Special Report

March 2021

Nuclear Energy in Ghana

HUBERT FOY & ISABEL BOSMAN

African perspectives
Global insights

SAIIA
SOUTH AFRICAN INSTITUTE OF INTERNATIONAL AFFAIRS

Executive summary

Ghana's emerging nuclear power programme is the culmination of nearly 60 years of socio-economic and political developments under successive governments since independence in 1957. As far back as 1961, President Kwame Nkrumah's government instituted a major atomic policy initiative, the Kwabenya Nuclear Reactor Project. Although the nuclear programme never took off as intended, for both political and economic reasons, the government of Ghana recently decided to renew its commitment to establish a nuclear power programme and use nuclear power to drive economic transformation and development.

One of the main reasons for this decision is electricity supply in Ghana, which has been outstripped by electricity demand for decades. The resulting energy crises have been ruinous for the country's economy. Ghana has experienced recurring electricity shortages over the course of roughly four decades: 1983–4; 1997–8; 2003; 2006–7; and, most recently, 2011–2017. In 2014 the economic impact of the power crisis was particularly severe, leading to a daily loss in production of $2.1 million, equating to $680 million or 2% of overall gross domestic product.

Ghana's population is projected to grow to roughly 38 million by 2030. It is expected that residential and industrial demand for electricity will increase at the same time. Furthermore, the government plans to rapidly industrialise the economy over the next four decades. Since current capacity cannot supply competitively priced electricity in a reliable and secure manner, nuclear power is being considered as a viable addition to the country's energy mix.

Ghana is approaching nuclear power in a responsible manner. It is following the International Atomic Energy Agency's (IAEA) Milestones Approach, which is a comprehensive guide for the establishment of nuclear power programmes that sets out three phases imperative to 'developing the infrastructure necessary to support a nuclear programme'. In the past three years Ghana has been visited twice by an IAEA Integrated Nuclear Infrastructure Review (INIR) team to review the ongoing development of the country's nuclear infrastructure.

The IAEA review team was generally satisfied with Ghana's progress, noting in particular the country's Nuclear Regulatory Act No. 895 of 2015. It highlighted the act's focus on 'nuclear safety, radiation protection, nuclear security and non-proliferation/safeguards', as well as its identification and stipulation of 'the responsibilities of the main stakeholders' in the development of a nuclear power programme.

In addition, Ghana has demonstrated responsible nuclear behaviour by becoming a member of numerous international agreements, instruments and initiatives with the 'potential to enhance human resource development, transfer of nuclear science and technology know-how'. Notably, Ghana has not expressed reservations about joining any

of these. To comply with its obligations and benefit from privileges provided under its international commitments, Ghana has enacted several laws, formulated policies, and worked to institutionalise them.

While significant steps have been taken to establish a nuclear programme in Ghana, much work lies ahead. The development and operation of a nuclear power plant is a mammoth task and requires long-term commitment and planning, as well as large-scale financial and human capital investment. With regard to financing, Ghana has already approached Russia, China and the Republic of Korea for assistance, as it would cost $8–$10 billion to build the plant. The government is also securing public buy-in for the project through a series of awareness-raising, public outreach and education activities. It hopes to build the plant by 2030.

Abbreviations & acronyms

Act 204	Atomic Energy Commission Act
Act 588	New Ghana Atomic Energy Commission Act
Act 895	Nuclear Regulatory Authority Act
CPF	Country Programme Framework
CSO	civil society organisation
CT	computed tomography
EBRT	external beam radiation therapy
GAEC	Ghana Atomic Energy Commission
GDP	gross domestic product
GEDAP	Ghana Energy Development and Access Project
GHARR-1	Ghana Research Reactor-1
GIF	Gamma Irradiation Facility
GIIF	Ghana Infrastructure Investment Fund
GNPP	Ghana's nuclear power programme
GNPPO	Ghana Nuclear Power Programme Organisation
HDR	high dose rate
HEU	highly enriched uranium
IAEA	International Atomic Energy Agency
INIR	Integrated Nuclear Infrastructure Review
IPP	independent power producer
LDR	low dose rate
LEU	low enriched uranium
linac	medical linear accelerator
MNSR	Miniature Neutron Source Reactor
MRI	magnetic resonance imaging
NEPIO	Nuclear Energy Programme Implementation Organisation
NES	National Electrification Scheme
NNP	nuclear non-proliferation
NNRI	National Nuclear Research Institute
NRA	Nuclear Regulatory Authority
NSS	nuclear safety and security

SDGs	Sustainable Development Goals
SHEP	Self-Help Electrification Scheme
SNAS	School of Nuclear and Allied Sciences
VALCO	Volta Aluminium Company

Authors

Hubert Foy

is the Founding Director of the African Centre for Science and International Security based in Accra, Ghana. His areas of interest include nuclear security, non-proliferation and arms control, disarmament verification and global missile systems proliferation.

Isabel Bosman

is a Konrad Adenauer Stiftung research scholar at SAIIA working with the African Governance and Diplomacy Programme.

Acknowledgment

SAIIA is grateful to the Norwegian Ministry of Foreign Affairs for supporting the 'Atoms for Africa's Development' project.

About SAIIA

SAIIA is an independent, non-government think tank whose key strategic objectives are to make effective input into public policy, and to encourage wider and more informed debate on international affairs, with particular emphasis on African issues and concerns.

SAIIA'S special reports are fairly lengthy analytical papers, usually reflecting on and analysing the findings of field research.

Cover image

Nuclear reprocessing plant (Steve Allen/Getty Images)

Contents

Executive summary 2

Abbreviations & acronyms 4

Authors 6

CHAPER 1 9

Introduction 9

CHAPTER 2 11

Electricity situation 11

- Electricity access 12
- Demand vs supply 14
- Electricity generation mix 17

CHAPTER 3 18

Nuclear energy evolution 18

- 1961–1966 19
- 1993–2012 19
- 2012–2019 20
- Nuclear normative framework 22

CHAPTER 4 27

Nuclear governance status 27

- Nuclear legislation and policies since 1961 27
- Major nuclear governance entities 30
- Study reports 31

CHAPTER 5 32

Nuclear power development status 32

CHAPTER 6 34

Uranium sector in Ghana 34

- HEU to LEU conversion 35
- Uranium reserves 36

CHAPTER 7 38

Nuclear power issues 38

National position 38
Legal framework 39
Funding and financing 40
Stakeholder involvement 40

CHAPTER 8 42

Non-power nuclear energy applications 42

Ghana Research Reactor-1 42
Gamma Irradiation Facility 43
External beam radiotherapy therapy 44
Brachytherapy equipment 46
Radiological imaging 46

CHAPTER 9 48

Conclusion 48

CHPATER 10 49

Recommendations 49

CHAPER 1

Introduction

Ghana's interest in nuclear technology dates back to the 1950s. The earliest nuclear research conducted in the country took place at the University of Ghana, Legon (then the University College of the Gold Coast) in 1952, and involved the use of radioactive strontium in experiments on monkeys.[1] These experiments were conducted to study chronic irradiation and haematological control of these animals as a basis of consideration for human risk. During the same decade, a radioactive fallout monitoring service was established by the same university department, supported by the Ministry of Defence.[2] At Ghana's independence in 1957, a number of institutions throughout the country were using radioisotope techniques and ionising radiation in scientific research. There was a general awareness among academic and political communities of the benefits of the atomic field to human prosperity and economic development.

> Today the use of peaceful nuclear technology can play a critical role in helping Ghana achieve its development objectives and targets under the Sustainable Development Goals

Today the use of peaceful nuclear technology in these fields – human prosperity and economic development – can play a critical role in helping Ghana achieve its development objectives and targets under the Sustainable Development Goals (SDGs). The best-known peaceful application of nuclear technology is electricity production. Currently, Ghana is pursuing the nuclear power option as part of its energy mix. The future construction of a nuclear power plant to supply electricity, if successful, will enhance national energy security in meeting growing energy demand, mitigate climate change impact, and allow technology transfer. Non-power nuclear energy uses, including radioisotope techniques and ionising radiation applications, already have a positive impact on the lives of millions of Ghanaians.

What remains unclear, however, is the progress that has been made in introducing the first nuclear power plant in Ghana. This report aims to contribute to an understanding of

1 Ghana Atomic Energy Commission, "History of Ghana Atomic Energy Commission", https://gaecgh.org/?page_id=4242#:~:text=The%20Ghana%20Atomic%20Energy%20Commission%20was%20established%20by%20an%20Act,other%20institutes%20under%20the%20Commission.

2 GAEC, "History of Ghana Atomic".

Ghana's nuclear energy sector. It first looks at the country's electricity situation, and then outlines its nuclear energy evolution. The third section covers Ghana's normative framework, while the fourth examines its nuclear governance system. This is followed by an overview of Ghana's uranium sector. The sixth section discusses Ghana's nuclear power issues, and the seventh highlights non-power nuclear energy applications in the country. The report concludes with a summary of findings and practical recommendations.

CHAPTER 2

Electricity situation

From the household to industrial and service sectors, access to electricity has become a determining factor in economic progress and development.[3] This is particularly evident in the case of Ghana, where repeated electricity crises have disrupted meaningful economic progress. Access to electricity has been assigned prime importance on the international development agenda, with SDG 7 'establish[ing] universal access to modern energy by 2030 as an agreed commitment of the global community'.[4] This section outlines the history of the electricity sector in Ghana before moving on to electricity access, issues of electricity demand and supply, and current sources of electricity.

The electricity sector in Ghana dates back to the early 1900s, with the establishment of a number of isolated diesel generator plants across the country. The first of these was established by the Gold Coast Railway Administration at Sekondi in 1914 and was used primarily by the railway system. Later, in 1928, electricity supply from the Sekondi generator plant was extended to Takoradi, and by 1955 supply had been extended to Accra, Bolgatanga, Kumasi, Nsawam, Tamale and Tema. For much of its early history, the electricity sector mostly served the needs of industry and institutions such as hospitals and schools.[5] Diesel generator plants remained the primary source of electricity in Ghana until 1972, when hydropower was introduced to the energy mix upon the completion of the Akosombo Dam. The hydroelectric project made additional generation capacity in the electricity sector possible and paved the way for other hydropower projects in the country.[6]

In spite of its well-established electricity sector, Ghana has experienced recurring power shortages over the course of roughly four decades: 1983–4; 1997–8; 2003; 2006–7; and, most recently, 2011–2017.[7] The social, economic and environmental impact of each crisis has been considerable. According to World Bank estimates, the 2006/7 power crisis led to a loss in gross domestic product (GDP) growth of 1%.[8] In 2014 the economic impact of the power crisis was particularly severe, having led to a daily loss in production of $2.1 million, equating to a loss of $680 million or 2% of overall GDP.[9] The World Bank has identified unreliable

3 Ebenezer Nyarko Kumi, "The Electricity Situation in Ghana: Challenges and Opportunities" (Center for Global Development Policy Paper 109, CGD, Washington DC, 2017), https://www.cgdev.org/sites/default/files/electricity-situation-ghana-challenges-and-opportunities.pdf.

4 UN Conference on Trade and Development, "Energy: The Lifeblood of Sustainable Development", in *The Least Developed Countries Report 2017*, 3, https://unctad.org/system/files/official-document/ldcr2017_ch1_en.pdf.

5 Kumi, "The Electricity Situation in Ghana"; see also Institute of Statistical, Social and Economic Research, "Guide to Electric Power in Ghana" (Resource Center for Energy Economics and Regulation, ISSER, Legon, July 2005).

6 Kumi, "The Electricity Situation in Ghana".

7 Kumi, "The Electricity Situation in Ghana".

8 World Bank, *Energizing Economic Growth in Ghana: Making the Power and Petroleum Sectors Rise to the Challenge*, Report (Accra: World Bank, Energy Group – Africa Region, June 2013), http://large.stanford.edu/courses/2018/ph241/owusu-adjapong1/docs/wb-jun13.pdf.

9 Kumi, "The Electricity Situation in Ghana".

electricity supply as one of the biggest constraining factors on economic growth in Ghana.[10] These electricity crises are the result of electricity supply shortages, linked in turn to fuel shortages, including natural gas, and dropping water levels in the country's main hydropower plants. Electricity shortages in Ghana have become such regular occurrences that a special term, *dumsor*, has been adopted to describe the phenomenon.[11]

Electricity access

Electricity access is a nebulous concept whose definition varies among scholars.[12] What most definitions have in common is their emphasis on electricity access in the household, as well as the industry and services sectors.[13] Importantly, as Kumi notes, simply 'having a house connected to the grid' does not constitute electricity access; electricity access also incorporates the provision of a 'reliable supply of affordable electricity in the household'.[14] In other words, only once a connection to an electricity grid is providing an uninterrupted supply of electricity can it be said that electricity access has been achieved. This is the general understanding applied in this report when referring to electricity access.

