 10, 2019.
102 CGN, "Profile".
103 Overy, "Part One: Nuclear Energy".
104 CNNC, "Profile".

from economic, social, political and environmental challenges.[105] In developing countries, particularly those with political instability, these issues are exacerbated. The experience of Westinghouse in the Philippines highlights this – the project began in 1976 and was a disaster for all concerned. Following accusations of bribery, mismanagement and safety issues,[106] combined with political upheaval and anti-nuclear sentiment,[107] the project culminated in legal disputes and a reactor that never entered operation.[108] More recently, in 2016, Westinghouse and the Nuclear Power Corporation of India began formalising an agreement to build six AP-1000 reactors.[109] The project has since been beset with problems, including Westinghouse's declaring bankruptcy in 2017,[110] a contentious land acquisition process,[111] and the government of India cutting back plans for new NPP builds by two-thirds.[112]

Large-scale construction projects, including NPP builds, come with inherent risks and challenges

For NPP vendors operating in Africa, financial resilience and a willingness to accept a higher level of risk than for projects in developed countries will be necessary.

Competition among global vendors in the African market may also be affected by the economic and political influence of their host country. Historical affiliations such as those between France and its former colonies, and Russia and formerly communist African states, may help vendors from these countries. In some cases, however, perhaps most notably with France's history in Algeria, this will be a distinct disadvantage.

In the 1960s France carried out multiple nuclear weapon tests near the town of Reggane in Algeria. Even after Algeria had gained independence from France in 1962, the French maintained a military presence in the region and continued with their nuclear test programme in the Algerian Sahara. Residents of southern Algeria reported a strange rise in medical issues that first appeared during the 1970s and persist to the present day. Several

105 Karim Eldash, Emad Abd-Raboh and Zakariya El-Dars, "Risk Management in the Design Phase of Large-Scale Construction Projects" (Conference Paper, 20th IMPA World Congress on Project Management, Shanghai, October 2006).
106 Brian Dumaine, "The $2.2 Billion Nuclear Fiasco", *Fortune Magazine*, September 1, 1986.
107 Mark Gino Aliperio, "The Bataan Nuclear Power Plant in the Philippines: A Nuclear Plant, and a Dream, Fizzles", Energy Central, June 18, 2020.
108 Bloomberg News, "Westinghouse Pact with Philippines", *The New York Times*, October 16, 1995.
109 PTI, "US-based Westinghouse to Build 6 Nuclear Power Plants in India", *The Times of India*, June 8, 2016.
110 Diane Cardwell, "Westinghouse Files for Bankruptcy, in Blow to Nuclear Power", *The New York Times*, March 29, 2017.
111 Surabhi Bhandari, "As Kovvada Nuclear Plant Nears Completion, Farmers, Fisherfolk Await Rehabilitation", Land Conflict Watch, February 8, 2021.
112 Dan Yurman, "India Slashes Plans for New Nuclear Reactors by Two-Thirds", *Energy Post*, April 16, 2018.

reports also revealed that the radioactive plutonium used was responsible for high levels of skin cancer in southern Algeria, among many other illnesses.[113]

When the French finally left Algeria, they buried contaminated objects throughout the area. Because of the Saharan winds in the region, the sand covering these nuclear waste tombs was blown away. France never informed the people living there of residual radiation hazards, and so they began using these contaminated items. More than half a century later, France has yet to shoulder full responsibility for this dark colonial legacy.[114]

Africa's huge potential for growth – and the entry of new players into the African market – has changed the investment landscape on the continent. Until the mid-2000s competition for economic and political influence in Africa was largely the domain of the US and Europe.[115] Since then China has taken the lead in many respects. According to an Ernst and Young report published in 2019, the largest investors of capital in Africa are China, France, and the US, with China investing more than France and the US combined.[116]

Much of China's recent surge of investment in Africa falls under the umbrella of the Belt and Road Initiative (BRI), a global infrastructure development strategy launched by the Chinese government in 2013. The scope and diversity of the BRI is astonishing. In May 2021 the official website of the BRI listed 140 countries, including 46 in Africa,[117] that have signed cooperation agreements with China. Many projects are underway or have already been completed.

