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Of what is the nuclear power the name? Development challenges and issues in the African and global context

Mouhamadou Moustapha DIOUF

Nuclear Engineering Engineer, ENSAM Paristech, France. Nuclear Physics Researcher, LPQS.
Email : mm-diouf@outlook.fr

Abstract This article discusses the importance of nuclear power as an essential solution for sustaining global socio-economic development while reducing CO2 emissions. The author, of Senegalese origin, highlights the potential of nuclear power in the African context, notably through the use of modular reactors - the best option - for electricity generation and research reactors in the manufacture of radioisotopes for nuclear medicine or agriculture.

Keywords nuclear power plant, research reactor, SMR, electricity in Africa, climate

Introduction

For the first time in the history of presidential programs in Senegal, it was not until the early 21st century that a nuclear vision appeared under auspicious circumstances. In its programmatic opus entitled "Le projet" [1], the new government sets out a series of proposals for peaceful nuclear energy. We don't need a long-winded argument to corroborate this assertion — as long as it's not mere wishful thinking —: on page 50 of the 84-page "Project", published on Saturday March 9, 2024, these proposals are legion!

However, it would be a mistake to overlook the fact that nuclear power is often perceived as an enigmatic source of energy in sub-Saharan Africa, and its possible introduction in Senegal raises a variety of debates and questions. But what is it, then, that makes nuclear energy so remarkably important, and why should its name and potential be given greater prominence in Africa, and particularly in Senegal?

Energy to light and heal us...

In the modern era, nuclear energy, the primal locus of principles imperceptible to the naked eye, remains fundamentally one of the most impressive technological inventions.

Although it sometimes seems ignored, underestimated or misunderstood by the average person, it offers an unrivalled breakthrough in the field of energy, and has been evolving continuously for over seven decades. And yet, it is undeniable that Africa, and more specifically Senegal, deserved to discover this prodigious technology.

In our view, the fundamental duty of science — and its always science that we try to express ourselves through — is an alethic duty, i.e. a process of elucidating the world and nature in order to improve our quality of life and understanding. Whether this task succeeds or fails is almost contingent; its true value lies in this: through it, we discover that the universe is a great enigma, and that this enigma finds its most mysterious expression in us.

This mystery of science, and of nuclear energy in particular, haunted us for five years, so deeply, with such a power of infatuation (what the nuclear sciences have taken from us, a part of our patriotism, will never be returned to us, and so much the better in a sense: Senegal and humanity need the application of cutting-edge

science), that we decided, for the supreme interest, to raise awareness among neophytes, to write a book. The result was Sénégal - route vers le nucléaire, published in 2021 (a book designed to spread influence and democratize nuclear knowledge, and to serve as a guide to setting up an electronuclear program in Senegal) [2]. It therefore became clear to us that nuclear technology has the power to contribute, and will undoubtedly contribute, to solving the socio-economic challenges facing Senegal, Africa and beyond.

In response to the title of this article, "What's nuclear power all about?", we should start by considering it as a singularly incantatory and multifaceted technology. Indeed, nuclear power is more than an isolated force; it is a fundamental pillar of modern society. It powers our transport, fuels our industry and lights our cities. As the main generator of electricity, nuclear power is as vital as water itself, which it can become, in a way, the source of abundance, with desalination (I'll come back to that below!). Technically, this technology harnesses the energy produced by the controlled fission of heavy atoms such as uranium or plutonium (radioactive materials), generating heat that fuels the generation of steam which, condensed in turboalternator units, is transformed into a precious source of electricity. For this reason, and because nuclear power uses uranium as a fuel — a very dense resource compared to fossil fuels (gas, oil, coal...) — we have followed suit; but who is this "we"?

Yes! very dense in the sense that, for electricity production, the nuclear combustion of 1 gram of uranium is equivalent to the combustion of 1.6 tonnes of oil. No, we're under no illusions: to back this up, there's a million times more energy in 1 kilogram of uranium than in

1 kilogram of oil [3]. Of course, a nuclear power plant uses much — really a lot! — less "fuel" than fossil fuel power plants, and much less space and materials than wind or solar power. What, then, can low-carbon energy mean, i.e., among the various sources available to us, those that emit very little carbon dioxide (CO2)? The answer, or at least a comparison of the figures, may surprise you: nuclear power emits 6 grams (g) of CO2 per kilowatt-hour (kWh) of electricity produced, while gas, oil and coal emit 443 g CO2/kWh, 778 g CO2/kWh and 1058 g CO2/kWh respectively [4]. Figure 1 shows emissions from the main sources, as well as the global average.