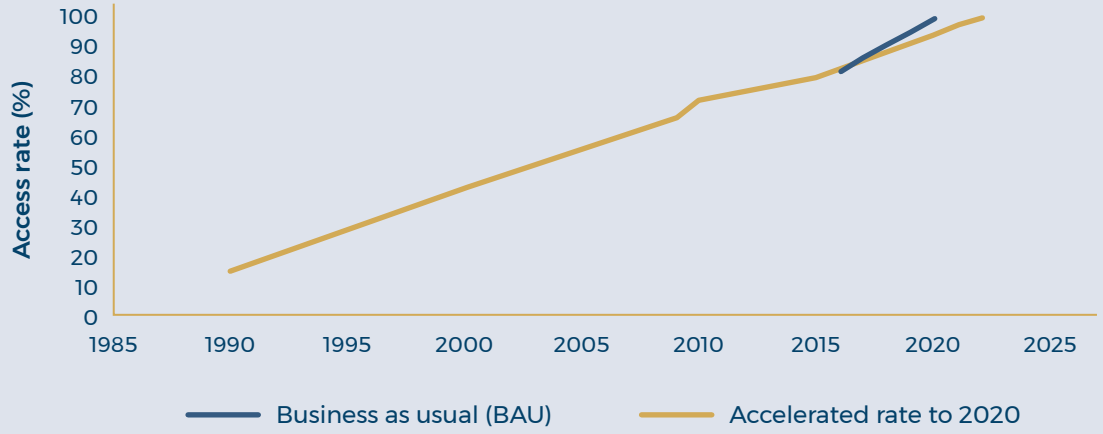
Ghana has instituted several electrification policies and implemented numerous projects aimed at addressing its recurring electricity crises and economic transformation. Two of these projects have had a significant impact on improving the country's electricity access rate: the National Electrification Scheme (NES) and the Ghana Energy Development and Access Project (GEDAP). The NES was instituted in 1989 with the policy objective of improving the electricity access rate – at the time between 15% and 20% – over 30 years to ensure universal access to reliable and affordable electricity by 2020.[15] The GEDAP, a World Bank-funded project scheduled to run from 2007–2022, has a twofold objective: to 'improve the operation efficiency of the electricity distribution system and increase the population's access to electricity', and to 'transition Ghana to a low-carbon economy through the reduction of greenhouse gas emissions'.[16]

Overall, these electrification schemes have succeeded in improving the electricity access rate in the country. Since the institution of the NES, the GEDAP and related projects, electricity access has increased from 62.5% in 2009 to 75.7% in 2015 and 82.4% in 2018.[17] By 2019 the electricity access rate in Ghana reached 85%.[18] While Ghana has thus come close to realising the goal of the NES, universal electricity access will not be achieved by the

10 World Bank, *Energizing Economic Growth*.
11 Kumi, "The Electricity Situation in Ghana".
12 UNCTAD, "Energy: The Lifeblood", 3.
13 UNCTAD, "Energy: The Lifeblood".
14 Kumi, "The Electricity Situation in Ghana", 8.
15 Kumi, "The Electricity Situation in Ghana".
16 Ebenezer Nyarko Kumi, *Ghana Energy Development and Access Project*, Financial Report (Accra: World Bank, 2019), http://documents1.worldbank.org/curated/en/864281606729516602/pdf/GEDAP-Financial-Report-2019-pdf.
17 Kumi, "The Electricity Situation in Ghana", 7.
18 Energy Commission Ghana, Strategic Planning and Policy Directorate, *National Energy Statistics 2000–2019* (Accra: Energy Commission Ghana, 2020), http://www.energycom.gov.gh/files/ENERGY%20STATISTICS-2020.pdf.

end of 2020. Figure 1 illustrates the rate of electrification in Ghana since the inception of the NES. In the quarter century since its inception, up to 2015, electricity access increased at a rate of 2.6% annually under standard conditions. This has not been enough to achieve universal access, and ultimately Ghana will fall short of its end goal of universal electricity access by roughly 5%.[19] Kumi notes that universal access to electricity can more realistically be achieved by 2022. Electricity access would have had to have accelerated to 4.38% some years ago if the country were to achieve universal access by the end of 2020.[20]

Figure 1 Electricity access in Ghana since the start of electrification projects



Source: Ebenezer Nyarko Kumi, "The Electricity Situation in Ghana: Challenges and Opportunities" (Center for Global Development Policy Paper 109, CGD, Washington DC, 2017), https://www.cgdev.org/sites/default/files/electricity-situation-ghana-challenges-and-opportunities.pdf

Ghana's current electricity access rate of more than 80% is among the highest in sub-Saharan Africa and at one point was the highest in the region.[21] This achievement was made possible by the complementary contributions of the NES and GEDAP.[22] The NES was implemented under the auspices of the National Electrification Master Plan and saw

Ghana's current electricity access rate of more than 80% is among the highest in sub-Saharan Africa and at one point was the highest in the region

19 Kumi, "The Electricity Situation in Ghana", 7.
20 Kumi, "The Electricity Situation in Ghana", 7.
21 Government of Ghana, Ministry of Energy, "Overview of the Ghana Power Sector", https://www.energymin.gov.gh/sector-overview.
22 Kumi, "The Electricity Situation in Ghana".

the creation of the Self-Help Electrification Scheme (SHEP), which helped significantly to accelerate electrification. Through SHEP local communities supplied 'low voltage electricity poles and electricity meters' themselves, thereby bringing government costs down and ensuring electricity access ahead of the National Electrification Master Plan schedule.[23]

Demand vs supply

Electricity demand and supply are two sides of the same coin. Electricity supply refers to the dependable capacity available for consumption. Electricity demand, on the other hand, refers to the aggregate cumulative electricity needs of bulk customers, including residential, non-residential and industrial customers. Rapid population increases, modernisation, urbanisation and an expanding commercial and industrial base increased electricity demand significantly. For a long time, Ghana faced a demand for electricity that significantly outweighed the available supply. Electricity demand in the first decade of the 2000s increased at roughly 7% annually, primarily owing to 'population growth, economic aspiration of the country and the extension of electricity to rural areas'.[24] This number is significantly higher than the average increase in electricity access. With GDP growth of roughly 7.1% in 2019, Ghana's economy is one of the fastest growing on the continent – a title it has held since 2017.[25] It is therefore imperative that it can supply enough electricity to match the needs of its developing economy.

With GDP growth of roughly 7.1% in 2019, Ghana's economy is one of the fastest growing on the continent. It is therefore imperative that it can supply enough electricity to match the needs of its developing economy

In an ironic twist, Ghana now faces the opposite scenario – its economic development is constrained due to an over-supply of electricity. Because of the severity of the electricity crisis in 2014, which not only resulted in a significant loss in GDP but also saw growing unemployment in crucial sectors of the economy, the government increased the number of private/independent electricity suppliers.[26] From 2014 to 2017 it entered into 43 power purchasing agreements with three independent power producers (IPPs).[27] Through these

23 Kumi, "The Electricity Situation in Ghana", 8.

24 Benjamin Nyarko, Edward Akaho and Isaac Ennison, "Nuclear Power for Future Electricity Generation in Ghana: Issues and Challenges" (IAEA-CN-164-2S03, International Atomic Energy Agency, Vienna, 2011), https://www-pub.iaea.org/MTCD/publications/PDF/P1500_CD_Web/htm/pdf/topic2/2S03_B.J.B.%20Nyarko.pdf.

25 African Development Bank, "Ghana Economic Outlook", https://www.afdb.org/en/countries/west-africa/ghana/ghana-economic-outlook.

26 Samuel Asumadu Sarkodie, "Lessons to Be Learnt from Ghana's Excess Electricity Shambles", *The Conversation*, August 5, 2019, https://theconversation.com/lessons-to-be-learnt-from-ghanas-excess-electricity-shambles-121257.

27 Sarkodie, "Lessons to Be Learnt".

agreements Ghana was able to make up its electricity supply deficit, but soon there was an excess of electricity supply.[28] Electricity demand could not keep up with supply, while electrification has not yet been able to satisfy demand or necessity. The problem with Ghana's current excess electricity supply is that the government is paying up to $500 million per year for electricity that is not used. This is putting additional strain on the country's economy.[29]

Electricity in Ghana is sourced primarily from hydropower and thermal power plants, and the country also boasts crude oil, natural gas and renewable energy sources such as wind and solar energy.[30] At one point, hydropower was its main source of electricity. It has since been gradually displaced by thermal power plants after domestic oil and gas sources were discovered.[31] However, its main sources of electricity have had issues in terms of consistency. Recurring droughts have been directly linked to the electricity supply crises the country has experienced. This will no doubt only become more severe in the face of climate change impacts.[32] Furthermore, operating thermal power plants is notoriously expensive even when fuel is sourced domestically, and the resources required are finite. Recent projections have suggested that domestic resources for thermal power plants in Ghana will run out by 2045.[33] Table 1 (outlines generation capacity from the country's different electricity sources.

The Volta River Authority, the Bui Power Authority and various IPPs are responsible for electricity generation in Ghana.[34] From these generation companies, electricity is conveyed to separate distribution companies. This process is managed by Ghana Grid Company Ltd and takes place through the National Interconnected Transmission System.[35] Once the transmission process has taken place, electricity is distributed to consumers via the Electricity Company of Ghana, in the south of Ghana, and the Northern Electricity Distribution Company, in the north.[36]

Ghana's population is projected to increase to roughly 38 million by 2030.[37] It can be expected that residential and industrial demand for electricity will increase as the population grows. The country will therefore require more power plants to meet this anticipated demand hike. Historically, there is a clear link between the expansion of industry and the expansion of the energy sector. The Akosombo Dam owes its existence in part to the establishment of the Volta Aluminium Company (VALCO), a prominent aluminium smelter in Ghana and sub-Saharan Africa.[38] The VALCO plant was constructed

28 Sarkodie, "Lessons to Be Learnt".
29 Sarkodie, "Lessons to Be Learnt".
30 IAEA, *Country Nuclear Profiles (2018 Edition): Ghana* (Vienna: IAEA, 2018), https://www-pub.iaea.org/MTCD/Publications/PDF/cnpp2018/countryprofiles/Ghana/Ghana.htm.
31 IAEA, *Country Nuclear Profiles*.
32 IAEA, *Country Nuclear Profiles*.
33 IAEA, *Country Nuclear Profiles*.
34 Kumi, "The Electricity Situation in Ghana".
35 Kumi, "The Electricity Situation in Ghana".
36 Kumi, "The Electricity Situation in Ghana".
37 Population Pyramid, "Population Pyramids of the World from 1950 to 2100: Ghana 2030", https://www.populationpyramid.net/ghana/2030/.
38 Volta Aluminium Company Limited, "History", http://www.valcotema.com/index.php/2015-08-20-16-20-34/history.

