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OPPORTUNITIES AND CHALLENGES OF DEPLOYING SMRS IN DEVELOPING COUNTRIES

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Introduction

- Energy is the backbone of development.

- The average annual energy consumption per capita in Africa is ranged from ~ 50 to 3600 kWh/year with average of around 500 kWh/year compared to a world average of around 3,000 kWh/year.

- Due to their flexible designs, Small Modular Reactors (SMRs) promise flexible power generation for a wide range of users and applications with high safety features and proliferation resistance.

- The main goal of SMRs is to significantly decrease the weight of nuclear power financing in volume and time compared to larger reactors.

Africa Electricity Consumption

~ 42% is consumed by the northern region, ~ 33% by South Africa, and the remaining 25% by all the other African countries.

Country/region	Total electricity consumption (GW·h/yr)	Average electrical power per capita (kWh per year)
North region	258,157	1,400
South Africa	210,304	3,590
Other Africa	~160,000	~175
Total Africa	**~ 654,000**	**~ 500**
Total World	**23398000**	**3,080**

Data is cited/generated from:
https://en.wikipedia.org/wiki/List_of_countries_by_electricity_consumption (access, July 2022)

Why Nuclear Power?

- Many developing countries suffer from severe electricity shortages.
- The best way to strengthen a country's energy security is by increasing the diversity and resiliency of energy supply options. Expanding nuclear power would increase diversity in the electricity supplies.
- Africa is the lowest continent emission of carbon dioxide per capita. The CO_2 emissions per capita in Africa is less than one-fourth of the average of the world.
- Generation of electricity from nuclear energy helps in keeping the continent clean.

	CO_2 emissions (Million tons)	CO_2 emissions per capita (kg/year)
Total Africa	1254	~ 950
Total World	32018.2	~ 4100

Data is cited/generated from: Statistical Review of World Energy 2021 | 70th edition: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf (access, July 2022).

Nuclear Reactors in Africa

Research Reactors:

Country	Facility name	Type	Thermal power (kW)	Neutron flux ($cm^{-2}\ s^{-1}$)
Algeria	NUR	Pool	1000	5.0×10^{13}
	Es-Salam	Heavy water	15 000	2.0×10^{14}
Democratic Republic of the Congo	TRICO II[1]	TRIGA Mark II	1000	3.0×10^{13}
Egypt	ETRR-1[1]	Tank WWR	2000	3.6×10^{13}
	ETRR-2	Pool	22 000	2.7×10^{14}
Ghana	GHARR-1	MNSR	30	1.0×10^{12}
Libya	IRT-1[2]	Pool, IRT	10 000	2.0×10^{14}
	TNRC	Critical assembly	0.1	1×10^{7}
Morocco	MA-R1	TRIGA Mark II	2000	7.1×10^{13}
Nigeria	NIRR-1	MNSR	34	1.2×10^{12}
South Africa	SAFARI-1	Tank-in-pool	20 000	4.0×10^{14}

Ref.: IAEA Research Reactors in Africa, A directory 2020 Edition

Power Reactors:

South Africa is the only country in Africa with a commercial nuclear power plant in Koeberg.

Embarking Countries

(the countries were divided into 3 tiers based on government support for nuclear energy, timelines and infrastructure activities).

Source: AFRICA NUCLEAR INDUSTRY REPORT, 2022 Edition: www.nuclearbusiness-platform.com (aceess, July 2022).

Deployment of SMRs in developing Countries

Opportunities

- Lower initial capital investment.
- Siting flexibility.
- Enhanced safety, security and nonproliferation.
- Wide range of users and applications.
- Open to adaptation of international and/or regional licensing.
- Increasing interest in SMRs.

Challenges

- Infrastructure needed.
- Financing nuclear energy.
- Licensing challenges.
- Spent Fuel and Waste Management
- Public acceptance.
- Invest in a first-of-a-kind technology.
- Cost performance depends on many parameters (Complicated feasibility study)

Opportunities (1/6)

Lower initial capital investment

- SMRs can be an attractive option for countries that do not have a huge budget or construction sites; they can begin with a small generating capacity and expand it in parallel with their economic growth.

- The lower, overall capital outlay implies that private investors will face lower capital at risk.

- In countries with small and weak electric grids, SMRs can be installed module by module to meet growing demand and these countries can connect SMR with very little investment on the gird (Because the addition of a large power plant (1000 MW(e) or more) can lead to grid stability problems—the general "rule of thumb" is that the unit size of a power plant should not exceed 10 percent of the overall electricity system capacity).