While BRI projects are mostly related to facilitating trade and commerce, there are also energy projects such as the Karuma hydroelectric dam in Uganda. The financing for this project was provided through a loan by the China Export and Import Bank, covering 85% of the cost. The construction contract was awarded to Sinohydro, a Chinese company. Many of these BRI projects follow a similar model – funding is provided, at least in part, through loans by Chinese financial and government institutions, and Chinese companies are awarded contracts.[118] The scale of Chinese lending related to the BRI in Africa is unsurprisingly echoed by the fact that China is now the largest holder of African debt.[119]

Despite some well-documented concerns, problems and controversies, the BRI has supplied desperately needed infrastructure projects in many African countries.[120]

113 Orano, interview.
114 Orano, interview.
115 Reality Check Team, "What Are the US's Intentions in Africa?," *BBC News*, August 1, 2019.
116 Negus Advisory, "Foreign Direct Investment in Africa (2019)".
117 Belt and Road Portal, "*List of Countries That Have Signed Cooperation Documents with China to Jointly Build the* 'Belt and Road'"; Green Belt and Road Initiative Center, "Countries of the Belt and Road Initiative (BRI)".
118 "Chinese Contractors Grab Lion's Share of Silk Road Projects", *Financial Times*.
119 "China Is Africa's Top".
120 Pearl Risberg, "The Give-and-Take of BRI in Africa", *New Perspectives in Foreign Policy* 17 (April 2019).

As China's economic influence on the continent has risen, that of the US has steadily declined since 2014.[121] Recently, however, the US has begun focusing more on its involvement in Africa. In order to increase trade and investment between the US and Africa, the US government launched the Prosper Africa initiative and, in 2020, Kenya and the US began negotiations on a free trade agreement.[122] It is also worth noting that the US is the largest contributor of foreign aid to Africa, financing almost a quarter of all foreign aid efforts across the continent.[123]

While France is a major trading partner and investor in Africa, like the US, its economic influence in Africa has been eclipsed by China in recent years.[124] In addition to French initiatives aimed at increasing trade with Africa,[125] the EU is making EU–Africa relations a priority, with a long-term goal of creating a free trade agreement between the two regions.[126]

Until recently, the level of Russian investment in Africa has been comparatively small. This is changing now, with Russian exports to Africa increasing by 40% between 2015 and 2019.[127] African countries and Russia reportedly also signed deals valued at $13.95 billion following the first Russia–Africa summit in 2019. At this summit, President Vladimir Putin announced that forming mutually beneficial ties with African nations 'is now one of Russia's foreign policy priorities'.[128]

Like Russia, South Korea has historically not been a major player in the African market. Prior to 2006, when president Roh Moo-hyun announced South Korea's Initiative for African Development, its involvement in Africa was negligible. Since then several large South Korean companies have established a significant presence in Africa. Korea Telecom (KT) completed a nationwide mobile network in Rwanda in 2018 and other African countries have shown interest in partnering with KT in developing their national mobile networks.[129] Other South Korean companies, such as Samsung and LG, are also major players in the African electronics market.[130]

Although all the vendor countries discussed here clearly recognise Africa's potential, China's established dominant economic influence and the competition from its state-sponsored companies will be difficult to counter.[131]

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121 Statista, "Direct Investment Position of the US in Africa from 2000 to 2019", August 4, 2021.

122 Witney Schneidman and Brionne Dawson, "The US and Kenya Launch Negotiations on a Free Trade Agreement. Will They Succeed?", Brookings, July 29, 2020.

123 AU, The Africa-EU Partnership, "Financing the Partnership".

124 Landry Signé, "France–Africa Relations Challenged by China and the European Union", Brookings, February 5, 2019.

125 Ministère de l'Europe et des Affaires Étrangèrs, "French Diplomacy in Africa: Global Issues — Ministry for Europe and Foreign Affairs".

126 EU Parliament, "A Comprehensive EU Strategy for Africa Trade and Investments" (Briefing, EU Policy Department for External Relations, Brussels, 2020).

127 ITC Trade Map, "List of Importers for the Selected Product".

128 ITC, "List of Importers".

129 "KT Expands in Africa with Success in Rwanda", *Business Ghana*, May 29, 2018.

