Status Report - HEXANA (France)

Downloaded on: Nov 17, 2026 2:27 PM CET

Published Date : Oct 29, 2024 5:57 PM CET

1. Overview

- ☐ **In Operation**
- ☐ **Under Construction**
- ☐ **Described in**

Link to PRIS	--

- ☑ **New Concept**

Number of Units	--
Year	2030

Reference Plant

Name of Site	--
Link to PRIS	--
Net Power Output (MWe)	150
Gross Power Output (MWe)	--

1.1 Introduction

HEXANA is an industrial startup company in the field of nuclear. It was launched in 2023 with the support from the French Alternative Energies and Atomic Energy Commission (CEA), a key Research Technology Organisation (RTO) in scientific and technological research in France in low carbon energies (e.g. nuclear and renewable). It benefits from the CEA's and EDF's technologies, know-how and patents to develop a Gen4 small advanced modular reactors (AMRs). It intends to develop an AMR based on the sodium-cooled fast reactor (SFR) technology, a proven nuclear technology, that incorporates a high-temperature heat storage device. SFRs are of great interest with respect to nuclear waste management, and there is renewed interest for this technology worldwide: they do not need natural or enriched uranium fuels to operate, but rather use depleted uranium combined with recycled plutonium collected from the reprocessing of Gen3 reactors spent fuels (MOX). With no natural or enriched uranium used, which represent half of conventional nuclear gas emissions and no critical resources (e.g. lithium, helium, cobalt, etc.), waste management, environmental protection and sustainability are greatly improved over the long term. Further, those reactors shall contribute to reducing its volume of high-level nuclear waste within the scope of closing the nuclear fuel cycle. Through the France 2030 programme "Innovative Nuclear Reactors", CEA is committed to supporting startups looking to promote decarbonisation through the development of innovative reactor projects

matching with a better management of fuel resources and the nuclear waste reduction.

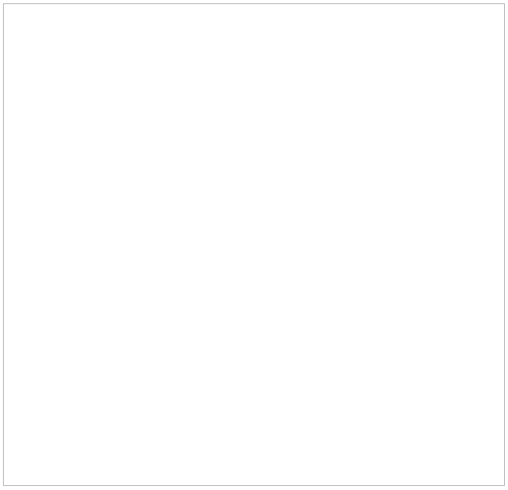


Figure 1. Design concept of HEXANA

At present, 43% of global CO2 emissions come from the industry and transports, and industrial energy is driven by fossil fuels at 90%. With its system, HEXANA has set itself the mission to remove their use of fossil fuels and to decarbonise energy-intensive and hard-to-abate industries (e.g. steel, chemistry, cement, refining, maritime and aviation fuels) with a sustainable nuclear solution that meets their requirements in terms of long-term competitiveness and power supply levels, while enabling upcycling using recyclable fuel. The facility will comprise two small reactor units (400 MWth each) that will supply a heat storage device specially designed to manage fluctuating demand for electric power from the industries and electric grids. It will be equipped with an energy conversion system to ensure the flexible production of electricity on demand, making it possible to compete with gas-fired power stations and to provide process heat directly to energy-intensive industries within proximity. This will also represent the expected solution to support renewable energies and complement their intermittency production thanks to its flexibility. Production is expected to be on site, directly based on an industrial cluster. With both electricity and high temperature process heat (500°C), the latter will be able to capture CO2, to produce steam, hydrogen and synthetic fuels, and to commit firmly to the decarbonisation process.