TABLE 1 TOTAL INSTALLED GENERATION CAPACITY, DECEMBER 2019			
Plant		**Installed capacity (MW)**	**Dependable capacity (MW)**
Hydro	Akosombo	1,020	900
	Kpong	160	105
	Bui	400	360
	Total	**1,580**	**1,365**
Thermal	Takoradi Power Company (TAPCO)	330	300
	Takoradi International Company (TICO)	340	320
	Tema Thermal 1 Powqer Plant (TT1PP)	110	100
	Cenit Energy Ltd	110	100
	Sunon Asogli Power (Ghana) Limited	560	520
	Tema Thermal 2 Power Plant (TT2PP)	87	71.5
	Kpine Thermal Power Plant	220	200
	Karpowership	470	450
	Ameri plant	250	230
	Trojan*	44	39.6
	Genser*	95	85
	Amandi	203	190
	AKSA	370	350
	Cenpower	360	340
	Total	**3,549**	**3,296.1**
Renewables	Safisana Biogas*	0.1	0.1
	VRA Solar*	2.5	2
	BXC Solar*	20	16
	Meinergy*	20	16
	Total	**42.6**	**34.1**
	Grand total	**5,171.6**	**4,695.2**

Source: Energy Commission Ghana, Strategic Planning and Policy Directorate, *National Energy Statistics 2000–2019* (Accra: Energy Commission Ghana, 2020), http://www.energycom.gov.gh/files/ENERGY%20STATISTICS-2020.pdf

in 1964 and became operational in 1967. Its construction followed on the heels of the decision taken in the 1950s to launch the Akosombo hydropower project.[39] VALCO was viewed as 'the economic justification' for the establishment of the hydropower plant and consumed a significant portion of the electricity generated by the plant.[40] As one of the biggest consumers of hydroelectricity in Ghana, VALCO's operations have been negatively affected by the droughts that have caused electricity supply shortages since the 1980s. The company even had to shut down operations a number of times between 2003 and 2011, with electricity supply being one of the main reasons for this.[41]

39 VALCO, "History".

40 VALCO, "History". See also Kumi, "The Electricity Situation in Ghana".

41 Aluworks Ltd., "The Aluminium Industry in Ghana", https://www.aluworks.com/nu/the-aluminium-industry-in-ghana/.

Aside from these electricity supply and demand struggles, Ghana also faces a number of issues in terms of the generation, transmission and distribution of electricity. These include financial shortcomings, 'legacy debt', the 'over-contracting of new plants' and a significant shortage of 'strong, transparent regulatory precedents to drive competition'.[42] The country would benefit tremendously from 'diversifying' its electricity sources with an emphasis on incorporating more renewables. It should also consider incorporating both public power producers and IPPs in its prepaid metering system, revising its tariff regime, and 'promoting energy efficiency programs'.[43]

Electricity generation mix

Electricity can be generated through the use of wind, solar, biomass, hydroelectricity, natural gas, coal and nuclear sources. Electricity sources in Ghana have evolved in three main phases, beginning with diesel generator plants and moving to hydropower and then thermal power. Renewable energy, particularly wind, solar and traditional biomass, has also begun to be incorporated in the country's electricity generation mix.[44] The country has significant solar power potential, but is prevented from benefitting fully from this resource because of the cost of the technology.[45]

Ghana was assigned lower-middle-income country status by the World Bank at the end of 2010.[46] The country has developmental aspirations and aims to industrialise, modernise its agriculture, and attract foreign direct investment in energy-intensive industries in order to provide economic opportunities for its young and fast-growing population. By the centenary of its independence, Ghana aims to have established itself as a highly industrialised economy.[47] Industrialisation requires cost-effective, reliable and sustainable electricity supply. Its current electricity supply problems cannot be addressed by simply adding more hydro-, thermal-, solar and wind power plants. Ghana will have to consider a range of alternative energy sources in its quest for industrialisation. Nuclear power has been suggested as an energy source that can meet the demands of the residential, industry and transport sectors and that can drive its industrialisation efforts.[48]

The country has significant solar power potential, but is prevented from benefitting fully from this resource because of the cost of the technology

42 USAID, "Ghana: Power Africa Fact Sheet", https://www.usaid.gov/powerafrica/ghana.
43 Kumi, " The Electricity Situation in Ghana", i.
44 IAEA, *Country Nuclear Profiles*.
45 IAEA, *Country Nuclear Profiles*.
46 GET-Invest, "Market Information: Ghana", https://www.get-invest.eu/market-information/ghana/.
47 IAEA, *Country Nuclear Profiles*.
48 IAEA, *Country Nuclear Profiles*.

CHAPTER 3

Nuclear energy evolution

Arguably, the most important peaceful use of nuclear energy is the generation of electricity. A national nuclear programme relies on one or more nuclear reactors to do so. Each reactor generates and controls nuclear fission reactions that split atoms held at the core – or nucleus – of uranium atoms. The process of nuclear fission creates thermal energy that is transferred to an internal cooling agent (most commonly water). This cooling process generates steam and is responsible for spinning a turbine linked to a generator, via which electricity is ultimately generated.[49]

Arguably, the most important peaceful use of nuclear energy is the generation of electricity

Ghana's emerging nuclear power programme is the culmination of nearly 60 years of socio-economic and political developments under successive governments. Ghana's first president, Kwame Nkrumah (1957–1966), was a staunch supporter of pan-Africanism[50] and championed nuclear energy.[51] Nkrumah's quest for global recognition for Ghana and the well-being of the country centred on securing access to energy for its population. He recognised that Ghana's, and by extension Africa's, development and rapid industrialisation required access to reliable, sustainable and sufficient electrical power.[52] Ghana's nuclear

Ghana's emerging nuclear power programme is the culmination of nearly 60 years of socio-economic and political developments under successive governments

49 Christina Nunez, "What Is Nuclear Energy and Is It a Viable Resource?", *National Geographic*, March 26, 2019, https://www.nationalgeographic.com/environment/energy/reference/nuclear-energy/#:~:text=Nuclear%20power%20is%20generated%20by,to%20a%20generator%2C%20producing%20electricity; Energy Education, "Nuclear Power Plant", https://energyeducation.ca/encyclopedia/Nuclear_power_plant.

50 African American Registry, "Kwame Nkrumah Fathered Pan-Africanism", 1996, https://aaregistry.org/story/kwame-nkrumah-fathered-pan-africanism/.

51 See IAEA, *Country Nuclear Profiles*; Linda Asante Agyei, "Nkrumah Lays Foundation for Atomic Reactor … in 1964", *My Joy Online*, September 3, 2007, https://www.myjoyonline.com/opinion/nkrumah-lays-foundation-for-atomic-reactor-in-1964/.

52 See Agyei, "Nkrumah Lays Foundation".

power programme (GNPP) was born during the Nkrumah administration and its nuclear history and major related developments can be divided into three periods: 1961–1966; 1993–2012; and 2012–2019.

1961–1966

In 1961 Nkrumah's government instituted a major nuclear policy initiative, the Kwabenya Nuclear Reactor Project, and set up an institutional structure, the Ghana Atomic Energy Committee, alongside it to oversee its implementation. The Kwabenya Nuclear Reactor Project was established with the intention to 'introduce nuclear science and technology into the country, and to exploit nuclear energy in its peaceful applications for the solution of problems of national development'.[53] The initial oversight body, the Ghana Atomic Energy Committee, would be replaced by the Ghana Atomic Energy Commission (GAEC) in 1963, with the passing of the Atomic Energy Commission Act No. 204 in the same year. This act established the GAEC as 'the sole agency in Ghana responsible for all matters relating to peaceful uses of atomic energy'.[54] It also established the Kwame Nkrumah Nuclear Research Institute, now known as the National Nuclear Research Institute (NNRI).[55]

On 25 November 1964 Nkrumah delivered an inspired pro-nuclear speech at the laying of the foundation stone for the construction of the GAEC buildings at Kwabenya.[56] Nkrumah's nuclear policies, his government's enactment of Act 204, his pro-nuclear power speech and the construction of the GAEC infrastructure set a positive tone for the forward trajectory of nuclear development in Ghana. However, there was a midcourse halt. Ghana abandoned its pursuit of nuclear energy for electricity generation in 1966 owing to a military coup that toppled the Nkrumah government.[57] Interest in nuclear energy remained largely dormant for some 30 years owing to economic ruin and political uncertainty. It was only briefly revived in the late 1990s when electricity supply shortages began to plague the country once more.[58]

1993–2012

Ghana began rebuilding, although minimally, on the nuclear foundation laid by Nkrumah by the time Jerry J Rawlings, who had come to power through a coup, was in office for the second time, from 1981–2000.[59] Rawlings has been described as the leader who 'led the country through the difficult years of economic recovery and succeeded in giving back

53 IAEA, *Country Nuclear Profiles*.
54 GAEC, "History of Ghana Atomic"; see also IAEA, *Country Nuclear Profiles*.
55 National Nuclear Research Institute, "About Us", https://nnri.gaecgh.org/about-us/.
56 Agyei, "Nkrumah Lays Foundation".
57 IAEA, *Country Nuclear Profiles*.
58 IAEA, *Country Nuclear Profiles*.
59 John Adedeji, "The Legacy of JJ Rawlings in Ghanaian Politics, 1979–2000", *African Studies Quarterly* 5, no. 2 (2001): 1–27, https://asq.africa.ufl.edu/files/Adedeji-Vol-5-Issue-2.pdf.

to Ghanaians their national pride'.[60] An amendment to Act 204 in 1993 established the Radiation Protection Institute and the Biotechnology and Nuclear Agriculture Research Institute.[61] Although a nuclear energy programme was not established at this time, a concrete step in the expansion of the country's nuclear research programme was taken in 1994 when Ghana acquired a 30-kW tank-in-pool, Miniature Neutron Source Reactor (MNSR) – the Ghana Research Reactor-1 (GHARR-1) – from China with the help of the International Atomic Energy Agency (IAEA).[62]

The electricity crisis of 1997/8 led to a brief reconsideration of nuclear energy for electricity generation, suggested as a solution to the water shortage problems experienced with hydropower. However, it was abandoned as soon as the electricity crisis was resolved.[63] Another significant legislative move in the nuclear field occurred in 2000 when Parliament enacted the new Ghana Atomic Energy Commission Act No. 588, which came to replace Act 204. Act 588 enabled the GAEC to 'undertake commercialisation of its research and development results'.[64]

Following the progress in Ghana's nuclear power programme under Rawlings between 1993 and 2001, there have been further advances in terms of nuclear policy development, legislation and regulation under presidents John Kufuor (2001–2009), John Atta Mills (2009–2012), John Dramani Mahama (2012–2017) and Nana Akufo-Addo (2017 –).[65]

In 2006, under the Kufuor administration, the Graduate School of Nuclear and Allied Sciences (SNAS) was created by the GAEC with the support of the IAEA and University of Ghana, Legon.[66] SNAS is committed to training postgraduate students 'in the techniques of nuclear science application in areas such as agriculture and medicine'.[67] Students at SNAS conduct extensive research using GHARR-1 in the fields of 'neutron physics, particle radiation transport, nuclear instrumentation and exploitation of nuclear energy for power generation'.[68]

2012–2019

Ghana's plans to establish a nuclear power programme saw the most progress during this period. In a crucial step towards creating a progressive nuclear power programme, the inauguration of Ghana's Nuclear Energy Programme Implementation Organisation (NEPIO) and the Ghana Nuclear Power Programme Organisation (GNPPO) took place in September

60 Adedeji, "The Legacy of JJ Rawlings", 1.
61 GAEC, "History of Ghana Atomic".
62 IAEA, *Research Reactors in Africa* (Vienna: IAEA, 2011), https://www.iaea.org/sites/default/files/18/09/research-reactors-in-africa.pdf.
63 IAEA, *Country Nuclear Profiles*.
64 GAEC, "History of Ghana Atomic".
65 Chuka Obiorah, "Presidents of Ghana – A Comprehensive List", *Buzz Ghana*, 2018, https://buzzghana.com/presidents-ghana/.
66 Elizabeth Ama Agyeman and Albert Bilson, "Research Focus and Trends in Nuclear Science and Technology in Ghana: A Bibliometric Study Based on the INIS Database", *Library Philosophy and Practice* 1212 (February 27, 2015), https://digitalcommons.unl.edu/libphilprac/1212/.
67 IAEA, *Country Nuclear Profiles*.
68 IAEA, *Country Nuclear Profiles*.

2012. The GNPPO has been tasked with 'coordinat[ing] the activities of all stakeholder institutions involved in the planning of the nuclear power programme'.[69]

Further progress was made in 2015 through the enactment of the Nuclear Regulatory Authority Act No. 895 under the Mahama administration.[70] The Nuclear Regulatory Authority Act establishes the Nuclear Regulatory Authority (NRA), whose function is to 'provide for the regulation and management of activities and practices for the peaceful use of nuclear material or energy, radioactive material or radiation'.[71] It also makes provision for 'the protection of persons and the environment against the harmful effects of radiation hazards' and should 'ensure the effective implementation of the country's international obligations'.[72] The NRA has replaced the GAEC's Radiation Protection Board. In addition to the functions already mentioned, the NRA is also responsible for reviewing applications for any 'activities involving radiation', as well as the 'authorisation of practices involving ionising and non-ionising radiation sources and devices', and should oversee the inspection of any nuclear installations.[73] The creation of an independent nuclear regulatory regime in Ghana is a positive step towards creating a conducive environment for investment in nuclear power.