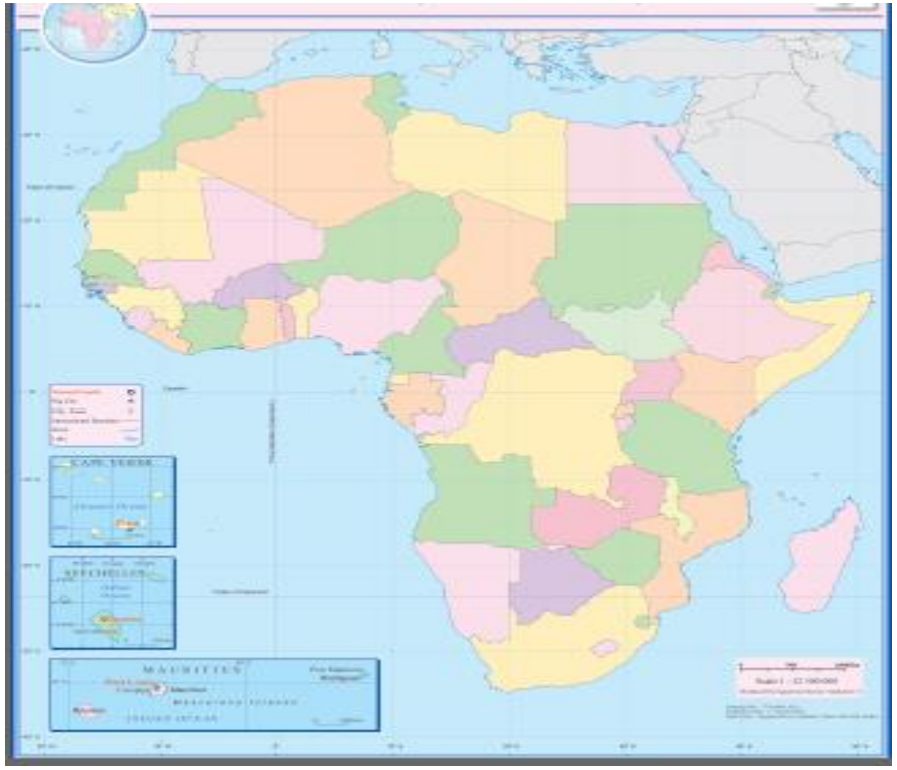
- Factory fueled/refueled reactors could substantially reduce the required infrastructure effort in a recipient country regarding nuclear fuel cycle and radioactive waste.

Opportunities (2/6)

Siting flexibility

SMRs can be constructed in sites that lack the infrastructure to support a large unit:

- Sites with smaller electrical markets
- Isolated areas and smaller grids.
- Sites lack large water bodies.
- Site for unique industrial applications.



https://www.esa.gov.eg/files/maps/Africa_E.pdf

- Large areas in Africa and many countries lack large water bodies.
- For these areas/countries the waste heat would be dumped using cooling towers.

Opportunities (3/6)

Enhanced safety, security and nonproliferation

- SMR with passive safety features (negative reactivity thermal coefficient, sufficient forced convection and passive cooling, ….)
- SMR with sealed reactor core design enhance the security and nonproliferation:

- It is impossible to steal fuel of the core if the core can remain sealed until the shipment to the back-end facility.
- Enhancing the proliferation resistance.

- SMR designs that can be built under the ground:

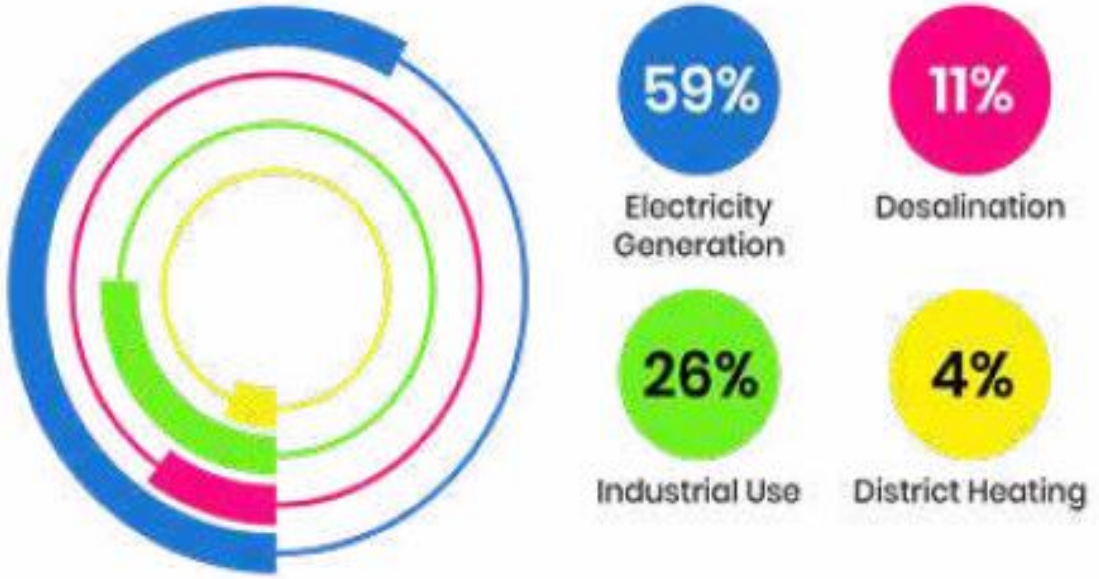
- Enhancing reactor Security.
- Enhancing the proliferation resistance.
- More protection from natural (*e.g.* seismic or tsunami according to the location) or man-made (*e.g.* aircraft impact) hazards.