1.2 Development Milestones

2023	Preliminary studies within CEA
2026	Conceptual design
2028	Basic design
2030	Detailed design
2030	Target first concrete for the FOAK plant
2035	FOAK operation
2050	Up to 40 in operation in Europe

1.3 Design organization or vendor company

1.4 Links to designer/vendor website

1.5 Design Description

HEXANA system provides two reactors associated with a thermal storage unit offering flexible power delivery in response to the needs of its customers (electricity and/or heat) for industrial process needs. HEXANA integrates design options offering high guarantees from the point of view of safety, relying in particular on passive safety devices. HEXANA is primarily targeting the decarbonization of energyintensive and highly greenhouse gas-emitting industrial processes, with the combined production of heat and electricity, bases for the production of hydrogen or synthetic fuels. The SFR heat (500°C) gives access to all the amenities needed to defossilize our economy : steam, hydrogen, CO2 capture, synthetic fuels, green steel, chemical molecules, fresh water by desalination, ammonia, fertilizers… HEXANA select the SFR technology also as part of a circular economy by using available nuclear materials : depleted uranium and plutonium from PWR spent fuel. This choice avoids any dependency on the import of uranium and offers a strategic advantage in terms of sovereignty and sustainability. With the SFR technology, HEXANA produces very low carbon energy estimated at 2.5 gCO2/kWh, which is a key asset. If the main features of the SFR reactor are already proven technologies, HEXANA brings some major breakthroughs in the reactor design and in the use of nuclear energy in order to perfectly match with industrial needs.

- The design is made modular thanks to, in particular, a compact vessel. This is crucial for competitive issues and this enables to twin two modules on site efficiently so that the energy delivery is continuous;
- It includes heat storage tanks to ensure a high flexibility of the heat delivery, and a strong decoupling between the operation of the nuclear island and the power conversion system. The nuclear island is working on a base-load mode, increasing its plant capacity and reliability, its lifetime and, as a consequence, its revenue;
- The whole concept is not built in a full electrical paradigm, neither in a small hybridisation prospect for which a small amount of heat is extracted from a Power Conversion System optimized for electricity production. Conversely, it is designed in an integrated way so that the industrial end-user is fed with the right balance of electricity and heat, and heat at the right temperature(s) level(s). In other words, HEXANA ambition is to become a taylor-made solution to guarantee an optimized energy delivery as an efficient substitute to fossil fuels. If optimized for the hydrogen production, this approach results in the production of 200 tons of H2 per day for a twinned configuration. When compared to H2 production with a PWR featured by the same core power and the same thermal coupling possibilities between the reactor and the Solid Oxide Electrolyzer Cell (SOEC), HEXANA produces 25% more H2 than the PWR. This value reaches +50% if thermal coupling cannot be achieved with the PWR

1.6 Licensing Application Support Documents

1.7 Reactor Unit in PRIS

2. Category Fields

Table 1: ARIS Category Fields

ARIS Category	Value	Units of Examples

Current/Intended Purpose	Prototype/FOAK	e.g. Commercial – Electric/Non-electric, Prototype/FOAK, Demonstration, Experimental
Main Intended Application (once commercial)	Baseload, Non-electric (High temperature process heat)	e.g. Baseload, Dispatchable, Off-grid/Remote, Mobile/Propulsion, Non-electric (specify)
Reference Location	Inland	e.g. On Coast, Inland, Below-Ground, Floating-Fixed, Marine-Mobile, Submerged-Fixed (Other-specify)
Reference Site Design (reactor units per site)	Dual Unit	e.g. Single Unit, Dual Unit, Multiple Unit (# units)
Core Coolant	Na	H2O, D2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
Reactor Core Size (1 core)		e.g. Thermal Power < 30 MWth, 30 MWth ≤ Thermal power < 1000 MWth, 1000 MWth ≤ Thermal power ≤ 3000 MWth, Thermal power > 3000 MWth
Reactor Type	SFR	e.g. PWR, BWR, HWR, SCWR, GCR, GFR, SFR, LFR, MSR, ADS
Reactor Size	SMR	e.g. PWR, SMR
Neutron Moderator	None	e.g. H2O, D2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
NSSS Layout		e.g. Loop-type (# loops), Direct-cycle, Semi-integral, Integral, Pool-type
Primary Circulation	Forced	e.g. Forced (# pumps), Natural
Thermodynamic Cycle		e.g. Rankine, Brayton, Combined-Cycle (direct/indirect)
Secondary Side Fluid		e.g. H2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
Fuel Form	Fuel Assembly/Bundle	e.g. Fuel Assembly/Bundle, Coated Sphere, Plate, Prismatic, Contained Liquid, Liquid Fuel/Coolant