130 Otavio Veras, "Unpacking South Korea's Engagement with Africa", How we made it in Africa, September 6, 2018.

131 Dinko Hanaan Dinko, "China's 'Mask Diplomacy' Wins Influence Across Africa, During and After the Pandemic", *The Conversation*, March 10, 2021.

International politics may also be a factor in Africa's nuclear market. Tensions between the US and Russia[132] and the US and China[133] have escalated over the last few years. In Africa, the US views China's rapid expansion of influence with alarm and is developing policies intended to address this perceived threat. In a March 2021 speech on US foreign policy, Anthony J Blinken, the US Secretary of State, said, 'Our relationship with China will be competitive when it should be, collaborative when it can be, and adversarial when it must be. The common denominator is the need to engage China from a position of strength.'[134] Similarly, Russian expansion in Africa has not gone unnoticed in Washington.[135] Although concerns about a new *de facto* Cold War being played out in Africa[136] seem overly alarmist, countries pursuing projects in nuclear technology will need to consider the larger geopolitical landscape before signing contracts. There is an argument to be made that the political tensions between the US and China, or the US and Russia, may push African countries towards vendors from France and South Korea.

ROSATOM, CNNC and CGN are state-owned companies. There are advantages and disadvantages when comparing state ownership to private enterprise. One advantage is that state-owned companies do not necessarily have the sole aim of making a profit.[137] China, and, more recently, Russia are focused on increasing their respective influence in Africa, and it is not inconceivable that these companies could effectively be used by their respective governments to trade profit for influence in their dealings on the continent.

Of all the factors impacting new nuclear projects in Africa, financing will be a crucial consideration. As noted earlier, China is the largest holder of African debt, offering state and commercial loans at reasonably attractive terms and seemingly willing to accept more risk than other international creditors.[138] The practice of China's acting as both supplier and investor in BRI projects is also seen in the nuclear market. For example, CNNC's project in Argentina was, at least in part, financed by Industry Commercial Bank of China.[139]

This level of lending (not solely from China), compounded by the economic impact of the COVID-19 pandemic, has caused problems for some African countries, leading them to seek debt relief.[140] In addition, international pressure on China to adopt more rigorous and transparent loan mechanisms is increasing.[141] Despite this, it continues to invest heavily in Africa and will no doubt be an attractive option for many African countries.

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132 Anna Chernova, Zahra Ullah and Rob Picheta, "Russia Reacts Angrily After Biden Calls Putin a 'Killer'", *CNN*, March 18, 2021; "US Imposes Sanctions on Russia Over Cyber-Attacks", *BBC News*, April 16, 2021.

133 "Amid High Tensions, China Warns US Against Taking Superior Position on Global Affairs", *ANI News*, April 5, 2021; "A Quick Guide to the US–China Trade War", *BBC News*, 2020.

134 Anthony J Blinken, "A Foreign Policy for the American People", US Department of State, March 3, 2021.

135 Eric Schmitt and Thomas Gibbons-Nef, "Russia Exerts Growing Influence in Africa, Worrying Many in the West", *The New York Times*, January 29, 2020.

136 "A New Cold War in Africa", *AfroWorldNews*, December 11, 2019.

137 Hosbeg, "Advantages and Disadvantages Of State Owned Enterprises".

138 David Dollar, "Understanding China's Belt and Road Infrastructure Projects in Africa", *Global China*, September 2019.

139 Africa Nuclear Business Platform, "Chinese Nuclear Industry Participation".

140 Amadou Mahtar Ba, "Why Debt Relief in Africa Is Necessary to Recover from COVID-19", ONE, January 11, 2021.

141 Eric Claude Olander, "What to Do About the Lack of Chinese Loan Transparency in Africa?", The China–Africa Project, November 12, 2020.

As can be seen from Table 2, many of the recently signed agreements involve ROSATOM and Chinese vendors, seemingly indicating their level of commitment to expanding in the African nuclear market. With several African countries expressing interest in nuclear technology, the market is potentially huge. Combined with the long lead times involved in preparing for and implementing these projects and the global interest in African markets, there is plenty of opportunity and time for other vendors to catch up. Many of the vendors have a wealth of experience and expertise, and their expansion into the growing African nuclear market is surely only a matter of time. Although KEPCO is a relatively recent entrant to the global nuclear market, the company has been successful with domestic NPP projects. As the KEPCO NPP in the UAE begins commercial operation this year, the success of this project will enhance the company's global reputation. While SMR technology from vendors like NuScale and SMART Power Company undoubtedly has the potential to be hugely successful, the time frames of bringing the technology to market, questions around the final costs, and a hesitancy to be among the first countries to try this design may prove detrimental. In the short term, it seems unlikely that these vendors will make significant inroads into the African market.