The creation of an independent nuclear regulatory regime in Ghana is a positive step towards creating a conducive environment for investment in nuclear power

On the technical front, Ghana has also made significant progress. In the last three years, under the Akufo-Addo administration, Ghana has been visited twice – in 2017 and 2019 – by an IAEA Integrated Nuclear Infrastructure Review (INIR) team to review the ongoing development of the country's nuclear infrastructure. Such review missions allow for the exchange of knowledge between IAEA member states that are considering nuclear power programmes, and international experts in the field.[74] INIR review missions are grounded in the IAEA Milestones Approach, a set of clearly defined guidelines for the implementation of a nuclear power programme. According to the Milestones Approach, three phases need to

69 IAEA, *Country Nuclear Profiles*.
70 "IAEA Offers Support to Ghana", *World Nuclear News*, March 21, 2016, https://www.world-nuclear-news.org/Articles/IAEA-offers-support-to-Ghana.
71 Government of Ghana, Nuclear Regulatory Authority Act, 2015, 5, https://inis.iaea.org/collection/NCLCollectionStore/_Public/47/076/47076480.pdf?r=1.
72 Government of Ghana, Nuclear Regulatory Authority Act.
73 Nuclear Regulatory Authority, Ghana, "Welcome to the Nuclear Regulatory Authority, Ghana", https://www.gnra.org.gh/.
74 IAEA, "IAEA Reviews Ghana's Nuclear Power Infrastructure Development", January 23, 2017, https://www.iaea.org/newscenter/pressreleases/iaea-reviews-ghanas-nuclear-power-infrastructure-development.

be completed in the infrastructure development of any nuclear power programme.[75] The completion of each respective phase leads to achievement of a specific milestone.[76]

A Phase 1 INIR mission was conducted in Ghana from 16–23 January 2017 after it was requested by the GAEC in 2015, and a self-evaluation report was submitted to the IAEA by the GNPPO.[77] The IAEA expert team that conducted the review mission concluded that Ghana had made admirable progress in the establishment of its nuclear power programme, but that much still had to be done. Some of its most important recommendations were that the country conduct more studies on the subject in order to make well-informed decisions going forward; that the legal framework be evaluated and expanded in order to make provision for and support nuclear power; and that the country reach out to potential stakeholders in order to prepare for Phase 2.[78]

A Phase 1 follow-up mission was conducted in Ghana from 21–24 October 2019. The review team concluded that since the first review mission two years prior, Ghana had completed eight of the 12 recommendations and six of the eight suggestions offered previously.[79]

It is essential to understand the various policies, laws and legislation that have contributed to the development of today's GNPP.

Nuclear normative framework

International conventions, treaties, protocols and other similar instruments provide a framework of norms or rules upon which detailed global and national nuclear safety, safeguards and security measures can be constructed. Nuclear safety is an umbrella term that refers to both the 'prevention and mitigation of nuclear accidents' and its subsequent impact, as well as the 'physical protection of nuclear materials and equipment from theft or tampering'.[80] Responsible nuclear behaviour is therefore of the utmost importance for all nuclear power-emerging states, including Ghana, and goes hand in hand with the peaceful use of nuclear technology. Ghana has demonstrated its commitment to responsible nuclear behaviour and standards by ratifying relevant international nuclear instruments, entering into bilateral agreements with responsible nuclear partners, and joining major multilateral nuclear organisations. Notably, Ghana has not expressed reservations about or placed conditions on joining any international agreements, especially in the nuclear field.

75 IAEA, "Milestones in the Development of a National Infrastructure for Nuclear Power" (Nuclear Energy Series NG-G-3.1 [Rev.1], IAEA, Vienna, 2015), 5.

76 IAEA, "Milestones in the Development".

77 IAEA, *Mission Report on the Integrated Nuclear Infrastructure Review (INIR) – Phase 1* (Vienna: IAEA, 2017), 5, https://www.iaea.org/sites/default/files/documents/review-missions/inir-mission-to-ghana-january-2017.pdf.

78 IAEA, "IAEA Reviews Ghana's Nuclear".

79 Elisabeth Dyck, "IAEA Reviews Progress of Ghana's Nuclear Infrastructure Development", IAEA, October 24, 2019, https://www.iaea.org/newscenter/news/iaea-reviews-progress-of-ghanas-nuclear-infrastructure-development.

80 Justin Alger, *A Guide to Global Nuclear Governance: Safety, Security and Nonproliferation*, Nuclear Energy Futures Special Publication (Waterloo: Centre for International Governance Innovation, 2008), https://www.cigionline.org/sites/default/files/a_guide_to_nuclear_power.pdf.

Notably, Ghana has not expressed reservations about or placed conditions on joining any international agreements, especially in the nuclear field

This section draws on a comprehensive guide by Justin Alger to the international legal documents that govern the nuclear non-proliferation and nuclear safety and security. It lists some of the most important international guidelines for nuclear governance and those most relevant to the Ghanaian context, by date and subcategory, as classified by Alger.[81]

TABLE 2 INTERNATIONAL LEGAL PROVISIONS GOVERNING NUCLEAR NON-PROLIFERATION (NNP) AND NUCLEAR SAFETY AND SECURITY (NSS)

Relevant legal provision	Description	Category
G-8 Non-Proliferation Experts Group	Informal agreement	NNP
Statute of the IAEA	IAEA exclusive agreement	NNP; NSS
Partial Test Ban Treaty	Multilateral agreement	NNP
Vienna Convention on the Civil Liability for Nuclear Damage	Multilateral agreement; also linked with IAEA	NSS
Outer Space Treaty	Multilateral agreement	NNP
Nuclear Non-Proliferation Treaty	Multilateral agreement	NNP
Seabed Treaty (Treaty on the Prohibition of Nuclear Weapons and Other Weapons of Mass Destruction on the Seabed and the Ocean Floor and the Subsoil Thereof)	Multilateral agreement	NNP
Convention Relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material	Multilateral agreement; linked with International Marine Organization	NSS
Zangger Committee/NPT Exporters Committee	Informal agreement	NNP
Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter (London Convention)	Multilateral agreement	NSS
Nuclear Suppliers Group	Informal agreement	NNP
Convention on the Physical Protection of Nuclear Materials	Multilateral agreement	NSS
Convention on Early Notification of a Nuclear Accident	Multilateral agreement; linked to IAEA	NSS
Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	Multilateral agreement; linked to IAEA	NSS
Convention on Nuclear Safety	Multilateral agreement; linked to IAEA	NSS
African Nuclear Weapon-Free Zone Treaty (Pelindaba Treaty)	Multilateral agreement	NNP

81 For a comprehensive description of all legal guiding documents, see Alger, *A Guide to Global Nuclear.*

Comprehensive Nuclear Test Ban Treaty	Multilateral agreement	NNP
Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management	Multilateral agreement	NSS
Convention on Supplementary Compensation for Nuclear Damage	Multilateral agreement	NSS
UN Security Council Resolution 1373	UN exclusive agreement	NSS
Proliferation Security Initiative	Informal agreement	NNP
Code of Conduct on the Safety of Research Reactors	IAEA exclusive agreement	NSS
UN Security Council Resolution 1540	Informal agreement; UN exclusive agreement	NNP
Global Threat Reduction Initiative	US-initiated agreement	NNP
Convention on the Prevention of Nuclear Terrorism	Multilateral agreement	NNP; NSS
IAEA Fundamental Safety Principles	IAEA exclusive (non-binding) agreement	NSS
US–Russia Global Initiative to Combat Nuclear Terrorism	Combined US–Russia initiated agreement	NNP
Global Nuclear Energy Partnership	US-initiated agreement	NNP

Source: Justin Alger, *A Guide to Global Nuclear Governance: Safety, Security and Nonproliferation*, Nuclear Energy Futures Special Publication (Waterloo: Centre for International Governance Innovation, 2008), https://www.cigionline.org/sites/default/files/a_guide_to_nuclear_power.pdf

Apart from the legal documents that provide the normative framework for nuclear governance, there are also a number of multilateral organisations, oversight bodies and advisory bodies that offer their assistance to both countries with nuclear programmes and some multilateral organisations committed to nuclear governance best practice. Commitments to nuclear non-proliferation and nuclear safety and security can also be made through bilateral agreements.[82] What should be kept in mind when discussing international treaties is that international law itself is still a somewhat uncertain field. In a number of instances, treaties or agreements are not binding, and even when signed might only come into force once a certain quota of signees has been obtained. It is also not possible to enforce international law in quite the same way as a country's domestic laws. Treaties and other international agreements are more often than not a matter of incentive.

Ghana has ratified or acceded to several international treaties, conventions and protocols related to nuclear non-proliferation and nuclear safety and security, as well as the civil liability regime. Since it joined the IAEA in 1960, Ghana has been a cooperative member of a number of international initiatives with the 'potential to enhance human resource development, transfer of nuclear science and technology know-how, and the implementation of the nuclear power programme in the country'.[83] Table 3 lists the countries and/or organisations that have an existing agreement with Ghana.

82 Alger, *A Guide to Global Nuclear.*

83 IAEA, *Country Nuclear Power Profiles.*

TABLE 3 NUCLEAR AGREEMENT COUNTRIES AND/OR ORGANISATIONS WITH GHANA

Country/organisation	Title of agreement/description	Entry into force/ approved
IAEA Agreement	Agreement on the Privileges and Immunities of the IAEA[a]	1963
IAEA Safeguards Agreement	Application of Safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons[b]	1975
IAEA Technical Cooperation Agreement	Revised Supplementary Agreements Concerning the Provision of Technical Assistance by the IAEA (RSA)[c]	1989
IAEA Technical Cooperation Agreement; China	IAEA TCP GHA/1/010 (Miniature Neutron Source Reactor)[d]	1994
IAEA Agreement	Convention on the Physical Protection of Nuclear Material[e]	2002
IAEA Safeguards Agreement	Additional protocol to existing 'Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons' agreement[f]	2004
IAEA Technical Cooperation National Project	Planning for Sustainable Energy Development – Ghana Country Study[g]	2004
US	Global Nuclear Energy Partnership[h]	2007 (replaced by International Framework for Nuclear Energy Cooperation in 2010)
Russia (ROSATOM)	Memorandum of Cooperation (varying focus areas, nuclear infrastructure most importantly)[i]	2011
IAEA	Country Programme Framework (CPF) of Ghana[j]	2011
IAEA Agreement	Convention on Nuclear Safety[k]	2011
Russia (ROSATOM)	Agreement for Cooperation in the Peaceful Use of Nuclear Energy in Ghana[l]	2015
IAEA Agreement	Amendment to Convention on Physical Protection of Nuclear Material from 2002[m]	2016
IAEA Agreement	Third CPF 2017–2021[n]	2016
IAEA Agreement	Convention on Early Notification of a Nuclear Accident[o]	2016
IAEA Agreement	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency[p]	2016
South Korea (Agreement between GNPPO and Korea Electric Power Corporation's International Nuclear Graduate School [KINGS])	Scholarships for the KINGS Master's Degree in Nuclear Power Plant Engineering Programme were given to three staff members from the Volta River Authority[q]	2018
China	Agreement for Cooperation in the Peaceful Use of Nuclear Energy[r]	2018 (eight bilateral agreements signed of which one dealt with nuclear)
IAEA Technical Cooperation	Establishing Nuclear Power Infrastructure for Electricity Generation – Phase IV[s]	2018

Russia (Agreement between GAEC and Tomsk Polytechnic, supported by ROSATOM)	Memorandum of Cooperation in the Field of Training Specialists for the National Nuclear Industry[t]	2019
IAEA Technical Cooperation	African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology[u]	2019
IAEA Agreement	Vienna Convention on Civil Liability for Nuclear Damage[v]	2020
IAEA Agreement	Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention[w]	2020

a IAEA, "Country List: Ghana, Republic of", https://www.iaea.org/resources/legal/country-factsheets.

b IAEA, "Country List: Ghana".

c IAEA, "Country List: Ghana".

d IAEA, *Country Nuclear Power Profiles*.

e IAEA, "Country List: Ghana".

f IAEA, "Country List: Ghana".

g IAEA, *Country Profile: Ghana* (Vienna: IAEA, 2009), https://www-pub.iaea.org/mtcd/publications/pdf/cnpp2009/countryprofiles/Ghana/Ghana2009.html.

h IAEA, *Country Nuclear Power Profiles*.

i IAEA, *Country Nuclear Power Profiles*.

j IAEA, "Ghana Signed New Country Programme Framework (CPF)", February 18, 2011, https://www.iaea.org/newscenter/news/ghana-signed-new-country-programme-framework-cpf.

k IAEA, "Country List: Ghana".

l Kester Kenn Klomegah, "Russia's Rosatom and Ghana's Power Ministry Sign Nuclear Agreement", *Modern Ghana*, July 3, 2015, https://www.modernghana.com/news/621056/russias-rosatom-and-ghanas-power-ministry-sign.html.

m IAEA, "Country List: Ghana".

n IAEA, "Ghana Signs Its Third Country Programme Framework (CPF) for 2017–2021", September 28, 2016, https://www.iaea.org/newscenter/news/ghana-signs-its-third-country-programme-framework-cpf-for-2017-2021.

o IAEA, "Country List: Ghana".

p IAEA, "Country List: Ghana".

q IAEA, *Mission Report*, 5.