Fuel Lattice Shape		e.g. Square, Hexagonal, Triangular, Cylindrical, Spherical, Other, n/a
Rods/Pins per Fuel Assembly/Bundle		e.g. #, n/a
Fuel Material Type	Oxide	e.g. Oxide, Nitride, Carbide, Metal, Molten Salt, (Other-specify)
Design Status	Conceptual Design	e.g. Conceptual, Detailed, Final (with secure suppliers)
Licensing Status		e.g. DCR, GDR, PSAR, FSAR, Design Licensed (in Country), Under Construction (# units), In Operation (# units)
Neutron Spectrum	Fast	e.g. Fast, Thermal

3. Parameter Fields

Table 2: ARIS Parameter Fields

ARIS Parameter	Value	Units of Examples
Plant Infrastructure		
Design Life	60	Years
Lifetime Capacity Factor		%, defined as Lifetime MWe-yrs delivered / (MWe capacity * Design Life), incl. outages
Major Planned Outages		# days every # months (specify purpose, including refuelling)
Operation / Maintenance Human Resources		# Staff in Operation / Maintenance Crew during Normal Operation
Reference Site Design		n Units/Modules
Capacity to Electric Grid	150	MWe (net to grid)
Non-electric Capacity		e.g. MW(th) heat at x °C, m3/day desalinated water, kg/day hydrogen, etc.
In-House Plant Consumption		MWe
Plant Footprint	15000	m2 (rectangular building envelope)
Site Footprint		m2 (fenced area)

Emergency Planning Zone		km (radius)
Releases during Normal Operation		TBq/yr (Noble Gases / Tritium Gas / Liquids)
Load Following Range and Speed		x – 100%, % per minute
Seismic Design (SSE)		g (Safe-Shutdown Earthquake)
NSSS Operating Pressure (primary side)		MPa(abs), i.e. MPa(g)+0.1, at core outlet
NSSS Operating Pressure (secondary side)		MPa(abs), i.e. MPa(g)+0.1, at secondary side outlet
Primary Coolant Inventory (incl. pressurizer)		kg
Nominal Coolant Flow Rate (primary)		kg/s
Nominal Coolant Flow Rate (secondary)		kg/s
Core Inlet Coolant Temperature	400	ºC
Core Outlet Coolant Temperature	530	ºC
Available Tempeature as Process Heat Source		ºC
NSSS Largest Component	Reactor vessel	e.g. RPV (empty), SG, Core Module (empty/fuelled), etc.
- NSSS Largest Component Length	14000	mm
- NSSS Largest Component Diameter	9000	mm
- NSSS Largest Component Thickness		mm
- NSSS Largest Component Weight		tonne
Reactor Vessel Material		e.g. SS304, SS316, SA508, 800H, Hastelloy N
Steam Generator Design		e.g. Vertical/Horizontal, U-Tube/ Straight/Helical, cross/counter flow
Secondary Coolant Inventory		kg