Conclusion

Several African states have expressed an ambition to increase their use of nuclear technology in a peaceful manner to achieve national, continental and global development goals.

International actors such as the IAEA and multinational energy corporations remain active in Africa. This paper has outlined the role of the IAEA in preparing African states' programmes, as well as the nuclear vendors that are actively seeking a larger market share in Africa.

Nuclear power projects are challenging irrespective of their location, but in Africa some of these challenges will be particularly pronounced when compared to more developed regions. Possible issues include power grid infrastructure, knowledge and expertise, corruption and financing.

SMR technology has the potential to address many challenges in Africa. A large, nationwide power grid is not necessarily required and the project costs are envisaged to be a fraction of those required for a conventional NPP. While there are many companies worldwide researching and developing SMR technology, Russia currently has the only SMR in operation that is producing power commercially. Any vendor that can deliver an efficient, proven and cost-effective variant of this technology will have a clear advantage in the African market.

In Africa, there is a general lack of knowledge of and expertise in all phases of nuclear programmes. Establishing the necessary regulatory frameworks and training programmes

is a costly and time-consuming process. African states must maximise the assistance and guidance provided by global and continental initiatives to support preparations for nuclear programmes. Further assistance from vendor countries, such as the cooperation between China and Kenya to educate nuclear experts and that between ROSATOM and Rwanda to build a nuclear research centre, will also enhance local knowledge and expertise.

Corruption is endemic across most of Africa, and there is no simple solution to combat what, in some instances, has become deeply entrenched in all levels of government. Without the will to empower institutions tasked with combatting corruption and holding guilty parties accountable, this issue will continue to plague the continent. As far as NPP projects are concerned, vendors could mitigate the effects of corruption by operating with greater transparency themselves. If there is a clear disclosure of bidding processes and understanding of how, where, and by whom funds are being used, the impact of corrupt practices can be reduced.

Financing is likely to be the deciding factor in many instances

Financing is likely to be the deciding factor in many instances. Few, if any, African countries can fund multi-billion-dollar projects themselves. Vendors and investors will need to provide solutions with little to no upfront costs, along with competitive electricity prices. The huge level of investment in Africa already evident by China and, increasingly, Russia is indicative of their determination to develop their respective interests on the continent. In the nuclear technology sector both countries are pursuing opportunities, with ROSATOM seemingly making greater inroads thus far. In order to compete with ROSATOM, CNNC and CGN, vendors from other countries would benefit greatly from an increased level of support from their respective governments. While the US and EU have stated their intentions to further develop economic and political ties with Africa, their rate of progress and level of commitment appear to be falling behind that of Russia and China. In the short term at least, Russia and China are likely to remain the major players in the African nuclear power market.

Developments in the market will be influenced by many factors that cannot be predicted. The complexity and challenges of the African market have, of course, been affected by the COVID-19 pandemic. This is an ongoing catastrophe, with over 4 million lives lost[142] and a global recession deeper in terms of gross domestic product (GDP) growth than the financial crisis of 2008.[143] While the pandemic continues to impact the global economy, the African Development Bank Group forecasts continent-wide growth in GDP of 3.4%

142 Worldometer, "COVID-19 Coronavirus Pandemic".
143 Kimberly Amadeo, "Your Guide to the 2020 Recession", The Balance, May 12, 2021.

in 2021. This is based on assumptions such as the resumption of tourism, recovering commodity prices, easing of pandemic-related restrictions, and the effective deployment of vaccines.[144] Despite this optimistic forecast, the reality is that there is a great deal of uncertainty in the environment in which stakeholders in any nuclear build project will have to operate.

144 African Development Bank Group, "African Economic Outlook 2021".

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Cover image

A picture taken on June 5, 2018 shows the storage area for vitrified nuclear waste at the nuclear waste reprocessing plant of Beaumont-Hague, northwestern France (Charly Triballeau/AFP via Getty Images)

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