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Nuclear energy: report on the expertise of France

Working paper submitted by France

At a time when increasing numbers of countries wish to acquire nuclear power capacities, France is prepared to respond to their aspirations in accordance with its commitments under article IV of the Nuclear Non-Proliferation Treaty by offering its expertise to any country that fulfils all its international obligations, including those under the Treaty, and carries out peaceful activities in good faith.

Thanks to more than 70 years of experience, France has mastered the whole value chain in the production of nuclear power, making it an ideal partner to effectively support countries that wish to increase the share of nuclear power in their energy mix in the long term.

With this in mind, France's expertise is built on an integrated nuclear sector supported by a coherent, ambitious energy policy (part 1). It encompasses sale of technologies (part 2), services (part 3) and nuclear safety cooperation (part 4) and offers tailored financial solutions designed in collaboration with partners (part 5).

1. France has an integrated nuclear sector supported by a coherent, ambitious energy policy

A. Nuclear power in French energy policy

France has an energy policy that supports security of supply and its ambitious environmental and climate goals.

Nuclear power is a decarbonized, competitive and manoeuvrable energy source that contributes to national energy independence. Current crises and the resulting rising energy costs further heighten the importance of national sovereignty.

With 56 reactors across 18 sites, France has the largest nuclear plant fleet per capita worldwide. France is therefore one of the six countries worldwide that has already achieved the goal set by the Intergovernmental Panel on Climate Change (IPCC) of generating at least 80 per cent of power from decarbonized sources and is the lowest emitter of CO_2 per capita of the Group of Seven (G7) industrialized countries.

The President of France recently expressed his intention of launching a new programme to build six EPR2 nuclear reactors, as well as studies for another eight, in order to guarantee France's energy independence and achieve carbon neutrality by 2050. He also stressed the importance of complementarity with continued massive development of renewable energy.

B. France's nuclear sector is united around a shared ambition: promoting French nuclear technology to meet the needs of the global market

The nuclear industry of France accounts for 6.7 per cent of its industrial jobs: more than 220,000 qualified employees. That makes it the country's third-largest industrial sector and a driver of exports. The sector's considerable strength lies in the French network of suppliers and contractors, which are known worldwide for their industrial expertise, skills and ability to work on every stage in a plant's life cycle, from construction to dismantling through operation and maintenance, and on the whole nuclear fuel cycle.

The sector in France is built around the five leading operators (EDF, along with the National Agency for Radioactive Waste Management (ANDRA), the Alternative Energies and Atomic Energy Commission (CEA), Framatome and Orano), the professional association (GIFEN) and the Strategic Committee on the Nuclear Sector (CSFN), which are driven by a common goal: promoting French nuclear technology to meet the needs of the global market.

2. France exports a range of reactors that can meet all types of electricity needs

A. France builds on pressurized water reactor technology to address new global energy challenges

France has a diverse portfolio of products suited to different markets and capable of addressing its partners' needs. Its reactors are the pressurized water reactor (PWR) type, based on advanced "Generation III" technology. This French technology is fully compliant with the safety and security standards and safeguards established by the International Atomic Energy Agency (IAEA) and the European regulatory framework.

The latest generation EPR (1,650 MWe) is the flagship French reactor. This high-power reactor can deliver energy to highly populated territories with significant electricity demand.

Building on lessons learned from completed or ongoing EPR projects, an optimized version of the EPR, or "EPR2", is being developed to be more competitive, especially in terms of cost and construction duration. The EPR2 is the first reactor to be wholly digitally designed and is conceived for integration in grids with a high proportion of renewable energy in the mix.

The medium power EPR (1,200 MWe), based directly on technology from the standard EPR, can provide energy to areas that require less electricity or where grid capacities are more limited.

France is also speeding up the development of its small modular reactor (SMR) programme, which is receiving strong financial support under the France Relance and France 2030 plans.

The most advanced French SMR project is NUWARD, led by EDF. With an output of 340 MWe (2 reactors producing 170 MWe each), it offers a robust, credible solution for the future replacement of coal-fired power plants in isolated regions with

less dense electricity grids or industrial areas with decarbonized energy needs. According to EDF, the first plant should be ready in France by 2030. EDF and the Nuclear Safety Authority support initiatives to promote high safety levels and harmonize high safety goals. The Authority is in close cooperation with its Finnish and Czech counterparts to contribute to convergence of processes for the authorization of such reactors, particularly in a European framework (an initiative on the development of SMRs was launched in 2021) or at the multilateral level at IAEA (the Nuclear Harmonization and Standardization Initiative).