Pressurizer Design		e.g. separate vessel, integral, steam or gas pressurised, etc.
Pressurizer Volume		m3 / m3 (total / liquid)
Containment Type		Dry (single/double), Dry/Wet Well, Inerted, etc.
Containment Volume		m3
Spent Fuel Pool Capacity and Total Volume		Years of full-power operation / m3
Non Electric Application		-
Core Delta Temperature	130	ºC
Fuel/Core		
Single Core Thermal Power	400	MW(th)
Refuelling Cycle	12-18	months or “continuous”
Fuel Material	MOX	e.g. UO2, MOX, UF4, UCO
Enrichment (avg./max.)	<28% of Pu	%
Average Neutron Energy		eV
Fuel Cladding Material		e.g. Zr-4, SS, TRISO, E-110, none
Number of Fuel “Units”		Specify as Assembly, Bundle, Plate, Sphere, or n/a
Weight of one Fuel Unit		kg
Total Fissile Loading (initial)		kg fissile material (specify isotopic and chemical composition)
% of fuel outside core during normal operation		Applicable to online refuelling and molten salt reactors
Fraction of fresh-fuel fissile material used up at discharge		%
Core Discharge Burnup	110	MWd/kgHM (heavy metal, eg U, Pu, Th)
Pin Burnup (max.)		MWd/kgHM
Breeding/Conversion Ratio		Fraction of fissile material bred in-situ over one fuel cycle or at equilibrium core
Reprocessing		e.g. None, Batch, Continuous (FP polishing/actinide removal), etc.

Main Reactivity Control	Control rods	e.g. Rods, Boron Solution, Fuel Load, Temperature, Flow Rate, Reflectors
Solid Burnable Absorber		e.g. Gd2O3
Core Volume (active)		m3 (used to calculate power density)
Fast Neutron Flux at Core Pressure Boundary		n/(cm²*s)
Max. Fast Neutron Flux		n/(cm²*s)
Core Control Rod Absorber		-
Core Soluble Neutron Absorber		-
Safety Systems		
Number of Safety Trains	Active / Passive	% capacity of each train to fulfil safety function
- reactor shutdown	N/A	- / - / -
- core injection	N/A	- / - / -
- decay heat removal	Active/Passive	- /- / -
- containment isolation and cooling	N/A	- / - / -
- emergency AC supply (e.g. diesels)	N/A	- / - / -
DC Power Capacity (e.g. batteries)		Hours
Events in which Immediate Operator Action is required		e.g. any internal/external initiating events, none
Limiting (shortest) Subsequent Operator Action Time		Hours (that are assumed when following EOPs)
Severe Accident Core Provisions		e.g. no core melt, IVMR, Core Catcher, Core Dump Tank, MCCI
Core Damage Frequency (CDF)		x/reactor-year (based on reference site and location)
Severe Accident Containment Provisions		e.g., H2 ignitors, PARs, filtered venting etc.
Large Release Frequency (LRF)		x/reactor-year (based on reference site and location)

Overall Build Project Costs Estimate or Range (excluding Licensing, based on the Reference Design Site and Location)		
Construction Time (nth of a kind)		Months from first concrete to criticality
Design, Project Mgmt. and Procurement Effort		Person-years (PY) [DP&P]
Construction and Commissioning Effort		PY [C&C]
Material and Equipment Overnight Capital Cost		Million US$(2015) [M&E], if built in USA
Cost Breakdown	%[C&C]/%[M&E]	
- Site Development before first concrete		(e.g. 25/10) (30/40) (20/25) (20/10) (5/15) (----------) (to add up to 100/100)
- Nuclear Island (NSSS)		
- Conventional Island (Turbine and Cooling)		
- Balance of Plant (BOP)		
- Commissioning and First Fuel Loading		
Factory / On-Site split in [C&C] effort		%/% of total [C&C] effort in PY (e.g., 60/40)
Nuclear System		
System Steam Flow Rate		kg/s
System Steam Pressure		MPa
System Steam Temperature		ºC
System Feedwater Flow Rate		kg/s
System Feedwater Temperature		ºC
Reactor Core		
Active Core Height		m
Equivalent Core Diameter		m
Average Linear Heat Rate		kW/m
Average Fuel Power Density		kW/kgU
Average Core Power Density		MW/m3
Outer Diameter Of Fuel Rods		mm

4. Plant Layout, Site Environment and Grid Integration

SUMMARY FOR BOOKLET

The nuclear island is segregated from the conventional island and the end-user industrial customer.