R Republic of Ghana, Ministry of Foreign Affairs and Regional Integration, "Ghana and China Sign Eight Cooperation Agreements, Memoranda of Understanding", September 5, 2018, https://mfa.gov.gh/index.php/ghana-and-china-sign-eight-cooperation-agreements-memoranda-of-understanding/.

s IAEA, "Establishing Nuclear Power Infrastructure for Electricity Generation – Phase IV", January 1, 2018, https://www.iaea.org/projects/tc/gha2004.

t "Russia and Ghana Launch Cooperation in Nuclear Education", *Mining Review Africa*, January 13, 2020, https://www.miningreview.com/energy/russia-and-ghana-launch-cooperation-in-nuclear-education/.

u IAEA, "The Text of the African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology", April 3, 2020, https://www.iaea.org/the-text-of-the-african-regional-co-operative-agreement-for-research-development-and-training-related-to-nuclear-science-and-technology-afra.

v IAEA, "Country List: Ghana".

w IAEA, "Country List: Ghana".

Source: Compiled by authors

As Table 3 shows, Ghana is no stranger to international cooperation in the nuclear field. It is indicative of the country's commitment to the establishment of a nuclear power programme.

CHAPTER 4

Nuclear governance status

The successful implementation of any nuclear power programme is dependent on public confidence in the project and the technology itself.[84] Ghana's nuclear regulatory framework has changed significantly during the course of its history and some of the necessary legal safeguards and regulatory bodies have already been established. What follows is a description of Ghana's nuclear governance system between 1961 and 2019.

The successful implementation of any nuclear power programme is dependent on public confidence in the project and the technology itself

Nuclear legislation and policies since 1961

The success of international treaties and other agreements is often dependent on a set of complementary domestic legal safeguards. In other words, to commit to international treaties countries need to commit to the same principles domestically. To comply with its obligations and benefit from privileges provided under the international instruments outlined in the previous section, Ghana has enacted several laws, formulated policies and worked to institutionalise them. These national laws and policies cover the core issues dealt with previously: nuclear non-proliferation and nuclear safety and security. Table 4 lists the main laws and regulations dealing with nuclear power in Ghana.

TABLE 4 DOMESTIC LEGAL SAFEGUARDS

Law/regulation	Short name	Enactment year
Ghana Atomic Energy Act	Act 204	1963
Factories, Shops and Offices Act	Act 328	1970
Ghana Ports and Harbours Authority Act	Act 1986	1986
Environmental Protection Agency Act	Act 490	1994
Public Utilities and Regulatory Commission Act	Act 538	1997

84 Kenneth Luongo, "Strengthening Nuclear Governance", Partnership for Global Security, January 1, 2018, https://partnershipforglobalsecurity.org/strengthening-nuclear-governance/.

Energy Commission Act	Act 541	1997
Atomic Energy Commission Act	Act 588	2000
Public Procurement Act	Act 663	2003
Ghana Shipping Act	Act 645	2003
Volta River Authority Development (Amendment) Act	Act 692	2005
National Petroleum Authority Act	Act 691	2005
Minerals and Mining Act	Act 703	2006
National Energy Policy	NEP	2010
Renewable Energy Act	Act 832	2011
Coordinated Programme for Economic and Social Development Policies	CPESDP	2014–2020
Nuclear Regulatory Authority Act	Act 895	2015
National Science, Technology and Innovation Policy	NSTIP	2017–2020

Source: Compiled by authors

In line with recommendations made by the IAEA following the initial review of the country's nuclear infrastructure development, Ghana has begun to amend legislation in order to accommodate nuclear and ensure best practice.[85]

Regulations

Ghana's NRA forms part of the 'advisory body and technical wing' of the GNPPO.[86] The NRA comprises three directorates and 10 departments. Two of these departments – Nuclear Safety, Security and Safeguards, and Emergency Preparedness and Response – have been tasked with overseeing the development of nuclear power-related regulations.[87] The process of drafting such regulations is structured as follows: the various directorates are responsible for drafting regulations, which are reviewed first by an Inter-Directorate Committee and then by the Executive Committee, Technical Committee and the Board.[88] Importantly, the NRA involves stakeholders from the initial drafting of regulations in a participatory role, incorporating their input through various 'Workshops, Public Meetings and involvement in Committees'. Once this process has been completed, regulations are ready to be reviewed by Parliament and gazetted.[89]

85 IAEA, *Mission Report*.

86 Government of Ghana, Seventh Review Meeting of the Convention on Nuclear Safety, *National Report Presented by the Republic of Ghana in Compliance with the Convention on Nuclear Safety Obligations*, 2017, 6, https://www.iaea.org/sites/default/files/ghana_cns_nr_7th_2017.pdf.

87 Government of Ghana, *National Report in Compliance*.

88 Government of Ghana, *National Report in Compliance*, 13

89 Government of Ghana, *National Report in Compliance*, 13

The drafting of regulations by the NRA contributes to its mission of guaranteeing the 'implementation of the provisions of NRA Act 895'.[90] In 2017, 20 regulations relating to different categories were under development. These ranged from 'nuclear safeguards', 'siting of nuclear installations', 'nuclear power generation in Ghana' and 'ration of a nuclear and radioactive waste management facility' to the 'education, training, qualification and certification of personnel of a nuclear installation'.[91] The regulations cover a wide range of factors that have to be taken into account in a nuclear power programme and as such represent an important step in its development.

Within a year, a number of these regulations were in the review phase.[92] The drafting of various regulations has also been scheduled for 2018–2023. Regulations relating to 'licensing', 'nuclear security' and 'design' were scheduled for 2018; 'emergency preparedness and response', 'transport' and 'construction of nuclear installation' for 2019.[93] Regulations on 'nuclear liability and civil damage fees and charges' and an 'integrated management system for facilities' were scheduled for drafting in 2020. Between 2021 and 2023 the country is expected to have drafted regulations on the 'commissioning of nuclear installations', the 'operation of nuclear installations', the 'decommissioning of nuclear installations' and 'mining of radioactive materials' and lastly, by 2023, 'nuclear power generation in Ghana'.[94]

Apart from these regulations, the NRA is also preparing a number of 'guidance documents' that correspond to the general focus areas of the regulations. So far, 11 such documents are in development:[95]

- NRA Guidelines on Preparing Emergency Response Plan Fixed Facilities;
- NRA Guidelines on Preparing Emergency Response Plan Mobile Facilities;
- NRA Guidance Document for Development of Safety Case and Security Plan for the Borehole Disposal System;
- NRA Authorisation Guidelines for Radiotherapy Facilities;
- NRA Authorisation Guidelines for Industrial Radiation Applications;
- NRA Authorisation Guidelines for Nuclear Medicine Facilities;
- NRA Authorisation Guidelines for Radioactive Waste Management Facilities;
- NRA Authorisation Guidelines for Diagnostic Radiology Facilities;

90 Government of Ghana, *National Report in Compliance*, 8.
91 Government of Ghana, *National Report in Compliance*, 8–9.
92 RG Abrefah, "Regulatory Infrastructure for Nuclear Power Programme in Ghana", Nuclear Regulatory Authority, Ghana, Presentation, https://agighana.org/uploaded_files/document/c9971219bfc94016763c2e1899faa70d.pdf.
93 Abrefah, "Regulatory Infrastructure for Nuclear", 16.
94 Abrefah, "Regulatory Infrastructure for Nuclear", 16.
95 NRA Ghana, "Download", https://www.gnra.org.gh/index.php/download.

- Criteria for Appointment of Persons with Responsibility for Radiation Safety at Facilities as well as Other Occupationally Exposed Workers;
- Structural Shielding and Room Layout Requirements for Starting a Diagnostic X-Ray Installation; and
- NRA Licensing Procedures.

Major nuclear governance entities

A number of stakeholders will play a part in the development of Ghana's nuclear power programme. These consist of government ministries; nuclear regulatory bodies; key players from the energy sector; and development partners. Table 5 lists the relevant stakeholders.[96]

TABLE 5 STAKEHOLDERS IN THE DEVELOPMENT OF GHANA'S NUCLEAR POWER PROGRAMME

Category	Description
Government bodies	
Ministry of Energy	Primary functions include overseeing energy policies, from the formulation to the enactment phases; also has a supervisory role
Ministry of Environment Science and Technology	Tasked with ensuring that technological and scientific progress aligns with environmental safeguards
Ministry of Finance and Economic Planning	Tasked with ensuring that funds are allocated appropriately and developing appropriate policies
Public Utilities and Regulatory Commission	Supervisory role, ensuring fair utility prices and completion
Nuclear regulatory bodies	
GAEC	Advisory role; also tasked with drafting nuclear legislation and conducting research
NRA	Regulatory role; licensing body; also responsible for training activities
Key players from energy sector	
Ghana Grid Company	Responsible for electricity transmission; oversight body, monitoring the energy market
Energy Commission	Advisory role (to Ministry of Energy), regulatory body
Development partners	
Environmental Protection Agency	Advocate for environmental protection on development agenda; supervisory role; promote use of renewables
National Development Planning Commission	Driver of development through research and policymaking

Source: International Atomic Energy Agency, *Country Nuclear Profiles* (2018 Edition): Ghana, (Vienna: IAEA, 2018), https://www-pub.iaea.org/MTCD/Publications/PDF/cnpp2018/countryprofiles/Ghana/Ghana.htm

96 ?

The GAEC is generally regarded as the institution that will spearhead the development of Ghana's nuclear power programme through the five institutions and the graduate school it has created. The various institutions that operate under the auspices of the GAEC are expected to 'undertake research into peaceful and safe application of nuclear energy, science and technology, and biotechnology, in sectors such as agriculture, energy, environment, geology, health and industry'.[97] These institutions are the:[98]

- Nuclear Power Institute;
- NNRI;
- Radiation Protection Institute;
- Biotechnology and Nuclear Agriculture Research Institute; and
- Radiological and Medical Research Institute

Study reports

Following the first IAEA review of Ghana's progress, the country was praised for having conducted a number of studies 'required for the government to make a knowledgeable commitment to a nuclear power programme' that involved a representative sample of local stakeholders.[99] These studies include 'energy planning studies' grouped under the Strategic National Energy Plan (2006–2020); Planning for Sustainable Energy Development (2004–2030), the Ghana country study that came to an end in 2010; and the Generation Master Plan Study for Ghana (2011–2026). The Presidential Committee also compiled a feasibility report in 2007.[100] This is by no means an exhaustive list of the studies conducted by the GAEC and other parties in the development of the nuclear power programme. Broad categories for such studies include siting, grid assessment, technological availability, human resource development, and funding.[101]

97 IAEA, *Country Nuclear Power Profiles*.
98 IAEA, *Country Nuclear Power Profiles*.
99 IAEA, *Mission Report*, 11.
100 IAEA, *Mission Report*, 23.
101 IAEA, *Mission Report*, 23.

CHAPTER 5

Nuclear power development status

Nuclear energy generation has been part of national energy policy discussions under all of Ghana's administrations over the past three decades, owing to the severity of the recurring power supply crises. Consideration of nuclear energy as a long-term solution intensified as the electricity crises became more frequent. Throughout these crisis periods, successive administrations intervened by installing small hydro and thermal plants, which are quicker to deploy and cheaper to set up than nuclear plants. Yet these were stop-gap measures, and the issues will resurface in due course owing to the country's industrialisation needs, increasing urbanisation, and the growing climate change impact on hydropower generation. To meet Ghana's industrialisation aspirations, current capacity, even with the addition of more low-capacity thermal plants, will not be sufficient to supply competitively priced electricity in a reliable and secure manner.

After the completion of the 2019 follow-up INIR mission, GNPPO Chairperson and Ghana's Deputy Minister of Energy William Owuraku Aidoo said that 'the energy forecast in the medium to long term requires [an] alternative source like nuclear power to diversify our energy supply base and to enhance energy security to achieve the industrialisation agenda'.[102] Aidoo also believes that nuclear energy can steer the country's development agenda towards success.[103] Ghana has a close relationship with the IAEA and welcomes its guidance in the establishment of its nuclear power programme. The agenda Ghana is following to develop nuclear power aligns closely with the recommendations and guidelines of the IAEA, especially as outlined in the IAEA Milestones Approach.