B. France has renowned expertise in reactors and receives requests worldwide

Of the 441 reactors currently online worldwide, the French sector services almost 400. Three EPRs have been brought online worldwide: two in Taishan (China), where Unit 1 produced 11.95 TWh of electricity in 2019, a global record; and one in Olkiluoto (Finland) in March 2022, which will eventually supply 15 per cent of the country's electricity. Three more are under development: one in Flamanville (France), in the late stages of construction, and two at Hinkley Point C (United Kingdom).

Through EDF, France works to build long-term partnerships by taking part in developing and upskilling for local nuclear sectors. For example, EDF is working with more than 3,600 British companies for the Hinkley Point C worksite. Discussions are underway with several States for the building of new reactors, with the same aim of forging long-term partnerships.

3. France works with its international partners throughout the life cycle of their nuclear facilities

France's nuclear sector has renowned expertise across all aspects of nuclear facilities (operating reactors, engineering, manufacture, maintenance, etc.).

A. Supplying equipment and operating and maintaining plants abroad

The average operational life of a plant is at least 40 years, and maintenance operations are carried out to ensure operation in compliance with the highest safety and security standards. The historical experience of EDF enables it to deliver its expertise and the innovations it has observed or developed over time to all its plants around the world.

Framatome has the widest portfolio of maintenance services for all French or foreign reactor technologies, geared to optimizing performance and extending operational life while meeting the highest safety standards. Framatome has worked on operating or building more than 380 reactors worldwide.

B. The fuel cycle

Framatome and Orano offer a wide range of services covering the whole nuclear fuel cycle, from uranium mining to management of spent fuel and conversion, enrichment and assembly of fuel. Their international services are supported by wide-ranging experience of different types of fuel and reactor.

With its Orano Mining subsidiary, Orano is one of the world's top three natural uranium producers, delivering 6,529 tons in 2020. It is a mining actor handling all steps in the production of natural uranium, including exploration, development, production, marketing and site re-development. Orano is also a key player in the fields of conversion (Western leader) and enrichment (third globally). Exports make up around 60% of the activity of its subsidiary, Orano Chimie Enrichissement.

Orano offers comprehensive services relating to management of spent fuel (recycling, characterization, storage, processing, packaging and optimization of volumes). Its technologies are used by many countries.

Lastly, Orano transports nuclear material under the highest safety and security standards: its logistics subsidiary carries out around 6,000 transports annually worldwide and is in constant, active dialogue with coastal States.

Framatome has specialized in the design, development and production of fuel and supplies almost 125 reactors worldwide operating under various technologies.

C. Waste management and dismantling of plants

Orano provides dismantling and waste management services for plants built in France and abroad, as well as for fuel cycle facilities. Orano has taken part in more than 160 reactor dismantlement projects worldwide, including in the United States, Germany and Japan.

Through its Cyclife subsidiary, EDF also provides dismantlement and waste packaging services prior to recycling or permanent storage for plants built in France and abroad. Cyclife advises its international customers as regards dismantling strategies to ensure efficient management of radioactive and non-radioactive waste.

ANDRA is tasked with safe long-term storage of all French radioactive waste. It operates three surface storage centres and is responsible for the Cigéo geological storage project. ANDRA supports the French nuclear sector with its complete mastery of the cycle and has developed its own expertise in all aspects of long-term management of radioactive waste, which it makes available to its foreign partners.

4. France offers its partners its expertise for the development and enhancement of their human resources capacities and research programmes

A. The sector's institutional and industrial actors offer a wide range of training and cooperation internationally

At the institutional level, the International Institute of Nuclear Energy (I2EN) is a major player in training for international partners, coordinating the 100 or so training programmes in France that lead to qualifications.

The National Institute of Nuclear Sciences and Technologies (INSTN), attached to CEA, is an applied training school for low-carbon energy and health technology. The INSTN has been an IAEA Collaborating Centre since 2016. It trains partners in nuclear power programmes, research programmes, and programmes to develop nuclear applications for health.