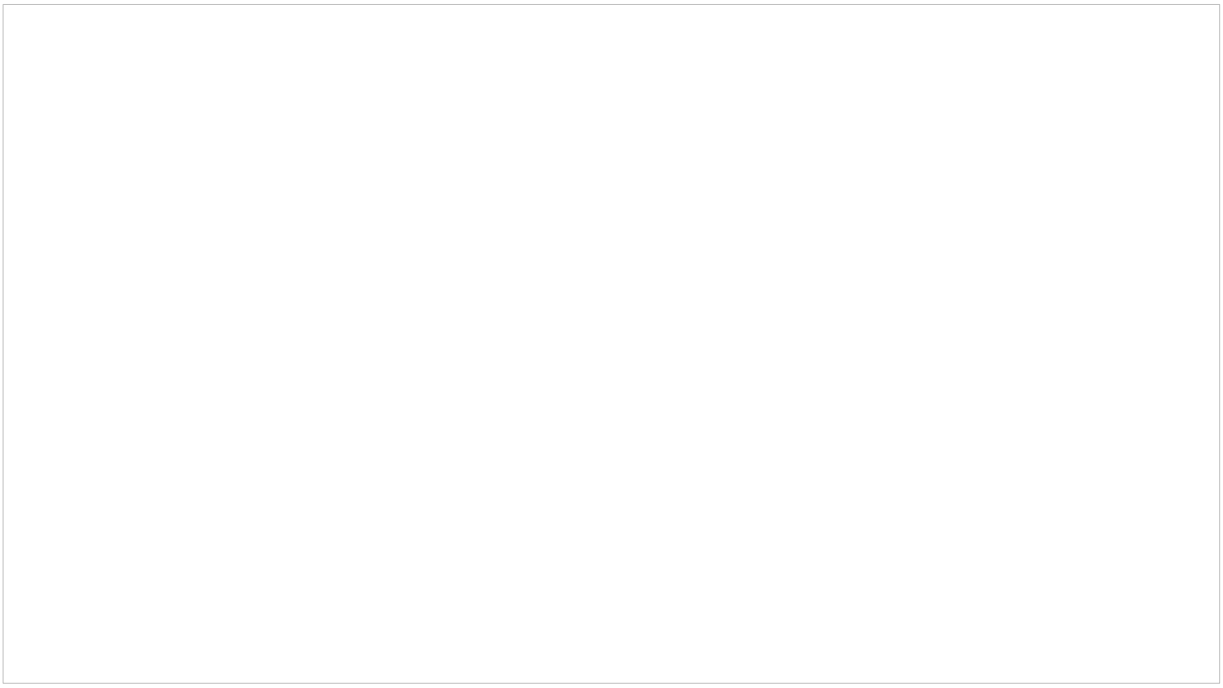


Figure 2. Plant layout arrangement

4.1 Site Requirements during Construction
4.2 Site Considerations during Operation
4.3 Grid Integration

5. Technical NSSS/Power Conversion System Designn

SUMMARY FOR BOOKLET

Nuclear Steam Supply System

The Nuclear Island includes the sodium primary circuit with the core and main components and the sodium secondary circuits up to th sodium/salt heat exchangers. The molten salt thermal energy storage system, the steam generators and the Rankine power conversion system are located outside the nuclear island.

Reactor Core

The reactor core is composed by 80 fuel sub-assembly. The fuel is MOX pellets with depleted or natural uranium and plutonium from PWR spent fuels. The fuel pins are located in an hexagonal can.

Reactivity Control

For the reactivity control function, the design includes control rods made of moving rods inside the core with a neutron absorber (boron carbide). Two independent systems are implemented with strong redundancy and diversification. For HEXANA, we work also on a passive device that can drop neutron absorber when the sodium becames too hot, without I&C. That kind of device was studied during the ASTRID project.