Opportunities (4/6)

Wide range of users and applications

From SMR survey in Africa where 221 senior officials participated from 43 government organizations across 23 African countries:

What is the purpose of deploying SMR technology?



(Source: Africa SMR report, 2022 edition)

Opportunities (5/6)

Open to adaptation of international and/or regional licensing

From SMR survey in Africa where 221 senior officials participated from 43 government organizations across 23 African countries:

Will your country be open to adopting international or regional standardized regulation and licensing for SMR technology?

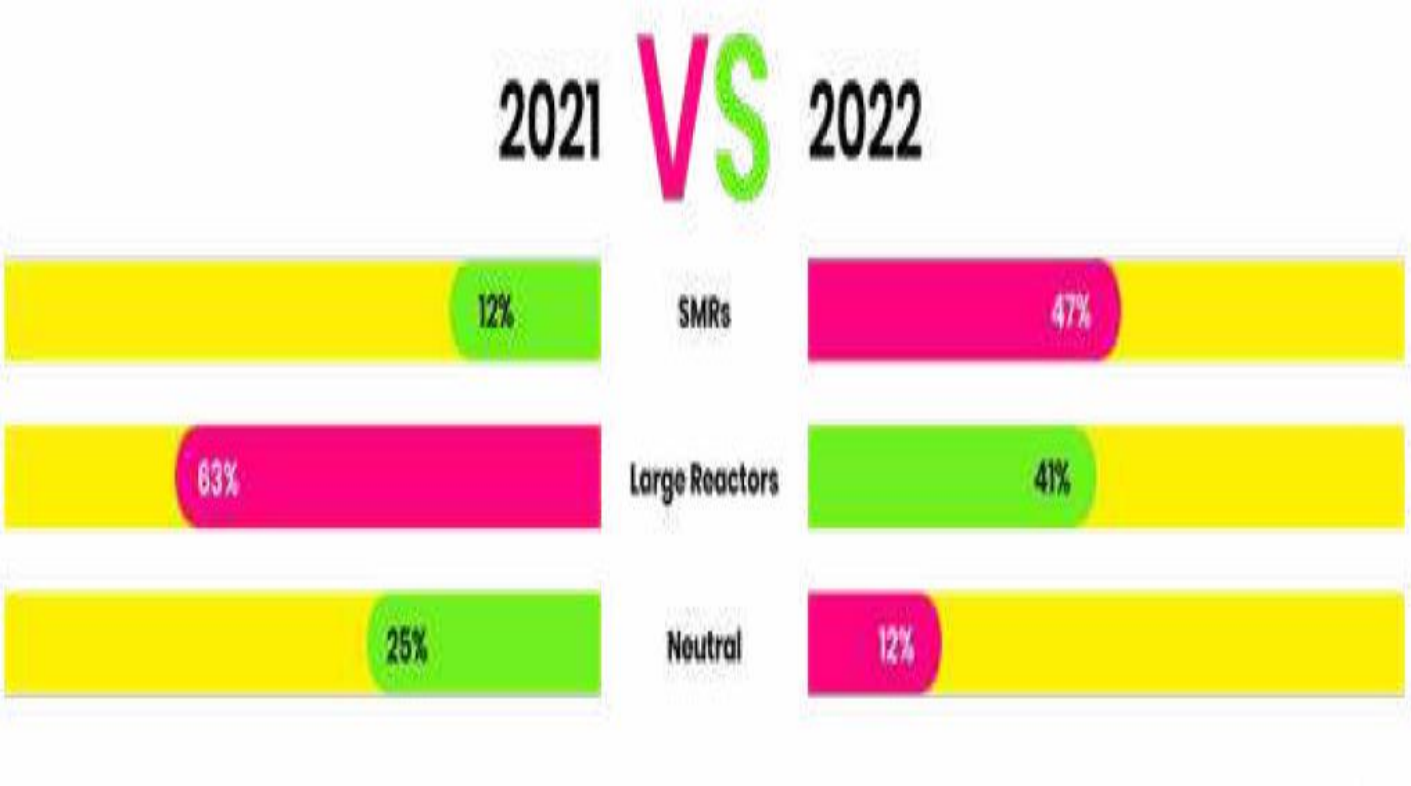
(Source: Africa SMR report, 2022 edition)