Having fulfilled the Phase 1 requirements under the three milestone phases, a country should be ready to commit to the next phase of the development process, or it could end the development of a nuclear power programme. Only when the country proceeds can it be said that the first milestone has been achieved. The second milestone is achieved once contract negotiations for the construction of a nuclear plant are underway. The third milestone is achieved once the entire process of planning and construction has been completed and a nuclear power plant is in operation.[104]

In order to complete each phase in the development of a nuclear power programme, a country has to fulfil specific criteria relating to 19 infrastructure issues as laid out in the IAEA 'Milestones' document. The INIR mission to Ghana 2017 was requested by the government and involved a comprehensive assessment of the status of all 19 these infrastructure

102 Dyck, "IAEA Reviews Progress".
103 Dyck, "IAEA Reviews Progress".
104 IAEA, "IAEA Milestones Approach"

issues.[105] This initial review established that the country still had a lot of work to do before more concrete steps, such as the construction of the nuclear power plant, could be taken. It provided a welcome sense of direction, as the review team pointed to specific focus areas.[106] The 2017 review culminated in 12 recommendations and eight suggestions by the IAEA Review Team. In 2019, after a follow-up mission to the country had been completed, it was confirmed that Ghana had had fulfilled eight recommendations and followed six suggestions.[107]

> The 2019 IAEA review team advised that further action was needed with regard to 'government funding, stakeholder involvement planning, fuel cycle options for the first nuclear power plant and goals for local participation'

Although Ghana made significant progress between the two reviews and preparations for certain Phase 2 activities have already begun, the 2019 IAEA review team advised that further action was needed with regard to 'government funding, stakeholder involvement planning, fuel cycle options for the first nuclear power plant and goals for local participation'.[108]

It is believed that the main forward-looking future action left to assist the government in its decision-making is the completion of the comprehensive report by the GNPPO. If the Akufo-Addo cabinet decides to move forward with the nuclear power programme, the GNPPO and other national nuclear instructions will embark on the Phase 2 activities.

105 IAEA, "IAEA Reviews Ghana's Nuclear".
106 IAEA, "IAEA Reviews Ghana's Nuclear".
107 Dyck, "IAEA Reviews Progress".
108 Dyck, "IAEA Reviews Progress".

CHAPTER 6

Uranium sector in Ghana

Uranium is most commonly used to fuel nuclear reactors. Nuclear reactors can be used in many different areas, although some of their more mainstream uses include electricity generation, research, medical treatment and even propelling ships such as submarines or aircraft carriers.[109] Uranium is found in the rocks that make up the crust of the Earth and does not typically occur in high concentrations. Commonly found in a concentration of two to four parts per million, a typical sample of natural uranium consists predominantly – some 99.3% – of the isotope uranium-238 (U-238), while uranium-235 (U-235) makes up roughly 0.7%.[110] The isotope U-235 is the main fuel source for nuclear reactors.[111] Its atoms are split apart easily and can sustain a chain reaction by yielding a lot of neutrons and energy.

Since U-235 occurs in very low levels in natural uranium samples, it has to go through a process of enrichment after it has been mined in order to be used as a fuel. Following enrichment, the concentration of U-235 increases significantly, to 3–5%, which is also the appropriate concentration of U-235 for use in nuclear reactors.[112] The level of enrichment of uranium isotopes is an important factor to consider in nuclear energy. Enriching uranium beyond a certain point increases the risk of nuclear weapons' being developed. When enriched so that the percentage of the uranium-235 isotope is more than 20%, uranium is referred to as highly enriched uranium (HEU), while anything under 20% qualifies as low enriched uranium (LEU). LEU is the preferred uranium fuel since HEU, especially when enriched up to 90%, qualifies as weapons-grade uranium.[113] The existence of proven uranium reserves and the removal of weapons-grade U-235 from Ghana are important issues in the context of its nuclear ambitions.

HEU to LEU conversion

Ghana is one of eight countries that operate a research reactor in Africa.[114] The country is home to a 30kW, low-power MNSR, which it acquired from China in 1994.[115] GHARR-1 is located in Legon-Accra and used mainly for neutron activation analysis and a variety

109 World Nuclear Association, "What is Uranium? How Does it Work?", https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/what-is-uranium-how-does-it-work.aspx.
110 World Nuclear Association, "What is Uranium?".
111 World Nuclear Association, "How is Uranium Made into Nuclear Fuel?", https://www.world-nuclear.org/nuclear-essentials/how-is-uranium-made-into-nuclear-fuel.aspx.
112 World Nuclear Association, "How is Uranium Made".
113 Nuclear Threat Initiative, "Why Highly Enriched Uranium Is a Threat", August 1, 2011, https://www.nti.org/analysis/articles/why-highly-enriched-uranium-threat/.
114 IAEA, *Research Reactors in Africa*.
115 "Ghanaian Reactor at Full Power After Fuel Conversion", *World Nuclear News*, August 11, 2017, https://www.world-nuclear-news.org/Articles/Ghanaian-reactor-at-full-power-after-fuel-conversi; see also IAEA, *Research Reactors in Africa*, 14.

of research and training purposes.[116] Until very recently, GHARR-1 was running on HEU fuel enriched to 90.2%.[117] The risks associated with uranium enriched to this level are significant. Growing fears of HEU landing in the hands of terrorist organisations spurred an international movement to eradicate the civilian use of HEU and convert all reactors running on HEU to LEU fuel.[118]

Ghana is one of eight countries that operate a research reactor in Africa. The country is home to a 30kW, low-power MNSR, which it acquired from China in 1994

In line with international convention, a process to convert all Chinese MNSRs running on HEU fuel to LEU fuel began in 2006. GHARR-1 was the first of five reactors to qualify for HEU conversion.[119] Its conversion was a decade-long process,[120] with the replacement of the HEU core with an LEU core taking place between August 2016 and July 2017. This was overseen by China and Ghana, but also involved the IAEA and US.[121] The conversion process cost more than $20 million, covered by the US government under its Global Threats Reduction Initiative.[122] At the completion of the conversion process on 13 July 2017, GHARR-1's 90.2% HEU core had been replaced with a 13% LEU core.[123] The old HEU core, containing roughly 1kg of HEU, was flown back to China on 26 August 2017 where it is kept in safe storage.[124]

The conversion from HEU to LEU fuel was a monumental moment in Ghana's nuclear history. It was the first country to have completed the conversion outside of China. Through the conversion process, stakeholders in Ghana's nuclear programme, including scientists and engineers, gained knowledge and skills in HEU–LEU conversion processes. The successful conversion also demonstrates Ghana's commitment to global nuclear non-proliferation obligations and nuclear security measures. Owing to its success, the GAEC now also trains nuclear scientists from around the world in nuclear reactor conversion.[125]

116 IAEA, *Research Reactors in Africa*; see also "Ghanaian Reactor at Full Power".
117 "Ghanaian Reactor at Full Power".
118 IAEA, "Minimising Civilian Uses of Highly Enriched Uranium", June 19, 2006, https://www.iaea.org/newscenter/news/minimizing-civilian-uses-highly-enriched-uranium.
119 "Ghanaian Reactor at Full Power".
120 Richard Stone, "US–China Mission Rushes Bomb-Grade Nuclear Fuel Out of Africa", *Sciencemag.org*, August 31, 2017, https://www.sciencemag.org/news/2017/08/us-china-mission-rushes-bomb-grade-nuclear-fuel-out-africa.
121 "Ghanaian Reactor at Full Power".
122 "Development Partners Paid $20m to Repatriate Ghana's Uranium to China", Sightline U3O8, May 17, 2018, https://sightlineu3o8.com/2018/05/devt-partners-paid-20m-to-repatriate-ghanas-uranium-to-china/.
123 "Ghanaian Reactor at Full Power".
124 Stone, "US–China Mission Rushes".
125 Babalwa Bungane, "Ghana Atomic Energy Commission, a Global Leader in Nuclear Research", *ESI Africa*, August 1, 2019, https://www.esi-africa.com/industry-sectors/research-and-development/ghana-atomic-energy-commission-a-global-leader-in-nuclear-research/.

Uranium reserves

The presence of uranium reserves is an important dimension of Ghana's nuclear programme. Exploring for uranium deposits is the first step in the nuclear fuel cycle. Many factors drive uranium exploration, including demand, price, success history, failure history and knowledge curve.[126] There are four main sources of uranium in nature, with 'oxidised deposits' sometimes considered a fifth. The four predominant types are 'igneous rocks, hydrothermal vein deposits, sedimentary rocks, and deposits of doubtful and perhaps complex origin'.[127] Uranium is predominantly found in granitic magmas located in the Earth's crust.[128] Most of the world's uranium and radium come from mesothermal pitchblende veins, which in turn are separated into two types. The first type yields earth metals such as gold, lead, silver and copper, and the second type base metals such as nickel. This second type of mesothermal pitchblende has yielded much of the world's uranium supply.[129]

The presence of uranium reserves is an important dimension of Ghana's nuclear programme

Gold makes up some 80% of Ghana's annual mineral revenues.[130] In 2019 Ghana overtook South Africa to become Africa's leading gold producer.[131] However, there is currently no uranium mining activity in Ghana, neither from granitic magma nor as a by-product of gold mining, despite the long history of prospecting in the country. In 1952 it tried to mine uranium for the first time, but multiple reviews found that the thorium content in rocks were too low (0.1%) and unremarkable to warrant mining operations.[132] Subsequent studies conducted between 1953 and 1976 also spoke against the potential for uranium mining. An improvement in natural uranium reserves was confirmed between 1982 and 2008. Studies conducted during this time showed that the presence of uranium had increased over the years and with it, the country's ability to mine uranium.[133] A further increase

126 Kurt Kyser, "Exploration for Uranium", in *Uranium for Nuclear Power: Resources, Mining and Transformation*, ed. Ian Hore-Lacy (Sawston: Woodhead Publishing, 2016), 53–76.
127 JK Gustafson, "Uranium Resources", *The Scientific Monthly* (1949): 115.
128 Gustafson, "'Uranium Resources'", 115.
129 Gustafson, "Uranium Resources", 115.
130 Samuel B Dampare, Thomas K Adu and Akwasie B Asumadu-Sakyi, "Undiscovered Uranium Resources in Ghana" (Presentation, IAEA Workshop "Application of United Nations Framework Classification 2009 [UNFC-2009] for Uranium Resources", Johannesburg, November 10–14, 2014), https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc/UNFC_ws_SouthAfrica_Nov2014/20-S.Dampre-Ghana.pdf.
131 Felix Njini, "The African Nation Built on Gold Loses Its Crown to a Rival", *Bloomberg*, June 9, 2019, https://www.bloomberg.com/news/articles/2019-06-09/nation-built-on-gold-loses-its-african-crown-to-rival-ghana.
132 Dampare, Adu and Asumadu-Sakyi, "Undiscovered Uranium Resources".
133 Dampare, Adu and Asumadu-Sakyi, "Undiscovered Uranium Resources".

in uranium concentration in rocks was confirmed between 2010 and 2012, reported at <10ppm, a clear indication that Ghana stood a high chance of striking a uranium deposit. Some areas for potential mining have since been identified.[134]

Given the strong correlation between gold and uranium, there is a chance of finding uranium deposits in Ghana in commercial quantities, based on its extensive gold reserves and the small traces of uranium already found in gold mines.[135] In 2016 there were informal talks on Ghana–India cooperation in the mining sector, including uranium mining.[136] While these developments are promising, further studies are needed. Following its Phase 1 review of the nuclear power programme in Ghana, the IAEA review team concluded that it would be beneficial to Ghana to continue pursuing the possibility of domestic uranium mining and yellowcake production. It also recommended that Ghana build on the results of prior studies on uranium prospecting and monitor those areas where some potential has been identified. The IAEA also envisages a more engaged role for Ghana on the nuclear front in the West African region by trading yellowcake for electricity.[137]

134 Dampare, Adu and Asumadu-Sakyi, "Undiscovered Uranium Resources".

135 Wise Uranium Project, "New Uranium Mining Projects in Africa: Ghana", May 19, 2020, https://www.wise-uranium.org/upafr.html#GH.