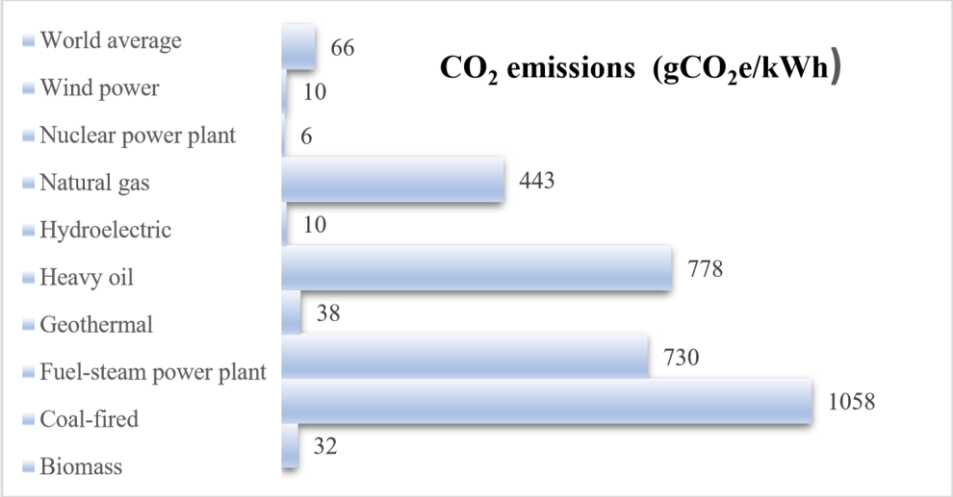

Figure 1: The emissions of energy for electricity production in CO_2 equivalent (CO_2e) in grams per kilowatt-hour of final.

Having said that, our world is a sad place, given the number of fossil-fired power plants installed or under construction. By the way, in the IPCC's sixth assessment report, we — and by "we" we mean everyone who is aware of one of the three greatest dangers facing us today: biological warfare, nuclear warfare and global warming — read that global warming over the next twenty years will reach the threshold of 1.5 degrees Celsius (beyond this threshold, the consequences become very serious, even asymptotic, of irreversible global warming). The same report's obscure bonfire has ignited here at home, showing that greenhouse gas emissions due to human activity have raised temperatures by around 1.1 degrees Celsius since pre-industrial times [5]. So, we've now reached an average earth temperature of 289.25 Kelvin. Not so with nuclear power. Nuclear power plants help to reduce dependence on fossil fuels and can help to achieve CO2 emission reduction targets — it

seems that far too many people confuse the white plume escaping from nuclear power plant towers with the release of CO_2 (pollutant and toxic)! We say it again: sometimes we're out of hope, but it's in despair that we fight best. Driven by passion, we will continue to carry out this mission, that of popularization.

So, what is a nuclear power plant? What motivates many nations, particularly the most advanced, to invest in this civil application of nuclear energy? The explanation lies in their commitment to the research and development of cutting-edge technologies, an investment that stimulates economic growth and consolidates their position on the international stage. In fact, these nations are firmly committed to ensuring their energy independence, recognizing that without it, any development project, no matter how majestic, remains sterile. As we emphasized in our recent book [6] published by L'Harmattan Senegal in March 2024, it is imperative to understand that no robust development project can succeed without a well-controlled energy supply capable of meeting the complex demands of industrial demand. Indeed, a thriving industry requires substantial energy consumption to support its operations. A nuclear power plant can meet this demand, continuously and cost-effectively, without releasing toxic emissions into the atmosphere — if it is operated properly. In economic terms, their performance remains hard to beat: a competitive tariff of 35.95 FCFA [7] per kWh of production, in stark contrast to the 114 FCFA paid by the average Senegalese for 1 kWh of electricity consumed at the social tariff [8].