Reactor Pressure Vessel and Internals

The reactor is a sodium pool type reactor, meaning that all main components are located in the primary vessel (primary pumps, sodium heat exchangers, fuel handling machine).

Reactor Coolant System and Steam Generator

Two sodium secondary loops are located between the primary circuit and the conventional island. The conversion system includes sodium/salt heat exchangers, a thermal energy storage system (TES) with two molten salt storage tanks, four steam generators and a Rankine power conversion system (PCS). For the heat removal function, an advantage of SFR is that we can use sodium/air heat exchangers and sodium circuits that operates without electricity or water, completely passively. This is related to the very good thermal properties of the sodium fluid (heat conductivity). For the HEXANA design, we plan to have two systems (again with strong redundancy and diversification), one with sodium circuits and sodium/air heat exchangers connected to the secondary circuits and one through the primary vessel, by cooling the reactor pit. That kind of system is efficient only if the power of the reactor is not too important, which is the case for HEXANA (400 MWth).

Pressuriser

No pressure in a Sodium Fast Reactor

Primary pumps

Two primary pumps are located in the primary vessel. No specific issue is expected as these materials have a good operational feedback in France in Phenix and Superphenix.

Instrumentation and Control Systems

I&C systems developed fro Phenix, SuperPhenix and ASTRID in France are sufficiently known to provide a good operation and safety level. Some specific I&C systems will be developed by HEXANA for the overall control of the plant between the nuclear island, the thermal energy storage and the conventional island.

5.1 Primary Circuit
5.2 Reactor Core and Fuel
5.3 Fuel Handling

5.4 Reactor Protection
5.5 Secondary Side
5.6 Containment/Confinement
5.7 Electrical, I&C and Human Interface
5.8 Unique Technical Design Features (if any)

6. Technology Readiness

SUMMARY FOR BOOKLET

Testing Conducted for Design Verification and Validation

Most of components are well known due to SFR good operational feedback in France. Testing is necessary for specific design parts of the design :

- Sodium/salt heat exchangers
- Overall system operation (sodium+ thermal energy storage+steam generators)
- Fuel handling in the reactor
- Expansion bellows for sodium systems
- Reactor vault cooling system

The qualification is scheduled with several partners during the conceptual design and basic design.

Design and Licensing Status

The Conceptuel Design phase will be conducted during 18 months until march 2026, when a Safety Case will be submitted to the french safety authorities. Then the Basic Design will last until early 2029 with the submission of a Building Permit demand. In parallel, sever al security cases are planned concerning non-proliferation issues and physical protection.

6.1 Deployed Reactors
6.2 Reactors under Licensing Review
6.3 Reactors in the Design Stage

7. Safety Concepts

SUMMARY FOR BOOKLET

Engineered Safety System Approach and Configuration

For the safety framework, the WENRA objectives will be applied, as they were already the reference for the previous SFR project in France (ASTRID). HEXANA wants to implement an holistic approach “3S by design” to take into account early in the design process not only Safety requirements but also Security and Safeguards. HEXANA is a Gen4 system and will apply the basis safety approach

promoted within the International GenIV Forum. The SFR Safety Design Criteria will be implemented within the design.

Safety Approach and Configuration to Manage DBC

Several systems are designed to fulfill the DBC requirements with the sufficient level of diversification to ensure enough reliability for prevention and mitigation of DBC. For Decay Heat Removal systems, at least one of the two systems will be designed to fulfill its requirements in fully passive mode.

Safety Approach and Configuration to Manage DEC

HEXANA considers severe accidents conditions in DEC as part of the fourth level of defense-in-depth. A Practical Elimination approach will also be implemented to complete the safety demonstration.