Opportunities (6/6)

Increasing interest in SMRs

From SMR survey in Africa where 221 senior officials participated from 43 government organizations across 23 African countries:

What type of Nuclear Reactor Technology would your country be keen to priorities?



(Source: Africa SMR report, 2022 edition)

Challenges (1/6)

Infrastructure needed to introduce nuclear energy:

- Independent national nuclear regulatory authority.
- Research reactor program (if applicable) and university level training in nuclear science and engineering.
- Preparedness and emergency plan.
- A domestic radiation protection and environmental monitoring systems.
- Establishing a program for nuclear waste management.

Challenges (2/7)

Human Resources capability

From SMR survey in Africa where 221 senior officials participated from 43 government organizations across 23 African countries:

What's the current level of Human Resources (HR) capability in your country to embrace nuclear technology?

(Source: Africa SMR report, 2022 edition)

Challenges (3/7)

Financing nuclear energy

- Financing of any project depends on the capital required and the risks involved.

- Financing nuclear energy is a big challenge considering:

- High capital cost per kWh.
- Long construction times.
- Regulatory risk.
- Political risk.

- **Financing nuclear energy needs** national policy support.

Challenges (4/7)

Licensing challenges

- The lack of experience with innovative designs presents a substantial problem in examining and approving the safety standards.
- Standardized SMR designs would lead to standardized regulatory processes through harmonization.
- For developing countries, the resources and guidance provided by the IAEA has been crucial in the development of their regulatory regime.
- Apart from the IAEA, several of the developing countries such would be engaging with the developed Nuclear Regulatory authorities for their nuclear regulatory activities.
- Developing counties should construct reactors that has proven technologies such as LWRs and therefore, the principals adopted for a large nuclear power plant can be applied to a SMR plant.

Challenges (4/7)

Spent Fuel and Waste Management

- Countries with established nuclear power programmes have been managing their spent fuel for decades.
- For these countries, management of spent fuel arising from new nuclear plant installations shouldn’t pose a challenge if they opt to deploy new plants based on current technologies.
- Countries that are new to nuclear power should carefully consider spent fuel management and establish relevant capabilities and infrastructure as they work on introducing nuclear energy.
- A few advanced reactor designs such as MSR, and SFR may increase the volume of nuclear waste in need of management and disposal. The excess waste volume is attributed to the use of neutron reflectors and/or chemically reactive fuels and coolants in advanced reactor designs.

(source: THE ROLE OF SMALL MODULAR REACTORS IN THE ENERGY TRANSITION, 2023)

Challenges (5/7)

Invest in a first-of-a-kind technology

- SMR is a new technology and some countries do not want to invest in a first-of-a-kind technology.
- They are waiting to be built and tested elsewhere in order to become proven technology in the continent.

Challenges (6/7)