136 Wise Uranium Project, "New Uranium Projects".

137 IAEA, *Mission Report*.

CHAPTER 7

Nuclear power issues

The development and operation of a nuclear power plant is a mammoth task that requires long-term commitment and planning, as well as large-scale financial and human capital investment. This is especially the case with a nuclear power plant that has very specific 'safety, security and safeguards requirements'.[138] The IAEA notes that it takes countries on average 10–15 years from the consideration of nuclear power to its first power plant's becoming operational. This is testament to the commitment needed to undertake such a project.[139] Ghana has shown interest in nuclear power for a much longer period, but the true test of its commitment has only just begun and the next decade or so will be crucial. It hopes to have completed its first nuclear power plant by 2030.[140]

The country will have to follow the infrastructure and technical assistance requirements laid out in the IAEA 'Milestones' document. Close cooperation between Ghana and the IAEA should also be prioritised. In particular, the country should pay attention to the outcomes of the review missions that have already taken place and follow their recommendations if it is to achieve its goal of generating nuclear power by 2030. As noted previously, the objective of the first INIR mission to Ghana was to assess the progress it had made in setting up its nuclear infrastructure. IAEA review missions are guided by the 'Milestones' document, which outlines 19 nuclear infrastructure review areas. Each review evaluates the progress made under these categories and provides recommendations and suggestions based on the evaluation.[141] This report focuses on four of the 19 categories and explores the recommendations made by the IAEA on 'national position'; 'legal framework'; 'funding and financing'; and 'stakeholder involvement'.[142]

National position

Establishing a country's national position is one of the infrastructure issues that the IAEA 'Milestones' document highlights for newcomers to the nuclear power field. There are three dimensions to a clearly defined national position. The first involves long-term commitment to the various safety and security requirements of a nuclear power plant, as well as a commitment to nuclear non-proliferation. The second relates to the establishment of an NEPIO, while the third requires clearly defining a national strategy for the development

138 IAEA, "Milestones in the Development".
139 IAEA, "Milestones in the Development".
140 Magdalene Teiko Larnyoh, "Ghana to Generate Nuclear Power by 2030", *Pulse*, January 23, 2020, https://www.pulse.com.gh/bi/strategy/ghana-to-generate-nuclear-power-by-2030/sk23lk5.
141 See IAEA, "Milestones in the Development"; IAEA, *Mission Report*.
142 See IAEA, *Mission Report*.

of a nuclear power programme.[143] States have to demonstrate achievement of all three conditions to check the national position box *in toto*.

The IAEA review team was generally satisfied with Ghana's progress in the first dimension, noting in particular the country's Nuclear Regulatory Act and its explicit focus on 'nuclear safety, radiation protection, nuclear security and non-proliferation/safeguards'.[144] It also noted the act's identification and stipulation of 'the responsibilities of the main stakeholders'.[145] in the development of the nuclear power programme. The country was lauded for its adherence to international legal guidelines on nuclear safety and security.[146]

In terms of the second dimension, Ghana's NEPIO – the GNPPO – was established in 2012 with a clear mandate and documents guiding its activities. Overall, the IAEA review team was satisfied with the set-up of the GNPPO, but it did recommend that more be done to secure funding so the GNPPO can complete its activities under Phase 1 (initial considerations).[147]

In terms of the third dimension, Ghana has made significant progress in studies conducted for the compilation of a 'comprehensive report, defining and justifying the national strategy for nuclear power'.[148] However, although progress has been significant, this dimension has not yet been fulfilled and the review team advised that the country continue to conduct Phase 1 studies so a well-informed commitment to nuclear power can be made.[149] Such studies must include projected timelines and, where they are older than 10 years, have to be updated. Once the studies have been completed in accordance with established standards, the comprehensive report should undergo parliamentary review.

Legal framework

Establishing a legal framework is another essential infrastructure dimension recommended in the IAEA 'Milestones' document. Such a legal framework comprises three conditions that states have to demonstrate they have met: 'Adherence to all relevant international legal instruments'; 'Plans in place for the development of a comprehensive national nuclear law'; and 'Plans in place to enact and/or amend other legislation affecting the nuclear power programme'.[150] In both these latter dimensions the IAEA review team suggested that Ghana still had some minor work to do.

Ghana is yet to accede to some of the relevant international legal instruments, and also needs to review is domestic laws, amend these where necessary, and draft regulations

143 IAEA, *Mission Report*.
144 IAEA, Mission Report.
145 IAEA, Mission Report.
146 IAEA, *Mission Report*, 19.
147 IAEA, "Milestones in the Development", 5.
148 IAEA, *Mission Report*, 22.
149 IAEA, *Mission Report*.
150 IAEA, *Mission Report*, 14.

prescribed under Act 895.[151] One way to expedite adherence to international legal instruments is for the GNPPO to establish a comprehensive list of relevant nuclear power treaties and agreements and identify which ones need action. Regarding regulations, the NRA should seek support from the IAEA or partner governments/institutions to share best practices and provide technical advice on how to draft or revise specific regulations and guidelines.

Funding and financing

As noted earlier, a nuclear power programme is expensive – it will cost $8–$10 billion to build Ghana's first nuclear power plant. In order to cover this cost, Ghana has approached Russia, China and the Republic of Korea for financial assistance.[152] Government commitment to the establishment of a nuclear power plant has to consider sustainable financing strategies within officially defined parameters. With this purpose in mind the Ghana Infrastructure Investment Fund (GIIF) was established. The objective of the GIIF is to 'stimulate economic growth by investing in flagship infrastructure projects, including energy'.[153] A funding proposal was submitted to the GIIF by the GNPPO that provides cost estimates for the full range of infrastructure issues highlighted by the IAEA.[154] While the budget provided an initial estimate, this is likely to increase over time, as additional expertise might be needed for some tasks not fully anticipated in the initial estimates. The IAEA review recommended that further attention be paid to cost estimates heading into phases 2 and 3. In particular, the team suggested that funding for radioactive waste and spent fuel be prioritised.[155]

Stakeholder involvement

The IAEA lists 'open and transparent stakeholder involvement' as the key component of this category and emphasises that the public 'and other relevant interested parties receive information about the benefits and risks of nuclear power, including the "non-zero" potential for severe accidents'.[156] The IAEA review team found that the GNPPO had already engaged national stakeholders in the development of the nuclear power programme and created both a stakeholder engagement strategy and a communications strategy. A series of awareness-raising, public outreach and education activities were also identified, such as workshops, seminars and publications.[157]

151 IAEA, *Mission Report*, 37–39.
152 Michael Creg Afful, "Ghana Needs Almost US $10 billion to set up Nuclear Power Plant – Owuraku Aidoo", *Ghana Web*, December 19, 2018, https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Ghana-needs-almost-US-10billion-to-set-up-nuclear-power-plant-Owuraku-Aidoo-710110.
153 IAEA, *Mission Report*, 30.
154 IAEA, *Mission Report*.
155 IAEA, *Mission Report*.
156 IAEA, *Mission Report*.
157 IAEA, *Mission Report*.

The review team found that the country had yet to develop a stakeholder involvement plan, which differs from the stakeholder engagement plan in that it specifies the activities that follow from the engagement phase. These include clearly outlining the responsibilities of all parties involved, and the timeframes of actions required.[158] The GNPPO stated at the time of the first INIR mission that it planned on developing a stakeholder involvement plan after it had conducted a public survey on the nuclear power programme. Both these developments were listed as areas where significant work still had to be done.[159]

Ghana would do well to reflect on the historical role of civil society organisations (CSOs) as stakeholders in national development. CSOs have played a notable role in advancing democratic governance in the country. In 2014 there were more than 2 500 registered CSOs in Ghana.[160] While there are currently no CSOs in Ghana that advocate for or against nuclear energy, such organisations could become key stakeholders. The country's National Energy Policy lists CSOs as among the key stakeholders and seeks to 'ensure a fair balance between the aspirations of Government and the interests of industry players, academia, local communities, civil society and other key stakeholders'.[161]

It can be expected that once the president of Ghana makes an official declaration and commits to a nuclear power plant, this will trigger intense national discourse that may result in the rising of pro- or anti-nuclear CSOs. As Odonkor and Adams argue, '[S]ocial acceptance of nuclear energy is critical for its successful implementation.'[162] These authors also found that 'social risk investment' represents the 'most significant risk associated with the introduction of nuclear power in Ghana'.[163] It is therefore essential that surveys such as that suggested by the GNPPO are conducted to ascertain public opinion on nuclear power and ensure that all relevant stakeholders are included in the development of the nuclear power programme.

158 IAEA, *Mission Report*.

159 IAEA, *Mission Report*.

160 France in Ghana, "Civil Society", https://gh.ambafrance.org/Civil-Society-4127.

161 Government of Ghana, Ministry of Energy, *Medium Term Expenditure Framework for 2019–2022* (Accra: Ministry of Energy, 2019), 16, https://www.mofep.gov.gh/sites/default/files/pbb-estimates/2019/2019-PBB-MoEn.pdf.

162 Stephen T Odonkor and Samuel Adams, "An Assessment of Public Knowledge, Perception and Acceptance of Nuclear Energy in Ghana", *Journal of Cleaner Production* 269 (2020): 1.

163 Odonkor and Adams, "An Assessment of Public Knowledge".

CHAPTER 8

Non-power nuclear energy applications

Since the early 1950s Ghana has been at the forefront of acquiring and using nuclear energy technologies to drive human progress and national and regional development. Today, radiation science and technology are widely used across multiple sectors of the Ghanaian economy, including industry, transport, medicine, agriculture, food, research and teaching. However, many of these peaceful uses are less known to the public. This section looks at existing major non-power nuclear energy equipment, facilities and laboratories that have far-reaching benefits in modern Ghana. The major facilities are the Ghana Research Reactor-1 Facility, Multi-purpose Gamma Irradiation Facility, external beam radiotherapy centres, brachytherapy equipment, and radiological imaging centres. For each mechanism, laboratory or facility, a brief description of the technology is given, followed by information about its status, its intended use and practical impact.

Today, radiation science and technology are widely used across multiple sectors of the Ghanaian economy, including industry, transport, medicine, agriculture, food, research and teaching

Ghana Research Reactor-1

Technology: One of the leading nuclear technology uses in Ghana is GHARR-1, a low-flux Chinese MNSR acquired through a trilateral agreement involving Ghana, China and the IAEA in 1994.[164] As discussed, the 90.2% enriched HEU core that GHARR-1 relied on for a long time was replaced by a 13% enriched LEU core, a process completed in 2017. This conversion did away with the possibility of developing nuclear weapons.

Status: The reactor was installed in 1994 and has been safely operated for more than two decades. GHARR-1 is housed at the NNRI of the GAEC in Accra.[165]

Use: GHARR-1 was designed to be used by 'universities, hospitals and research institutes mainly for neutron activation analysis, production of short-lived radioisotopes, education and manpower development'.[166]

164 HC Odoi et al., "Implementation of Reactor Core Conversion Program of GHARR-1" (Paper, RERTR 2020 – 36th International Meeting on Reduced Enrichment for Research and Test Reactors, Seoul, October 11–14, 2015), https://www.rertr.anl.gov/RERTR36/pdfs/S2P1_Odoi_Paper.pdf.

165 Odio et al., "Implementation of Reactor Core".

166 Odio et al., "Implementation of Reactor Core", 1.

Impact: In practice, it has contributed to the improvement of analysis of mineral ores and enhanced training in nuclear sciences and technology. GHARR-1 is also a key piece of equipment in training programmes for SNAS students.[167] The research conducted through the use of GHARR-1 has benefitted a number of sectors, including agriculture, mining, geology and healthcare. Research studies include the analysis of borehole water near mining areas (irradiation), nuclear waste management and soil fertility. GHARR-1 is also expected to be used in forensic research and investigation in future.[168]

Gamma Irradiation Facility

Technology: The Gamma Irradiation Facility (GIF) is equipped with a multi-purpose 1 850 TBq cobalt-60 gamma irradiator source.[169] Gamma irradiation is a method of sterilisation and is applied most commonly in the medical field, where it is used to sterilise instruments. This type of sterilisation is effective for killing 'microorganisms, such as fungi, bacteria, viruses and other potential pathogens'.[170] It is considered to be the most effective method of sterilising medical instruments.[171]

Status: The GIF was commissioned on 8 March 1995.[172] The facility underwent a number of upgrades in 2010 and had to implement various IAEA specifications on best practice in 2012.[173]

Use: The GIF, managed by the GAEC, offers its services to four companies and 15 hospitals. These services include the sterilisation/irradiation of single-use and reusable medical instruments and clothing worn by hospital staff, especially surgical clothes and bedding.[174]

Impact: Gamma irradiation has been used for several decades to sterilise items such as food and medical equipment.[175] This technology plays in invaluable part in keeping the population healthy since the sterilisation of medical instruments is a necessary component of limiting infection. It has also been used in pest and vector control using the Sterile Insect Technique.[176] Ghana offers the use of its GIF to surrounding countries, thereby extending its impact and benefits.[177]

---

167 Benjamin JB Nyarko, "The 30kW Research Reactor Facility in Ghana: Past, Present and Future Programmes", IAEA, Presentation, 2007, https://www-pub.iaea.org/mtcd/meetings/PDFplus/2007/cn156/cn156presentations/cn156_Nyarko.pdf.