Containment System

For the containment function, one key point of SFR pool-type design like HEXANA is that all the primary components (pumps, exchangers) are inside the primary vessel. The primary sodium therefore does not leave the primary vessel (difference with the water in a PWR). Besides, we have no pressure in the circuits (sodium is liquid at atmospheric pressure -> no need for pressure instead for PWR). Therefore there is no LOCA transient as in PWR thanks to the pool (integrated concept). In case of primary vessel sodium leakage, the reactor pit is design to collect the sodium safely and to stabilize the sodium level in the primary vessel, and to ensure the coolability of the core. The risk of draining the sodium outside of the core is therefore excluded by design. It is a big strength in the safety demonstration of designs like Phénix, SuperPhénix and HEXANA. This is not the case for loop type reactors.

Spent Fuel Cooling Safety Approach / System

HEXANA has a speficic operating condition that allow a very good level of reliability and availability. The two reactors are operated in baseload mode without any transient too unsure the operation. The flexibility of the production for the grid or the end-user is ensured by the Thermal Energy Storage System.

7.1 Safety Philosophy and Implementation
7.2 Transient/Accident Behaviour

8. Fuel and Fuel Cycle

SUMMARY FOR BOOKLET

Fuel Cycle Approach

The use of a SFR meets a triple challenge : the reuse of plutonium from PWR spent fuel, the reduction of dependence on uranium imports and the minimization of Long-Lived Radioactive Waste (LLRW) to be stored. HEXANA offers a SFR capable of meeting these challenges. A major challenge is that of

plutonium from PWR spent fuel, which would be by far the largest contributor to LLRW if it were not valued as a resource. It is reused once in France with MOX utilization in some of EDF PWRs. However, the inevitable degradation of the isotopic vector requires having SFR to sustainably reuse plutonium and stabilize its inventory on French soil, in quantity and quality. As a reminder, the current french fleet accumulates 120 t/year of spent MOX fuels. HEXANA therefore aims to be able to valorize used MOX, in support of ad hoc upstream and downstream industrial sectors. The second challenge is that of the uranium resource and its enrichment. Even if the known reserves, the diversity of suppliers and the current tension on the market do not suggest a real surge in prices in the short term, we can note a tripling of the price of uranium since the beginning of 2020 in the wake of other raw materials. These economic arguments remain relative for the moment: France has large stocks, a diversity of suppliers and the impact of the cost of U on the price of MWh is low. However, if a rapid and massive nuclear renaissance were to take place, tensions on the U market, or even on Pu stocks, could increase more quickly than the current rate of development of Fast Reactors. At the current rate, uranium stocks provide 100 to 150 years of resources. However, in the event of a global desire to achieve Net-Zero 2050 thanks in part to nuclear power, tensions could appear as early as the middle of the century. The issue remains geostrategic in the medium term (energy sovereignty) rather than a real short-term challenge. It should also be noted that the equivalent CO2 emissions of the current nuclear kWh are 50% due to uranium extraction and enrichment activities. A SFR with a closed fuel cycle can therefore reach an ultra-low carbon energy supply, up to 2.5gCO2éq/kWh, which is unbeatable.

Waste Management and Disposal Plan

In terms of core physics, it remains undeniable that plutonium from spent MOX fuels and depleted uranium from enrichment are materials that can be used in SFR and therefore in HEXANA reactors. Fast reactor MOX has been retreated in France since the 60's, before PWR fuels… HEXANA fuel can be retreated with current knowledge, it is included in our fuel specifications. The plutonium from HEXANA spent fuels can be reused for unlimited MOX fabrication, paving the way to the close fuel cycle. Only minor actinides can be considered as the final wastes to be included in each national disposal plans.

8.1 Fuel Cycle Options
8.2 Resource Use Optimization
8.3 Unique Fuel/Fuel Cycle Design Features

9. Safeguard & Physical Security

SUMMARY FOR BOOKLET

9.1 Safeguards
9.2 Security
9.3 Unique Safeguards and/or Security Features

10. Project Delivery & Economics

SUMMARY FOR BOOKLET

10.1 Project Preparation and Negotiation
10.2 Construction and Commissioning
10.3 Operation and Maintenance