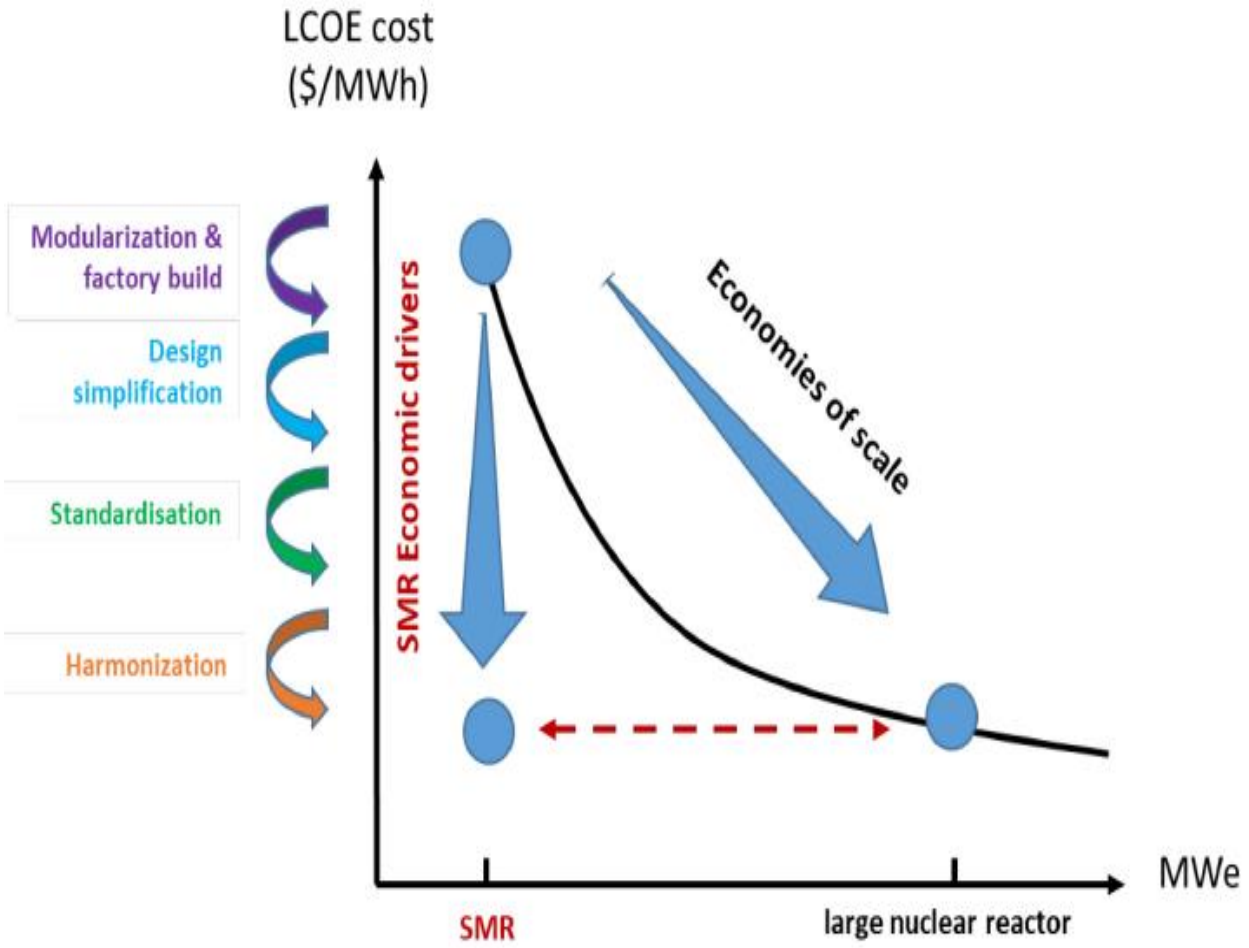
public acceptance

- Commercial nuclear power is sometimes viewed by the general public as a dangerous or unstable process.
- This perception is often based on three global nuclear accidents, its false association with nuclear weapons, and how it is portrayed on popular television shows and films.
- Deployment of nuclear power requires public acceptance, and public education.
- Fact-based information about nuclear energy through its social media is needed to educate the public on the benefits of nuclear energy.

Challenges (7/7)

Cost performance

- The economic performance of SMRs can be improved through series production thanks to simplification, standardization, modularization, and harmonization.
- These factors will be relatively more important to balance diseconomies of scale.



Source: NEA, 2020

Conclusions

- Deployment of nuclear power in African countries countries would enhance the electricity generation options and strengthen the energy security.
- Africa is the lowest continent emission of carbon dioxide per capita and use of nuclear energy is important for keeping low CO_2 emissions in the continent.
- SMRs can be an attractive option for countries that do not have a huge budget; they can begin with a small generating capacity and expand it in parallel with their economic growth and with little investment on the electrical gird.
- The features of SMRs including site flexibility and Enhanced safety, security and nonproliferation make such reactors the most suitable nuclear power reactors for African countries.
- There is increasing interest throughout the Africa continent in the deployment of SMRs however the infrastructure in most countries is till needs improvement.
- Developing counties may construct reactors that has proven technologies such as LWRs and therefore, the principals adopted for a large nuclear power plant can be applied to a SMR plant.
- Financing nuclear energy is a big challenge due to high capital cost and long construction times and associated risks which needs national policy support.
- SMRs cost performance depends on many parameters which complicate the feasibility study.

Thank you for your attention