Many countries, both developed and developing, recognize the importance of nuclear power plants in ensuring a stable and affordable energy supply. France, for example, derives 70% of its electricity from nuclear power, ensuring the continuous supply of electricity to a variety of sectors, including 15 Paris metro lines, the country's numerous RER trains and electric buses, 135 stadiums with at least 6,000 seats, 112 IGH (high-rise) buildings, as well as industries and some 30.8 million households.

Nuclear power plants worldwide

Worldwide, 432 reactors are in operation (operated by 32 countries) and 51 are under construction. The USA has the most (96), followed by France (56, and 1 under construction), China (49, and 16 under construction), Russia (38, and 2 under construction), Japan (33, and 2 under construction) [9], etc. Germany is the only country to have pulled out of nuclear power after the 2011 Fukushima accident in Japan, citing its relatively seismic location. Faced with this crude reality, the Germans are obliged to buy electricity from other countries, mainly France and Belgium.

In Africa, only South Africa has a nuclear power plant — the Koeberg plant, with its two reactors operational since 1984 and 1985 — which has contributed to its position as the continent's most developed nation. Recently, countries such as Nigeria, Egypt, Ghana and Kenya have launched nuclear power projects with Chinese, Russian, French and Canadian partners. In August 2023, Uganda announced the construction of two nuclear power plants in partnership with Russia and South Korea. In 2016, the International Atomic Energy Agency (IAEA) authorized Morocco to launch its civil nuclear program, in recognition of its experience and skills.

We must be aware, however, that the implementation of a successful electronuclear program requires heavy financing and broad political and popular support, over several years. This timeframe may not be adequate to meet Senegal's urgent electricity needs, especially with a population set to double over the next thirty years — and more generally for all the nations of sub-Saharan Africa, whose population is set to double by 2050 [10]. This is where SMRs (Small Modular Reactors) come in, offering a more suitable solution for Africa. More compact, factory-built and assembled on site, SMRs require less investment (up to three times less than conventional nuclear reactors) and are suited to isolated regions such as the provinces of Tanzania, where the rate of access to electricity in rural areas is just 23%, or places like Kolda and Kédougou in Senegal. These reactors, built in pairs of 150 MW, truly represent one of the most practical solutions for Senegal and other African countries.

Other peaceful nuclear applications

It's well known that the civil application of nuclear energy goes far beyond the simple production of electricity. One of its most important uses is the production of isotopes, which are chemical elements used in many fields, including medicine, for the diagnosis and treatment of cancer (cervical, uterine, breast, lung cancers, etc.). The

isotopes most commonly used for this purpose are iodine-125 and palladium-103, produced in reactors. With the exception of South Africa, which has its own research reactors to produce radioisotopes, African countries, including Senegal, have to import their radiopharmaceuticals. This is why Senegal is planning to ship a research reactor. Although the project has not yet reached any major milestones, in 2022, we had a discussion with Mr. Ndao, Director of Regulations and Authorizations at the Senegalese Radiation Protection, Nuclear Safety and Security Authority (ARSN) on the subject, during which he encouraged us to consider this initiative after passing on to me the draft nuclear law for the country, providing a basis for understanding the current regulatory situation.

Nuclear power for agriculture and fresh water

Where do Senegal and Africa fit into this dynamic? They are well positioned to benefit from the advantages of nuclear energy in this area. Beyond all these countries, there are the challenges of supplying fresh water and securing the food chain. All African countries should be able to benefit from food irradiation to improve their safety and nutritional value. What's more, given the continent's favorable geographical location for the use of nuclear energy to desalinate seawater, several nations could naturally consider nuclear power as a solution to their growing freshwater needs.

However, nuclear power also has applications in industry, district heating and hydrogen production (used in fertilizer production and oil refining).

In fact, nuclear energy is omnipresent in our daily lives. Unfortunately, some people associate it only with the atomic bomb, when in fact it's much more peaceful: safer, more economical and more efficient. In short, it's more than just the energy of the future; it's how we power our homes, get around and benefit from medical care. What could be better? We'll never stop saying it: it's dense, clean energy that saves lives, protects the environment and creates thousands of jobs!

We hope, finally, that this modest chronicle may shed some light on its nature, or to consider the absurd, may help African governments and leaders to assume their responsibilities.

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