168 IAEA, *Research Reactors in Africa*.

169 UN Security Council, "Note Verbale Date 5 November 2004 from the Permanent Mission of Ghana to the United Nations Addressed to the Chairman of the Committee", S/AC.44/2004/(02)/76 (December 10, 2004), https://media.nti.org/pdfs/ghana-1540-initial-report.pdf.

170 Aabha Dixit, "Better Health Care: Ghana Uses Radiation Technology to Sterilize Medical Items", *IAEA Bulletin* (September 2015): 6.

171 Dixit, "Better Health Care".

172 GAEC, *Using Nuclear Energy and Techniques to Alleviate Hunger, DIseases, and Control Environmental Pollution*, Annual Report (Accra: GAEC, 1995), https://inis.iaea.org/collection/NCLCollectionStore/_Public/29/061/29061224.pdf?r=1&r=1.

173 Dixit, "Better Health Care".

174 IAEA, "Scientific Forum 2015: Ghana Uses Radiation Technology to Sterilize Medical Items", August 5, 2015, https://www.iaea.org/newscenter/news/scientific-forum-2015-ghana-uses-radiation-technology-sterilize-medical-items.

175 Korea Atomic Energy Research Institute, *A Study on the Enhancement of Nuclear Cooperation with African Countries, Including Utilization of Radioisotope* (Vienna: IAEA, 2004), https://inis.iaea.org/collection/NCLCollectionStore/_Public/37/077/37077661.pdf?r=1&r=1.

176 KAERI, *A Study on the Enhancement*.

177 IAEA, "Scientific Forum 2015".

External beam radiotherapy therapy

Technology: External beam radiation therapy (EBRT) is one of three ways in which radiation is administered to treat cancer.[178] EBRT relies on radiation beams produced through 'radioactive sources, such as cobalt-60, that emit gamma rays; high-energy X-rays or photons produced by linear accelerators' or 'particle beams'.[179] Medical linear accelerators (linacs) and Cobalt-60 machines are two mainstream methods currently used for administering EBRT.[180]

Linac therapy units manipulate 'high-energy x-rays or electrons to conform to a tumor's shape and destroy cancer cells'[181] without causing damage to surrounding non-cancerous tissue. The linac is the most popular method for administering EBRT.[182] Cobalt-60 machines require radiation protection, since they emit a constant stream of radiation. They emit photons 'with a mean energy of 1.25 MeV'.[183]

Status: Currently there are three radiation oncology facilities in Ghana. The Korle-Bu Teaching Hospital, a public health facility, and the Sweden Ghana Medical Centre, a private facility, are both in Accra, while the Komfo Anokye Teaching Hospital, also a public facility, is in Kumasi.[184] Between the two government facilities there are three Cobalt-60 machines in use while the country is also home to five linacs.[185]

Use: Apart from their main purpose – cancer treatment – Cobalt-60 machines and linacs are used extensively to train oncologists and other doctors, biomedical engineers, medical physicists and healthcare professionals.[186]

Impact: Aside from the obvious benefits associated with the administration of radiation therapy in cancer treatment, Ghana's Cobalt-60 and linac equipment have also helped it to foster cross-border and international cooperation through training programmes and fellowships.[187] Ghana's radiotherapy facilities benefit cancer patients from neighbouring

178 David A Jaffray and Mary K Gospodarowicz, "Radiation Therapy for Cancer", in *Cancer: Disease Control Priorities* (Volume 3), eds. H Gelband et al. (Washington DC: International Bank for Reconstruction and Development and World Bank, 2015), https://www.ncbi.nlm.nih.gov/books/NBK343621/.

179 Jaffray and Gospodarowicz, "Radiation Therapy for Cancer".

180 BJ Healy et al., "Cobalt-60 Machines and Medical Linear Accelerators: Competing Technologies for External Beam Radiotherapy", *Clinical Oncology* 29, no. 2 (February 2017): 110–115.

181 RadiologyInfo, "Linear Accelerator", February 20, 2019, https://www.radiologyinfo.org/en/info.cfm?pg=linac.

182 RadiologyInfo, "Linear Accelerator".

183 Jaffray and Gospodarowicz, "Radiation Therapy for Cancer".

184 Joel Yarney et al., "Augmenting Cancer Control Efforts in a Limited Resource Setting by Leveraging International Collaborations in Radiation Oncology", *Applied Radiation Oncology* (June 2019), https://cdn.agilitycms.com/applied-radiation-oncology/PDFs/issues/ARO_06-19_Yarney.pdf.

185 Yarney et al., "Augmenting Cancer Control Efforts".

186 Yarney et al., "Augmenting Cancer Control Efforts".

187 Yarney et al., "Augmenting Cancer Control Efforts".

countries that do not possess such facilities.[188] Importantly, the availability of these services has seen far fewer Ghanaian cancer patients travelling abroad for radiotherapy.[189]

Brachytherapy equipment

Technology: Brachytherapy was introduced in the country in 1992.[190] It is a method of administering radiotherapy that involves 'the insertion of radiation-emitting sources directly within the tumor or adjacent body cavity'.[191] Through brachytherapy, a high dose of radiation is aimed directly at the affected area and, unlike EBRT, surrounding body tissue can be damaged – although minimally.[192] Cancer treatment by brachytherapy is administered in either a low dose rate (LDR) or high dose rate (HDR). These different dosage rates involve caesium and iridium, and cobalt-60 or 192 iridium respectively.[193]

Status: Ghana's National Radiotherapy Centre in Accra has an HDR Cobalt-60 brachytherapy machine for the treatment of prostate and thyroid cancer. Another facility in Kumasi offers LDR caesium brachytherapy, aimed at the treatment of cervical cancer.[194]

Use: Brachytherapy is used in the treatment of many different cancers, especially gynaecological cancers, breast cancer, brain and lung cancer, and skin cancer.[195]

Impact: Brachytherapy treatment technologies benefit the citizens of Ghana and other African countries by offering cancer treatment.

Radiological imaging

Technology: Radiological imaging refers to the range of technologies that make it possible for doctors to essentially see inside the body. These images can be created through 'ultrasound, magnetic resonance, nuclear medicine and X-rays'.[196] Radiological imaging enables doctors to 'identify and/or rule out medical problems, and to diagnose diseases'.[197] This technology differs significantly from the type of radiation used for cancer therapy.[198]

188 Emmanuel W Fiagbedzi and Cletus Ahadzie, "Radiotherapy in Cancer Treatment in Ghana: From the Past to Present", IAEA, Presentation, https://humanhealth.iaea.org/HHW/RadiationOncology/ICARO2/E-Posters/04_FIAGBEDZI.pdf.

189 See Verna Vanderpuye and Naa Adorkor Aryeetey, "Cancer Radiotherapy in Ghana", Cancer Control, 2016, http://www.cancercontrol.info/cc2016/cancer-radiotherapy-in-ghana/.

190 Fiagbedzi and Ahadzie, "Radiotherapy in Cancer Treatment".

191 Jaffray and Gospodarowicz, "Radiation Therapy for Cancer".

192 IAEA, "Cancer Treatment: Brachytherapy", https://www.iaea.org/topics/cancer-treatment-brachytherapy.

193 IAEA, "Cancer Treatment".

194 Vanderpuye and Aryeetey, "Cancer Radiotherapy in Ghana".

195 See Sweden Ghana Medical Centre, "Brachytherapy", https://www.sgmccancercentre.com/cancer-care/treatment-options/brachytherapy/ ; IAEA, "Cancer Treatment".

196 University of California, San Francisco, Department of Radiology and Biomedical Imaging, "Benefits of Using Radiation", https://radiology.ucsf.edu/patient-care/patient-safety/radiation-safety/benefits.

197 UCSF, "'Benefits of Using Radiation".

198 UCSF, "Benefits of Using Radiation".

Whereas the technologies described previously are used for treatment, radiological imaging is primarily a diagnostic tool.

Status: Two of the most well-known radiological imaging technologies – computed tomography (CT) scans and magnetic resonance imaging (MRI) – are commonly used in Ghana. The country's first CT scanner was installed at Korle-Bu Teaching Hospital in 1994. Since then the technology has spread to a number of private and public health facilities.[199] MRI was introduced to Ghana much later, and was first installed at Korle-Bu Teaching Hospital in 2006. More MRI machines have been included in the services of two other teaching hospitals in 2010, and the technology is in use in the private sector as well.[200]

Use: Radiological imaging technologies such as CT scanning and MRI are used to guide decisions on the necessity of surgery, limiting the need for exploratory surgeries'; 'improve cancer diagnosis and treatment'; shorten a patient's hospitalisation; and assist in the treatment of everyday issues such as injuries, heart conditions and strokes.[201]

Impact: Patients benefit from radiological imaging as it guides healthcare professionals on the treatment required. These technologies are versatile and can be used to diagnose a variety of conditions of varying degrees of complexity. Their benefits are universal and allow doctors to 'diagnose and manage their patients' diseases safely and rapidly'.[202]

199 Benard Botwe et al., "An Investigation into the Infrastructure and Management of Computerized Tomography Units in Ghana", *Journal of Medical Imaging and Radiation Sciences* 51 (2020): 165–172.

200 YB Mensah et al., "Magnetic Resonance Imaging (MRI) Utilization in a Ghanaian Teaching Hospital: Trend and Policy Implications", Ghana Med J. 54, no. 1 (2020): 3–9. doi:10.4314/gmj.v54i1.2, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7445703/.

201 UCSF, "Benefits of Using Radiation".

202 UCSF, "Benefits of Using Radiation".

CHAPTER 9

Conclusion

This report has reviewed the available information on the development of Ghana's nuclear power programme and its current peaceful uses of nuclear technology. It has elaborated on progress and shortcomings in the development of the nuclear power programme and surveyed the various non-power nuclear energy uses in Ghana. Ghana seems to be on track to establish a nuclear power plant by 2030. This has been welcomed after decades of nuclear power ambitions that remained unexplored. Ghana has extensive experience in non-power nuclear energy uses and should allow this experience to guide its nuclear power generation journey.

Overall, this report has highlighted the extensive application of nuclear energy across various sectors of human life that are less known to the public. It has provided insights into the widespread application and benefit of nuclear science and technology to humanity. One limitation has been the decision to exclude the non-electric applications of nuclear energy, such as cogeneration, heat production and desalination. These will be essential considerations in Ghana's nuclear power plant to address the country's water crisis, as well as community heating and cooling. A further study could examine the prospects of non-electric uses in nuclear newbuilt countries in Africa such as Egypt, Nigeria and Ghana.

CHPATER 10

Recommendations

- Ghana should plan effectively for every stage in the life of a nuclear plant. This includes having concrete steps in place for the treatment of nuclear waste, which should be outlined during the planning phase.
- Human capital investment is essential and the country would benefit from having local nuclear experts. Ghana's well-established nuclear research programme is greatly beneficial in this area and should continue to be supported.
- Ghana should think beyond its borders and consider the benefits of nuclear energy technology for itself and neighbouring countries.
- It is important that the country focus on those areas identified by the IAEA as still in need of work. Adhering to the recommendations and advice of the IAEA will make for smooth sailing.
- Transparency should be prioritised in the development of the nuclear power plant. A clear understanding of public opinion must be present.
- The country's legal framework should reflect its commitment to nuclear safety and security.
- Ghana should ensure that the nuclear power programme is developed in a stable political environment.
- The full potential cost of setting up and running a nuclear power plant should be known and understood from the outset.

African perspectives.
Global insights.

Jan Smuts House, East Campus, University of the Witwatersrand
PO Box 31596, Braamfontein 2017, Johannesburg, South Africa
Tel +27 (0)11 339–2021 • Fax +27 (0)11 339–2154
www.saiia.org.za • info@saiia.org.za