At the industrial level, French nuclear sector companies are highly committed to developing local human capital. They also offer targeted industrial training covering the whole nuclear energy production cycle. In March 2022, a Centre of Excellence in nuclear security was founded by French companies as part of the IAEA Nuclear Security Support Centre network. It brings together training programmes from French companies in nuclear security, notably with a view to operational implementation of IAEA standards by nuclear operators. EDF offers tailored training for those starting out, in partnership with IAEA, and offers on-site training of technicians who will work at the plants. Framatome hosts the Experimentation and Validation Centre for Operations on Nuclear Steam Supply Systems (CETIC), a full-scale facility for the training of operators. It is the only centre worldwide to recreate

real conditions for access and work on the major components of a pressurized water reactor.

B. France contributes actively to developing international safety standards

States using nuclear energy must establish a legal and regulatory framework compliant with international requirements and have an authority capable of exercising its authorization and control prerogatives. The excellence of its nuclear sector allows France to support them, building on the experience of its Nuclear Safety Authority and the Institute for Radiological Protection and Nuclear Safety (IRSN), the French technical support office (TSO).

The Authority is in intense, constant dialogue with its foreign counterparts, through participation in various groups, including the Western European Nuclear Regulators Association (WENRA) and the European Nuclear Safety Regulators Group (ENSREG). The Authority also responds to assistance requests from its counterparts, in synergy with European and international instruments, supporting the advised safety authority while leaving it responsibility for the control of nuclear facilities.

IRSN has long engaged in scientific and technological cooperation with safety bodies in many countries worldwide, working on research and evaluation in the fields of nuclear safety and radiation protection.

CEA, which is a research and development body as well as the operator of civilian and military nuclear facilities, has been a designated IAEA International Centre based on Research Reactors (ICERRs) since 2015, working in partnership with IRSN since 2021.

C. France, a major player in nuclear scientific and technological research

CEA, as a historic public body for multidisciplinary scientific and technological research, has built up a solid network of bilateral relationships, supported by advisers deployed to certain diplomatic posts, including in the United States, India and Japan. CEA engages in in-depth cooperation in very diverse and innovative fields such as decarbonized hydrogen and fourth-generation fast-neutron reactors. It also takes part at the European Union level in developing a European research area and nuclear power cooperation. Lastly, CEA works in supranational research infrastructure such as the European Organization for Nuclear Research (CERN) or ITER, for nuclear fusion. It also encourages the opening up of its major research infrastructure, such as the Jules Horowitz Research Reactor that is being built at Cadarache.

5. Collaboration with France in building nuclear reactors brings tailored, secured financing

The costs linked to developing, building and financing a new nuclear reactor can account for 65–85 per cent of the levelized cost of electricity (LCOE) in some projects. This measure is a key criterion for the initiators of projects for the construction of new nuclear power capacities and the public decision-makers concerned.

A. Competitive export credit conditions: a strong commercial argument

In Bpifrance Assurance Export, part of its public investment bank, France has an export credit agency that can guarantee up to 95 per cent of debt-based financing granted for French export contracts, in accordance with agreements with the Organization for Economic Cooperation and Development (OECD). On behalf of

France, Bpifrance insures the commercial loans granted to fund procurement from French companies, under certain conditions.

Since 2015, the SFIL public development bank can also refinance the loans granted by commercial banks (buyer's credit) guaranteed by France, helping increase liquidity capacity for projects by ensuring a very competitive rate. These fully operational and efficient arrangements have been used in several major French export projects. Bpifrance Assurance Export also offers an enhanced guarantee to cover 100 per cent of the refinancing of buyer credit granted by commercial banks that is itself guaranteed by the Government.

B. Solid experience in partnership-based financing of plants

France works with its international partners to establish financial structures to ensure secure, competitive financing of nuclear plants for export when the use of debt is considered, and therefore has the practical experience that contributes to project success.

In the United Kingdom, the Sizewell C project to build two EPRs could be subject to the regulated asset base model, making it possible to compensate investors from the plant's construction period onwards. If debt is raised specifically for the project, France is prepared to offer its export insurance tools in order to increase available liquidity for the project and strengthen the financial structure.

In China, EDF and Framatome supported the building of the Taishan nuclear plant, which involved export buyer's credit insurance.

Moreover, the French Government regularly supports the export of industrial equipment such as the Arabelle turbines of GE and the control solutions of Framatome. Public guarantees have also been used in the United States, Brazil and South Africa.